Program and Abstracts
Programme et Résumés

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

SCIENCE: ADDRESSING THE ISSUES
LES SCIENCES: DES SOLUTIONS AUX PROBLÈMES

Aviation Meteorology / Météorologie de l'aviation

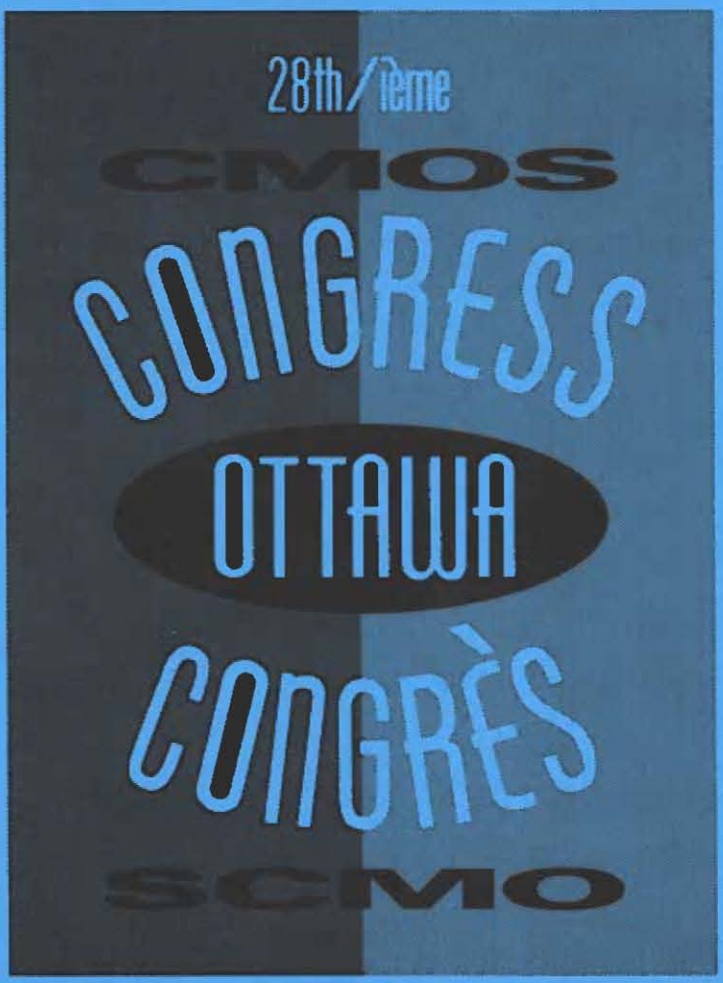
Middle Atmosphere Meteorology / Atmosphère moyen Météorologie

Climate / Climat

Agriculture and Forestry Meteorology / Météorologie agricole et forestière

Fisheries Oceanography / Océanographie des pêches

Operational Oceanography / Océanographie opérationnelle



MAY 30 TO JUNE 3 1994 • 30 MAI AU 3 JUIN 1994

GLOBAL CHANGE FORUM

MAY 30 1994 — CHANGEMENT À L'ÉCHELLE PLANÉTAIRE — 30 MAI 1994

Co-Editors: Paul-André Bolduc
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BIENVENUE à OTTAWA

Bienvenue à Ottawa et au 28e Congrès annuel de la SCMO. Vous trouverez ci-joint quelques renseignements pour vous aider à vous familiariser avec les facilités que nous utiliserons tout au long de la semaine. Prière de consulter les cartes locales sur la couverture arrière de ce document.

ARRIVÉE en VILLE

Il y a un service de navette aller-retour à heures fixes entre le Novotel et les autres grands hôtels et l'aéroport. La course dans une direction coûte 9,00 $ avec des départs tous les 30 minutes. Les tarifs pour les taxis sont entre 20 et 22 $.

HÉBERGEMENT

Le Novotel est situé au centre ville, à une distance de 5 à 10 minutes de marche de tous les endroits de rencontre du congrès. Les autres hôtels sont également à une distance de marche des lieux de rencontre quoique à une distance plus grande de l'Université.

Résidence de l'Université d'Ottawa: les résidences sont situées dans les édifices Stanton (STN) et Marchand (MRD). Le temps limite d'enregistrement est habituellement 16:30 heures et est disponible 24 heures par jour au Stanton Hall, 100, rue University. L'heure du départ est 10:30 heures. La plupart des lieux de rencontre à l'Université d'Ottawa sont directement opposés à ces deux résidences.

TRANSPORT LOCAL et STATIONNEMENT

Tous les lieux de rencontre sont bien desservis par les autobus d'OC-Transpo. Les visiteurs d'un jour à l'Université voyageant en auto devraient utiliser le garage situé au 100 Thomas More. Il y a des frais journaliers du lundi au vendredi; le stationnement est gratuit durant les fins de semaine.

LIEUX de RENCONTRE du CONGRÈS

Lundi, le 30 mai, le Colloque sur le changement à l'échelle planétaire se tiendra au Centre des conférences du gouvernement. Prière d'utiliser l'entrée située au 2, rue Rideau, en face de l'hôtel Château Laurier.

À l'Université, du mardi au vendredi, la plupart des sessions se tiendront au deuxième étage du Pavillon Morisset (MRT), situé près du Centre de l'Université (85 Université). Dépendant du nombre d'inscriptions au congrès, quelques sessions plénières pourront se tenir au Pavillon Marion (MRN), à quelques 5 minutes de marche, au sud de UCU. Les détails définitifs des salles seront fournis lors de votre arrivée à Ottawa.

REPAS

Un service de cafétéria est disponible au Centre Universitaire. Les heures sont: petit-déjeuner de 7 à 9 heures; déjeuner de 11 à 13:30 heures; Dîner de 17:00 à 19:00 heures. de plus, le marché Byward est à 10 ou 15 minutes de marche vers le nord, passé le Novotel) et offre une grande variété de restaurants.

WELCOME to OTTAWA

Welcome to Ottawa and the 28th Annual CMOS Congress. Here are a few notes to help you become familiar with the facilities we will use. Please consult the local maps on the back cover of this document.

ARRIVING in TOWN

There is a regular airport shuttle to and from the Novotel and other major downtown hotels. The one way cost is $9.00 with departures every 30 minutes. Taxi fares are approximately $20 to $22.

ACCOMMODATION

The Novotel is centrally located, being a 5 to 10-minute walk to Congress venues. Other downtown hotels are also within walking distance of our venues, although generally farther from the University.

University of Ottawa Residence: the Residences are located in the Stanton (STN) and Marchand (MRD) buildings. Check-in time is normally 4:30 pm. and is available 24 hours a day at Stanton Hall, 100 University. Check-out time is 10:30 am. Most of the University of Ottawa venues are directly opposite these residences.

LOCAL TRANSPORTATION and PARKING

All venues are <u>well</u> served by bus (OC-Transpo). Daily visitors at the University who arrive by car should use the parking garage at 100 Thomas More. There is a daily charge Monday to Friday; parking is free on weekends.

CONGRESS VENUES

On Monday, May 30th, the Global Change Forum will be held at the Government Conference Centre. Please use the entrance on 2 Rideau Street, directly across from the Chateau Laurier Hotel.

At the University, most of the sessions on Tuesday to Friday will be held on the second floor of Morisset Hall (MRT), which adjoin the University Centre (85 University). Depending on Registration, some plenary sessions may be held in Marion Hall (MRN) some five minutes' walk south of UCU. Final details of rooms will be provided upon your arrival in Ottawa.

MEALS

Cafeteria services are available in the University Centre. Hours are: Breakfast 7 to 9 am; Lunch 11 am to 1:30 pm; Dinner 5 to 7 pm. Also, the Byward Market area is a 10 to 15-minute walk (north, past the Novotel) and offers a wide variety of restaurants.

QUELQUES INFORMATIONS UTILES aux PARTICIPANTS

PROGRAMME SCIENTIFIQUE

Le programme est divisé en thèmes et sessions spéciales couvrant une grande variété de sujets d'importance actuelle en météorologie et océanographie. Chaque session est ouverte par un conférencier invité.

Les sessions plénières se tiendront dans l'Auditorium des Anciens (niveau de la rue au Centre Universitaire). Après chaque session plénière, une intermission de 5 minutes est prévue afin de permettre aux délégués(es) de se rendre aux sessions choisies. Il n'y aura pas d'intermissions entre les présentations. Cependant, les présidents de chaque session s'assureront que toutes les présentations se terminent à la même heure afin de faciliter les déplacements entre les sessions.

Les sessions doivent débuter à l'heure spécifiée dans le programme. Les délégués(es) sont priés(es) de respecter l'heure du début et de la fin des intermissions. L'intermission de mercredi après-midi durera exceptionnellement une heure pour permettre aux délégués(es) de visionner les affiches murales et de s'entretenir avec leurs auteurs.

Les résumés contenus dans ce programme ont été imprimés d'après l'ordre des présentations. Les résumés pour les affiches murales sont regroupés à la fin et sont présentés dans la session appropriée. Étant donné le grand nombre de présentations cette année, on n'a pas prévu de temps pour en faire un compte-rendu oral.

BUREAU d'INSCRIPTION

Le bureau d'inscription sera ouvert pendant toute la durée du congrès: dimanche soir au Novotel; le lundi au Centre de Conférences du gouvernement fédéral; le lundi soir et toute la journée du mardi au niveau de la rue près de l'Auditorium des Anciens de l'Université d'Ottawa; et, du mercredi jusqu'au vendredi, au deuxième étage du Centre Universitaire. Il sera utilisé comme centre d'information. Il y aura un tableau pour les messages où les délégués(es) pourront laisser ou recevoir des messages; ce tableau servira également à afficher les changements de programme de dernière minute.

ACTIVITÉS SOCIALES

A l'université, les activités sociales auront lieu à la cafétéria du Centre Universitaire; quelques activités pourront se tenir sur le patio extérieur du troisième étage si le température le permet.

Lundi: Cocktail de bienvenue - 17:30 à 20:00.

Mardi: Réception donnée par les exposants - 17:00 à 18:00.

Mercredi: Déjeuner en l'honneur de Patterson 12:10 à 13:40.
La médaille Patterson, décernée par le SEA pour service distingué rendu à la météorologie au Canada, sera présentée lors d'un déjeuner spécial qui aura lieu à la cafétéria du Centre Universitaire. On encourage tout le monde à y assister; les billets peuvent être achetés au bureau d'inscription au coût d'environ 12$.

Jeudi: Banquet annuel de la SCMO - salle de bal de l'hôtel Château Laurier - Cocktail à 18:30 - Banquet à 19:30.

SOME USEFUL INFORMATION for PARTICIPANTS

SCIENTIFIC PROGRAM

The program is divided into theme and special sessions covering a wide range of topics of current importance to meteorology and oceanography. Each session is opened by an invited speaker.

Plenary sessions will be held in the Alumni Auditorium (lower level of the University Centre); after these sesssions a five minute break allows delegates to reach concurrent session of their choice. There are no other breaks between papers, but session chairs will make sure that papers in all sessions end at the same time to facilitate movement from one session to another.

Sessions must start at the times specified in the program. Delegates are asked to observe carefully the starting and ending times of breaks. The breaks of Wednesday afternoon has been lengthened to one hour to allow delegates time to view posters and to talk with their authors.

Abstracts are printed in this program according to order of presentation of papers. Abstracts for poster papers are included at the end of the program in their appropriate sessions. Due to the large amount of presentations this year, no time is allowed for an oral presentation.

REGISTRATION DESK

The registration desk will be open throughout the Congress: Sunday night at the Novotel; on Monday at the Federal government Conference Centre; on Monday evening and all day Tuesday, at the lower level of the University Centre, near the Alumni Auditorium; and from Wednesday to Friday, on the second floor of the University Centre. It will function as an information centre. There will be a message board at the desk where delegates can leave or receive messages; the message board will also be used to post last minute changes in the program.

SOCIAL FUNCTIONS

Social functions at the University will be held in the cafeteria area of the University Centre; some functions may be held on the adjoining outdoor patio on the third floor, weather permitting.

Monday: Ice Breaker - 5:30 PM to 8:00 PM.

Tuesday: Exhibitor's reception - 5:00 PM to 6:00 PM.

Wednesday: Patterson Lunch - 12:10 PM to 1:40 PM.

The Paterson Medal, awarded by AES for distinguished service to meteorology in Canada, will be presented at a special luncheon to be held in the Cafeteria of the University Centre. Everyone is encouraged to attend: tickets can be purchased at the Registration Desk for approximately $12.

Thursday: CMOS Annual Banquet - Chateau Laurier Ballroom -
Cocktail at 6:30 PM - Dinner at 7:30 PM.

un MOT de notre PRÉSIDENT

Au nom du conseil de la SCMO, je suis heureux de vous souhaiter la bienvenue au 28e Congrès annuel de la Société canadienne de météorologie et d'océanographie. Le thème du congrès de cette année "Les Sciences: des solutions aux problèmes" est particulièrement important compte tenu que le congrès se tient dans la capitale canadienne. Plusieurs des problèmes environnementaux qui sont à l'esprit des canadiens, tel l'amincissement de la couche d'ozone, les toxiques chimiques et le réchauffement du climat, sont basés sur notre compréhension scientifique pour laquelle les membres de la SCMO jouent un rôle de premier plan. Dans le but d'amener ces problèmes au premier plan de la place publique, on a prévu tenir un colloque sur les changements à l'échelle planétaire pour le lundi, 30 mai comme un événement d'un intérêt plus général.

Le 28e Congrès a une signification toute spéciale pour moi, non seulement parce que je suis le président mais tout particulièrement parce que le 1er congrès de la Société canadienne de météorologie et d'océanographie (avant que les océanographes se joignent à nous) s'est également tenu à Ottawa (en 1967) auquel j'ai eu le plaisir d'assister. Je pense que les participants au congrès de 1967 seront fiers de constater avec moi l'évolution de la Société et sa croissance tout au long des 27 dernières années.

Je vous encourage grandement à participer aux différents événements tout au long de cette semaine à Ottawa: venez assiter à la réunion générale annuelle, venez vous régaler au banquet et participez à plusieurs sessions. J'ai toujours pensé que le Congrès de la SCMO était l'occasion de se rendre compte de ce qui se passe dans les différentes activités de la météorologie et de l'océanographie au Canada.

Encore une fois, bienvenue au Congrès.

Gordon McBean
Président

WORD from our PRESIDENT

On behalf of the CMOS Council, I am pleased to welcome you to the 28th Annual Congress of the Canadian Meteorological and Oceanographic Society. This year's Congress has the theme of "Science: Addressing the issues" which is particularly important in view of the Congress being held in our nation's capital. Many of the environmental issues that are foremost in the minds of Canadians, such as ozone layer depletion, toxic chemicals and climate warming, are based on the scientific understanding, for which members of CMOS have played a major role. To bring these issues more to the forefront of public attention, a Global Change Forum has been planned for Monday, 30 May, as a special event of broad interest.

The 28th Congress is of special significance to me, both because I am President but particularly because the 1st congress of the Canadian Meteorological and Oceanographic Society (before the oceanographers joined in) was also held in Ottawa (in 1967) which I had the pleasure to attend. I think the participants in the 1967 Congress will be pleased to see how the Society has evolved and grown over the past 27 years.

I encourage you to join fully in the activities of the Society during this week in Ottawa: come to the Annual General Meeting, savour the banquet and sample a range of sessions. I have always felt that the CMOS Congress was a real opportunity to find out what's happening in Canadian Meteorological and Oceanographic activities.

Again, welcome to the Congress.

Gordon McBean
President

COMPANIONS PROGRAM

PROGRAMME d'ACCOMPAGNEMENT

Individuals are free to take part in any or all of the activities. Full details will be provided in the package provided on registration. All tours are complements of CMOS, costs for the Canal trip and lunches are the responsibility of the individual. Many other attractions and activities are available in the National Capital Region at this time of the year.

Proposed program / Programme proposé

Date	Time Heure	Activity Activité
Tuesday, May 31 Mardi, 31 mai	09:40 AM	Tour of Parliament Visite du Parlement
	11:45 AM	Lunch at Le Café - National Arts Centre Déjeuner Le Café - Centre National des Arts
	01:30 PM 13:30	Rideau Canal Boat Tour (Group discount) Tour de bateau sur le canal Rideau (Tarif de groupe)
Wednesday, June 1 Mercredi, 1 juin	10:00 AM	Tour of National Art Gallery Visite du Musée des Beaux-Arts
Thursday, June 2 Jeudi, 2 juin	11:00 AM	Tour of Governor General's Residence Visite de la résidence du Gouverneur-Général
	12:30 PM 12:30	Lunch (Creperie - Restaurant in the Byward Market) Lunch - La Crêperie - Restaurant près du marché By
	02:30 PM 14:30	Walking Tour of Sandy Hill Promenade dans le quartier Côte de sable

Chacun est libre de participer à l'une ou l'autre des activités proposées. Tous les détails seront fournis au moment de l'inscription. Les visites sont une gracieuseté de la SCMO alors que les frais reliés aux repas et au tour de bateau sur le canal sont à la discrétion de chacun. La région de la capitale nationale offre plusieurs autres attraits touristiques et activités à ce temps-ci de l'année.

COMMITTEE MEETINGS

RÉUNIONS des COMITÉS

Pavillon MORISSET Building
University Centre - Centre Universitaire

Committee & Responsible persons Comité & personnes responsables	Day Jour	Time Heure	Room Salle
CMOS Scientific Committee Comité scientifique de la SCMO Dr. Ron Stewart	Sunday Dimanche	12:00 to/à 16:00	232
CMOS AO Editorial Board Comité éditorial AO de la SCMO Drs. Peter Smith & Charles Lin	Sunday Dimanche	14:00 to/à 16:00	233
PERD Currents Committee Comité PRDE sur les courants Dr. Bill Crawford	Sunday Dimanche	16:00 to/à 18:00	233
CNC-SCOR CNC-CSRO Mr. Brian Nicholls	Monday Lundi	08:00 to/à 14:30	232
Middle Atmosphere Modelling Modélisation de l'Atmosphère moyen Dr. Ted Shepherd	Monday Lundi	09:00 to/à 16:00	217
World Ocean Circulation Experiment (WOCE) Expérience circulation océanique mondiale (ECOM) Dr. Barry Ruddick	Monday Lundi	14:30 to/à 18:00	232
CMOS Education Committee Comité d'éducation de la SCMO Dr. Peter Taylor	Monday Lundi	19:00 to/à 23:00	232
CNC-ECOR CNC-ECOR Mr. Brian Nicholls	Tuesday Mardi	09:00 to/à 16:00	217
Operational Meteorology SIG GIS Météorologie opérationnelle Mr. Brian Paruk	Tuesday Mardi	12:10 to/à 13:20	232
CMOS Hydrology SIG GIS Hydrologie de la SCMO Dr. Rick Lawford & Terry Krause	Tuesday Mardi	20:00 to/à 23:00	232
CMOS Council Meeting Réunion du Conseil de la SCMO Dr. Gordon McBean	Tuesday Mardi	20:00 to/à 23:00	233
CMOS Annual General Meeting Réunion générale annuelle de la SCMO Dr. Gordon McBean	Wednesday Mercredi	19:00 to/à 22:00	209

SIG: Special Interest Group; GIS: Groupe d'intérêts spéciaux.

ACKNOWLEDGEMENTS

REMERCIEMENTS

The Congress organiztion committee is very greatful to the following organizations for their support and/or sponsorships or grants.

Le comité organisateur du congrès tient à remercier les organismes suivants pour leur support et/ou leur aide financière.

CORPORATE SPONSORS / ORGANISMES COMMANDITAIRES

MacDonald Dettwiler and Associates Ltd.

Environment Canada - Environnement Canada

Fisheries and Oceans - Pêches et Océans

National Defence - Défense Nationale

Royal Society of Canada - Société royale du Canada

Air Canada

COMMERCIAL EXHIBITORS / EXPOSANTS COMMERCIAUX

Labcor Technical Sales Inc., Anjou, Québec

Satlantic Inc., Halifax, Nova Scotia

InterOcean Systems Inc., San Diego, California

Vaisala Inc., Woburn, Massachussets

Richard Brancker Research Ltd., Ottawa, Ontario

World Weatherwatch / Aeroaqua Inc., Markham, Ontario

Dasco Equipment Ltd., Charlottetown, PEI

Speech Technology Research Ltd., Victoria, B.C.

Campbell Scientific Corp., Edmonton, Alberta

Allied Signal Aerospace, Montréal, Québec

Bytown Marine Ltd., Ottawa, Ontario

LOCAL ARRANGEMENTS COMMITTEE

COMITÉ ORGANISATEUR LOCAL

Chairman / Président

Michael Hawkes, Department of National Defence/Ministère de la Défense nationale

Members / Membres

Yvon Bernier, Retired/à la retraite
Paul-André Bolduc, Department of Fisheries & Oceans/Ministère des Pêches & océans
Rob Cross, Environment Canada/Environnement Canada
John Falkingham, Environment Canada/Environnement Canada
Michael Hewson, Environment Canada/Environnement Canada
Rebecca Milo, Department of National Defence/Ministère de la Défense nationale
Dick Stoddart, Department of Fisheries & Oceans/Ministère des Pêches & océans
Ken Yuen, Department of Fisheries & Oceans/Ministère des Pêches & océans

SCIENTIFIC PROGRAM COMMITTEE

COMITÉ du PROGRAMME SCIENTIFIQUE

Chairman / Président

Geoff Holland, Department of Fisheries & Oceans/Ministères des Pêches & océans

Members / Membres

Michael Ball, Transport Canada/Transports Canada
Brian Bornhold, Royal Society of Canada/Société royale du Canada
John Carr, Transport Canada/Transports Canada
Ron Doyle, Transport Canada/Transports Canada
Gilles Fournier, Transport Canada/Transports Canada
Barry Grace, Department of Agriculture/Ministère de l'Agriculture
Henry Lear, Department of Fisheries & Oceans/Ministère des Pêches & océans
Claude Lefrançois, Royal Society of Canada/Société royale du Canada
Jim Powell, Department of Fisheries & Oceans/Ministère des Pêches & océans
John Reid, Environment Canada/Environnement Canada
Philippe Rochette, Department of Agriculture/Ministère de l'Agriculture

The Canadian Meteorological and Oceanographic Society exists for the advancement of meteorology and oceanography in Canada.

La Société canadienne de météorologie et d´océanographie a pour but de stimuler l´intérêt pour l´avancement de la météorologie et de l´océanographie au Canada.

29th Annual CMOS Congress

Kelowna, British Columbia

May 29 to June 2, 1995

Theme -- Environmental Services: Clients, Innovation and Commercialization

Scientific Program Committee		Local Arrangements Committee
William Hsieh	**Chair**	Al Wallace
(604) 822-2821	**Telephone**	(604) 491-1510
(604) 822-6091	**Fax**	(604) 491-1506

Please contact the Local Arrangements Committee regarding general inquiries and the Scientific Program Committee for special workshops, etc. Exhibitors, please contact the Local Arrangements Committee to reserve your prime floor space.

Mark the Kelowna Congress on your agenda **now**. Come and visit the sunny Okanagan, and plan to extend your stay to enjoy the hospitality. Abstracts must be submitted prior to January 31, 1995.

29e Congrès annuel de la SCMO

Kelowna, Colombie Britannique

29 mai au 2 juin 1995

Thème -- Services environnementaux: les clients, l'innovation et la commercialisation

Comité du programme scientifique		Comité local organisateur
William Hsieh	**Président**	Al Wallace
(604) 822-2821	**Téléphone**	(604) 491-1510
(604) 822-6091	**Fac-similé**	(604) 491-1506

Prière de contacter le Comité local organisateur pour les renseignements d'ordre général et le Comité du programme scientifique pour les ateliers spéciaux, etc. Pour les exhibits, veuillez contacter le Comité local organisateur pour réserver votre place de choix.

Inscrivez **dès aujourd'hui** le congrès de Kelowna à votre agenda. Venez et visitez la vallée ensoleilée de l'Okanagan, et projetez de rester un peu plus longtemps pour jouir pleinement de notre hospitalité. Les résumés des présentations doivent nous parvenir avant le 31 janvier 1995.

INVITED SPEAKERS

CONFÉRENCIERS INVITÉS

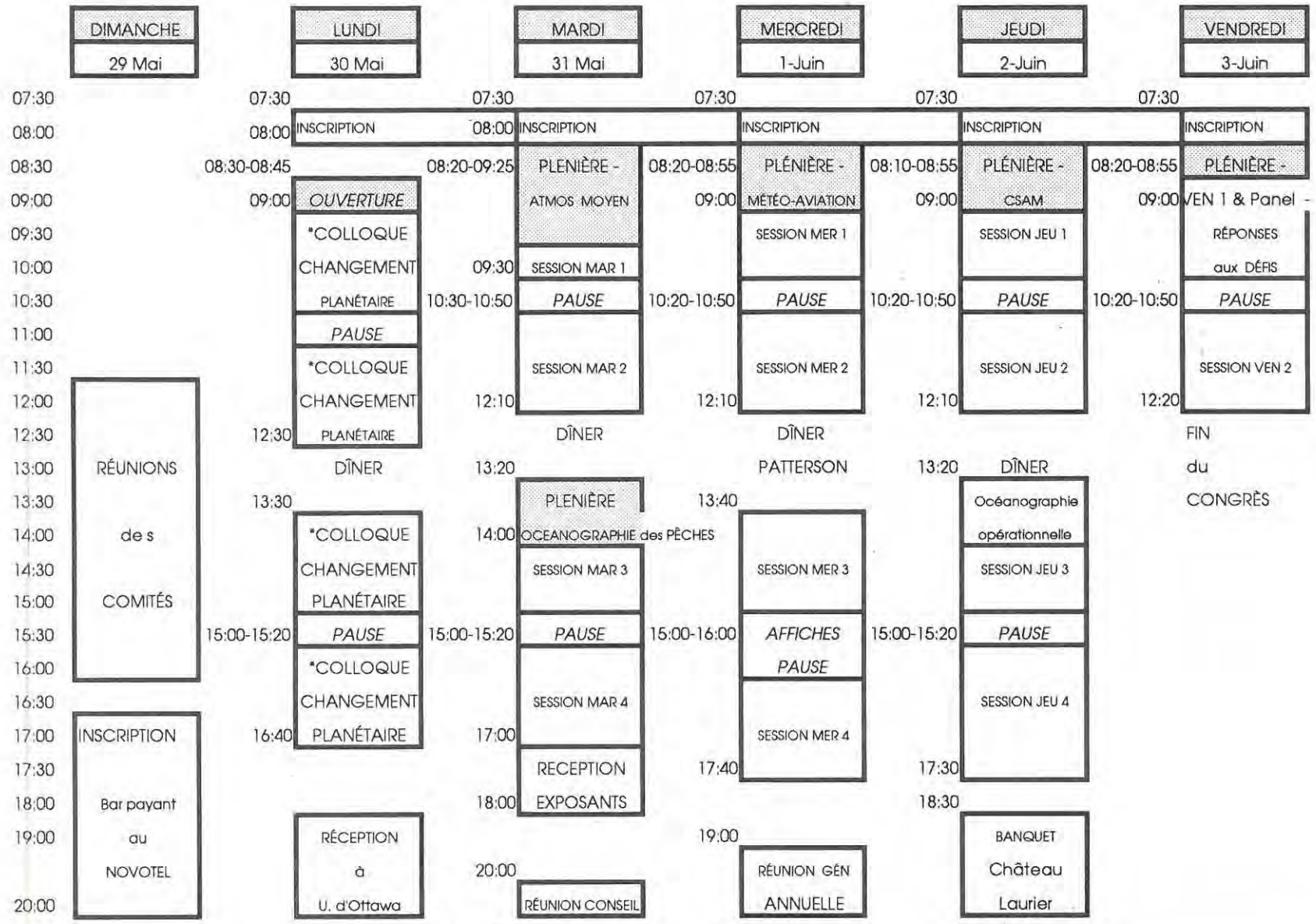
Global Change Forum
Colloque sur le changement à l'échelle planétaire

Gordon McBean	CMOS President and Forum General Chairman Président de la SCMO et du colloque
Sheila Copps (or alternate)	Minister, Environment Canada Ministre, Environnement Canada
Maurice Strong	Chairman, Ontario Hydro Président, Ontario Hydro
William Rees	Professor, University of British Columbia Professeur, Université de la Colombie-Britannique
Brian Morrissey	Assistant Deputy Minister, Agriculture Canada Sous-ministre adjoint, Agriculture Canada
Jon Grant	Chairman and CEO, Quaker Oats of Canada Ltd Président du conseil, Quaker Oats du Canada Limitée
Jim Bruce	Chair, Canadian Climate Program Board / Président, Comité intergouvernemental changement climatique
Anne McLellan	Minister, Natural Resources Canada Ministre, Ressources naturelles du Canada
Stephen Lewis	Former Canadian Ambassador to the UN Ancien ambassadeur du Canada aux Nations-Unies

Plenary Sessions / Sessions plénières

Session	Invited speaker / Conférencier invité
Middle atmosphere	Drs. J.Holton, U.of Washington & J. Gille, NCAR
Fisheries Oceanography	Dr. R. Beamish, DFO/MPO
Aviation Meteorology	Dr. John McCarthy, NCAR
CSAM	Dr.E. Hogg, CFS/SFC
Panel discussion	Hon John Gerrard, Secretary of State for Science Secrétaire d'État pour les Sciences
Panel discussion	Dr.W. Doubleday, DFO, A/ADM/SMA Science
Panel discussion	Dr. Peter. Morand, NSERC President/Président
Panel discussion	Dr. Gordon McBean, EC, ADM/AES, SMA/SEA

28e CONGRÈS ANNUEL de la SCMO (30 mai au 3 juin 1994)



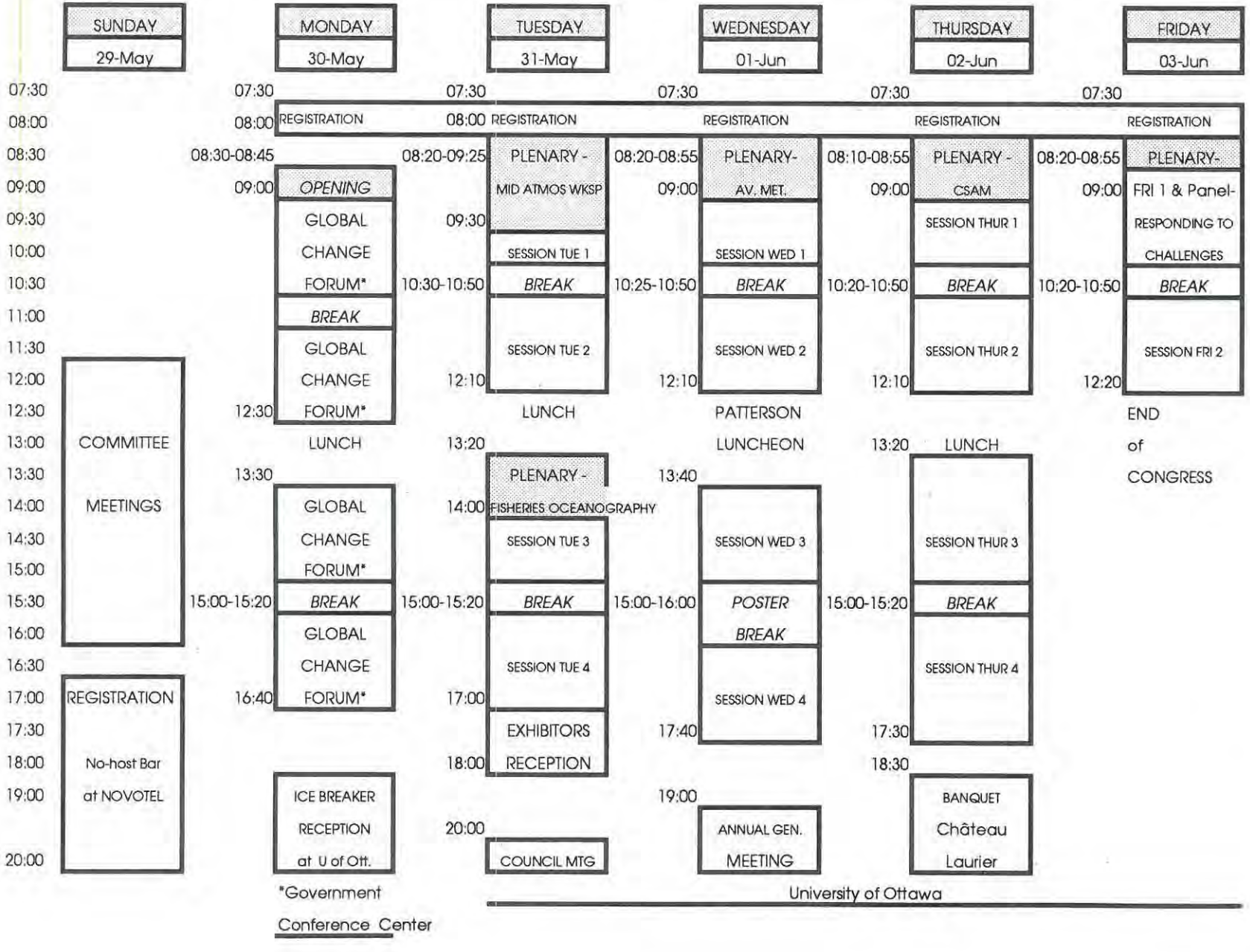
*Centre des conférences du Gouvernement

Université d'Ottawa

APERÇU de la SEMAINE

28/04/1994

28th ANNUAL CMOS CONGRESS (30 May - 3 June 1994)



WEEK AT A GLANCE

28/04/1994

MONDAY / LUNDI 30-05-1994

CMOS 1994 Congress

Global Change Forum
(Government Conference Centre - 2 Rideau Street)

09:00	Gordon McBean: Introduction
09:05	Sheila Copps (or alternate): Welcome/Bienvenue
09:20	Maurice Strong: *Sustainable Development: Global Change's Intelligent Solution ... or Enchanting Mirage/ Développement durable - changement à l'échelle planétaire: solution intelligente ou mirage enchanteur*
09:50	William Rees: *A New Global Economics/ Une nouvelle économie mondiale*
10:20	Health Break/ Pause santé
11:00	Brian Morrissey: *The Future of Renewable Natural Resources/ Le futur des ressources naturelles renouvelables*
11:30	Jon Grant: *Business on a Greener Planet/ Les affaires sur une planète plus verte*
12:00	Jim Bruce: *Climate Change - Implication for Canadians/ Changement climatique - implications pour les canadiens*
12:30	Lunch/ Dîner
13:30	Anne McLellan (or alternate): *Energy at the Crossroads/ L'énergie à la croisée des chemins*
14:00	Stephen Lewis: *The Population - Consumption Time Bomb/ Population - consommation: bombe à retardement*
14:40	Health Break/ Pause santé
15:10	Panel discussion/ Discussion du panel
16:40	End of Forum/ Fin du colloque

Congrès de la SCMO 1994

Colloque sur le Changement à l'échelle planétaire
(Centre de Conférences du Gouvernement - 2, rue Rideau)

CMOS acknowledges the help of **Environment Canada**, the **Department of Fisheries and Oceans** and the **Royal Society of Canada : Canadian Global Change Program** in organizing this event.

La **SCMO** remercie **Environnement Canada, Pêches et Océans** et **le programme canadien sur le changement climatique de la Société royale du Canada** de leur précieuse collaboration à l'organisation de cet événement.

08:15	Welcoming Remarks/Mots de Bienvenue			
0820-0925	PLENARY SESSION/ SESSION PLÉNIÈRE MIDDLE ATMOSPHERE WORKSHOP / ATELIER ATMOSPHÈRE MOYEN ROOM/ SALLE: ALUMNI AUDITORIUM / AUDITORIUM des ANCIENS **Current Challenges in Middle Atmosphere Modelling -J.Holton (Invited)** **Impact of UARS measurements on our understanding of the Middle Atmosphere- J.Gille (Invited)**			
	Air Quality Qualité de l'air **RM/SALLE 224** Chair/Président: Phil Davies	Atmospheric Data Assimilation Assimilation des données atmosphériques **RM/SALLE 232** Chair/Président: Pierre Gauthier	Modelling of Chemical Transport Modélisation du transport des produits chimiques **RM/SALLE Alumni Aud.** Chair/Président: Jack McConnell	WOCE ECOM **RM/SALLE 233** Chair/Président: B. Ruddick
0930-0950	Évaluation du dépôt sec des contaminantsgazeux aux sites du réseau REMPAFAQ. A.Robichaud, G. Boulet, G. Jacques	Some Limitations on Four- Dimensional Data Assimilation Imposed by the Nonlinearity in Barotropic ß-plane Turbulence. P.Bartello, M. Tanguay, P.Gauthier	Inclusion of Chemistry in the Canadian Global Spectral Forecast Model. J.W.Sandilands, et al	The Interactions of the Sub Polar and Sub Tropical Gyres to the South and East of the Grand Banks of Newfoundland. R.A.Clarke
0950-1010	Surface Mesonet Data for the 1993 Southern Ontario Oxidant Study. D. Sills, P. Taylor, J. Salmon	A New Three-Dimensional Analysis Algorithm for the Canadian Global and Regional Data Assimilation Systems. H. Mitchell, C. Charette, C. Chouinard	Statistical and Dynamic Ozone Forecasts for Canada. H.Ritchie, et al	Interdecadal Variability - A new Perspective. R. J.Greatbatch, S. Zhang, W. Cai
1010-1030	Temporal and Spatial Variability of Hebdomodal Cycles in Ozone Time Series from the Lower Fraser Valley, B.C. S.C.Pryor,D.G. Steyn	3D Variational Data Assimilation for a Global Spectral Model. P.Gauthier, P. Kocles	A Study of Winter Arctic Polar Chemistry with a 3-D Chemical Transport Model. J.W.Kaminski, et al	Measurement of Vertical Diffusivity in the North Atlantic Tracer Release Program. N.Oakey, B. Ruddick
1030-1050	**HEALTH BREAK/PAUSE SANTÉ**			
	Air Quality Qualité de l'air **RM/SALLE 224** Chair/Président: Phil Davies	Atmospheric Data Assimilation Assimilation des données atmosphériques **RM/SALLE 232** Chair/Président: Pierre Gauthier	MAM results and Downward Control Les résultats du "MAM" et le post-contrôle **RM/SALLE Aud. des Anciens** Chair/Président: Theodore G. Shepherd	WOCE ECOM **RM/SALLE 233** Chair/Président: B. Ruddick
1050-1110	Air Quality Modelling of the Lower Fraser Valley. M.Hedley, et al	The 4D-VAR Algorithm as a Sub-Optimal Kalman Smoother. R.Ménard,Roger Daley	Preliminary results from a climate Simulation made with the Canadian Middle Atmosphere model S.Beagley,et al	The Gulf Stream and Associated Currents at 50W: Relationship Between Sea Level and Volume Transport.WOCE. R.Hendry
1110-1130	Modelling of Ozone Formation at a Rural Site in Southern Ontario. D.Plummer,et al	Practical Problems Related to the Assimilation of Satellite Humidity Data. L.Garand	Sensitivity of ClimateSimulations to the Vertical Structure of Gravity - Wave Drag. N. McFarlane,S. Beagley, M.Lazare	Lagrangian Observations of Inertial Motions in the Northeast Pacific: Results from Multiple Satellite-Tracked Drifter Deployments. R. E..Thomson, P.H. LeBlond, A.B. Rabinovich
1130-1150	The relative roles of bromine and chlorine in polar sunrise depletion of tropospheric ozone A.Tang, J.C. McConnell	One-Dimensional Variational Assimilation of SSM/I and GOES Retrievals of Atmospheric Water Vapor.G.Deblonde	Estimates of Downward Control in the Canadian MAM. J.N.Koshyk, T.G. Shepherd	WOCE Hydrological Survey in the Sea of Okhotsk. C.Taylor
1150-1210	Cart Decision-Tree Analysis and Prediction of Maximum Surface Ozone for the Vancouver, Montreal and Atlantic Regions of Canada. W.R.Burrows	Planning for Variational Data Assimilation of TOVS Radiances in the Canadian Assimilation Procedure. C.Chouinard	Downward control and the role of gravity waves in determining the circulation of the polar wind stratosphere. B.Boville	Pacific Intermediate Water in the Sea of Okhotsk. H.Freeland, C.Wong, F. Whitney

1320-1400	PLENARY SESSION/ SESSION PLÉNIÈRE SPECIAL SESSION ON FISHERIES OCEANOGRAPHY / SESSION SUR L'OCÉANOGRAPHIE DES PÊCHES ROOM/ SALLE: ALUMNI AUDITORIUM / AUDITORIUM des ANCIENS **The Changing Sea Environment in Relation to Carrying Capacity and Ability to Support Commercial Fisheries.** R.J.Beamish (Invited)				
	Atmospheric -Surface Forcing Interaction de surface atmosphérique **RM/SALLE 231** Chair/Président: Tim Oke	Atm Dynamics-1 Dynamique de l'atmosphère-1 **RM/SALLE 233** Chair/Président: R. Laprise	Atmospheric Waves Ondes atmosphériques **RM/SALLE Alumni Aud.** Chair/Président: Norman A. McFarlane	Cloud & Precipitation physics Nuage & physique des précipitations **RM/SALLE 232** Chair/Président: Ed Lozowski	Fisheries Pêcheries **RM/SALLE 224** Chair/Président: R.J.Beamish
1400-1420	Comparison of heat fluxes from summertime observations in the suburbs of four North American cities. C.S.B.Grimmond, T. R. Oke	Dynamics of Forecast Errors and Extended Kalman Filtering for Burgers' Equation. R.Ménard	Internal Gravity Waves Breaking in the Middle Atmosphere. G.P. Klaassen, I.J. Sonmor	Miniature Supercellular and Non-Supercellular Tornadoes seen on the McGill Doppler Radar. H.P.Biron, S. Siok, A. Bellon	Spatial and Temporal Changes in the Fish Community of the Newfoundland-Labrador Shelf.. R.L.Haedrich, M. Guadalupe, Manuel C. Gomes
1420-1440	Relative efficiencies of turbulent transfer of heat, mass and momentum over a patchy urban surface. M.Roth,T. R. Oke	Sensitivity of simulated Madden-Julian oscillations to cumulus parameterization in CCC GCM. J.Sheng	Atmospheric Tides in the Mesosphere and Thermosphere As Seen by the Wind Imaging Interferometer (WindII) on the Upper Atmosphere Research Satellite. C. McLandress, et al	Numerical Simulation of a Long-Lived Mesoscale Convective System. Da-Lin Zhang, N. Bao	1430 Numerical Modelling of Cod Egg Retention of the Northeast Newfoundland Shelf. F. Davidson, B. De Young
1440-1500	A Coupling Mechanism for Wind and Waves. W.Perrie, L. Wang	Generation of Moist Potential Vorticity in Extratropical Cyclones. Z.Cao, H-R. Cho	Equatorial waves in planetary atmospheres. X.Li	The Role of Moist Symmetric Instability in the Precipitation over Central Alberta. G.W.Reuter, N. Aktary	
1500-1520	**HEALTH BREAK/PAUSE SANTÉ**				
	Atmospheric -Surface Forcing Interaction de surface atmosphérique **RM/SALLE 231** Chair/Président: Tim Oke	Atm Dynamics-1 Dynamique de l'atmosphère-1 **RM/SALLE 233** Chair/Président: R. Laprise	Observations of Gravity Waves Observations des ondes de gravité **RM/SALLE Alumni Aud.** Chair/Président: Gary P. Klaassen	Cloud & Precipitation physics Nuage & physique des précipitations **RM/SALLE 232** Chair/Président: Ed Lozowski	Fisheries Pêcheries **RM/SALLE 224** Chair/Président: R.J.Beamish
1520-1540	Numerical Modelling of Coastally Trapped Disturbances. P.L. Jackson, C.J.C. Reason	Interaction Between Slantwise Convection and Marine Cyclones: A Conceptual Picture and Sensitivity Studies. G.Balasubramanian, M.K. Yau	Rayleigh Lidar Observations of Atmospheric Thermal Structure and Gravity Wave Activity at Middle and High Latitudes. J.A.Whiteway, A.I.Carswell	An Investigation of a CASP II Winter Storm Producing a Prolonged Period of Ice Pellets. J. M.Hanesiak, R. E. Stewart	Variations in the Contribution of Transport to Changes in Animal Abundance: A Study of the Flux of Fish Larvae in Conception Bay. P.Pepin, J. Helbig
1540-1600	Wind-Driven Pressure Gradients Around an Island. R.H.Tyler, B.G. Sanderson	Development of a Boundary-Layer Model of Surface Frontal Passage. M.Pagowski	Absolute Temperature Measurements of the Mesopause using the UWO Sodium Lidar.C.T.Sparrow, R.J. Sica, P.S. Argall	Precipitation in Layer Clouds: Results from the Atlantic Stratocumulus Transition Experiment. P.Austin	Modelling the Evolution of Pelagic Egg Distribution in Conception Bay. J.Helbig, P. Pepin
1600-1620	Applications of the MSFD and NLMFSD Models to Flow over Askervein Hill. P.Taylor, et al	Non-Hydrostatic Simulations of Warm-Frontal Systems. K.K.Szeto, R.E. Stewart	Middle Atmosphere Studies with the UWO Radars. W.K.Hocking, T. Thayaparan, J.MacDougall	The Magnitude of Vertical Air Velocity Within Cirrus Clouds: Coherent Structures and Turbulence. I.Gultepe, D.O'C Starr, Dr. T. Uttal	Foodchain Control of Carrying Capacity in the Subarctic Pacific Based on Simulations with a Simple Coupled Physical-Biological Model. K. L.Denman
1620-1640	Boundary-Layer Parameterization of Drag over Small Scale Topography. D.Xu, P. Taylor, K. Ayotte	An Evaluation of Planetary Boundary Layer Models Using Large Eddy Simulation. K. W.Ayotte,C.H. Moeng	Lidar Measurements of Density and Temperature Fluctuations in the Middle Atmosphere at High Spatial-Temporal Resolution. R.J.Sica, P.S. Argall, C.T. Sparrow	An experimental investigation of the local heat transfer from hailstone models.G. Zheng, R. List	Deepwater Solitary Corals as a New Paleo-Oceanographic Archive: Desmophyllum Cristagalli as an Example from Orphan Knoll, Northwest Atlantic Ocean. A.Ruffman
1640-1700	A Simple Three Dimensional Model of Planetary Boundary Layer Flow. K.W.Ayotte, P. A. Taylor	Delivery of a Compressible Multi-Scale Modelling Tool - The MC2 Model - to the Canadian Atmospheric Research Community. R.Benoit, Y. Chartier, M. Desgagne	Tidal Influence on Atomic Oxygen Green Line Airglow Altitudes and Emission Rates at the Geographic Equator as Observed by WINDII. G.Shepherd, , C. McLandress, B.H. Solheim	The Process of Drop Collisions in Turbulent Clouds. A.S.Koziol, H.G. Leighton	Long-term trend in dissolved oxygen level in the St. Lawrence estuary. D. D'Amours et al

0820-0855	PLENARY SESSION/ SESSION PLÉNIÈRE SPECIAL SESSION ON METEOROLOGICAL RESEARCH TO MEET CANADA'S AVIATION NEEDS IN THE 21ST CENTURY SESSION SPÉCIALE sur la RECHERCHE ATMOSPHÉRIQUE pour RÉPONDRE aux BESOINS de l'AVIATION CANADIENNE du 21e SIÈCLE ROOM/ SALLE: ALUMNI AUDITORIUM / AUDITORIUM des ANCIENS Aviation Meteorology Research and Development - Dr. J.McCarthy(Invited)			
	GEWEX RM/SALLE 224 Chair/Président: T. Kruss	Middle Atmosphere modelling Modélisation de l'atmosphère moyen RM/SALLE 209 Chair/Président: Charles McLandress	Aviation Meteorology- Visions of the Future / Visions du futur RM/SALLE Alumni Aud. Chair/Président: Ron Doyle	Ocean Modelling Modélisation de l'océan RM/SALLE 232 Chair/Président: Gordon Swaters
0900-0920	Global Energy and Water Cycle Experiment (GEWEX). T. W.Krauss	Stratosphere-Troposphere Interactions Associated with Extra-Tropical Cyclogenesis. M.C.Reader, G.W. K. Moore	Aviation Weather Research and Development Strategic Plan. R.Doyle	Variability of Dynamics and Thermodynamics in Baie des Chaleurs: Observation and Modelling. J. Gan, R.G. Ingram
0920-0940	Validation of Cloud Parameterization Scheme Used in Numerical Weather Prediction Model by Using Satellite Observation. W.Yu. L. Garand	Improved Vertical Operators for Stratospheric Modelling. M.Tanguay, H. Ritchie	Problems and Challenges Facing the Aviation Community in Guiding the Future Aviation R & D. B.Dulic	Improved Calculation of Coastally Trapped Waves with Application to Their Scattering and Forcing. G.A.Schmidt
0940-1000	Determination of surface solar radiation budgets from satellite measurements. H.G.Leighton, K. Masuda, Z. Li,	The Middle Atmosphere Data Assimilation Project. R. Ménard, etal	Weather Forecasting in the 21st Century. G.Fournier	Numerical Study of Coastal Plumes in the Western Gulf of Maine: An Ideal Ocean Basin. J.Wang,
1000-1020	Solar Surface Net Radiation: A Comparison Between Satellite Estimation and GCM Simulation. H. W.Barker, Z. Li	Forcing of Stationary Planetary Waves in the Winter Stratosphere by Transient Eddies. T.C.Box, J.Derome	The FAA's Aviation Weather Development Program Research Activities: An OverviewK. L.Van Sickle, K. Klasinski	Subtidal Circulation Variability on the Scotian Shelf: A Retrospective Modelling Study. J.Sheng, K. Thompson
1020-1050	HEALTH BREAK/PAUSE SANTÉ			
	GEWEX RM/SALLE 224 Chair/Président: T. Kruss	Middle Atmosphere Radiation Radiation de l'atmosphère moyen RM/SALLE 209 Chair/Président: Jean-Pierre Blanchet	Météorologie de l'aviation- Detection Technologies 1/ Techniques de détection 1 RM/SALLE AUD. des ANCIENS Chair/Président: Branimir Dulic	Ocean Modelling Modélisation de l'océan RM/SALLE 232 Chair/Président: Gordon Swaters
1050-1110	The Impact of Global Climatic Changes on Long-Term Fluctuations in Some Hydrological Processes. A. V.Frolov	Development of the New CCC/GCM Radiation Model for Extension into the Middle Atmosphere. V.I.Fomichev, J.P. Blanchet	The Integrated Terminal Weather System. F. W. Wilson Jr.	Examination of the Veronis Effect. W.A.Gough
1110-1130	Synoptic Atmospheric Moisture Analyses for the Regional Evaporation Study. L.E.Welsh, G.B. Lesins, G.S. Strong	Adaption of the CCC/GCM Solar Radiation Model for Middle Atmosphere Simulations: Spherical Geometry and Spectral Resolution. M.Larocque, J.P. Blanchet	Monitoring of Aircraft Icing Hazard Using a Dual-Frequency Radar. M.E.J. Gosset, A.J. Illingworth, H. Sauvageot	Stability characteristics of deep water replacement in the Strait of Georgia R.Karsten, G.E. Swaters and R. Thompson
1130-1150	A Modelling Study on Evaporation from Lakes. J.Kwan	Calculations of scattered 300-750 nm solar radiation in the 20 km of the stratosphere at twilight and comparison with measurements. J.McLinden, et al	Transport Canada Proposed R&D Program for the development of a multi-parameter dual X-Ka Band Doppler radar for aviation meteorology applications. G. Fournier	The Effects of Surface Thermal Boundary Conditions on Eddy Simulation of Ocean. W.Xu, C. Lin
1150-1210	Improving Evaporation Estimates using Lined Reservoirs. G.S.Strong, R.G. Granger	The Influence of the Middle Atmosphere on the Surface Ultraviolet Radiation Environment. W.F.J.Evans	Automation of Meteorological Observations using Scene Photometry. B.W.Tansley	Modeling Steady-State Thermohaline Interleaving. D.Walsh, B. Ruddick

	Clouds & Climate Nuages et climat RM/SALLE 224 Chair/Président: Ron Stewart	Observations of Chemistry 1 Observations chimiques 1 RM/SALLE 209 Chair/Président: William E. Ward	Aviation Meteorology- Detection Technologies 2 Techniques de détection 2 RM/SALLE - Alumni Aud. Chair/Président: Gilles Fournier	
1340-1400	The effect of the large scale cloud homogeneity assumption on the shortwave radiative fluxes computed in GCMs. L.Oreopoulos, R. Davies	The Composition and Photdissociative Flux Measurement as flown on the NASA ER-2 High-Altitude Research Aircraft. C.T.McElroy, J.C.McConnell, M.J. Prather	Low-Cost Hazardous Weather Detection for Airports. C. H.Leyh, W. L. Rubin, J.J. Owenburg	
1400-1420	Parameterizations of Cloud Microphysical Characteristics and its Effect on Climate Change. I.Gultepe, G.A. Issac	Model Simulations of Heterogeneous Reactions in Sulfate Aerosol and PSC Particles: A Sensitive Study. M. Y.Danilin, J. McConnell	Directly Measured Vector Winds from an Inexpensive Bistatic Multiple-Doppler Network. J.Wurman	
1420-1440	On Modelling the Role of CCN on Cloud Microphysics and Radiation for GCM: The Twomey Effect. S.Nadon, J.P. Blanchet	SPEAM-2 Measurements made during STS-52. C.T.McElroy, S.G. MacLean, B. Tryggvason	Multiple Scattering Lidar Returns from Atmospheric Aerosols and Precipitation. D.L.Hutt, L. R. Bissonnette	
1440-1500	Effects of SO2 on the Atmospheric Water Cycle During the Formation of Continental Arctic Air Mass: Its Implication for Climate. E.Girard, J.P. Blanchet	Differences in Upper Troposhperic Ozone, NOy , and NOx/NOy between mid-latitude and tropical air masses. I.Folkins, A.J. Weinheimer	Lidar Remote Sensing of Cloud Properties. L. R.Bissonnette, D. L. Hutt	
1500-1600	**POSTER BREAK/PAUSE AFFICHES**			
	Climate - Change or Variation Climat - Changement ou variation RM/SALLE 224 Chair/Président: Bill Pugsley	Observations of Chemistry 2 Observations chimiques 2 RM/SALLE 209 Chair/Président: Wayne F.J. Evans	Météorologie de l'aviation- Algorithm Development / Algorithme de développement RM/SALLE -Aud. des Anciens Chair/Président: Ken MacDonald	Sea Ice Glace océanique RM/SALLE 232 Chair/Président: Dave Mudry
1600-1620	Canadian Temperature Trends and Extremes and the Relationship to Large-Scale Atmospheric Circulation. W.Skinner, T. Agnew	The Spatial Pattern of Ozone Depletion in 1993 from TOMS Data. D.Fox, W.F.J. Evans, J. Alfred	Climatological Study to Determine Microburst Occurence, Frequency of Occurence, and Location in Canada. T.B.Low	Under-Ice Characteristics in the Northeast Water polynya: Preliminary Results from Summer 1993 Fieldwork. P.Galbraith, R. G. Ingram
1620-1640	The Ocean as a Source for Rapid Interglacial Climate Fluctuations. A. J.Weaver	Scanning Radiaometer Imaging of the OH Nightglow. D.H.Turnbull, R.P. Lowe	Verification of the "Gust" Algorithim Using Doppler Radar Data. A.Bellon, I.I. Zawadzki	A Coupled Ice-Ocean Model for the Labrador Pack Ice. Q.Gui, C.L. Tang
1640-1700	Is the Global Climate System at a State of Self-Organized Criticality. M. R.Gipp	The Observation of Polar Mesospheric Clouds by the WINDII Instrument on UARS. W.F.J.Evans, L.R. LaFramboise, M.J. Pilgrim, R.H. Weins, G.G. Shepherd	Wet Microbursts: A Forecasting Approach. S.Siok, H.P. Biron, G. Fournier, A. Bellon	Sea-Ice Studies off Labrador and Newfoundland in February-March 1992. I.Peterson, S.J. Prinsenberg, M. Ikeda
1700-1720	Are Linear Regressions Adequately Describing Temperature Trends in Climate Change Analyses? R.Pocklington, R. Morgan*, K. Drinkwater	Planetary Scale Oxygen Greenline Emission and Dynamical Features Observed in January, 1993 with the WIND Imaging Interferometer on UARS. W.E.Ward, et al	Real-Time Estimation of Atmospheric Turbulence Severity From in-Situ Aircraft Measurements. L.B.Cornman	Sea Ice Monitoring and Modeling Site (SIMMS) - 1993. T.Agnew, D. Barber, E. LeDrew, R. DeAbreu, et al
1720-1740	Some Dynamical Consequences of Greenhouse Gas Warming. G.J.Boer	ODIN: A Satellite for Stratospheric and Mesospheric Studies. E.Llewellyn, I.C. McDade, W. Brooks, W. Evans, et al	Development of a New Low-Level Turbulence Analysis and Forecasting Index. D. I.Knapp, R. Dumais, MSgt. T.J. Smith	On the Source of Sea-Ice Cover Anomalies in the Arctic Basin. B.Tremblay, L.A. Mysak

0810-0855	PLENARY SESSION/ SESSION PLÉNIÈRE SPECIAL SESSION ON AGRICULTURAL AND FOREST METEOROLOGY / SESSSION SPÉCIALE sur l'AGRICULTURE et la MÉTÉOROLOGIE FORESTIÈRE ROOM/ SALLE: ALUMNI AUDITORIUM / AUDITORIUM des ANCIENS **Predicting Climate Change Impacts on the Wetsern Canadian Boreal Forest. E.H.Hogg (Invited)**			
	Aviation Meteorology-Forecasting & Modelling 1 Prédiction et modélisation 1 RM/SALLE 224 Chair/Président: Angèle Simard	**Cyclogenesis Cyclogénèse** RM/SALLE 209 Chair/Président: R. Laprise	**Climate & Agricultural Yields Climat et production agricole** RM/SALLE - Alumni Aud. Chair/Président: J.D. Boisvert	**Radar Meteorology Météorologie des radars** RM/SALLE 232 Chair/Président: I. Zawadski
0900-0920	The CMC Aviation Package. G.Desautels	An Evaluation of the Interaction Between Slantwise Convection and Marine Cyclogenesis. G.Balasubramanian, M.K.Yau	Quantifying Effect of Late Summer Hail on Corn Production. L.M.Dwyer, et al	Raindrop Spectra and Updraught Determination by Combining Doppler Radar and Disdrometer. A.Thomson, R.List, D.R. Hudak
0920-0940	Description and Verification of the Eta Model Post-Processor for Aviation Weather Forecasting. J.L.Mahoney, A.Marroquin	A Relationship Between 1000-500mb Thickness Anomalies and Active Periods of Rapid Cyclogenesis during CASP II. W.Wintels, J.R. Gyakum	Climatic Teleconnections from the Pacific Ocean to the North American Great Plains - Implications for Canadian Spring Wheat and U.S.A. Corn Yields. E.R.Garnett, J.Babb, M.L. Khandekar	Long Term Radar Observations of the Melting Layer of Precipitation and Their Interpretation. F.Fabry, I.I. Zawadzki
0940-1000	Progress in Developing the Aviation Gridded Forecast System. L.Sherretz	Interaction of Convection with a Baroclinic Environment in Surface Cyclogenesis. Da-Lin Zhang, R. Harvey	Long Term Trends and Variability of Simulated Spring Wheat Yields on the Canadian Prairies. D.W.Stewart, A. Bootsma, L.M.Dwyer	Doppler Radar Signatures of Precipitation in Major Winter Snowstorms. D.R.Hudak, R. Nissen, R. List
1000-1020	Volcanic Ash Dispersion Prediction: Research and Development for Aviation Products at the Canadian Meteorolgical Centre. R. D'Amours, et al	The Distribution and Variability of Sensible and Latent Heat Fluxes over the North Atlantic. G.W. K.Moore	Evaluation of Weather Generators for Risk Assessment in Canada. H.Hayhoe, D.Stewart	Characterizing the Evolution and Structure of Connective Cells with Radar Reflective Isosurfaces. P.R.Harasti, R. List
1020-1050	**HEALTH BREAK/PAUSE SANTÉ**			
	Météorologie de l'aviation-Forecasting & Modelling 2 Prédiction et modélisation 2 RM/SALLE 224 Chair/Président: Richard Verret	**Climate Variability and Interaction - 1 Variation et interaction du climat-1** RM/SALLE 209 Chair/Président: L. Mysak	**Forest and Agricultural Climatology Climatologie des forêts et de l'agriculture** RM/SALLE - Aud.des Anciens Chair/Président: B. Amiro	**Weather Forecasting-1 Prédictions météorologiques-1** RM/SALLE 232 Chair/Président: P. Merilees
1050-1110	Terminal forecasting using observations from an automatic weather station. W. Maynard	Sea Surface Temperature Anomalies and the Simulated Cyclone Climatology. S.J.Lambert	Estimating the Probability of Break-Even Yields for Continuous Wheat on the Canadian Praries. R.De Jong, J.Dumanski, A. Bootsma	Cloud Cover Parameterization in a Large-Scale Atmospheric Model. A.P.Dastoor
1110-1130	SHORT - A Statistical Forecast Technique for Preparation of Aviation Terminal Forecasts. L.J.Wilson	On the Interactions Between Synoptic Scale Eddies and the PNA Teleconnection Pattern. M.Kiesa, J. Derome, J. Sheng	Simulation of soil water variations for potato crop. M.H.Mahdian, J. Gallichand	A Non-Hydrostatic Variable-Resolution Global Model of the Atmosphere. J.Côté, et al
1130-1150	ITWS Gridded Analysis. F. W.Wilson Jr., R.E. Cole	Sea-Ice, Polar Amplification and Arctic Climate Warming. S.Gaumont-Guay, J.P.Blanchet	Evaluation of SAR for Soil Moisture Monitoring in Agriculture. J.D.Boisvert, H.J. Qwyn, H. Geng	Polar Lows in the Labrador Sea: A Case Study. G.W.K.Moore, M.C. Reader, J.York
1150-1210	Storm Motion Algorithm for the Terminal Doppler Weather. J.G.Weiler, C.T. Tan	Multivariate Analyses of Accumulation in Ice Sheets: Implications for Global Change. M. B.Giovinetto, H.J. Zwally, C.R. Bentley	Estimation of Photosynthetically Active Radiation Absorbed by the Vegetation from Space. L.Moreau, Z. Li	Diagnosing Extra-Tropical Development Through the Zwack-Okossi Equation. P.Bourgouin, P. Zwack

	Aviation Meteorology-Forecasting & Modelling 3 Prédiction et modélisation 3 RM/SALLE 224 Chair/Président: Carr McLeod	Climate Variability and Interaction - 2 Variation et interaction du climat -2 RM/SALLE 209 Chair/Président: L. Mysak	Boundary Layer Meteorology Meteorologie de la couche limite RM/SALLE Aumni Aud./ Aud. des Anciens Chair/Président: T.J. Gillespie	Atmospheric Dynamics-2 Dynamique de l'atmosphère-2 RM/SALLE 233 Chair/Président: M. Beland	Operational Oceanography Océanographie opérationnelle RM/SALLE 232 Chair/Président: K. R.Thompson
1320-1340	Microphysical Study of the Conditions for Presence of Supercooled Water within Precipitation and the Coupling with Radar Data. W.Szyrmer, I.Zawadzki, F.Turcotte	On the Modification of the High and Low-Frequency Eddies during ENSO Years: An Observational Study. H.Lin, J. Derome	Multiscale Distributions of Flux Intensities Above and Within a Forest Canopy. B.J.Turner, M.Y. Leclerc	Effects of Variable Wind Shear on a Diabatically Driven Mesoscale Circulation. G.W.Reuter, O. Jacobson	Electromagnetic Fields Induced by Ocean Currents. R.Tyler, L.A. Mysak
1340-1400	Aircraft Verification of the Icing, Cloud and Freezing Level Forecasts from the CMC Aviation Forecast Model. S.G.Cober, G.A. Issac, A. Tremblay	Cyclone Frequencies over Northern Canada and the Northern Atlantic. H.Björnsson, L.A. Mysak, R. Brown	Flux Patterns and Coincidence of Turbulent Structures in Regional Energy and Gas Exchange over Agricultural Areas. C.Mitic, et al	Large Amplitude IGW Excitation by Atmospheric Jets. B.R.Sutherland, W.R. Peltier	Lateral Intrusive Mixing - New Discoveries on an Old Front. B. Ruddick, D. Walsh
1400-1420	On the Forecasting of Supercooled Clouds. A.Tremblay, et al	Variability and the North Atlantic Oscillation. G.W. K.Moore	Multifractal Characterization of Aircraft-Based Measurements in a Turbulent Field. R.G. Pelletier	The Numerical Formulation of MC2 and its Validation on the Classical Mountain Wave Problem. R.Laprise, et. al.	A Near Real-Time Physical Oceanographic Analysis System. D.Bancroft
1420-1440	Towards the Improvement of Aviation Forecasting: The Validation of a Scheme for Mesoscale Prediction of Cloud and Precipitation Types from In Situ CASP II Aircraft Measurements and SSMI Observations. A.Glazer, et al	Midlatitude Atmosphere-Ocean Interactions: Observed. S.Peng, J. Fyfe	The Atmosphere Model to Assess the Safe Disposal of Canadian Nuclear Fuel Waste. B.Amiro	Vertical Propagation of Linear Mountain Waves in Atmospheres with Varying Damping Coefficients. R.H. Côté, R. Laprise	The IOS Oceanographic Bulletin Board. Howard Freeland
1440-1500	Short Term Forecasting to Support Aircraft Ground Anti-Icing Activities in Canada. M.Leduc, et al	Midlatitude Atmosphere-Ocean Interactions: Simulated. J.Fyfe, S. Peng	Source Strength Determination of Trace (Greenhouse) Gases from Agriculture using the Diffusion Equation. S.K.Kaharabata,P.H. Schuepp	Empirical Normal Mode Analysis of the Atmospheric Variability. G.Brunet, B. Dugas, H. Ritchie	Satellites, Oceanography and Society. D.Halpern *(withdrawn)
1500-1520	HEALTH BREAK/PAUSE SANTE				

	Météorologie de l'aviation - Information Systems / Systèmes d'information RM/SALLE 224 Chair/Président: Howard Poaluna	Climate Modelling Modélisation du climat RM/SALLE 209 Chair/Président: C. Lin	Tropospheric Ozone Ozone de la troposphère RM/SALLE Alumni Aud./ Aud. des Anciens Chair/Président: L. Dwyer	Weather Forecasting 2 Prédictions météorologiques2 RM/SALLE 233 Chair/Président: R. Milo	Operational Oceanography Océanographie opérationnelle RM/SALLE 232 Chair/Président: K. R.Thompson
1520-1540	Current and Future Issues Related to the Provision of Meteorological Service for International Air Navigation. O.M.Turpeinen	FIZ-C a Fast-Portable Version of the CCC/GCM Climate Model Family. J.P.Blanchet, D. Therrien	Niveaux d'ozone et lien avecs les facteurs météorologiques au site forestier du Duchesnay. Bilan 1988 - 1991. A.Robichaud	Meteorological Operations at the Canadian Meteorological Centre. R.Jones	Mapping Circulation on the Outer Continental Shelf. K. R.Thompson, D.A. Griffin
1540-1600	Prospects for Future Aircraft Weather Information Systems., J.E.Jordan, D.L.Marcotte	UQAM Regional Climate Model: Diagnostics of a One Month Simulation. D.Caya, et al	The Climatology of Regional Ozone Episodes in Eastern North America During 1980 to 1992. J.D.Fuentes, et al	Recent Developments with the Operational Regional Forecast System. J.Mailhot, et al	Summer Currents in Queen Charlotte Sound, British Columbia. W.Crawford, M. Foreman, P. Cummins
1600-1620	A Graphical Interface for Aviation Weather Guidance Display (Scribe/Aviation). R.Verret, et al	Spectral Analysis of Limited-Area Data Simulated by a Regional Climate Model. S. Turner, R. Lapris	Caractérisation des concentrations d'ozone troposphérique dans la région de Montréal. J.Dion, E. Torlaschi	A Framework for Operational Forecast Verification. R.Verret, et al	Forcing Field Assessment over Ocean Surface for Climatic Evolution of Ocean. M.Miyake
1620-1640	Automated surface observations: New tools - New Challenges P.Clark	Introduction d'une orbite elliptique dans le modèle de circulation générale canadien. B.Denis,N. McFarlane	Separating chemical contribution from surface deposition of airborne ozone fluxes in the San Joaquin Valley of California. Y.Guo, et al	Combining Lightning and Radar Data to Study Quasistationary Thunderstorms. S.Clodman	Vertical Structure of Currents on the Northern Grand Bank - a View from a Bottom Mounted Acoustic Doppler Current Profiler.C.L.Tang, D.J. Beliveau *(will be presented as a poster)
1640-1700	An Assessment of Voice PIREPS in Aviation Related Weather Research. B.Schwartz	Parameterization of dynamical sub-grid scale processes in a spectral GCM. J.N.Koshyk, G. Boer	Isoprene and Monoterprenes within and above a Deciduous Forest. D.Wang, ,et al	Helicity. G.Desautels, R, Verret, M. Leduc	
1700-1720	The U.S. National Meteorological Center Aircraft Database System 1994. B.Ballish, R. Crayton	Results from a Ten-Year AMIP Integration Performed with the Canadian Global Spectral Forecast Model. B. Dugas, H. Ritchie	Gradient-Based Measurements of Isoprene Fluxes Above a Forest Compared with Silmultaneous Branch Measurements in a Cuvette. T.J.Gillespie, et al	Ageostrophic Circulations and their Impact on Cyclone Development. P.Bourgouin, P. Zwack	

0820-0855	PLENARY SESSION/ SESSION PLÉNIÈRE PANEL DISCUSSION / DISCUSSION EN PANEL ROOM/ SALLE: ALUMNI AUDITORIUM / AUDITORIUM des ANCIENS **Responding to Challenges: Federal Secretary of State for Science, the Honourable John Gerrard (Invited)**			
	Weather Forecasting-3 **Prédictions météorologiques-3** **RM/SALLE 224** Chair/Président: S. Gravel	**Geophysical Fluid Dynamics** **Dynamique des fluides géophysiques** **RM/SALLE 209** Chair/Président: P. Taylor	**Panel Discussion** **Discussion en panel** **RM/SALLE Aumni Aud.** Chair/Président: G.Holland	**Remote Sensing** **Télédétection** **RM/SALLE 232** Chair/Président: Pierre Larouche
0900-0920			DFO ADM Science- W.Doubleday	
0920-0940	Numerical Simulation of Extreme Sea-States Associated with Recent Intense Storms in the Canadian Atlantic. M.Khandekar, R.Lalbeharry	Stability Characteristics for Isolated and Coupled Fronts over a Sloping Bottom. G.Swaters	NSERC President- P. Morand	Quality Analysis of the SRB Data: An Intercomparison of Two Satellite-Based Products. Z.Li
0940-1000	Description of the Weather Network Database. P.Dionne	A Hamiltonian Weak-Wave Model for Shallow-Water Flow. T.Shepherd	AES ADM- G. McBean	Bidirectional Dependancies of AVHRR Reflectance at Channel 1 and 2 over Land Surfaces. A.Wu, Z.Li
1000-1020	Hot Air Balloon Forecast Program at St. Louis, Missouri. J.Pedigo	Slaving Principles and Balanced Dynamics for Stratified Flows. O.Bokhove	Panel Discussion "Responding to Challenges"	Observational Evidence of average 3-D cloud effects from satellite measurements over the ocean. N.Loeb, R. Davies
1020-1050	HEALTH BREAK/PAUSE SANTÉ			
1050-1110	Precipitation Type Forecasting. G.Desautels, R. Verret	Rossby-Number Expansions, Slaving Principles and Balance Dynamics. T.Warn		Remote Sensing of Phytoplankton Pigments in the Gulf of St. Lawrence, Canada: Spatial and Temporal Variability. C.Fuentes-Yaco, et al
1110-1130	SCRIBE. R.Verret, G. Rabin, D. Vigneux, J. Marcoux, et al	Piecewise Linear Flow Profiles in Quasigeostrophic Stability Theory. M.D.MacKay, G.W. K. Moore		Observation of Gyre Circulation in the Labrador Sea from Geosat Altimetry. G.Han, M. Ikeda
1130-1150	Meteorological Performance of the Canadian Global Spectral Forecast Model. C.Beaudoin, et al	Wave-Activity and Stability Diagnostics for Semi-Geostrophic Theory. P.J.Kushner, T.G. Shepherd		Intelligent Information Processing for Electromagnetic Sensing of the Environment. S.Haykin
1150-1210	DERF Experiments with the Canadian Global Spectral Forecast Model. L.Lefaivre, B. Dugas, H. Ritchie	Assessment of the interactions between the slow transients and the synoptic-scale eddies in a T32 general circulation model J.Sheng		

Tuesday/Mardi a.m. Room/Salle:ALUMNI AUDITORIUM/ AUDITORIUM des ANCIENS

PLENARY SPEAKERS/ CONFÉRENCIER INVITÉS
MIDDLE ATMOSPHERE WORKSHOP / ATELIER ATMOSPHÈRE MOYEN

Current Challenges in Middle Atmosphere Modelling

J. Holton, University of Washington

Impact of UARS Measurements on our Understanding of the Middle Atmosphere

J. Gille, NCAR

Tuesday/Mardi a.m. Session 1 Room/Salle 224

Air Quality / Qualité De L'air

Chair/Président: Phil Davies

Évaluation du dépôt sec des contaminants gazeux aux sites du réseau REMPAFAQ

Alain Robichaud[1]
Gilles Boulet[2]
Ghislain Jacques[2]

[1]*Ministère des Ressources naturelles, Direction de l'environnement 930 Chemin Ste-Foy, 6 ième étage, Québec, G1S 4X5, P.Q.*

[2]*Ministère de l'Environnement et de la Faune, Direction des réseaux atmosphériques, 2360 Chemin Ste-Foy, 2 ième étage, Québec G1H 6R1, P.Q.*

Le réseau REMPAFAQ (réseau de mesure des polluants atmosphériques en milieu forestier et agricole) a été établi dans le but d'étudier les impacts environnementaux sur les écosystèmes forestiers et agricoles. Un des objectifs majeurs de ce réseau est d'estimer la variation temporelle et spatiale du dépôt total et, en particulier, de la fraction sèche de ce dépôt et d'en déterminer sa variation hebdomadaire, mensuelle et annuelle. Malgré le progrès récent des méthodes de mesure du dépôt sec gazeux, celles-ci demeurent essentiellement inapplicables aux mesures en réseau. Ceci a provoqué un intérest considérable pour une approche alternative où les flux de surface sont déduits d'une part des mesures de concentrations en continu et d'autre part d'une vitesse de dépôt qui dépend à la fois des mesures météorologiques près du sol et des caractéristiques physiologiques fondamentales du couvert végétal de surface. La présente étude vise à caractériser quantitativement le dépôt sec aux sites du réseau REMPAFAQ en fournissant une méthode dévaluation de la quanti d'ozone absorbée par le couvert végétal à partir des mesures en continu aux sites du réseau REMPAFAQ. Pour ce faire, on a fait appel à un modèle de résistances multiples (Voldner et al.. 1986) où la résistance de surface est donné par Weseley (1989) modifiée par les travaux de modélisation de Jarvis (1976) concernant la résistance stomacale. On examine les variations mensuelles et horaires des niveaux d'ozone, de la vitesse de dépôt et du dépôt sec pour différents sites du réseau REMPAFAQ. Les applications potentielles de la présente étude sont les suivantes: 1) préciser le bilan de masse des différents polluants

gazeux échantillonnés en évaluant les quantités absorbées par les végétaux sur I 'ensemble du réseau à partir des concentrations mesurées, 2) établir un lien plus étroit entre les dommages aux écosystèmes et les niveaux des contaminants échantillonnés en termes de dose absorbée par les végétaux (quantité de dépôt sec) et non en termes des concentrations mesurées (comme cela est fait de façon traditionnelle), 3) Évaluation des mesures d'absorption pour d'autres gaz y compris certains gaz effet de serre.

Surface Mesonet Data for the 1993 Southern Ontario Oxidant Study

David Sills[1,2], Peter Taylor[1] and James Salmon[3]

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[2]Weather North, Burlington
[3]Zephyr North, Burlington

Meteorological measurements were made from a surface mesonet of 11 stations deployed in southwestern Ontario (roughly between London and Windsor) for three months during summer 1993 in connection with the Southeastern Michigan Ozone Study (SEMOS) and the Southern Ontario Oxidant Study (SONTOS). The surface mesonet deployment and the data set will be briefly described and the data will be used, together with related synoptic data, to illustrate the surface flows occurring in two periods with high ground level oxidant concentrations.

Tuesday/Mardi a.m. Session 1 Room/Salle 232

Atmospheric Data Assimilation /Assimilation des données atmosphériques

Chair/Président: Pierre Gauthier

Temporal and Spatial Variability of Hebdomadal Cycles in Ozone Time Series from the Lower Fraser Valley, B.C.

S.C. Pryor and D.G. Steyn

Department of Geography
University of British Columbia

Tropospheric ozone concentrations vary on a number of time scales; diurnally, hebdomadally, seasonally and annually. The variation of ozone concentrations on these different temporal scales provides information regarding the processes of ozone formation, scavenging and transport, and variations of these processes from location to location. For example, the differential behaviour of tropospheric ozone concentrations on workday and weekends (the so-called "Sunday effect" or hebdomadal cycle in ozone concentration time series has been interpreted as providing information regarding the sources of precursors of ambient surface level ozone (i.e. in situ photochemical production v transport) and destruction processes (e.g. local scavenging of ozone by NO emissions), and even the feasibility of different pollutant reduction strategies; the relative effectiveness of NO_x, or VOC controls to reduce ambient ozone concentrations. The form of the diurnal variability of ozone concentration time series has also been used to provide information regarding the formation, destruction and transport of ozone at rural and urban sites, and the relative magnitude of these "processes" in producing the observed ozone concentrations.

The Lower Fraser Valley is experiencing rapid population growth and it has been hypothesized that this growth and development will increase total regional ozone loading and cause changes to the spatial pattern of ozone concentrations due to changing emissions patterns (and even perhaps, as has been suggested in Atlanta, as a result of the urbanization enhancing the urban heat island and increasing net ozone formation independently of emissions increases). In this study spatial and temporal variability of hebdomadal and diurnal cycles within surface level O_3 and NO_x, time series from the Lower Fraser Valley are examined, where necessary "declimatized" to reduce the impact of meterological variability, and interpreted in the context of spatial and longer term temporal variability of precursor (NO_x and VOC) emissions.

Some Limitations on Four-dimensional Data Assimilation Imposed by the Nonlinearity in Barotropic β-plane Turbulence

Peter Bartello, Pierre Gauthier and Monique Tanguay

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A 4Dvar analysis aims at providing information at scales smaller than the large scale observations. It does so by seeking initial conditions (at t=0) that best fits data over an assimilation interval $t \in [0,T]$. The extent to which a 4Dvar analysis can accurately reproduce the initial conditions at these smaller scales depends on the mechanism by which information is transferred from scale to scale. To better understand how this transfer works, we have investigated the most geophysically relevant transfer mechanism in as simple a context as possible: the enstrophy cascade of barotropic ß-plane turbulence.

Only identical twin experiments were performed so that observations were generated from a model state X^*_0 and the starting point of the minimization X_0 was taken to be totally uncorrelated with X^*_0. When observations are provided at all scales and at every timestep, convergence can be reached even Though this flow is highly nonlinear but only if T does not exceed the decorrelation time. It is observed that there exists an optimum length for the assimilation interval. At first, the quality of the fit improves as T increases: this is a consequence of the dynamics of the model for which the large scale component of the flow controls the development of the smaller scales. But if T is increased further, beyond the decorrelation time, the initial conditions are no longer capable of determining the model state at a time T later and convergence cannot be reached anymore. If only the large scale component of the synthetic observations is used as observations and for T Corresponding to this optimal length, the analysis only fits the large scale component initially but at the end of the interval (t = T), it has evolved towards the true state at all

A New Three-dimensional Analysis Algorithm for the Canadian Global and Regional Data Assimilation Systems

Herschel Mitchell[1], Cécilien Charette[1], Clément Chouinard[1], Richard Hogue[2] and Jacques Hallé[2]

[1]Direction de recherche en météologie

[2]Canadian Meteorological Centre
Atmospheric Environment Service
Dorval, Qc, Canada

A fully 3-d analysis algorithm has been developed to replace the Split vertical/horizontal scheme which has been used in operational data assimilation at the Canadian Meteorological Centre for more than 15 years. The new algorithm is more accurate than its predecessor, especially with regard to the treatment of single-level data, Stich as aircraft and surface reports, and this his permitted the utilization of a much larger quantity of aircraft data

(including ACARS). The treatment of satellite profiles (SATEMs) has also been significantly modified: in the new algorithm these reports are assimilated as thicknesses over relatively thick layers instead of mandatory-level temperatures, as was the case previously. In conjunction with the development of the new algorithm, the forecast and observational error statistics were also Updated

Following a brief description of these changes, their impact on data assimilation cycles and the ensuing forecasts will be presented.

3D Variational Data Assimilation for a Global Spectral Model

Pierre Gauthier[1] and Pierre Koclas[2]

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A 3D variational data assimilation system (3Dvar) is currently being developed for the operational global spectral model (Ritchie, 1991) of the Canadian Meteorological Centre. This 3Dvar analysis is similar to what has been implemented at NMC (Parrish and Derber, 1992) and at ECMWF (Pailleux, 1992). Although a 3Dvar analysis is equivalent to a multivariate optimum interpolation scheme (Lorene, 1988) when the same assumptions are made, they differ in practice by the fact that the analysis increments are built globally in spectral space and data selection algorithms are no longer required. There are several reasons in favour of 3Dvar. First of all, there is its ability to assimilate more easily observations indirectly related to model variables which is often the case for satellite data. Second, it is also possible to impose that some dynamical constraints be satisfied by the resulting analysis. Finally, a 3Dvar analysis is a necessary first step in the development of quadri-dimensional variational data assimilation deemed to be the most promising and feasible data assimilation approach for numerical weather prediction. Preliminary results obtained with this system will he presented to point out how the background error statistics influence the analysis, especially differences brought in by using a non separable representation of the forecast error correlations.

Tuesday/Mardi a.m. Session 1 — Room/Salle Alumni Aud. / Aud des Anciens

Modelling of chemical transport / Modélisation du transport des produits chimiques

Chair/Président:Jack McConnell

Inclusion of Chemistry in the Canadian Global Spectral Forecast Model

J.W. Sandilands[1], J.W. Kaminski[2], H. Ritchie[3], J.C. McConnell[1, 2, 4], and M. Danilin[4]

[1]Department of Physics and Astronomy, York University
[2]Centre for Research in Earth and Space Science, York University
[3]Reserche en Prévision numérique, Environment Canada
[4]Department of Earth and Atmospheric Science, York University

This work is part of a larger effort to include an interactive stratospheric chemical module in the Canadian Meteorological Centre Global Spectral Forecast Model for generating long range ozone forecasts. The chemistry module to be included [Kaminski, Ph.D. Thesis, 1994; Danilin, this congress] contains a complex description of stratospheric processes, including HO_x, NO_x, ClO_x, and BrO_x chemistry. Heterogeneous chemistry is allowed to occur not only on Type I and II PSC surfaces, but also on stratospheric sulphate aerosols. It is the eventual goal to use this chemistry module with the CMC SEF model in order to assess the impact of carrying ozone as a prognostic on long range forecasts. This phase of the work will concentrate on examining the effect of different spatial resolutions on chemical tracers, in order to determine the optimal horizontal and vertical resolution for the chemical module. Starting with simple sulphur aerosol chemistry, a sensitivity study of the 1991 Mount Pinatubo eruption will be examined to determine the interplay between chemical and dynamical terms of the continuity equation at low stratospheric heights. In addition a comparison with aerosols measurements from the AVHRR instrument will be undertaken in order to assess the quality of the lower stratospheric dynamical forecast of the CMC Global Spectral Forecast Model as revealed by the aerosol transport. A progress report on the status of this work will also be given at the Congress meeting.

Statistical and Dynamic Ozone Forecasts for Canada

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A. Dastoor (ARQI) and M. Vallée (ARMF)

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Using the Canadian Global Spectral Forecast model as a starting point, techniques are being developed in Canada to forecast total column ozone thickness for up to two days in advance. Two separate methods are under development. The first is a statistical "perfect prog" procedure which consists of a set of six regression equations relating the total ozone thickness to lower stratospheric and upper tropospheric meteorological variables such as temperature, vorticity and geopotential height. These equations have been run operationally during the summer of 1993 to produce total ozone forecasts for the northern hemisphere, using forecast values of the meteorological variables from the global model. The total ozone thickness forecasts are fed to an empirical relationship among ozone thickness, solar zenith angle and flux of ultraviolet radiation at the earth's surface to generate UV flux values for use in Canada's UV index forecast program. Verifications have been produced for 18h and 42h total ozone forecasts from the summer of 1993. Verifying observations come from the Canadian network of 13 Brewer spectrophotometers, and thus the results are valid for Canada only. The results indicate an overall error level of 11 Dobson units.

The other main thrust of the ozone forecasting program is the development of a dynamic ozone analysis and forecasting procedure. Again, the global spectral model is being used, with ozone incorporated in the model as a passive tracer. Initially, no sources and sinks of ozone are being considered; the ozone is simply advected in the model. For this, a three-dimensional initial ozone field is required, and is produced by carrying out a horizontal analysis of total column ozone, then distributing the ozone in the vertical. The first dynamical forecasts are currently being run. Work is proceeding in parallel on both the statistical and dynamical forecasting techniques, and intercomparisons will be presented at the conference.

A Study of Winter Arctic Polar Chemistry with a 3-D Chemical Transport Model

Jacek W. Kaminski, J. Wade Sandilands, John C. McConnell, and Michael Yu. Danilin

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York University,
North York, Ontario M3J 1P3

We have previously presented results from a 3-D global Chemical-Transport Model (CTM) that has been applied to simulate stratospheric conditions for the winter of 91-92 in the Northern hemisphere using objectively analyzed wind and temperature data from the Canadian Meteorological Centre. This winter simulation without sulphate reactions results in the production of CIO and its retention within a relatively isolated vortex. Here we present new results for the January (and February) 93 simullation both with and without sulphate chemistry. In the former case the air was heterogeneously converted in the model but it remained as mostly chlorine nitrate. We have improved the representation of heterogeneous chemistry in the model and included sulphate aerosols (cf Danilin, this congress) The role of the heterogeneous reactions on the sulfate aerosol and polar stratospheric clouds in the winter 93 scenario will be presented. Also, a comparisons of the model results with the available satellite data (TOMS, MLS) will be presented.

Tuesday/Mardi a.m. Session 1 Room/Salle 233

WOCE / ECOM

Chair/Président: B. Ruddick

The Interactions of the Sub Polar and Sub Tropical Gyres to the South and East of the Grand Banks of Newfoundland

R.Allyn Clarke

Ocean Circulation Division
Physical and Chemical Sciences
Bedford Institute of Oceanography

The Gulf Stream, Labrador Current and North Atlantic Current form loops, bifurcations, retroflections and eddies in the region of the ocean known as the Newfoundland Basin. The local bathymetry interacts with deep western boundary currents to produce fronts and boundaries between the new water masses from the Nordic and Labrador seas and those from the subtropical gyre and the South Atlantic. During the summer and fall of 1993, a WOCE control volume study was initiated in this region to provide firmer estimates of the sources and strengths of all the currents in this complex region. The programme involves a moored array of current meters and inverted echo sounders, RAFOS float releases within the main pycnocline and repeat hydrography with a full suite of tracers and along track Acoustic Doppler Current Profiler sections. The hydrographic sections are largely aligned along TOPEX/POSEIDON orbits. We will use the fall 1993 hydrographic data set to illustrate how the addition of the satellite, float and tracer data through numerical techniques will improve our estimates of the circulation field.

Interdecadal Variability - A New Perspective

Richard J. Greatbatch, Sheng Zhang and Wenju Cai

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North Atlantic sea surface temperature exhibited a general warming during the 1920's and 30's, followed by a cooling in the 1960's. There is evidence that the North Atlantic circulation may have played a role in

determining these changes, an idea that goes back to Ejerknes (1964). The GFDL coupled ocean-atmosphere model exhibits an interdecadal oscillation in the North-Atlantic in which changes in the thermohaline circulation in the ocean play a fundamental role. New ideas regarding the mechanism of this oscillation will be discussed.

Measurement of Vertical Diffusivity in the North Atlantic Tracer Release Program

Neil Oakey, Barry Ruddick

Department of Fisheries and Oceans
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Department of Oceanography
Dalhousie University
Halifax, N.S.

The North Atlantic Tracer Release Experiment (NATRE) has been done to study vertical mixing processes. The central focus of the experiment was the study of diffusion of a tracer injected in May 1992 in the eastern North Atlantic and followed for a year in three surveys by Ledwell and Watson. They measured diffusivity from the vertical rate of spread of the injected tracer.

In our studies of turbulence and microstructure using the EPSONDE vertical profiler we have estimated vertical diffusivity from two field experiments at six months and at one year after the injection of the tracer. These measurements enable us to independently estimate the vertical diffusivity from both temperature fluctuations and from turbulent dissipation. Our results from both these measurements are consistent with the direct tracer measurements and indicate a vertical diffusivity of order 1 to 2 x 10^{-5} $m^2 s^{-1}$ for the main pycnocline at a depth of about 300 meters in the Canary Basin. We have also used our microstructure results to try to identify the processes causing this mixing and also to test various models used in the study of mixing.

We will present results from the analysis of the restructure data obtained on the two cruises, including estimates of dissipation and identification of physical processes as well as outlining future work.

Tuesday/Mardi a.m. Session 2 — Room/Salle 224

Air Quality / Qualité De L'air

Chair/Président: Phil Davies

Air Quality Modelling of the Lower Fraser Valley

Mark Hedley, Rob McLaren, George Paraskevopoulos, Susan Bohme, Don Singleton

Institute for Environmental Chemistry
National Research council

In late July of 1985, the Lower Fraser Valley experienced ground level ozone concentrations in excess of the Canadian standard of 82 parts per billion. A nonhydrostatic meteorological model, MC2, which was developed by the Atmospheric Environment service Rescherche en Prévision Numérique and the université du Québec à Montréal and modified by the Institute for Environmental Chemistry is used to simulate the meteorology during

this episode. The air quality is modelled using CALGRID, a photochemical model written by the California Air Resources Board. Results of the simulations are compared against the measured ozone concentrations from several sites within the Lower Fraser valley.

Modelling of Ozone Formation at a Rural Site in Southern Ontario

D. Plummer

Centre for Research in Earth and Space Science
York University, North York, Ontario, M3J 1P3, Canada

J. McConnell, P. Shepson, D. Hastie, and H. Niki

Centre for Research in Earth and Space Science and
Centre for Atmospheric Chemistry
York University, North York, Ontario, M3J 1P3, Canada

A one-dimensional time dependent photochemical diffusion model has been used to simulate the chemical and vertical transport processes occurring at a rural location within Southern Ontario. The model output has been compared with the extensive measurements of key atmospheric trace gases which were made at a rural site in Southern Ontario as part of SONTOS (Southern Ontario Oxidant Study) during the summer of 1992. In particular, the measurements include various VOCS, odd nitrogen components and RO_x which have also been explicitly included in the model. This study focuses on the data obtained for the 6th August, 1992. During the day the air reaching the site was characteristic of clean air up until about 6:00 PM EDT when polluted air reached the site. For the relatively clean air period (with the winds from the west) the model is able to reproduce the observed variation of key species well. Under these clean air conditions, dry deposition of HNO_3 and PAN as well as a widespread NO flux from the soil, control the diurnal variation of NO_x and NO_y in the boundary layer. Isoprene, though the peak concentration is less than 0.3 ppb on this day, is clearly one of the dominant non-methane hydrocarbons. The effects of varying the NO_x and isoprene flux on the chemistry is also investigated.

The Relative Roles of Bromine and Chlorine in Polar Sunrise Depletion of Tropospheric Ozone

Apollo Tang[1], Jack C. McConnell[2]

[1] Department of Physics and Astronomy, York University
[2] Department of Earth and Atmospheric Science

Sudden and dramatic decreases in ozone occur during polar sunrise in the Arctic boundary layer. Measurements (direct and indirect) indicate the presence of active bromine and chlorine atoms. We have attempted to simulate some of the features of this phenomena using a simple 1-D model incorporating heterogeneous chemistry with measured alkanes, alkenes and acetylene. Simplistic assumptions regarding the heterogeneous chemistry suggest that the decrease in ozone may be driven by bromine chemistry while chlorine chemistry, although driving alkane destruction, does not play a major role in ozone destruction per se. In this study we investigate the role played by the self reactions of the R02 radicals generated in this low NOx environment by the Br and Cl atoms and in particular look for evidence of 'finger prints" of the halogen atom chemistry.

Cart Decision-Tree Statistical Analysis and Prediction of Maximum Surface Ozone for the Vancouver, Montreal, and Atlantic Regions of Canada

William R. Burrows
Environment Canada, Atmospheric Environment Service, Meteorological Research Branch
Downsview, Ontario

Mario Benjamin
Environment Canada, Atmospheric Environment Service - Quebec Region

Stephen Beauchamp
Environment Canada - Atmospheric Environment Service - Atlantic Region

Edward R. Lord, Douglas McCollor, Bruce Thomson, Walter Gilles
Environment Canada, Atmospheric Environment Service - Pacific Region

Prediction of daily maximum surface ozone (O_3) concentration was begun in the spring of 1993 for selected Canadian regions in order to advise the public of air quality. There is a need for forecast guidance, particularly for prediction of surface O_3 concentration levels near or exceeding the Canadian warning standard of 82 ppb. Occurrences of O_3 in such concentrations are relatively rare in the three regions, with probability of occurrence in the range 2% to 5% at most sites, thus reliable prediction is difficult. Mesoscale numerical meteorological-photochemical models are not currently available for routine use in operations, but the capability exists for development and use of multi-variable statistical forecast techniques for prediction of daily maximum O_3 concentration. Surface and upper air meteorological predictors and other predictors were matched with several years of observed daily maximum O_3 concentrations for the months of May to September. Classification and Regression Tree (CART) decision-tree analysis was done for five sites in the Vancouver-Lower Fraser Valley region, eight sites in the Montreal urban area, and four sites in the Atlantic region. The decision-trees were found to fit the data reasonably well, and the rules for node-splitting were found to be physically realistic. Variance explained by the CART decision-trees and importance rankings of predictors are shown for the sites and details of the decision-tree for one site in each region are presented.

Same-day forecasts (issued the morning of the day of validity) were tested with independent data for Vancouver and Montreal for each of the five years 1988-1992. (There was insufficient number of years of data for the Atlantic region to do the test). Forecast accuracy is enhanced by using the ensemble of separate forecasts for all sites in a small region to make one forecast that applies everywhere in the region. Verification of ensemble forecasts show the technique has reasonably good skill in forecasting surface O_3 concentrations near or exceeding the Canadian warning standard. A computer version of the technique has been provided for use in the regional forecast offices.

Tuesday/Mardi a.m. Session 2 — Room/Salle 232

Atmospheric data assimilation / Assimilation des données atmosphériques

Chair/Président: Pierre Gauthier

The 4D-VAR Algorithm as a Sub-optimal Smoother

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The Kalman smoother is a generalization of the Kalman filter algorithm, which permits the processing of future

observations. The Kalman smoother can be derived from stochastic control theory, which is a generalization of the four dimensional variational (4D-VAR) algorithm, that does not require a perfect model. The error characteristics and the four dimensional (spatial and temporal) weights for the perfect and imperfect models are examined. It is found that future observations improve the analysis particularly when the flow is inviscid or unstable and the model is perfect. It is also shown that applying the 4DVAR when the model is actually incorrect, causes significant errors on the forecast/analysis statistics and weights given to observations particularly at the beginning and end of the association period.

Practical Problems Related to the Assimilation of Satellite Humidity Data

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The Canadian Meteorological Centre (CMC) currently assimilates full disk GOES retrievals of humidity profiles derived at six standard levels. The profiles are statistically inferred from cloud classification using infrared alone at night and visible and infrared in daytime. The 6.7μ water vapour channels is also used to infer upper tropospheric humidity from cloud class dependent relationships (see Garand, JAM 1993). A central problem is to give proper weight to the data with respect to the background field (6-h forecast). Original weights based on collocation with radiosondes were found to be too largewith 6-h forecast becoming more and more similar to satellite data observed at the same time. One explanation is the cumulative influence of the data (200 km resolution every six hours). An other reason is that the horizontal correlation of errors was neglected. These correlations were found to be non negligible for neighbouring soundings of the same cloud cover class up to about 400 km. We will present modeled correlations of horizontal errors based on real data as well as results of WITH-SAT versus NO-SAT 10-day assimilation cycles showing the influence of the Satellite humidity data on analyses and forecasts.

One-dimensional Variational Assimilation of SSM/I and GOES Retrievals of Atmospheric Water Vapour

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Total Precipitable Water (TPW) retrieved from Special Sensor Microwave/Imager (SSM/I) brightness temperatures and specific humidity retrieved from Geostationary Operational Environmental Satellite (GOES) radiances are assimilated using a one-dimensional (1-D) variational assimilation technique. The time periods analyzed are for 15 days in June 1991 and March 1992. Both satellite retrieval techniques are empirically based. The study is divided into two parts.

First, collections with radiosondes are performed to assess the quality of the satellite water vapour retrievals. A global collocation study over the oceans between SSM/I TPW retrievals and 6-h numerical weather prediction forecasts (trial fields) of TPW shows that the rmse (root mean square error) are comparable: 4.7 kg/m^2 and 5.0 kg/m^2 respectively. A collocation study over both the oceans and land between GOES retrieved TPW and 6-h forecasts of TPW yields respective values for the rmse of 4.6 kg/m^2 and 4.4 kg/m^2 in the mid-latitudes and 6.8 kg/m^2 and 5.9 kg/m^2 in the tropics.

Secondly, SSM/I TPW and GOES specific humidity are assimilated via a 1-D variational technique which minimizes the error variance of the analyzed (or assimilated) field. The 6-h numerical weather prediction forecast of humidity is used as a background field. The rmse of the analyzed field of TPW is reduced by 1 kg/m^2 with respect to the 6-h forecast when SSM/I TPW is assimilated and 0.6 kg/m^2 when GOES retrievals of specific humidity are assimilated. In the upper levels of the troposphere (above 600 mb), the reduction in rmse of

specific humidity is largely due to GOES retrievals whereas in the lower atmosphere (850 mb to 700 mb) the reduction is mostly due to the assimilation of SSM/I TPW. This emphasises the complementarity of using multisensor retrievals.

Planning for Variational Data Assimilation of TOVS Radiances in the Canadian Data Assimilation Procedure

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Satellite data has been used in the current Optimum Interpolation (OI) System at the Canadian Meteorological Centre (CMC) for over fifteen years and yet their impact is still at best marginally positive. There are serious difficulties in assimilating these data and many are related to intermediate processing steps related to converting radiance data to a form acceptable by current OI analysis systems, i.e. layer-mean temperature soundings. This is currently done by NESDIS and the products are Commonly referred to as SATEM and TOVS sounding. Currently, only the SATEM soundings are assimilated in a final 3D-OI step with all other data types.

In a variational approach, the minimization of the analysis error is done in the respective spaces of each type of observations and there is no need for the first step of the current system which involves converting radiances LO intermediate layer-mean temperatures. Effectively, with the help of the forward radiative transfer model find its adjoint, it is possible LO minimize the error directly in radiance space. Further, in it full 3D-VAR system, all radiance dat@i lire treated together consistently with the trial field and all other types of data in one minimization principle. The current OI system's use of SATEM data will be presented and compared to a proposed hybrid 1D-VAR/3D-OI based system using TOVS data and the relative merits of each highlighted with results. Finally, the extension of the 1D-VAR system to the full 3D-VAR system will be discussed.

Tuesday/Mardi a.m. Room/Salle Alumni Aud./ Aud. des Anciens

MAM results and Downward Control / Les résultats du "MAM" et le post-contrôle

Chair/Président: T.G. Shepherd

Preliminary Results From a Climate Simulation made with the Canadian Middle Atmosphere Model

Stephen Beagley and Jean de Grandpre

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York University

John Fyfe and Norman McFarlane

Canadian Centre for Climate Research
University of Victoria

The Canadian middle Acmosphere model is currently being developed as a global atmospheric general circulation model which fully resolves the region between the surface and the mesopause. A preliminary, but nearly state of the art version of this model has been constructed from an upwardly extended version of the third generation Canadian Climate Centre AGCM. A multi-year simulation has recently been completed with this model. A brief description of this model is provided and selected results from this simulation are presented and compared where possible with observed climatic data.

Sensitivity of Climate Simulations to the Vertical Structure of Gravity-Wave Drag

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Although parameterizations of orographic gravity-wave drag are now commonly used in AGCMs there remains considerable uncertainty as to the vertical structure and magnitude of the drag force which should be applied. Estimates produced by Klinker and Sardeshmukh (1992) suggest that the parameterizations based on Palmer et al (1986) or McFarlane (1987) may overestimate the mechanical dissipation in the lower stratosphere. Other more recent formulations impose a substantial part of the drag force in the troposphere below the level where gravity-wave breaking usually occurs in the lower stratosphere. This paper presents results from an ensemble of simulations for the northern winter season made with upwardly extended versions of the Canadian Climate Centre GCM which resolve the stratosphere and (for a subset of the simulations) the mesosphere as well as the troposphere. These simulations demonstrate that the response to varying the magnitude and vertical structure of the gravity-wave drag is quite variable, in part because stratospheric warmings occur-red for some smaller magnitudes of the gravity-wave drag force but not for larger values or when there was no imposed gravity-wave drag.

Estimates of Downward Control in the Canadian MAM

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Results from the first climate run of the Canadian Middle Atmosphere Model are used to estimate the "downward control" associated with various resolved and parameterized mechanical drag processes. The resolved drag processes consist of the Eliassen-Palm flux convergence, while the parameterized drag processes include gravity-wave drag, Rayleigh friction, and vertical and horizontal diffusion. Particular emphasis is placed on the vertical extent of the control in certain critical regions such as the tropical and extratropical tropopause, and the stratospheric polar vortices. The results are compared with the recent observational and modelling analyses of Rosenlof & Holton (1993). The downward-controlled circulation is also compared with the diabatic circulation in the model, in order to assess the validity of the assumptions underlying the downward control principle.

"Downward Control" and the Role of Gravity Waves in Determining the Circulation of the Polar Winter Stratosphere

Byron A. Boville, National Center for Atmospheric Research

One of the major problems found in general circulation model simulations of the middle atmosphere is that the austral winter polar vortex is much too strong and the polar temperatures are much too cold throughout the middle and upper stratosphere. It is shown in this paper that this bias can be removed by including the effects of gravity waves which break almost entirely in the mesosphere. The easterly momentum forcing produced by the breaking gravity waves results in downward motion on the poleward flank of the jet. The adiabatic compression associated with the downward motion can significantly increase the polar temperatures down to below 30 km. The mechanism is demonstrated in a simple two-dimensional model and shown to work when applied in a general circulation model (the NCAR CCM2). It is inferred that gravity wave breaking plays an important role in the dynamics of the Antarctic polar vortex, although the parameterizations used in this study are probably not very accurate representations of the gravity wave spectrum present in the atmosphere.

Tuesday/Mardi a.m. Session2 — Room/Salle 233

WOCE / ECOM

Chair/Président: B. Ruddick

The Gulf Stream and Associated Currents at 50W: Relationship between Sea Level and Volume Transport

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Long-term moored current measurements south of the Grand Banks along 50W obtained during 1988-1990 show a Gulf Stream with an energetic barotropic component. The measurements also reveal weakly vertically-sheared westward mean flows between the Gulf Stream and the Grand Banks to the north which provide a link between the subpolar and subtropical circulations in the western North Atlantic. Proxy sea-level records along the mooring line were created by spatial integration of the direct measurements, augmented by measurements of geostrophic shear from historical hydrographic measurements at the uppermost levels. Simultaneous measurements of sea-level variability from the GEOSAT altimetric mission were use to validate the proxy sea-level records. Regression models relating sea-level and mass transport were then developed. This approach shows promise for monitoring upper-level mass transport using sea-level measurements from future altimetric missions.

Lagrangian Observations of Inertial Motions in the Northeast Pacific: Results from Multiple Satellite-tracked Drifter Deployments.

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We examine the spatial and temporal scales of wind-induced inertial motions observed in the upper layer of the northeast Pacific using clusters of shallow and deep satellite tracked drifters deployed as part of the Canadian contribution to the World Ocean Circulation Surface Velocity Program (WOCE-SVP). A total of 85 drifters have been deployed within this program. Focus is on two-hourly sampled positional data from nine drifters deployed during August and September 1990 in the general vicinity of Station P (50 N, 14 W) where water property structure was available for the time of drifter deployments. By using clusters of drifters, in which individual buoys were separated initially by distances of 100 m, we are able to examine buoy dispersion and spatial coherence patterns over a wide range of space and time scales. The combined use of shallow (15 m) and deep (120 m) drogued drifters makes it possible to examine simultaneous motions above and within the main pycnocline. Because of the comparatively short time between satellite fixes, we are able to compare space-time and frequency-wavenumber characteristics of the near-inertial motions with those of higher frequency semidiurnal tidal motions.

WOCE Hydrological Survey in The Sea of Okhotsk

Colin Taylor

University of British Columbia

Until recently, only limited hydrological data on the Sea of Okhotsk has been available to western scientists. This area of the world providing ventilated water to the North Pacific and a full study of the area could define this sea Intermediate Water. In Sept. 93, an international expedition of Canadian, Russian and American scientists conducted hydrological surveys at over 30 points in the area, extending along a line from approximately 45N 154E in the Pacific, through the Bussol about 58N 142E on the Kashevarov Bank. CTD data collected along this line illustrates an intense thermocline at the surface of the sea, with a temperature minimum at about 80m as well as vertical mixing in the upper 1200m of the Bussol that depth, the water properties at the testing stations were relatively similar across the strait.

Pacific Intermediate Water in the Sea of Okhotsk

Howard Freeland, C. Wong and Frank Whitney

Institute of Ocean Sciences, Sidney, B.C.

The densest water formed in the Pacific Ocean formed in the N.W. Pacific,is the Pacific Intermediate Water (PIW) formed probably in the Sea of Okhotsk or along the Kamchatka Peninsula. It is important to know how much Intermediate Water is formed, and how rapidly it is formed since this puts limits on the ventilation rate of the N. Pacific.

In September 1993 a joint Canada/U.S./Russia cruise occupied 30 stations comprising the most western segment of WOCE line P1 from the open Pacific, through the Bussol' Strait (Kuril Islands) and through the Sea of Okhotsk. Sampling was for the standard CTD variables, nutrients, carbonate chemistry and CFC-11 and CFC-12.

The talk will present a picture of some aspects of the deep circulation in the Sea of Okhotsk. In particular it will present evidence for deep water exchange through the Bussol' Strait and will discuss the properties of PIW within the Sea of Okhotsk. A distinct water mass has been observed within the Sea that has sigma-t values ranging from 27.0 to 27.3, somewhat greater than the values normally attributed to PIW in the N. Pacific (26.8 to 27.1). The CFC-11/CFC-12 ratio indicates that this water mass is old, and was last in equilibrium with the atmosphere around 1970. Thus it is concluded that PIW has not recently been formed in the Sea of Okhotsk, and that this Sea is not a major site for ventilation of the N. Pacific.

Tuesday/Mardi p.m. Room/Salle:ALUMNI AUDITORIUM/ AUDITORIUM des ANCIENS
Session 3

PLENARY SPEAKERS/ CONFÉRENCIER INVITÉS
SESSION ON FISHERIES OCEANOGRAPHY
SESSION SUR L'OCÉANOGRAPHIE DES PÊCHES

The Changing Ocean Environment in Relation to Carrying Capacity and Ability to Support Commercial Fisheries

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Understanding the reasons for abundance fluctuations of fishes is necessary for the management of fish stocks. Abundance changes can occur because of human actions such as too high a fishing mortality or because of natural abundance changes. Natural abundance changes can be short-term or interannual changes and long-term or interdecadal changes, complicating attempts to identify environmental factors that cause fish abundance changes. Strategic management of fisheries requires separating fishing effects from environmental effects because rebuilding strategies will be different if abundance declines result from overfishing or from environmental factors. If declines in abundance are mainly a result of a natural change in carrying capacity, management actions would not be expected to rebuild abundance to previous levels.

In the Pacific there are several examples of the importance of including ocean effects in fisheries management. The Pacific halibut fishery is managed using a model that assumes there are long-term natural abundance trends. Extreme fluctuations in the abundance of the very important Japanese sardine stocks are believed to be largely independent of the fishery. Recent studies have identified long-term, climate-ocean-related fluctuations in the abundance of Pacific salmon. Even when fishing effects are believed to be responsible for declines in abundance, such as in the very large walleye pollock fishery, a case can be made that implicates the ocean environment.

Understanding the reasons for abundance changes is not only necessary for effective and efficient fisheries management now, but it is also essential if we are to management fisheries in the changing environment of the future.

Tuesday/Mardi p.m. Session 3 Room/Salle 231

Atmospheric - Surface forcing / Interaction de surface atmosphérique

Chair/Président: Tim Oke

Comparison of Heat Fluxes from Summertime Observations in the Suburbs of Four North American Cities

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Directly measured energy balances for suburban areas in Chicago, Los Angeles, Sacramento and Tucson are presented in the form of ensemble plots of the diurnal patterns of the fluxes and the flux partitioning. In general the diurnal form of the energy partitioning is very similar for the four cities, suggesting that simple parameterization schemes may be appropriate. The greatest discrepancy is found for Chicago where frequent rain events interrupt the patterns. In the other cities daytime Bowen ratios appear to be related to the amount of irrigation of urban vegetation

Relative Efficiencies of Turbulent Transfer of Heat, Mass and Momentum over a Patchy Urban Surface

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The study uses observational data from a suburban site in Vancouver, B.C. to investigate the relative facility with which heat, water vapour and momentum are transported by turbulence in the unstable surface layer. The ratios of linear correlation co-efficients r_{wT}/r_{uw} and r_{wq}/r_{uw} increase approximately linearly with instability and are generally smaller than typical rural values, due to bluff body effects. The ratio r_{wT}/r_{wq} is greatest near neutral and larger than unity at all stabilities. This inequality may be caused by the complex source/sink patterns of the urban surface, cloud effects on the radiative forcing and by the unusually well developed interaction between the surface and boundary layer. Inequality of transfer between T and q will make it difficult to measure turbulent fluxes for cities using standard gradient approaches.

Tuesday/Mardi p.m. Session 3 — Room/Salle 233

Atmospheric dynamics - 1 / Dynamique de l'atmosphère-1

Chair/Président: R. Laprise

A Coupling Mechanism for Wind and Waves

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We present a simple model for the dynamics which couple the atmospheric boundary layer and wind-generated waves.

The model is empirically motivated by parameterizations for the seastate-dependent drag coefficient and sea surface roughness derived by Smith et al (1992) from HEXOS measurements. Estimates are made for the effect the coupling dynamics has on predicted sea state parameters such as spectral wave energy and sea surface fluxes of momentum. Results are verified with observations collected during the CAL/VAL experiment of Dobson and Vachon (1994). We demonstrate that inclusion of the coupling dynamics is important in order to systematically improve wave modelling. The effect of the coupling dynamics is particularly important for young waves in the presence of high wind speeds. A tendency to improve estimates of maximum wave heights is achieved.

Dynamics of Forecast Errors and Extended Kalman Filtering for Burgers' Equation

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Typical solutions of Burgers' equation presents a frontogenesis stage followed by a decaying stage. The dynamics of the mean, variance and correlation of forecast errors is examined and compared with theory. The validity of the tangent linear approximation for predicting the variance and error correlation is assessed by comparing results with Monte Carlo simulations. The essentials of forecast error dynamics is established by using the continuous formulation for the evolution of forecast error statistics. Diagnostics are presented in terms of convergence of forecast errors due to the advection by the background wind. The effect of diffusion, although negligeable during frontogenesis is found to develop distinctive features in the forecast error correlation pattern. The ensemble mean forecast is investigated by using second order theory. Results are compared with Monte Carlo simulations. Also, implications for data assimilation of fronts are presented with extended Kalman filtering experiments.

The second part presents the effect of observations. The extended Kalman filtering theory is reviewed and we point out, that in addition to the tangent linear approximation, the application of EKF to NWP involves an approximation in the equation for the propagation of the covariance of forecast error errors. This appoximation changes the nature of the matrices calculated with this algorithm. Ensemble of realization of EKF with only one observation is used to assess the properties and limit of validity of EKF. Results showed that the position of the observation with respect to the front is of primary importance for EKF and that the size of the initial errors is secondary. It is showed that when the EKF is used in regimes where the tangent linear approximation is not strictly valid, the EKF produces, on average, a systematic estimation error with a bias towards the ensemble mean solution. When the system is observable, the EKF error bias is gradually removed as observational information accumulates, so that the estimated state converges toward the truth.

Sensitivity of Simulated Madden-Julian Oscillations to Cumulus Parameterization Schemes in CCC GCM

Jian Sheng

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The Maddon-Julian oscillation simulated by the Canadian Climate Centre general circulation model (CCC GCM) is identified by the technique of Principal Oscillation Pattern (POP) and compared with that observed in the real atmosphere. The results are based upon two Integrations of the CCC GCM, one with the parameterization of penetrative cumulus convection (EXPl) and the other with the moist convective adjustment scheme (EXP2)

From both integrations, the tropical Madden-Jullan oscillations can be detected as the first POP of the 200 hPa velocity potential along the Equator. The disturbances show a distinctive wave number one structure with the strongest local amplitude found in the longitudes corresponding to the region of Asian monsoon. The phase speed of the- eastward wave propagation is higher in the eastern Pacific and lower in the Monsoon region where the convective activities are strongest.

These features are in good agreement with the observations. In contrast to the real atmosphere, a double-peak structure of the velocity potential can be found in EXP2. The energy spectrum of the velocity potential peak at about 38 days for EXPI, which is somewhat shorter compared to the observed periods of 40-50 days. On the other hand, two spectral. peaks can be clearly identified for EXP2, one with a period of 24 days and the other with a much lonqer period, somewhere near 112 days - Both peaks appear statistically significant at 5% level. Long term data of the observed atmosphere show little indication of such spectral separation.

The wind and height fields associated with the first POP show very similar patterns in EXPL and EXP2. They resmble, to some extent, the baraclinic response of the.tropical flow to a heat source traveling eastward. At the upper level, Rossby waves propagate westward from the source region with winds generally following the height contour, whereas Kelvin waves propagate to the east with strong cross-contour flow near the Equator. At the lower level, the flow is essentially reversed, When the centre of the disturbance is moved to the eastern Pacific, its amplitude weakens.

In summary, the CCC GCM does a reasonable job, in both EXPL and EXP2, of simulating the structure of the Madden-Jullian oscillations. The penetrative convection scheme gives a better shot at simulating the frequency of the disturbances, although the waves still traval too fast in the model. The moist convective adjustment scheme, on the other hand, assigns two different frequencies to the oscillation. It is seen that the simulation of the Madden-Julian oscillation is sensitive to the details of the cumulus parameterization scheme used in the model.

Generation of Moist Potential Vorticity in Extratropical Cyclones

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Department of Physics
University of Toronto

The mechanism of moist potential vorticity (MPV) generation in a three-dimensional adiabatic and frictionless flow is investigated. It is found that MPV generation is governed by baroclinic vectors and moisture gradients. Negative (positive) MPV can be generated in the region where baroclinic vectors have a component along (against) the direction of moisture gradients. According to the numerical simulation of a typical midlatitude cyclone, negative MPV first appears in the north end of the cold front zone at the development stage and then intensifies in the bent-back warm front at the mature stage. After the cyclone matures, the negative MPV regions progress toward the unsaturated part of the warm core, and take place along the cold front in an unsaturated environment.

It is found that the Boussinesq form of the governing equations does not capture the significant development of MPV in midlatitude cyclones.

Tuesday/Mardi p.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 3
Atmospheric Waves / Ondes atmosphériques
Chair/Président: Norman McFarlane

Internal Gravity Wave Braking in the Middle Atmosphere

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We present results from analyses of the stability of nonhydrostatic plane internal gravity waves. The present analyses differ from previous studies (e.g. Fritts and Yuan 1989) in that the propagating nature of the basic finite amplitude wave is taken into account, and three-dimensional perturbations are considered. The roles played by various mechanisms such as Kevin-Helmholtz instability, convective instability and slantwise-static instability are examined in detail. It is shown that gravity wave instabilities differ in significant ways from their steady flow counterparts. The present results suggest significant revisions to the standard picture of the saturation of vertically propagating internal waves. Implications with respect to momentum transport and the parameterization of gravity wave drag will be discussed.

Atmospheric Tides in the Mesosphere and Thermosphere as seen by the Wind Imaging Interferometer (WINDII) on the Upper Atmosphere Research Satellite.

Charles McLandress, B.H. Solheim, Y. Rochon and G.G. Shepherd

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WINDII, the Wind Imaging Interferometer on board the Upper Atmosphere Research Satellite measures winds, temperatures and emission rates from a variety of atmospheric species. In this presentation wind data for March and April 1993, obtained from the OI 557.7 nm (green line) emission, is analyzed to identify migrating solar tides.

The tides are extracted by separating each day's wind measurements into ascending and descending orbits, zonally averaging these fields and then binning the entire two month's data into one hour intervals of local solar time. The resulting dataset, which is a function of local time, latitude and altitude, is then sliced in different ways to examine either the latitudinal structure of the wind fields at fixed local times or the local time behaviour at specific latitudes.

The structure of the wind fields reveals distinct patterns of symmetry and antisymmetry with respect to the equator. At low latitudes in the 90 to 120km altitude range the propagating diurnal tide with a vertical wavelength of about 25 km is clearly visible. At higher latitudes features characteristic of the semidiurnal tide are seen. in the upper thermosphere the vertical variations diminish, which is indicative of strong diffusive processes in this part of the atmosphere. Finally, a comparison of these observations to the Forbes' 1982 tidal model is presented. The WINDII data and the model results show remarkable similarity with the WINDII data, however, showing a slightly shorter vertical wavelength of the diurnal propagating tide.

Equatorial Waves In Planetary Atmospheres

XiaoqingLi

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Two types of numerical model based on the linearized primitive equation on an equatorial β-plane have been developed in order to study impact of equatorially trapped planetary waves on the dynamics of planetary atmospheres. Compared to some other recent 2-dimensional numerical model in this context, improvements and extension have been made to consider the effects of wave breaking and saturation process and a radiation condition at the top boundary.

For the Earth's atmosphere, emphasis is placed on the well-known quasibiennial oscillation (QBO) and its forcing agents, the Kelvin and mixed Rossby-gravity waves. Results of a linear analysis of small amplitude wave with thermal and mechanical dissipation indicate that wave parameters such as the wave number and phase speed of the dominant forcing modes are determined by the position of 'spectral windows which arise from the requirement that waves must propagate upwards freely in the troposphere but be absorbed with stratosphere in order to force the QBO. Wave breaking and saturation is found to be crucial in the formation of the QBO in order to produce a realistic forcing structure of the easterly wind phase. One unexpected, result is that a decrease in the amplitude of the waves may actually slightly increase the strength of the zonal mean wind and reduce the period of the oscillation. The effects of some other parameters have also been explored in detail.

A similar phenomenon to the QBO has recently been identified in the Jovian equatorial stratosphere, and takes the form of an equatorial temperature fluctuation with period ~ 4 year (the so called quasi-quadrennial oscillation (QQO)). This phenomenon has been successfully simulated in our models, which shows the possibility that the QQO results from the action of equatorially trapped planetary waves excited from below. The wave parameters are also determined by the position of 'spectral windows' by analogy with the QBO. In Jupiter's atmosphere the excitation of these waves and their propagation through different zonal mean flows are discussed in some detail. Also, the use of equatorial wave structure and propagation as a diagnostic probe of the possible wind structure are discussed, the feasibility of testing these idea using the data to be obtained from ongoing Galileo mission are examined.

Tuesday/Mardi p.m. Session 3 — Room/Salle 232

Cloud & Precipitation physics / Nuage & physique des précipitations

Chair/Président: Ed Lozowski

Miniature Supercellular and Non-supercellular tornadoes Seen on the McGill Doppler Radar

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Aldo Bellon
McGill University

Most major tornadic episodes are associated with relatively persistent supercellular storms. Such storms have been found to grow in environments which are characterized by strong buoyancy energy and strong vertical wind-shear. Radar reflectivities with such storms indicate intense echoes at mid to high levels and a characteristic weak echo region evident in vertical cross-sections. DOPPLER velocities indicate the development of a meso cyclone at mid levels prior to the tornado touching ground.

Tornadoes have also been known to occur with storms that do not meet the classical supercellular mould. Two such types of events have been identified over Quebec, and can be described as a miniature supercellular storm and a non-supercellular tornado. Both these events are compared to similar storms studied elsewhere.

Similar to the classical supercell, the miniature variety has a relatively persistent precipitation core. However, reflectivities at mid-levels are weaker and storm tops are much lower than the classical variety. The DOPPLER velocities with the miniature case indicated a meso-cyclone which reached the mid levels. In the non-supercellular case, reflectivities at mid levels were also weak. The DOPPLER wind field with the second case also showed a convergence zone along which the tornadic cell eventually developed and a meso-cyclone was only evident at low-levels.

Numerical Simulation of a Long-Lived Mesoscale Convective System

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Recent observations have shown that mesoscale convective systems (MCSS) often form to the lee of the Rocky Mountains and undergo several diurnal cycles before entering into the Atlantic ocean (e.g., Wetzel et al. 1983; Fritsch et al. 1994). These systems also tend to drop a significant amount of rainfall over their journey to the ocean. Unfortunately, these events still remain a "hit" or "miss" type of prediction by both operational models and subjective forecasts.

In this study, we present an 84-h simulation of an MCS that produced the 19-20 July 1977 Johnstown, Pennsylvania, flash flood, and later developed into a tropical storm, as analyzed by Bosart and Sanders (1981). An improved version of the PSU/NCAR mesoscale model (Anthes and Warner 1978) with a fine-mesh length of 25 km was used for this study. The important model features used includes a) a two-way interactive nested-gid procedure; b) the Blackadar boundary-layer scheme; c) the Kain-Fritsch (1990) cumulus parameterization scheme; d) an explicit moisture scheme containing predictive equations for cloud water (ice) and rainwater (snow); and e) a modified version of the Garand (1983) cloud-radiation interactive scheme. The model was initialized at 1200 UTC 19 July 1977 using the same procedures and the same dataset as those used by Zhang and Fritsch (1986). The model reproduces very well the structure and evolution of a squall line, a mesoscale convective complex and a midlevel mesovortex during the first 12-h integration, and later the dissipation of the MCSS. The model also simulates very well the generation of new convection as the system drifts into the Atlantic ocean, and the subsequent intensification into a tropical storm when it is overtaken by a large-scale cold frontal system near the end of 84-h integration. The results are in remarkable agreement with the analysis of Bosart and Sanders (1981), including the location, structure and intensity of the storm up to 84 hours.

It is found that a) the inertial stability of an embedded mesovortex is primarily responsible for the long-lived nature of the system (the convectively generated mesovortex could be well maintained in the model up to 72 h); b) the radiative cooling near the cloud top provides a favorable destabilization mechanism for the continued overturning within the cloud layer, particularly when moist convective is inactive; and c) the surface sensible and latent heat fluxes over the ocean produce a convectively unstable environment in the lowest layers before the system moves into the ocean.

The results have important implications with respect to the warm-season quantitative precipitation forecasts and the predictability of MCSS, since no other studies have demonstrated such successful 3-4 day integration of a midlatitude MCS that developed in a weak-gradient environment.

The Role of Moist Symmetric Instability in the Precipitation over Central Alberta

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Sounding data and rainfall measurements (from a two year period) were analyzed to assess the occurrence of moist symmetric instability over Central Alberta. The moist Richardson number calculated from a each of the observed sounding was compared with the observed precipitation amounts falling within the next 12 hours.

About 20% of the annual soundings were convectively stable, yet had the potential for moist symmetric instability.

However, a strong seasonal dependence was evident: During the winter about 40% of all soundings had moist symmetrical unstable layers, whereas only 2% of the summer soundings were symmetrically unstable. The values for spring and fall were about 20%. About 15% of the total precipitation falling at Stony Plain was associated with soundings that were convectively stable, yet moist symmetrically unstable. During winter more than half the snow was associated with slantwise unstable conditions.

A case study of multiple snow bands aligned in the direction of the thermal shear will be presented to clarify the likely relationship between roll circulations forced by moist symmetric instability and the radar observed precipitation field.

Tuesday/Mardi p.m. Session 3 Room/Salle 224

Fisheries Oceanography / L'Océanographie des pêches

Chair/Président: R. J. Beamish

Spatial and Temporal Changes in the Fish Community of the Newfoundland-Labrador Shelf

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In the past 14 years, biomass and mean sizes have all declined in the marine fish community on the Newfoundland-Labrador shelf. This decline was common to all commercial groundfish and to many non-commercial ones as well. Since about 1985, the biomass decline has been accompanied by major shifts in the geographic distribution of almost every species. Some species disappeared from inshore, others disappeared from the north, and others did both. Some species appear to have had major shifts in abundance (north to south or inshore to offshore) whereas other species exhibited a biomass decline in one area but maintained a rather uniform level in others. Multivariate analysis of groundfish survey data identified four groundfish assemblage areas on the shelf, i.e. areas characterized by an homogeneous faunal composition. Distribution patterns of the assemblages remained relatively stable from 1978 until 1987, but have entered a period of dramatic change since then. Changes in the distribution patterns of individual species anticipated changes at the community level. Intense exploitation of groundfish is the most likely explanation for the decline of fish biomass on the Newfoundland-Labrador Shelf. The shifts in distribution observed, however, suggest that broad-scale environmental effects may also be at work.

Numerical Modelling of Cod Egg Retention of the Northeast Newfoundland Shelf

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A time-dependent, two-dimensional velocity field is used to study the interannual variations of cod egg and larval dispersion on the Newfoundland and Labrador shelf. The model uses a steady state mean flow derived from a diagnostic

calculation of objectively analysed density data for the Northeast Newfoundland Shelf. Time-dependent currents are generated using a slab model driven by observed winds, following the approach of Pollard-Millard. We study the advection of the eggs and larvae using numerical Lagrangian drivers and by applying the model to the advection-diffusion of a patch. We show that northerly spawning locations are more favourable than southerly spawning locations for northern cod (2J3KL). As well, we identify favourable and unfavourable zones of retention on the Newfoundland shelf. The Lagrangian drift model is compared to observed drifter data.

Tuesday/Mardi p.m. Session 4 — Room/Salle 231

Atmospheric - Surface forcing / Interaction de surface atmosphérique

Chair/Président: Tim Oke

Numerical Modelling of Coastally Trapped Disturbances

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Coastal Trapped Disturbances (CTD), have been analysed along the west coast of North America as surface pressure ridges resulting both from atmospheric Kelvin waves, and, under different synoptic forcing, from gravity currents. They last 2 to 6 days, and occur several times per month in summer causing significant and sudden changes to coastal weather: clear skies are replaced by stratus; air cools by as much as 20þ C; and sudden wind shifts occur with gusts up to 20 m s^{1}. They are trapped by a subsidence inversion below the crests of barrier-like coastal mountains and propagate northward along the coast until friction or poorly understood orographic effects lead to dissipation. Typical horizontal scales are 1000 km along-shore, and 100 km acrossshore. Analytical and observational studies indicate that dynamics forced by topography is responsible for non-steady behaviour which makes forecasting these events so difficult. In particular, gaps (such as valleys and fjords) and bends in the coastline (such as capes and peninsulas), have been observed to slow or stop CTD propagation. A powerful method of exploring these topographic effects is by simulating CTD with a mesoscale numerical model. Initial results from the modelling effort will be discussed.

Wind-Driven Pressure Gradients around an Island

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Observations on the southern shelf of the island of Peurto Rico indicate that the alongshore westward tradewinds lead to an alongshore pressure gradient that tends to oppose the wind stress.

A simple model of a cylindrical island with a shelf under low-frequency windstress is capable of explaining these observations. The solutions are given for the pressure and flow fields, and are extendable to both reduced gravity and barotropic models. Also, in the limit that the coastal radius goes to zero (while the radius to the shelf edge is finite) the solutions for a seamount are obtained.

The alongshore pressure gradients at the shelf edge are independant of the parameters describing the island's size and may be useful in describing sea-surface setup along .....

Applications of the MSFD and NLMSFD Models to Flow over Askervein Hill

Peter Taylor[1], Keith Ayotte[2,3], James Salmon[4], John Walmsley[2], Wensong Weng[2] and Dapeng Xu[1]

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Data collected during the 1982-3 Askervein experiments on atmospheric boundary-layer flow over a hill (Taylor and Teunissen, 1987) include mean flow and turbulence integral statistics from 3 lines of 10m towers on the hill (Salmon et al, 1988) and from taller profile towers at an upwind reference location (RS - 50m), the hilltop (HT - 50m), the hill centrepoint (CP - 16m) and the upwind hillfoot (UK - 30m) - see Mickle et al (1988). There are also Tala kite profiles to several hundred metres and detailed topographic data (based on 2m contours). Soon after the field study, extensive comparisons were made against predictions from the linear MS3DJH model (Walmsley et al, 1986) as well as some studies with the initial, linear mixed spectral, finite difference model (MSFD) of Beljaars et al (1989), a 2D higher order closure model (Zeman and Jensen, 1987) and with a 3D non-linear finite element model (Raithby et al, 1987).

Since that time there has been considerable development of the MSFD model (e.g. Karpik, 1988, Ayotte et al, 1994) and a non-linear extension of that model (NLMSFD, Xu and Taylor, 1991) has been developed. The Askervein field data are probably still the best available on flow over a hill of this scale and it seemed appropriate to revisit them. The paper will present selected results of our intercomparisons.

Boundary-Layer Parameterization of Drag over Small Scale Topography

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Sub-grid scale terrain variations at macro and meso-scales exert a drag on the atmospheric boundary-layer flow over them and consequently have an influence on large-scale atmospheric circulations. To incorporate this sub-grid scale effect in

regional and global weather and climate models, a parameterization of small scale topography is needed. This can, in principle, be achieved by adjusting drag coefficients, or by evaluating an effective roughness length.

There are several proposals (Wood and Mason, 1993, Belcher et al, 1993, Taylor et al, 1989) regarding the parameterization of drag over small-scale topography. We review these proposals and make comparisons between them, utilising results from an efficient numerical model of boundary layer flow over topography with second order turbulence closure (NLMSFD - Xu et al, 1994). Model results cover an extensive range of parameters, such as hill shape, hill slope, roughness length and horizontal scale. We focus on 2D and 3D neutrally stratified atmospheric surface layer results but extensions to the PBL and to stable stratification are in progress.

A Simple Three-Dimensional Model of Planetary Boundary Layer Flow over Topography

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This presentation describes the development of a simple three-dimensional linear model of planetary boundary layer flow. The model is based on the Mixed Spectral Finite Difference model of Beljaars *et al.* (1987), using the full second order turbulence closure of Launder, Reece and Rodi (1975). The model uses a steady state solution to the fully non-linear model equations over a horizontally homogeneous surface to specify the zero-order, upwind profiles of mean and turbulent quantities. This method of zero-order solution specification includes coriolis forcing and Reynolds stresses which vary throughout the depth of the boundary layer. Due to the complexity of the closure and linearization of the model equations, the author has developed an automated method of source code generation to produce both the time dependent model used to specify the zero-order solution and the 3-dimensional model of flow over topography. This method makes use of symbolic manipulation to generate model source code and allows the modeler to deal with model equations at a level similar to that of handwritten equations while generating finite difference and/or spectral representations of the model equations ready for compilation. Model results are presented for model runs over a simple isolated hill.

Tuesday/Mardi p.m. Session 4 — Room/Salle 233

Atmospheric dynamics - 1 / Dynamique de l'atmosphère-1

Chair/Président: R. Laprise

Interaction between Slantwise Convection and Marine Cyclones: A Conceptual Picture and Sensitivity Studies

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McGill University

A two layer primitive equation model is used to understand the interaction between slantwise convection and large scale marine cyclogenesis. A simple representation of the planetary boundary layer as well as shallow and deep cloud types are considered. Convective plumes are assumed to travel along angular momentum surfaces. The following conceptual picture regarding the interaction between convection and cyclones is proposed: Convection leads to rapid frontogenesis and the formation of bent-back warm front. The sudden surge of cold advection in the regions of the bent-back warm front then forces the upper level heights over the cyclone centre to fall in a rather dramatic way. Increased upper level vorticity advection interacts with the low-level system leading to explosive cyclogenesis.

A three layer model is constructed to test the sensitivity of the bent-back warm front and the explosive deepening to various model parameters. It was found that: a) The thermal gradient in the bent-back warm frontal region and the final deepening strongly depend on the cloud mass fraction at the top of the planetary boundary layer. b) Shallow clouds are relatively insignificant in affecting the dynamics of explosive cyclones. c) The surface drag force weakens the development of strong horizontal wind shear and the bent-back warm front. d) The thermal gradient in the bent-back warm front gradually increases with the thermodynamic disequilibrium between the sea surface and the atmospheric boundary layer. e) Enhanced vertical wind shear increases the deepening rate. However, the symmetry in the wave development and strong pressure falls near the warm front are associated with slantwise convection. f) Weak low level stability has significant impact on cyclogenesis. g) The effect of stable condensation is to moderately accelerate the development of the baroclinic wave.

Development of a Boundary-layer Model of Surface Frontal Passage

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Dept of Earth and Atmospheric Science
York University

Detailed examination of surface cold frontal passages over Sable Island during the 1986 Canadian Atlantic Storms Programme (CASP I) showed relatively broad frontal zones (order 70 km) and in many cases the change in wind direction started 15-60 min ahead of the temperature decrease. Taylor et al (1993) suggested that this was a mesoscale blocking effect, not linked to wind shifts associated with preceding warm fronts, upper level cold fronts or warm conveyor belts, but rather dependent on stable stratification in the warm air ahead of the front. Studies of inland surface frontal passages in the vicinity of Toronto show much narrower frontal zones (20 km for cold fronts) and concurrent wind shifts and temperatures changes. As an initial step in developing a model of the blocking ahead of cold fronts some 2D hydrostatic model simulations of blocking ahead of simple topographic features were run by Taylor and Ayotte (1994). These models used Mellor-Yamada (1974) q^2l closure (level 2.5). A 2D hydrostatic primitive equations model of boundary-layer frontal structure is currently being developed. Results for simple turbulence closures have been obtained and the turbulence closure is being refined.

Non-hydrostatic Simulations of Warm-frontal Systems

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Warm-frontogenesis is simulated by using a 2-d cloud-resolving numerical model. Frontogenesis is forced by both large-scale confluence and along-front temperature advection in the model. Detailed cloud microphysics and high resolutions are used so that both the mesoscale and larger-scale responses can be adequately simulated. The effects of precipitation on the evolution and structure of warm-frontal systems will be illustrated by comparing results from the dry and moist

simulations. Evolution of the frontal inversion layer and its effects on the surface precipitation type will also be discussed in light of the model results.

An Evaluation of Planetary Boundary Layer Models using Large Eddy Simulation

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This presentation describes a comparison between one-dimensional (or profile) forms of a number of simple turbulence closure models currently in use within Global Circulation Models and output from a Large Eddy Simulation (LES) model. The evaluations are made in the context of assessing the ability of the closure models to correctly simulate bulk exchange parameters important in global circulation modeling. These parameters include surface heat and momentum fluxes, layer averaged mean values of momentum, temperature and transported scalars within the boundary layer, as well as heat, momentum and scalar entrainment fluxes at the top of the boundary layer. The models evaluated are of six different generic types including:

- *K(Ri)* (Louis, 1979, Louis, Tiedtke and Geleyn, 1981).
- Single Point (Mellor and Yamada, 1974, 1982, Andren, 1990)
- *K*-Profile (Troen and Mahrt, 1986, Holtslag *et al.*, 1990, and Holtslag and Boville, 1993)
- Mixed-Layer (Tennekes and Driedonks, 1981 and Driedonks, 1982)
- Stability Bounds models (Price and Weller, 1986)
- Multi-stream Exchange (Stull, 1984, 1985, 1993. Blackadar 1976, 1978, Zhang and Anthes 1982).

The comparison takes place over a matrix of nine cases ranging from neutral stratification to strongly convective PBL'S. The thermal structure varies from no capping inversion in the neutral case to a strong capping inversion in the highly convective case. In addition baroclinic forcing is introduced in two of the convective cases.

The comparisons are via indices based on layer averaged and point-for-point difference between the LES model output and the closure model profiles. Comparison results for the ten model/nine case matrix will be presented.

Delivery of a Compressible Multi-Scale Modelling Tool - MC2 Model - to the Canadian Atmospheric Research Community

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At Recherche en Prévision Numerique (RPN) and at Université du Québec à Montréal (UQAM), a group has worked actively since May 1992 to provide a versatile modelling tool, applicable to a variety of needs of of the Canadian research community. Their starting point has been the fully-elastic non-hydrostatic model developed recently by Drs. Andre Robert, Monique Tanguay and Rene Laprise. A first interim progress report on MC2 was presented at the CMOS 1993 Congress.

The team's commitment has been to adapt the model coding to current CMC-RPN standards, to provide an extensive users' guide document, to include all necessary features (such as nesting, boundary layer, convection, radiation) needed for the known current applications and to maintain a central model library (with contributed modules from the community)

that allows easy porting to various computers. By January 1994, the objective was finally reached for a first time, with a delay relative to plans, and the delivery of the model to research groups has begun. Support to remote users as well as contributions to the central community model library can now be expected to take place.

A survey of sample results from MC2 users is presented and project status is described.

Tuesday/Mardi p.m. Session 4 Room/Salle 232

Cloud & Precipitation physics / Nuage & physique des précipitations

Chair/Président: Ed Lozowski

An Investigation of a CASP II Winter Storm Producing a Prolonged Period of Ice Pellets

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On February 1-2, 1992 during the CASP II field experiment, a major storm produced a prolonged period (6h) of ice pellets over St. John's, Nfld. The objective of this study is to better understand the storm's internal structure and to identify specific characteristics which contributed to the prolonged ice pellet duration. Preliminary results have identified at least 2 key features which may be responsible for the prolonged duration. First, a sub-saturated region within the inversion led to a reduction of the melting rate of particles so they could refreeze in the lower sub-freezing region. This sub-saturated region may have formed within the descending branch of an organized circulation aloft identified by Doppler observations. Second, a cold core of air between the surface and inversion was critically important for refreezing of partially melted particles. An air mass transformation model was used in order to show that air originating over sea ice in this case produced colder near-surface temperatures than would air originating over sea water. The occurrence of sea ice therefore contributed to the ice pellet episode as well. A conceptual model of this storm has been developed. Storms with shorter durations of ice pellets will be investigated to further illustrate the unique characteristics of this storm.

Precipitation in Layer Clouds: Results from the Atlantic Stratocumulus Transition Experiment

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The Atlantic Stratocumulus Transition Experiment (ASTEX) offered a unique opportunity to study the Lagrangian evolution of two marine boundary layers using multiple aircraft and satellite measurements. In the first Lagrangian, the National Center for Atmospheric Research Electra and the British Meteorological office Hercules aircraft took turns tracking a precipitating, convecting marine boundary layer over a 48 hour period in the central Atlantic (Azores). During this period the boundary layer rapidly deepened, as the cloud changed from a well-mixed Stratocumulus layer to a 1500 meter-deep layer filled mainly with cumuli. Thermodynamic profiles show the evolution of a decoupled surface layer beneath the stratus deck, and microphysical measurements indicate that the cumuli, penetrating into the overlying stratus,

were able to produce local rain rates exceeding 10 mm/day. A simple stochastic coalescence model and simultaneous satellite observations of cloud optical depth during this period indicate that the stratocumulus layer was too thin by itself to produce rain rates of this magnitude, illustrating the role played by underlying cumuli in triggering and feeding precipitation in decoupled boundary layers of this type.

In contrast, precipitation was suppressed during much of a second Lagrangian observation period in moderately polluted air. Here the higher cloud condensation nuclei concentration produced cloud droplet populations with mean radii of less than 8 microns. Autoconversion (i.e. the collision production rate of embryonic raindrops) is more than an order magnitude smaller than in the cleaner clouds observed during the first Lagrangian, so that little precipitation reached the ground in spite of large liquid water contents in the underlying cumuli. We will contrast these two cases with observations from several well-mixed precipitating stratocumulus clouds in order to better understand how simple parameterizations of precipitation efficiency will have to be modified in more realistic models of decoupled stratocumulus boundary layers.

The Magnitude of Vertical Air Velocity Within Cirrus Clouds: Coherent Structures and Turbulence

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Cirrus clouds in the upper troposphere exhibit not only coherent structures but also chaotic motions. Because of measurement difficulties, cirrus clouds were not studied in detail until last decade. Cirrus cloud can be important for climate change and aviation. In this research, observations taken by aircraft and radar were used to investigate dynamical structures within cirrus clouds during FIRE 11 field project which took place over the Kansan region of USA. Cirrus formed over land on November 26 and December 6 1991 are studied to analyze dynamical structures including coherent structures and turbulence. Fluctuations are calculated along constant flight altitude legs approximately 50 km long in space. The scales of structures larger than 10 km are removed from the analysis using a running average technique. The parameter of vortex spirality and coherence coefficient are used to analyze the swirling and coherent structures within cirrus clouds. Results showed that the size of coherent structures estimated from aircraft measurements ranged from 0.2 km up to 10 km. They were comparable to those found from doppler radar measurements. Vertical air velocity for both days was found to be between a few cm s^{-1} up to 1 m s^{-1} in both small and large mesoscale structures. Overall, the values of dynamical parameters for November 26 case because of large vertical shear of horizontal wind were estimated to be much more stronger compare to those of December 6 case.

An Experimental Investigation of the Local Heat Transfer From Hailstone Models

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Previous theories on heat and mass transfer of hailstones by Schumann (1938), Ludlam (1950, 1958) and List (1963,1977) treated such transfer as homogeneous and isotropic. Until now, the treatment of hailstones in numerical modelling has assumed spherical particles with homogeneous conditions over the whole surface. Recent laboratory experiments revealed

surface temperature differences between the equator and pole of hailstones as large as 5.8 C (List et al., 1989). Although a new, non-isotropic heat and mass transfer theory of hailstone has been developed (Garcia and List, 1992), specific investigations are necessary to explain the differences between theory and experiments and to imp-rove our insight into non-homogeneous heat and mass transfer processes.

Experiments were carried out in an icing tunnel which can simulate natural cloud conditions, The local surface temperatures of hailstones were measured using an AGEMA infrared imaging system. A numerical model was developed to calculate the time evolution of the temperature distribution and the heat conduction within the hailstone and hence, the surface heat flux. Then, the latitude-dependent Nusselt number, $Nu\phi$, was determined. Experimental results indicated that the heat transfer of a hailstone is nonhomogeneous, non-isotropic and latitude-dependent. The variation of $Nu\phi$ was found to be a function of Reynolds number, Re, aspect ratio, þ, and surface roughness, B. The experiments also found that fall mode of the hailstones significantly influences the variation of $Nu\phi$.

On the Process of Drop Collisions in Turbulent Clouds

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Convective clouds are characterized by various levels of turbulence. Yet, the role of turbulence (if any) in the process of collisional growth of small cloud droplets has not been explained. We examine both the quantitative effect of turbulence on collision efficiencies and the mechanisms by which turbulence may affect collisions.

The scope of this research is restricted to small rigid droplets which can be treated with help of the Stoksian microhydrodynamics. The calculations are performed for collector drops 5, 10, and 15 μm in diameter.

A special attention is paid to the influence of parameters characterizing turbulence on collision rates. We assume that the turbulence wavenumber spectrum is scaled by the rate of energy dissipation and the kinematic viscosity, and that the frequency spectrum is scaled by the r.m.s. turbulent velocity. With constant kinematic viscosity, we systematically explore the significance of the other two parameters on drop collisions.

Tuesday/Mardi p.m. Session 4 Room/Salle 224

Fisheries Oceanography / L'Océanographie des pêches

Chair/Président: R. J. Beamish

Variations in the Contribution of Transport to Changes in Animal Abundance: A study of the Flux of Fish Larvae in Conception Bay

Pierre Pepin and Jim Helbig

Northwest Atlantic Fisheries Centre

Short term variations in the flux out of Conception Bay of several species of fish larvae were measured to determine their contribution to changes in measured abundance. The mass flux out of Conception Bay was measured daily over a 10 day

period using an acoustic doppler current profiler. Larval concentrations were measured simultaneously with a multimesh 4m tucker trawl. Fluctuations in flux were associated with changes in wind forcing. The variations in larval flux contributed 25 to 75% of the change in numbers for the different species. Consequently, failure to account for the contribution of physical processes to apparent mortality has a significant impact on the investigation of potential biological processes influencing the survival of larval fish.

Modelling the Evolution of Pelagic Egg Distribution in Conception Bay

Jim Helbig and Pierre Pepin

Northwest Atlantic Fisheries Centre

Two weeks of surface currents observed with HF radar are used to drive a two-dimensional advection-diffusion model of fish egg distribution in Conception Bay, Newfoundland. The model is used to predict horizontal distributions of three separate species that exhibit different vertical distributions. Significant skill is demonstrated in all predictions. Spatial patchiness is discussed.

Foodchain Control of Carrying Capacity in the Subarctic Pacific Based on Simulations with a Simple Coupled Physical - Biological Model

Kenneth L. Denman

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A simple coupled mixed layer / planktonic foodweb model of the euphotic layer has been developed that is forced by annual and daily cycles of solar heating and an annual cycle of surface heat losses. The model can simulate annual cycles with or without a spring bloom (characteristic of the subarctic Pacific or the North Atlantic) depending on either the initial slope of the curve specifying the dependence of primary production on light or on the maximum depth of winter mixing. I have performed a simulation of a High Nutrient-Low Chlorophyll region such as the subarctic Pacific, with 50% of the losses recycled within the euphotic zone and 50% lost from the system, but with no resupply of nitrates from below. The resulting summer peaks and winter troughs in phytoplankton biomass decrease with an e-folding time of about 260 days, dropping by a factor of more than 1000 in 5 years, underscoring the importance of physical supply of nutrients to these regions regardless of the possibility of iron limitation. In the subarctic Pacific, the primary supply of nutrients to the euphotic layer is upward transport (of 10 to 30 m/yr) from below required by Ekman divergence in the surface waters. As this Ekman divergence is forced by wind stress curl associated with the atmospheric Aleutian Low pressure system, interannual variation of the Aleutian Low should be linked to interannual variation in the biological production of the plankton ecosystem and hence to the carrying capacity for the salmon species that spend part of their adult life in the subarctic Pacific.

Deepwater Solitary Corals as a New Palaeo-oceanographic Archive: Desmophyllum cristagalli as an example from Orphan Knoll, Northwest Atlantic Ocean

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The use of foraminifera in ocean sediments to date apparent salinity and/or temperature changes recorded in stable isotopes is limited to a precision of about 1,000 years because of the effects of bioturbation which tend to blur the signal. The HUDSON 78-020 cruise, while rock dredging at 1,628 m (uncorrected) on one of the bedrock mounds on top of Orphan Knoll 550 km northeast of Newfoundland, had a serendipitous recovery of a large collection of dead, Mn-coated, pieces of the solitary ahermatypic coral Desmophyllum cristagalli. The collection lay at the Atlantic Geoscience Centre for eleven years and was unexamined until 1989.

Initial ^{14}C dating, sponsored by Geomarine Associates, INSTAAR, two museums, and the Atlantic Geoscience Centre along with recent B.Sc. Honours thesis work at McMaster University using U/Th dating has shown that the collection contains individuals that range in age from 4,000 to about 76,000 y BP. One large pseudocolony appears to have lived from 12,400 to 11,100 y BP and this spans the onset of the Younger Dryas climatic event wherein the northern hemisphere returned to glacial conditions. The top of this colony records a dramatic change in $\delta^{18}O$ of > 2 per mil suggesting a rapid shift in the thermohaline circulation at the start of the Younger Dryas. If one assumes a constant growth rate for the pseudocolony then the apparent return to glacial conditions occurred over about a 50-year period.

Deep-ocean, solitary corals have to some extent been curiosities of the abyss and they have a very limited scientific following. However these corals, which are relatively immune to the confounding effects of fluctuating sedimentation rates, bioturbation and sediment transport, represent a new and potentially extremely valuable archive of palaeo-oceanographic data. These corals also offer an opportunity to couple ^{14}C and absolute U-series dates to extend the current calibration of the ^{14}C timescale.

Tuesday/Mardi p.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 4

Observations of Gravity Waves / Observations des ondes de gravité

Chair/Président: Gary Klaassen

Rayleigh Lidar Observations of Atmospheric Thermal Structure and Gravity Wave Activity at Middle and High Latitudes

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A Rayleigh lidar is employed to study middle atmospheric thermal structure with particular emphasis on the properties and influence of internal gravity waves. The technique involves range-resolved detection of molecular backscattered laser radiation to obtain relative density and absolute temperature profiles with high spatial and temporal resolution (300m, 5min) within the upper stratosphere and mesosphere. Gravity waves, observed in temperature fluctuations, are characterized by their vertical variation of amplitude, associated available potential energy density and vertical wave number spectra.

Observations have been carried out on a routine basis at Toronto (42°N) since June of 1991 using a Nd:YAG laser-based system. This has provided many interesting case studies as well as a developing climatology. We have recently installed

a Differential Absorption Lidar (DIAL) system at Eureka Weather Station (80þN) which can also function as a respectable Rayleigh lidar. Measurements during February and March of 1993 provided the first observational study to focus on the effect of stratospheric warming on gravity wave propagation. Observations were also carried out at Eureka this past winter (1993/94). General results and selected examples from both locations will be presented.

Absolute Temperature Measurements of the Mesopause using the UWO Sodium Lidar

C.T. Sparrow, R.J. Sica and P. S. Argall

Department of Physics
The University of Western Ontario
London, Ontario, Canada

Absolute temperature measurements in the vicinity of the mesopause between 80 and 105 km can be measured using sodium resonance fluorescence lidar. A layer of atomic sodium exists In this region as a result of meteoric ablation. A tunable laser is used to measure the lineshape of the sodium D2 line which consists of 6 hyperfine components which are Doppler broadened to form a lineshape which depends on temperature. The University of Western Ontario's Purple Crow Lidar is able to make high resolution measurements (24 m vertical resolution, 60 s temporal resolution from 30 to 105 km. Relative temperature profile measurements are made using Rayleigh lidar from 30-90 km. Because these two profiles overlap, absolute temperature measurements can be made from 105 down to 30 km. By studying temperature variations, internal gravity wave parameters may be deduced. These parameters are important in determining both the energy and momentum budgets in the middle atmosphere. This paper will discuss the method of determining the absolute temperature profile from raw photon count returns, including the effects of saturation of the sodium layer and monitoring of the transmitted frequency.

Middle Atmosphere Studies with the UWO Radars

W.K. Hocking, T. Thayaparan and J. MacDougall

The University of Western Ontario

The University of Western Ontario now has two radars which can be used for studies of the middle atmosphere. One is a medium-frequency radar which is currently running unattended and is measuring middle atmosphere winds every 5 minutes in the height region 60 to 100 km. We have accumulated over one year of data from this system, and results are presented showing atmospheric tides and gravity waves over a full year. Especially good agreement with current tidal models has been obtained during portions of the year.

The second instrument is a very high frequency radar which can measure atmospheric winds in the troposphere and lower stratosphere. It can also be used to measure winds in the upper middle atmosphere by utilizing meteor drifts. Preliminary results from this instrument will also be discussed. In particular, excellent agreement with recent radiosonde comparisons will be illustrated.

Lidar Measurements of Density and Temperature Fluctuations in the Middle Atmosphere at High Spatial-Temporal Resolution

R.J. Sica, P.S. Argall and C.T. Sparrow.

Department of Physics
The University of Western Ontario
London, Ontario, Canada

The University of Western Ontario's Purple Crow Lidar (PCL) can measure the high temporal and spatial variability of density and temperature in the middle atmosphere. Density and temperature profiles from 30 - 90 km are measured using the Rayleigh-scatter technique and from 80 - 105 km using resonance-fluorescence from atmospheric sodium. The PCL is among the best equipped facilities in the world to make these measurements, in large part due to an MF radar used to measure winds in the middle atmosphere near the PCL (Drs. Manson (University of Saskatchewan), MacDougall and Hocking (UWQ)), an ST radar (Dr. Hocking), high resolution spectrometers and imagers (Drs. Lowe and Turnbull (UWO)) and the largest telescope in Canada for the PCL lidar receiver (built with the expertise provided by Dr. Borra and colleagues at Laval University). The high performance factor of the PCL allows useful temperature and density profiles in the middle atmosphere to be obtained at high vertical resolution (< 2km) in a few minutes. Initial measurements from the PCL will be presented that illustrate the behaviour of the middle atmosphere over Southern Ontario at high temporal and spatial scales.

Tidal Influence on Atomic Oxygen Green Line Airglow Altitudes and Emission Rates at the Geographic Equator as Observed by WINDII

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The night airglow green line emission at 557.7 nm arising from the O(1S) level of atomic oxygen arises from the recombination of atomic oxygen to its molecular state. The Wind Imaging Interferometer (WINDII) on the Upper Atmosphere Research Satellite observes this emission, and inverts the observed radiances to true height profiles of volume emission rate, in photons cm^-3 s^-1. From a photochemical model, these results can be further converted to atomic oxygen concentrations in the altitude range 85 to 105 km. This airglow emission, and thus the atomic oxygen concentrations, undergo exceptionally large diurnal changes at the geographic equator, which by comparing WINDII tidal winds with model tidal winds are shown to result directly from the diurnal tide. in the evening, downward winds bring oxygen-rich atmosphere from 105 km down to the emission region, creating strong emission, while in the morning, the vertical winds are upward, closing off the supply of atomic oxygen, and reducing the emission intensity. This observation provides a new understanding of airglow emission at the equator, the behaviour of atomic oxygen there, and the dynamical influence of tides on the upper atmosphere. It also demonstrates a strong linkage between the stratosphere and the upper atmosphere.

Wednesday/Mercredi a.m. Room/Salle:ALUMNI AUDITORIUM/ AUDITORIUM des ANCIENS

PLENARY SPEAKERS/ CONFÉRENCIER INVITÉS
SPECIAL SESSION ON METEOROLOGICAL RESEARCH TO MEET CANADA'S AVIATIONS NEEDS IN THE 21st CENTURY
SESSION SPÉCIALE sur la RECHERCHE ATMOSPHÉRIQUE pour RÉPONDRE aux BESOINS de l'AVIATION CANADIENNE du 21e SIÈCLE

Dr. J. McCarthy, NCAR

Wednesday / Mercredi a.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 1

Aviation Meteorology Visions of the Future / Météorologie de l'aviation visions du futur

Chair/Président: Ron Doyle

Aviation Weather Research and Development Strategic Plan

John Carr

Transport Canada Aviation

Introduction

The aviation weather service safety goal is to systematically reduce the number of aircraft accidents and incidents that have a weather related cause factor. The efficiency goals are to minimize weather related diversions and to facilitate maximum air traffic flow by providing clear, accurate and timely weather information to aviation users, and to produce such weather information at the lowest possible cost. The effectiveness goal in military weather services is to use weather information to gain tactical advantage in the successful accomplishment of the mission.

Future System Requirements

A fundamental aviation weather product change is on the planning horizon. For all users, this next generation of information products could, for the first time, facilitate a complete, intuitive understanding of the prevailing and forecast state of the atmosphere by depicting it in both plan and cross-sectional views. For air traffic management personnel, within those terminal areas where aircraft traffic levels can justify the cost, the current and forecast state of the atmosphere could be displayed in a time-based, cubic ("four dimensional") form in combination with projected aircraft flight path information. The basic suite of products for pilots, briefers and despatchers can best be described by visually imagining a series of plan and profile view colour computer images of a specific flight route and level, upon which has been superimposed the forecast weather elements of concern, such as icing, turbulence and areas of convective hazard. Access could be via personal computer modem calls to a regional data base. These sophisticated products will be primarily derived from a gridded numerical weather model.

This gridded atmospheric model will be fed from a sophisticated network of data acquisition devices, including airborne and satellite sensors, systematically distributed to service the forecast requirements of the aviation

community. It follows that the interdependent data acquisition, forecast production and dissemination processes will have to undergo some fundamental changes to enable them to deliver such intuitively clear weather information to the users. These changes will be driven by a major research and development effort.

Research and Development Effort

The challenge in this research and development effort will be to provide a computerized integration of the weather data into a cohesive set of products that are immediately understandable by pilots, briefers, despatchers and controllers.

A significant R&D effort will be required to advance from the current discrete text-based, coarse resolution products to intelligently integrated, graphically-based high resolution products. To accomplish this, research activities will be focussed in five main areas:

- new detection, data acquisition and data transmission technologies, to service unique aviation user requirements in a timely manner;
- integration of data through the use of intelligent integration techniques;
- improved numerical model products tailored to the needs of the aviation user;
- improved forecasting methodologies using integrated information from sensors and numerical models; and
- graphic display techniques to efficiently disseminate products which are intuitively comprehensible to the aviation user community.

Problems and Challenges Facing the Aviation Community in Guiding the Future Aviation Weather R & D

Branimir Dulic

Transport Canada Aviation

Introduction

The Strategic Plan for Aviation Weather Research and Development is developed based on a requirement for safer and more efficient aviation system. This paper attempts to further clarify the information content required to fulfil the ideas presented in the Plan, presents possible problems and challenges including identification of optimum technologies, direction of future R & D efforts, and achievement of desirable quality information at a minimal cost.

General

The identified problems are that forecasts are not accurate enough. Many products lack adequate time and space resolution and the information is not specific to a/c type, and its 4D path.

To be able to have an accurate user friendly display of the 'state of the atmosphere' consistent, but tailored differently for each user, it should be clearly understood that the products could be only as good as the quality of information. The requirements for improved information would eventually drive meteorological research in all of the following areas: data acquisition (meaning sensors), information integration, physics of meteorological phenomena, modelling, application of AI, etc.

Priorities and implications

From the aviation point the priorities are set up on basis that safety comes first, and efficiency second. Efficiency parameters should be used to evaluate and rank desirabilities for increased quality of information. For example, what would be the impact of grid reduction to 15 km, from the present 80 km. What kind of emerging and existing technology combination would be ideal to fulfil those needs? Then the problem becomes more complex: Would the same technology combination be capable of providing other information with only marginal increase in cost? For example: should we be looking at the sensors to integrate both ATC surveillance and the meteorological role, like the proposed rapid scan multiparameter doppler radar?

Information required and sensor utilization

It would be essential to have the ability to accurately forecast the time, location and characteristics including intensity of aviation weather hazards up to several hours in advance.

For example, let us focus on the severe event typical for the Canadian climate: snow and icing on the ground. How much snow will fall on runways? How long will deicing fluids stay on the aircraft? Answers would require knowledge of the snowfall rate, air temperature, aircraft wing temperature, and much more. The question is how to obtain the information? What sensor(s) could be used? For example, the proposed multiparameter X/Ka band doppler radar originally intended for cloud observations could also be used to determine the type of precipitation, and cloud structure.

In addition, the proposed use of the subject radar (particularly its X-band part) could be expanded to get the 3D wind picture (current and forecast) needed not only for microburst and other hazards, but also to feed the proposed wake vortices model.

Weather Forecasting in the 21st Century

Gilles Fournier

Transport Canada

Introduction

This paper presents a vision of aviation meteorology forecasting in the context of the automated air traffic management environment of the 21st century, and discusses aviation weather R&D activities needed to get there.

Historical Development

The conceptual cyclone model developed in the 1920s allowed for prediction by providing a sequence of events attached to cyclones. Then large scale quantitative models set the stage of numerical weather prediction when electronic computers became available in the 1940s. Meteorological satellites began operations in the 1960s. Today, a new era in observation is just starting with the advent of advanced weather sensors, providing a detailed quantitative view of atmospheric systems. Improved observations and increased computer power have allowed the production of reliable numerical weather forecasts at enhanced resolution.

Weather Forecasting Today

Despite the progress achieved in detecting and understanding mesoscale phenomena, little of it is available to the operations yet.

Today, the forecaster uses a workstation through which he/she gets a variety of graphical products based on observed basic meteorological parameters or numerical weather model output. Then, the forecaster combines some of the

products in an attempt to depict the weather situation in 3D. The next step is to relate this 3D picture to knowledge, and this is done by applying a combination of pattern recognition, conceptual models, and individualized physical models. Then a combination of weighed techniques, including numerical model output, are applied to forecast the evolution of the current conceptual model, and extract the weather elements needed for the final aviation weather products.

Some interactive AI tools permitting limited scenario testing and on-the-job-training are just coming on line. Part of the forecasting process is being automated. However, the extent of the automation is not sufficient to support the forecaster's and aviation weather user's roles. These limitations will be presented and discussed.

Weather Forecasting in the 21st Century

In the 21st century, conceptual advances and the application of more powerful technologies, including computing and remote-sensing, will interact to produce advances in aviation meteorology. Much R&D effort will continue to be dedicated to mesoscale phenomena and severe weather, opening new R&D and operational initiatives on mesoscale detection and prediction, on the modernization of the weather services, and advancing our understanding of atmospheric processes and systems, especially severe weather.

The forecaster's roles of assuring the quality of the products, adding value to them, and preparing specialized products will expand. The forecaster will be supported by intelligent interactive tools, integrating data and information, using more quantitative and statistical high-resolution models, and providing extensive and fast scenario testing and in-situ training.

R&D Activities

To get to the weather forecasting office of the 21st century, research and development activities should be focussed in the following main areas: physical characteristics of meteorological phenomena; detection, data acquisition and transmission; data integration; numerical modelling; forecasting; and data dissemination and display.

The FAA's Aviation Weather Development Program Research Activities: An Overview

K.L. Van Sickle
NSF Aviation Weather Program Coordinator

K. Klasinski
FAA Program Manager
Aviation Weather Development Program (ARD-80)

The FAA is developing the Integrated Terminal Weather System (ITWS) and Aviation Weather Product Generator (AWPG) to provide near-term improvements in safety, capacity and efficiency for the air traffic system and aviation industry. Underpinning the development of these system acquisitions are basic research activities that not only contribute to the immediate needs but are also supporting longer-term improvements. Projects in weather analysis and forecasting and aviation sensors are fulfilled at research laboratories and universities. Research on inflight icing and ground deicing, turbulence, ceiling and visibility, and airborne humidity sensors will ultimately lead to improvements in these areas. Work in oceanic weather, aviation weather training tools and ground based icing sensors is also planned. An overview of current and planned research activities is described.

Wednesday / Mercredi a.m. Room/Salle 224
Session 1

GEWEX

Chair/Président: T. Krauss

Global Energy and Water Cycle Experiment (GEWEX)

Terry W. Krauss, National Hydrology Research Centre

The objective of the Canadian GEWEX Programme is: To contribute to the international GEWEX Programme in areas of special Canadian interest and expertise and to contribute towards the better understanding and prediction of changes to Canada's water resources arising from climatic change. A central goal of the Canadian implementation strategy is: To develop the ability to model the water and energy balances of the Canadian Arctic Basin on spatial scales of 100 km and temporal scales of one month. It is proposed that a series of large-scale hydrological and related atmospheric and land-atmosphere studies be conducted during GEWEX Phase I (1992-98) to be called the Mackenzie GEWEX Study (MAGS). Within the Mackenzie Basin, there are many important cold-region phenomena such as snow and ice processes, permafrost, arctic clouds and radiation interactions, etc., that will be essential components of any global climate system model.

Several classes of studies make up the Canadian GEWEX programme. They are:

1. Field "point" studies to understand the important physical processes.
2. Studies to relate these physical processes to variables which will be used in hydrologic and atmospheric models at the "basin" scale.
3. Using these basin scale studies, develop physically based parameterization schemes suitable for meso- to macro- scale modelling. Individual parameterization schemes would be tested and validated at meso- and macro-scales.
4. Incorporation of parameterization schemes into hydrologic-atmospheric models. Integrated models would be tested and validated at a range of scales from basin to meso- to macro-scales.

The programme is planned as an integration of scientific activities in atmospheric science and hydrology, of university and government researchers, and of funding support from several sources. An update of activities related to the implementation of the Canadian GEWEX programme will be given at the conference.

Validation of Cloud Parameterization Scheme used in Numerical Weather Prediction Model by using Satellite Observation

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Progress has been achieved during the last decade in the development of more physically based cloud schemes in which the cloud physical processes are presented in a more and more explicit manner. This closer "look" at physical processes needs a new approach of model validation from observed data. This is the main objective of the present study. We developed a methodology for validating the cloud schemes using satellite data (GOES, SSM/I, etc.), in

which special attention is given to the comparison of cloud cover, cloud liquid/solid water, precipitation, and radiation fields. This methodology is applied to the validation of a prognostic cloud scheme (Sundqvist, 1989) used in RPN (Recherche en Prévision Numérique) research and now nearly ready for operations. Preliminary results show the cloud scheme is capable of reproducing the main cloud systems at middle latitudes. The geographical distribution of precipitation simulated by the model is very similar to that estimated from SSM/I data. Outgoing longwave radiation is also realistic when compared to satellite observations.

Determination of Surface Solar Radiation Budgets From Satellite Measurements

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It has been demonstrated previously that it is possible to obtain the surface net solar radiation from satellite measurements of the outgoing flux, in terms of the column water vapour amount and solar zenith angle. This conclusion was based on radiative transfer calculations and supported by comparisons of retrieved surface fluxes with measurements from radiometers mounted on towers. Although there were appreciable differences between individual pairs of retrieved and measured net solar fluxes, there was no significant bias in the differences, regardless of whether skies were clear or cloudy. Thus averages of many measurements, such as would be used to determine monthly mean fluxes, will have small errors.

In spite of this good agreement, there are several factors that were omitted from the original parameterization that must influence the relationship between the fluxes at the surface and the top of the atmosphere. Ozone amount, aerosol type, surface pressure, and cloud height are obvious examples. Modification to the original parameterization will be presented that take into account these effects. The new parameterization will be used to generate a global climatology of the net surface solar radiation from ERBE data.

Solar Surface Net Radiation: A Comparison between Satellite Estimation and GCM Simulation

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Solar surface net radiation (SSNR) is the major component of energy exchange between earth's surface and atmosphere. SSNR is controlled by complex climatic processes, primarily involving clouds, atmospheric humidity, and surface properties. SSNR can therefore serve as a useful diagnostic parameter for testing global climate models (GCMs). Knowledge of the SSNR has improved considerably, thanks to recent advances in satellite observation and inversion techniques. Satellite-based estimates of SSNR should, however, be validated against ground-truth observations. This study first validates satellite-based estimates of SSNR against global surface radiation measurements, These values of SSNR are then compared with those simulated by the Canadian Climate Centre GCM. From the comparison, some deficiencies of the GCM are identified. Satellite estimates of the monthly-mean SSNR are estimated from the Earth Radiation Budget Experiment (ERBE) data using the algorithm of Li et al. They are

compared to the Global Energy Balance Archive (GEBA) which consists of global radiation network measurements. The overall mean bias error is found to be near zero and the random error is estimated to be on the order of 5 Wm^{-2}. However, relative to satellite estimates, the GCM systematically over-estimates SSNR with differences of up to 30 Wm^{-2}. The maximum discrepancy is about ten times the radiative effect of doubling CO_2! Moreover, the disagreement for clear sides is comparable to that for all sides, suggesting that cloud properties may not be the major cause of the differences, While further investigations into the differences are under way, some deficiencies in the GCM have been identified. For example, it was established that solar absorption by water vapour was too weak and water vapour content was too low. As a result, the GCM was outfitted with a new absorption parameterization that is derived from state of-the-art spectroscopic data.

Wednesday / Mercredi a.m. Room/Salle 209
Session 1

Middle Atmosphere modelling / Modélisation de l'atmosphère moyen

Chair/Président: Charles Mc Landress

Stratosphere-Troposphere Interactions Associated with Extra-tropical Cyclogenesis

M. Catherine Reader and G. W. Kent Moore

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There is considerable evidence that certain types of synoptic and mesoscale extra-tropical cyclones, such as polar lows, are generated by the interaction between an upper-level potential vorticity anomaly and a surface baroclinic zone; the cyclonic flow of the high PV air of a stratospheric intrusion can reinforce the surface temperature anomaly and its associated circulation. We use a variety of satellite data, aircraft measurements and objectively analyzed fields to investigate, in detail, the structure and origin of these tropopause features and their role in cyclogenesis for a number of storms (including several from the CASP II experiment). Remarkably, upper-level vortex merging may contribute to this triggering mechanism in some cases.

We emphasize the use of satellite column ozone data, from the TOMS and TOVS instruments, in the identification of mesoscale tropopause features implicated in cyclogenesis. Both data sets are able to resolve many intrusions of ozone-rich stratospheric air that are associated with such tropopause distortions. Preliminary examination of the TOMS data set, which gives daily global coverage, suggests a possible relationship between the occurrence of polar lows and polar vortex fragments. The TOVS data, from the NOAA series satellites, has the advantage of being simultaneous with corresponding AVHRR imagery. Using ozone data retrieved from several infrared TOVS channels, we have identified storms which appear ta have ozone anomaly precursors which aren't readily visible in the TOMS data. Considering the relative scarcity of conventional meteorological information in the polar regions, ozone data provides a potentially useful tool for the study of such storms.

Improved Vertical Operators for Stratospheric Modelling

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Observations of atmospheric disturbances reveal that their amplitudes increase in the stratosphere according to a $p^{-1/2}$ structure (p=pressure). This results from the fact that conservation of energy with vertical propagation implies that amplitude increases as density decreases. The present idea is to incorporate this $p^{-1/2}$ structure in the vertical discretized operators of our sigma level global spectral model.

The following example concerns the vertical structure of the normal modes superimposed on an isothermal basic state at rest. With a sigma (s) vertical coordinate, we have to solve the eigenvalue value problem :

$$\frac{d^2V}{ds^2} + \frac{dV}{ds} + \lambda V(s)=0$$

with appropriate boundary conditions. Here $s=\ln(\sigma)$ and the eigenvalue λ is the inverse of the equivalent depth. The analytic solution is

$$V(\sigma) = \sigma^{-1/2}[V + \cos(n \ln\sigma) + V \sin(n \ln\sigma)]$$

where $\lambda = n^2 + 1/4$ is determined by zeroing a derived determinant. Notice the $\sigma^{-1/2}$ structure of the analytic solution.

Two vertical discretizations will be compared. Discretization #1 uses a finite-element discretization of the previous second-order problem. Discretization #2 first replaces the dependent variable V by V bar where $V = \sigma^{-1/2}$ V bar. A finite-element discretization is then applied.

Significant improvement is found in the first four analytic vertical modes with the greatest equivalent depths. For example, the relative error for internal modes 3 and 4 is about 10% with discretization #1, and is reduced to be only about 1% with discretization #2. The basic idea of directly incorporating the $p^{-1/2}$ structure in the vertical discretization can be applied also to the Helmholtz equation involved in the semi-implicit scheme and to the hydrostatic equation. Those new operators are currently being tested in our sigma level global spectral model.

The Middle Atmosphere Data Assimilation Project at the NASA/Goddard Space Flight Center

Richard Ménard, Peter Lyster, Steve Cohn
Data Assimilation Office

Lynn Sparling
Atmospheric Chemistry and Dynamics Branch

Laboratory for Atmospheres
NASA/Goddard Space Flight Center
Greenbelt, Maryland

The Data Assimilation Office and the Atmospheric Chemistry and Dynamics Branch of the NASA/Goddard Space Flight Center are currently starting a constituent data assimilation project for the middle atmosphere. The aim is to produce a global multilayer analysis of constituent data for the middle atmosphere using a massively parallel implementation of a Kalman filter. The analysis will incorporate UARS, LIMS and possibly other sources of data into a constituent transport model. An estimation of the analysis error will also be provided. A discussion of the full project will be presented.

Forcing of Stationary Planetary Waves in the Winter Stratosphere by Transient Eddies

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Centre for Climate and Global Change Research, McGill University

A steady-state primitive equations model is used to study the structure of stationary planetary waves in the Northern Hemisphere stratosphere. The zonal mean circulation is specified using observed January mean data, as is the wave structure at the lower boundary of 100 hPa. Numerical solutions are then found for the structures of zonal wavenumbers 1 to 3 throughout the Northern Hemisphere stratosphere. The January means of the transient eddy vorticity flux divergence and heat flux divergence have been calculated using observed data, and applied as an additional forcing term in the model.

Experiments have been per-formed using data from four years, 1982-84 and 1986. The model has been run using only forcing by stationary waves at the lower boundary, and using both this lower boundary forcing and forcing by transient eddies throughout the model domain. In a linear version of the model, inclusion of the transient eddy forcing is found to result in a significantly better simulation of the observed stationary wave structure than that produced by lower boundary forcing alone, for three of the four years studied. Work is in progress to carry out a similar comparison employing a nonlinear version of this model.

Wednesday / Mercredi a.m. Room/Salle 232
Session 1

Ocean Modelling / Modélisation de l'océan

Chair/Président: Gordon Swaters

Varibility of Dynamics and Thermodynamics in Baie Des Chaleurs: Observation and Modelling

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Data analysis and numerical modelling were used to study the varibility of both dynamics and thermodynamics in Baie des Chaleurs (BdC, 65.566.5W, 47.5-48.5N). Observations were collected from current moorings and CTD profiles in 1990 and 1991. The 2 1/2 layer model, embedded with bulk mixed layer model, is forced with observed atmosphere fluxes and a remote current field. The results from observations show that the current energy in the high frequency band (<5 days) at all depths in the bay was dominated by semi-diurnal (M_2) tide. It also revealed dynamically active inertial motions in the bay. For the low frequency band (>5 days), stronger energy was evident between 5-10d, with the peaks of near-10d and near-5d along the north shore. The spectra for temperature and salinity show similar features, though the strongest energy was focussed near the density interface. The energy between 5-10d is believed to be the results of wind-induced upwelling along the north shore. Corresponding downwelling occurred on the south shore. The generated internal Kelvin waves propagated along the bay. The model was able to reproduce observations above. Monthly circulation from both observations and model indicated that the variability of circulation and thermal field in the bay strongly depended on resultant effects of the prevailing

westerly wind and and westward remote forcing (Gaspe Current, GC). The model experiments suggested that the effects of GC varibility may intensify the wind induced fluctuations in the bay. Important effects of river runoff are also addressed.

Improved Calculation of Coastally Trapped Waves with Application to Their Scattering and Forcing

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Many applications of low-frequency coastally trapped wave theory, including scattering problems and finding the wind-forced modes, rely upon the orthonormality and completeness of the free modes on the shelf. Traditional methods of calculating these modes have used two-dimensional finite difference grid methods which are impractical for calculating the higher modes to the required accuracy. Also, since each mode is calculated separately, the computed inner product between modes can be quite large.

A new direct method of calculation in the low frequency continuously stratified case is introduced. This uses a Green's function to reduce the problem to a one dimensional integral across the shelf. This then reduces to a linear eigenvalue problem for the phase speed and values of the pressure on the shelf and which can be solved using standard methods. Much
higher resolution is acheived and all required modes are found simultaneously.

The numerical method is then applied to the solution of scattering problems as the topography changes. Detailed answers to questions such as how much coastally trapped wave energy passes through straits or over ridges abutting the coastal shelf are provided. The method also allows the wind-forced response to be determined to any required accuracy.

Numerical Study of Coastal Plumes in the Western Gulf of Maine: An Ideal Ocean Basin

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A three-dimensional numerical modelling of the coastal plume in an ideal basin for the western Gulf of Maine, based on the observations, is carried out to examine the dynamic properties of the plume under the tidal forcing. The purpose of this paper is to reveal possible effects of different factors on the coastal plume in an ideal basin before applying this model to the realistic ocean. The control run in a sloping bottom mimicking the western Gulf of Maine reproduces a southward advection speed of 14 km/day, consistent to the observed 13.3 km/day. Strong vertical mixing resulted from M_2 tide dramatically retards the moving speed and changes the vertical structure. A systematical sensitivity study is also conducted in the following themes: internal parameter dependence, physical dynamic dependence, and geometry dependence. In the theme of parameter dependence, the horizontal mixing coefficient plays little role in determining the plume moving speed and structure within a certain range; also, the plume is not sensitive to the bottom friction coefficient. In the theme of dynamics dependence, a run with no

Coriolis force produces a symmetric fresh water plume, generating a well known fact; the ambient mean alongshore flow speeds up the plume advection southward; the run with linear momentum equations produces an almost identical structure of the control run; the larger (smaller) density difference between the river fresh water and the ambient water produces a faster (slower) southward moving speed, which is, in generally, consistent with the laboratory experiments; the alongshore wind from the south (upwelling favourable wind) completely destroys the southward moving coastal plume and results in a seaward spread of the fresh water due to the seaward Ekman transport; the plume becomes thinner. In contrast, the wind from the north (downwelling favourable wind) squeezes the plume onto the shore, deepening the thickness of the fresh water at the coast with a faster southward moving speed; the offshore (onshore) wind produces a similar scenario (but not as efficient) as the south (north) wind. In the theme of the geometry dependence, the run for the flat bottom of 10 m (30 m) produces a comparable (faster) moving speed of the plume, because the latter allows a thicker fresh water depth in the upper layer to develop which consistent with the theoretical estimate in a two-layer flow. The offshore extension of the plume is much larger in the flat bottom than in the sloping bottom.

Subtidal Circulation Variability on the Scotian Shelf: A Retrospective Modelling Study

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We have developed two numerical models for the study of low-frequency circulation variability on the Scotian Shelf. One is a barotropic model for the three-dimensional wind-driven shelf circulation, and the other is a diagnostic model for the steady density-driven circulation. Both models are computationally efficient and have been successfully used for hindcasting, nowcasting and short-time forecasting circulation on the Scotian Shelf. The barotropic, wind-driven model has been used to examine the response of the Scotian Shelf to the wind and backward-boundary forcing. It was found that the model-predicted variability of the alongshelf transport agrees well with current observations. The diagnostic model has been used to estimate the steady flow on Western Bank and has led to the discovery of a semi-permanent gyre.

Wednesday / Mercredi a.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 2

Aviation Meteorology Detection Technologies I /Techniques de détection de la météorologie de l'aviation I

Chair/Président: Branimir Dulic

The Integrated Terminal Weather System

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The Integrated Terminal Weather System (ITWS) is an aviation weather information system for the terminal area. It is the part of the FAA Aviation Weather Development Program that is specifically directed to the needs of terminal operations. This system is intended to provide the weather information that is required to enhance the safety and efficiency of terminal area operations and to improve the capacity of the airport, especially during times of adverse weather. The users of ITWS information are air traffic controllers, their supervisors, airlines operations personnel, managers of airport operations, and automation systems that are designed to assist in planning terminal operations. The temporal and spatial accuracy requirements for ITWS products are sharper than for enroute products, and the timescale of planning and decisionmaking for terminal operations is short compared with other parts of the air traffic control system. A typical aircraft is under terminal control for about 15 minutes and planning is often geared to 30 minute needs. There is a time criticality for safety products such as microburst alerts. For these reasons, ITWS products are primarily based on automated interpretation of sensor data, contrasting them from the model interpretation by forecasters that characterizes enroute products. Foremost among the terminalarea sensors is the Terminal Doppler Weather Radar (TDWR). The combination of TDWR information with products from the WSR88D ASR9 radars is fundamental to many ITWS algorithms.ITWS products are designed to meet a variety of needs. Safety products that extend TDWR capabilities include enhanced microburst warnings, microburst predictions, and enhanced gust front detection and tracking. Terminal operations efficiency is enhanced by the winds analysis and forecasts and Weather Impacted Airspace (WIA) warnings, which assist with planning terminal routes and runway configurations. The Snowfall Rate product supports aircraft deicing and runway snow plowing operations. Precise short-term ceiling and visibility forecasts will sharpen the ability to anticipate changes in the Airport Acceptance Rate.

The work described has been sponsored by the Federal Aviation Administration. The U.S. government assumes no liability for its contents or use thereof.

Monitoring of Aircraft Icing Hazard using a Dual-frequency Radar

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A main threat to aviation systems is the occurrence of aircraft icing, when cloud water rimes on the cabin, leading to an enhancement in the aircraft weight and a change in aerodynamics, as well as a loss of visibility. This is likely to occur when an aircraft goes through a region of cloud containing a substantial amount of supercooled water - water still maintained in its liquid phase though above the freezing level. Mixed clouds are unstable and their inner structure evolves with time, making the location of such hazardous areas unpredictable on a theoretical basis, and difficult to observe with remote sensors available now. We believe, that an instrument able to monitor and map regions of high supercooled water content would bc useful to pilots, especially when the cloud cover consists of spread stratiform clouds which the aircraft must fly through.

Propose to use a dual-wavelength radar to discriminate between water and ice in clouds.

The reflectivity measured by a millimetric radar provides a three dimensional picture of cloud structure. If the radar is equipped with a second frequency, one can measure, in addition, the dual-wavelength differential attenuation and derive amounts of both ice and water within the cloud.

The method is being field tested at Chilbolton (Berkshire, U.K.) where the existing 3 GHz radar has just been

complemented with 35 GHz radar.

We shall present the basis of ice-water retrieval from dual frequency measurements, discuss the expected accuracy and resolution and their dependence on the technical characteristics of the instrument.

Preliminary results from case studies obtained during the 3/35 GHZ experiment carried out at Chilbolton will be shown.

Transport Canada Proposed R&D Program for the Development of a Multi-Parameter Dual X-Ka Band Doppler Radar for Aviation Meteorology Applications

Gilles Fournier

Transport Canada Aviation

Introduction

Transport Canada Aviation plans will be presented for the design and development of a prototype multi-parameter dual X-Ka band research Doppler radar for detection of parameters relevant to aviation.

Preliminary System Requirements

The preliminary requirements were for a cloud sensing system capable of detecting the cloud bulk parameters relevant to air operations and supporting research and development in aviation meteorology.

Feasibility Study for Multi-parameter X-Ka Band Doppler Radar

Transport Canada Aviation contracted the McMaster University's Communications Research Laboratory for a feasibility study to determine possible upgrades to their IPIX radar to permit millimetre wave operation. The objectives and the findings of the study will be presented.

Key Features of the Multi-Parameter System

The key features of the proposed system will be discussed. These features will extend the range of observable radar parameters to the rate of attenuation and differential attenuation, depolarization ratio, differential reflectivity, and differential propagation phase shift, measured at single frequencies, at two frequencies, or at two polarizations. For example, differential attenuation at X- and Ka-band along with reflectivity could be used to compute median drop diameter in resolution volume, total water content, and even to separate ice from liquid water. Also, discrimination between light and moderate precipitation and cloud layers would be possible using differential attenuation at X- and Ka-band (for light precipitation), and dual polarization at X- and Ka-band (for moderate precipitation). Ice clouds could be identified by their low attenuation at Ka-band.

Plans for the Future

The development of the proposed system would take 1.5 to 2 years and cost $2.5 - 3 Million. But, before the development of the system starts, a study to examine the possible use of the same proposed technology to infer icing conditions will be conducted. Indeed, it is expected that the proposed system could detect, discriminate and characterize those hydrometeors involved in an icing event, either in-flight or on the ground.

The proposed multi-parameter dual X-Ka band research Doppler radar system will be a highly versatile tool for novel research into cloud processes as well as other weather phenomena. The knowledge acquired in the development and use of such a system could lead in the medium term to the development of a core sensor of an intelligent atmospheric information processing system for the detection and classification of weather phenomena impacting aviation, primarily within the terminal area.

Automation of Meteorological Observations using Scene Photometry

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The recent advent of low-cost digital image capture technology has made it practical to automate the visual and information processing tasks of the meteorological observer. One such task is the visual estimate of meteorological optical range or MOR (also called runway visual range or RVR, when the observer is located near an airport). We describe a low-cost prototype "hands-free" system for acquiring photometric and calorimetric data from scenes typical of those viewed by human observers for estimating MOR. Using adaptive image capture control, the system automatically obtains the optimal photometric information needed to estimate MOR over a wide variety of illumination conditions. The system can be designed to cover an arbitrarily wide field of view and arbitrary degree of spatial precision. The dynamic range of the system is greater than 50 dB, which makes possible its use under a wide range of illumination conditions.

Algorithms have been developed for estimating MOR and for obtaining various kinds of information from captured images on a cyclical basis. These algorithms are derived from analysis of the human visual tasks currently used to obtain visibility information. System functions for photometric image capture, scene information extraction, communication., archiving and error checking are described. Pilot work has shown that a variety of photometric and/or calorimetric measures can be obtained from the system that are potentially useful for lighting maintenance, airside safety, sign and signal compliance, security, weather reporting functions within the airport environment as well as aspects of search and rescue.

Wednesday / Mercredi a.m. Room/Salle 224
Session 2

GEWEX

Chair/Président: T. Krauss

Impact of Global Climatic Changes on Long-Term Fluctuation in some Hydrological Processes

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Evaluation of the responses of large hydrological systems on climatic changes poses important scientific and practical problem. Climatic changes in river and lake basins lead to interruptions in the present long-term regime of river runoff and water bodies levels.

To simulate long-term fluctuations in river runoff and water bodies levels the dynamic-stochastical models are used. These models are physically-based ones, so that the process modelled is considered an output one in relation to some generative system with a physical structure which may be circumscribe mathematically. The model's dependencies on input and output process parameters allow us to estimate the systems response to changes in input processes. In our investigation we have used a dynamic-stochastical model with two-dimensional input process. This kind of model takes into account statistical dependencies between input process components, for example, between the river runoff to lake and the effective evaporation from its surface.

Using the model suggested, estimations of characteristics or long-term fluctuations in the level of the Caspian Sea, lakes Issyk-Kul, Ladoga, Ontario and the river runoff from the Neva and St. Lawrence rivers have been made for some climatic scenarios. These estimations may be used in water recourse planning.

Synoptic Atmospheric Moisture Analyses for the Regional Evaporation Study

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A Simple Moisture analysis scheme using Barnes interpolation is applied to a large subcontinental area around the Regional Evaporation Study (RES) field sites in Saskatchewan for the June-July 1991 experimental period. The effect of adding the RES mesoscale network data to the standard meteorological data on the analysis of moisture convergence is evaluated. The degree to which standard network surface observations can successfully supplement the network radiosonde data for moisture analysis is also assessed. Planned improvements to the moisture analysis system include incorporation of Regional Finite Element Model 50-km grid resolution data and surface precipitation amount estimates to enable the system to calculate atmospheric moisture budgets. Such a capability, when combined with surface moisture flux estimates and hydrologic modelling, will contribute to the understanding of the hydrologic cycle present in the MacKenzie River basin, a focus of the Canadian component of the Global Energy and Water-cycle Experiment.

A Modelling Study on Evaporation from Lakes

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Water loss by evaporation from lakes is affected by various factors in the surrounding environment. Near the water surface water vapour fluxes are controlled by turbulent diffusion. We should however consider local advection effects, because lakes, unlike oceans, are limited in extent and surrounded by topography. Thus evaporation from lakes can be affected by abrupt changes in surface conditions, such as surface roughness or temperature, and the humidity and wind profiles associated with the land/water transition. These changes are associated with the growth of internal boundary layer. Brutsaert (1982) has derived an analytical solution but it does not consider the growth of the internal boundary layer associated with the roughness change. A two dimensional model will be established to investigate evaporation from finite-sized water surfaces due to local advection modified by the associated internal boundary layer growth. This model is based on an extension of the "Guidelines" (Walmsley et al, 1989), which estimate the effects

on the airflow due to complex terrain and a change in surface roughness in neutral conditions. Model results will be presented and compared with available results from field experiments in small and medium sized lakes.

Improving Evaporation Estimates using Lined Reservoirs

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Two lined dugouts are being used to evaluate and fine-tune semi-empirical operational methods for estimating open-water evaporation over small water bodies. Each dugout is 30 m by 55 m by 4 m deep. One is partially covered during the summer with a special bubble material designed to reduce evaporation, while the second is left uncovered. Water levels, surface water temperatures, and meteorological factors over each dugout were continuously monitored during 1993.

Results from 1993 field tests will be presented, focusing on Morton's complementary relationship applied to small water bodies, and on Meyer's mass transfer method based on Dalton's Law. The suitability of using these techniques for daily estimates on small reservoirs will be discussed. since they are typically applied operationally for only monthly estimates. These methods may lead to more accurate estimates of evaporation over larger water bodies thus providing improved inputs to numerical weather prediction and climate change models, as well as improved operational planning in water apportionment, hydroelectric interests, and other water resource areas. Current plans are to continue the data collection program during 1994, using improved instrumentation, particularly those used to measure precipitation, water levels, and water temperatures.

Wednesday / Mercredi a.m. Room/Salle 209
Session 2

Middle Atmosphere Radiation / Radiation de l'atmosphère moyen

Chair/Président: Jean-Pierre Blanchet

Development of the New CCC/GCM Radiation Model for Extension into the Middle Atmosphere

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The Earth's climate is mainly determined by the radiative balance between incoming solar and outgoing terrestrial (IR) radiation components. For the surface climate tropospheric radiative transfer is most important and must include the effect of water vapour, carbon dioxide, ozone, clouds and aerosols. However like most GCM radiation codes, the CCC/GCM model assumes only Lorentz line shape and is subject to increasing error in calculations of diabatic heating at altitudes above 40 km. The increasing importance of Doppler line broadening above 40 km and the Non-

Local-Thermodynamic Equilibrium (NLTE) conditions above 80 km must be accounted for to simulate properly the middle atmosphere temperature and dynamics. Two constrains emerge in extending the radiation code to the middle atmosphere: (1) the calculation time which increases as a quadratic function of the number of model levels and (2) the quality of the tropospheric and surface climate. The strategy to develop the new CCC/GCM/MAM IR radiation code is to merge the best part of two state-of-the-art codes. The tropospheric Morcrettes's scheme used in the standard GCM and a new computer efficient scheme dedicated to the middle atmosphere. This new scheme computes directly diabatic cooling rates rather than irradiance as in the troposphere. Its computational efficiency reduces the calculation time by a factor 3. Matching of cooling rates is done by interpolation around 25 km of altitude. The new scheme remains upward compatible with the standard CCC/GCM and optimises the calculation time.

Adaptation of the CCC/GCM Solar Radiation Model for Middle Atmosphere Simulations: Spherical Geometry and Spectral Resolution

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Calculation of absorbed solar radiation in the middle stratosphere is required for diabatic heating, which control most of the atmospheric circulation, and photo-chemical reactions. Most Middle Atmosphere Models (MAM) use two distinct parameterization for those related processes. The reason is mainly the computer cost associated to the need for narrow band calculations in photo-chemistry. The CCC/GCM normally uses two spectral intervals: visible (0.3-0.7μm) and near-IR (0.7-4.0μm). This is adequate for calculation of heating rates but lacks' resolution in UV for photo-chemistry considerations. Following the modifications for the terrestrial radiation scheme, a dedicated solar code is developed for the middle atmosphere. This new model accounts for spherical geometry of atmosphere. In particular the heating rate at the polar sunrise terminator, where the ozone hole forms, is mostly influenced by solar radiation at zenith angle larger than 90 degrees. The effect of spherical geometry on atmospheric circulation will be discussed.

Calculations of Scattered 300-750 Nm Solar Radiation in the 20 Km of the Stratosphere at Twilight and Comparison with Measurements

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The NASA Stratospheric Photochemistry, Aerosol and Dynamics Expedition (SPADE) recently used a heavily-instrumented ER-2 to investigate the photochemistry of the 20-km region of the stratosphere with a view of understanding the possible impact of a proposed fleet of high speed civil aircraft. A small spectrophotometer designed to measure radiance in the spectral region 300-800 nm was mounted on the wing of the ER2. One of the authors (TM) is the Principal Investigator for this experiment. The instrument produced a large quantity of radiance and polarization data which are diagnostic of the light-scattering effects from sulphuric acid droplets. The analysis of these data will yield information about the density of sulphate aerosols in the 'far-vicinity' of the ER-2 which will complement the data collected by other instruments which measure the in-situ densities. In particular, a detailed understanding of the observed radiance values will provide a better understanding of the importance of multiply-scattered light near the terminator. This is important for photochemical modelling. The focus of this work is the completion of a multiple-scattering, radiative transfer model using the sucessive orders of scattering method. The contribution from ground reflected radiation will be included and, when coupled to a Mie scattering routine, will be

applied to stratospheric aerosols. An accurate description of the radiation field at twilight is critical to the sucess of this work. We present a preliminary comparison of the model with the measured radiances and the in-situ aerosol measurements.

The Influence of the Middle Atmosphere on the Surface Ultraviolet Radiation Environment

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The middle atmosphere affects the surface UVB levels because the ozone layer acts as a partial screen; there has been debate on how much UV levels have changed with the thinning of the ozone layer since other factors such as tropospheric pollution also strongly affect UV levels. Extraordinarily high-levels of ultraviolet (UVB) radiation were experienced in Ontario in 1993. Measurements of UVB radiation levels from sites north of Toronto and at Peterborough in 1992 and 1993 are described. This increase is attributed to a large thinning of the ozone layer which occurred in 1993. The ozone layer was about 15 % below normal from January to March, 1993. Over this period, the UV radiation levels were about 20 % higher than over the previous three years. This depletion has been attributed to the volcanic cloud from Mt. Pinatubo as well as to chemical destruction in a cold winter Polar vortex. The combined ozone depletion lowered the ozone at mid latitudes throughout the spring with resulting elevated UV radiation levels in spring and early summer. The ozone layer usually recovers by September as photochemical activity produces an approach to equilibrium. By October, 1993 the UVB levels and the ozone layer had returned to close to normal. The elevated UVB radiation levels in spring, 1993 may have produced observable biological effects. The photodissociation rates for gases such as ozone and nitrogen dioxide were also elevated on clear days in southern Ontario during 1993. This large increase in UVB radiation coincident with a corresponding thinning of the ozone layer in 1993, graphically demonstrates that the predicted future depletion of the ozone layer of 10 % by 2020 will cause a corresponding future increase of over 10 % in UVB levels and photodissociation rates.

Wednesday / Mercredi a.m. Room/Salle 232
Session 2

Ocean Modelling / Modélisation de l'océan

Chair/Président: Gordon Swaters

Examination of the Veronis Effect

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In this study we have run a number of numerical simulations to examine the 'Veronis effect' in an ocean general circulation model in a North Atlantic basin configuration. This effect is characterized by anomalous interior downwelling, east of the western boundary current. The impact of varying the horizontal diffusivity and the use of an isopycnal mixing parameterization are examined.

Several diagnostics are used. The net volume transport for a sector in the southern part of the domain, east of the western boundary is found to be the clearest indicator of the strength of the Veronis effect.

This effect is found to depend crucially on the horizontal diffusivity. The use of an isopycnal mixing parameterization significantly mitigates the interior downwelling problem but is constrained by the required use of a background horizontal diffusivity.

Stability Characteristics of Deep Water Replacement in the Strait of Georgia

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A theory is presented to describe the linear baroclinic instability of a deep water replacement current in the Strait of Georgia. The strait is modeled as a deep water channel with variable cross channel topography. The gravity current is modeled as a coupled density front on the sloping eastern bottom of the strait. The model equations correspond to an 'intermediate lengthscale' dynamical balance between the geostrophic frontal dynamics and the quasi-geostrophic surrounding water. The frontal dynamics evolve geostrophically but not quasi-geostrophically since the deflections in the frontal height are not small in comparison to the scale height of the front. The evolution of the frontal height is strongly coupled to the geostrophic pressure in the surrounding water through the hydrostatic balance which expresses continuity of the dynamic pressure across the frontal interface.

It is shown that the necessary conditions for instability is governed by the correlation of the slope of the bottom topography and the slope of the eddy boundary. It is also shown that the baroclinic stability characteristics are principally determined by a so-called non-dimensional interaction parameter which physically measures the ratio of the destabilizing baroclinic vortex-tube stretching/compression to the stabilizing topographic vorticity gradient.

The linear stability equations axe solved exactly for a parabolic density front on a wedge shaped bottom. In this case, growth rate and phase speed bounds, the existence of high wave number cutoffs are presented, and a semicircle theorem for unstable modes are presented. In addition, a detailed description of the spatial and temporal characteristics of the instabilities and the relationship of the parameters to the instabilities is give. It is demonstrated that, for physically realistic parameter values, the instabilities are manifested as amplifying Rossby waves in the slope water, and as amplifying anticyclones on the density front. The results are compared to the observed low frequency fluctuations in the Strait of Georgia.

The Effects of Surface Thermal Boundary Conditions on Eddy Simulation of Ocean

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The effect of the conventional restoring thermal surface bounadry condition,is examined by coupling an eddy-resolving ocean circulation model to a zero heat capacity atmospheric model. Two significant differences are obtained. First, both eddy and mean kinetic energy near mid-latitude free jet are increased. Second, the SST (sea surface temperature) anomaly and vertical profile of temperature variance are more realistic.

Modelling Steady-State Thermohaline Interleaving

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Thermohaline interleaving is frequently observed in regions of the ocean with compensating lateral gradients of heat and salt. The cross-frontal fluxes of heat and salt associated with interleaving motions can play an important role in the dynamics of oceanic fronts, and in the decay of some types of ocean eddies. In an attempt to predict the fluxes carried by fully developed interleaving and to assess their importance, we have developed a simple one dimensional numerical model which allows an investigation of the nonlinear equilibration of a linearly unstable disturbance.

The model runs demonstrate that even when the water column is initially unstable to salt fingering at all depths, the growing intrusions eventually cause diffusively stratified and unstably stratified convecting layers to form. In double-diffusively unstable regions of the water column the diffusivities are specified functions of the density ratio, while in statically unstable regions a conventional eddy diffusivity formulation is used. In addition, a minimum diffusivity Kmin representing the level of background turbulent mixing is specified, and it is found that the character of the solutions depends critically on the value of Kmin. The model evolves to an equilibrium state in which small scale vertical flux divergences are balanced by lateral flux divergences produced by along-layer advection. The background turbulent mixing permits such a balance by allowing the effective vertical flux ratio of the double-diffusive layers to vary as the intrusions grow. For small Kmin the growing intrusions reach a steady state reminiscent of a thermohaline staircase, with thick convecting layers separating fingering layers from weak diffusive interfaces. For larger Kmin the convecting layers are much thinner and may disappear altogether, leaving a series of diffusively stratified and fingering layers.

Wednesday / Mercredi p.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 3

Aviation Meteorology Detection Technologies II / Techniques de détection de la météorologie de l'aviation II

Chair/Président: Gilles Fournier

Low-Cost Hazardous Weather Detection for Airports

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Hazardous weather detection in the terminal area will significantly improve safety and operations efficiency at major airports. The compressed time and spatial scales of hazardous weather affecting aviation often necessitate a dedicated weather radar sensor, but costs limit the extensive deployment of current systems. Unisys Corporation has developed a "mini-TDWR" (Terminal Doppler Weather Radar) with a projected cost of $500K (US) to meet this need. Current system capabilities are: (i) 2 to 4 minute warning of hazardous microburst windshear within 10 Km of an airport; (ii) surface microburst windshear detection and track within 10 Km of an airport; (iii) precipitation detection within 10 Km of an airport. Capabilities being added in 1994 include: (i) gustfront detection and track within 30 Km; (ii) extended precipitation detection to 30 Km. The unique microburst warning ability of the system has resulted in naming this new radar system the Microburst Prediction Radar (MPR).

This paper describes the MPR pre-production prototype available for user demonstration in 1994, as well as, the MPR's previously demonstrated performance for microburst early warning and detection in Orlando Florida. Extending MPR range to 30 Km for hazardous weather detection is also discussed. Snowfall detection and measurement is explored as a potential MPR add-on product for Canadian airports which typically experience significant snowfall hazards.

Directly Measured Vector Winds from an Inexpensive Bistatic Multiple-Doppler Network

Joshua Wunnan

NCAR

A multiple-Doppler radar network can be constructed using only one traditional transmitting pencil-be-am radar and one or more passive low-gain nontransmitting receivers at remote sites. Radiation scattered from the pencil beam of the transmitting radar as it penetrates weather targets can be detected at the receive-only sites as well as at the active transmitter. The Doppler shifts of the radiation received at all the sites can be used to construct two- and three-dimensional wind fields in a manner similar to that used with traditional multiple-Doppler networks.

Accurate knowledge of the full, three-dimensional vector windfield throughout a volume of the atmosphere is extremely desirable for a number of varied applications. Aviation interests can directly benefit from this information since it allows the improved detection, prediction and modeling of hazardous events and economically costly windshifts. Bistatic systems can be deployed affordably to provide three-dimensional fields of full vector winds, including directly measured vertical precipitation particle velocities for numerous applications in meteorological research, aviation, forecasting, media, and education.

Bistatic multiple-Doppler networks have significant economic and scientific advantages accruing from the use of only single sources of illumination. The passive receivers in a bistatic network do not require expensive transmitters, moving antenna hardware, or operators. Thus they require only a small percentage of the investment needed to field traditional transmitting radars. Individual spatial volumes are viewed simultaneously from multiple look angles, minimizing storm evolution induced errors.

A dual-Doppler weather radar network consisting of only one transmitter and a non-transmitting, non-scanning, low-cost bistatic receiver was deployed in the Boulder, CO area during 1993. The Boulder network took data in a variety of weather situations, including low reflectivity stratiform snowfall, several convective cells, and a hailstorm. Dual-Doppler vector windfields were retrieved and compared to those from a traditional, two-transmitter dual-Doppler network. The favorable results from these comparisons indicate that the bistatic dual-Doppler technique is viable and practical.

Multiple Scattering Lidar Returns from Atmospheric Aerosols and Precipitation

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A lidar (LIght Detection and Ranging) can provide information on the optical and physical characteristics of atmospheric aerosols, clouds and precipitation by measuring the range resolved backscatter signal from laser pulses emitted into the atmosphere. Lidars have been used for years in meteorology to study cloud microstructure and in aviation to determine the cloud base height. The traditional lidar approach where the backscatter is measured with one field of view has limitations due to uncertainty in the aerosol backscatter to extinction ratio and to the contribution of multiple scattering to the signal. We have developed a multiple field of view (MFOV) lidar that measures simultaneously the lidar return with four concentric fields of view with half angles 3.8, 12.5, 25 and 37.5 mrad. The central field of view receives the direct backscattered power while the outer fields of view receive multiply scattered power. The distribution of power measured at each field of view is a function of the aerosol concentration and characteristic size along the beam path. By comparing lidar measurements to in-situ aerosol measurements we show that the lidar signals are consistent with existing theories of multiple scattering beam propagation. We also show that the MFOV lidar can detect the presence of suspended ice crystals or precipitation droplets within clouds.

Lidar Remote Sensing of Cloud Properties

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A multiple scattering lidar technique was developed for the remote Sensing of cloud properties. The technique is based an the simultaneous detection of infrared (1.054 pm) lidar returns at three concentric fields of view. This configuration allows the measurement of the multiple scattering contributions to the lid&r radiation backscattered by the cloud droplets. A simplified model of the field-of-view dependence of there multiple scattering contributions was obtained in the form of a series expansion in terms of the field-of-view angle. The measured data at the three fields of view are fitted to a second degree polynomial at each lidar range. By equating the numerical values of the coefficients of the fitted polynomial to the

theoretical expressions, we can solve simultaneously for the extinction coefficient and the average cross-section radius of the droplets as functions of distance along the pointing direction of the lidar.

The system operates at a wavelength of 1.054 pm. However, assuming that the droplet size distribution has the general shape of a Gamma function (three parameters), we can extrapolate to other wavelengths. Hence, the instantaneous visibility along any slant path direction,, in particular the glide path of a landing aircraft, can be determined at a typical refresh rate of 0.1 Hz. This visibility data is time- and range-resolved so that a pilot on an instrument approach through fog or low clouds could be kept informed, as the flight progresses, of the altitude and horizontal distance at which he will be able to see the runway features with a contrast better than some preset value. The system is limited in range to an optical depth of about 3-3.5, i.e. the limit of visibility. Another parameter of meteorological interest that can also be derived from our lidar measurements is the profile of the cloud liquid water content.

The paper describes the solution method and compares lidar-derived profiles of cloud liquid water content with aircraft measurements, and the extrapolated extinction coefficients at 0.55 pm and 10.6 um with *in situ* measurements performed along a mountain slope by means of extinction sensors mounted on a cable car.

Wednesday / Mercredi p.m. Room/Salle 224
Session 3

Clouds & Climate / Nuages et climat

Chair/Président: Ron Stewart

The Effect of the Large Scale Cloud Homogeneity Assumption on the Shortwave Radiative Fluxes Computed in GCMs

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Grid averaged cloud fraction and cloud optical depth are two of the major parameters that determine the shortwave (SW) flux budget and atmospheric SW heating rates in general circulation models (GCMs). Most GCMs use two methods to distribute cloud mass in their gridpoints once the conditions for cloud formation are satisfied: the water content prognosed or diagnosed is spread uniformly across the gridpoint which is assumed to be overcast (method 1); cloud water is homogeneously distributed within the fraction of the gridpoint which is prognosed or diagnosed to be cloudy (method 2). These two methods would of course give different SW fluxes for the same total cloud mass within the gridpoint. Moreover, the fluxes calculated with the above methods are expected to differ from the true SW flux over a real scene the size of a GCM gridpoint where the mass of condensate is usually distributed in a complex way among many cloud elements.

We use AVHRR global area coverage (GAC) radiance data which have a 4 km nominal resolution to explore the existence of systematic biases when applying methods 1 or 2 to calculate SW fluxes and examine how these differ for the various cloud regimes. We first separate clear from cloudy pixels based on criteria we develop from the SW and LW radiances of the scene and some of their combinations. We assign an optical depth of zero to the clear pixels and retrieve the optical depth of the cloudy pixels using look-up tables constructed using the discrete ordinates method of radiative transfer. We define [tau] as the optical depth obtained by linearly averaging the high resolution optical depths over some spatial scale and $<\tau>$ the optical depth obtained by inverting the linear average of an appropriate radiative quantity over the same scale. The linear averaging can include clear pixels (simulating method 1) or not (simulating method 2). We present the changes in the statistical properties of [tau] and $<\tau>$ as the averaging takes place over increasingly larger spatial scales for different cloud regimes and discuss implications for GCM modeling.

Parameterizations of Cloud Microphysical Characteristics and its effect on Climate Change

I. Gultepe and G.A. Isaac

The parameterization of cloud microphysical characteristics based on bulk parameters of the models is important to understand the effect of the clouds on climate change and the general circulation of atmosphere. Because of large grid scaling, the models cannot handle clouds in detail. The values of effective radius (r_{eff}) and liquid water content (LWC) are extensively used in the radiative transfer calculations. Single scattering properties such as extinction coefficient, single scattering albedo, asymetry factor, are also calculated from LWC and r_{eff}. For this purpose, extensive data sets from the North Atlantic Regional Experiment (NARE), Canadian Atlantic Storm Project (CASP) I-II and other Canadian field experiments have been analyzed. Clouds are divided into subsections, including stratiform and convective clouds. Measurements are averaged over various scales to obtain r_{eff} and LWC as a function of environment temperature, vertical air velocity fluctuations, and droplet concentration. Preliminary results indicates that stratiform and convective clouds within the large scale models can be represented by using model output and derived parameterized equations. Such parametrizations would enable us to calculate single scattering properties of droplets within various cloud types without expensive Mie theory calculations.

On Modelling the Role of CCN on Cloud Microphysics and Radiation for GCM: The Twomey Effect

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Global climate warming caused by increased emissions in the atmosphere of greenhouse gases (CO_2, CFC, methane and others) is a problem that retains the attention of many research groups. There are yet other important factors controlling the Earth's climate that need to be considered. The aerosol-cloud interaction and their optical properties are among them. The Twomey effect relates the increase of cloud albedo to the increase in concentration of Cloud Condensation Nuclei (CCN). This effect is observed in the tracks left by ships in coastal regions covered by marine strato-cumulus clouds. On the large scale, this process is hypothesised to have a cooling effect, counteracting the greenhouse warming effect. In order to include this process into a General Circulation Models (GCM), a parameterization of explicit cloud microphysics is required. A method that considers the concentration of CCN and the size distribution of droplets is proposed. This method is suitable for GCM application. It will allow us to evaluate the impact of increasing anthropogenic pollutants in the atmosphere and more specifically in the Arctic where a cooling trend is observed instead of the GCM predicted warming due to increasing CO_2.

Effects of SO_2 on the Atmospheric Water Cycle during the Formation of Continental Arctic Air Mass: Its Implication for Climate

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Recent analysis of lower troposphere temperatures for the last 40 years has shown no trace of the expected greenhouse warming in the Arctic. In this paper, we discuss the interpretation of recent climate models in terms of these new observations and analyses, in particular, the observed wintertime cooling trend. The rate of air mass transformation from maritime to continental polar air depends on the water vapour removal rate through condensation and precipitation. In turn, the removal of atmospheric water vapour reduces the greenhouse effect and enhances the cooling rate of the surface. In this study, a model is made to simulate the formation of the continental polar air mass. This model calculates aerosol

microphysics between 0.001 and 500 þm, which is from the nucleation range, through the accumulation mode, CCN activation, cloud droplets-ice crystal and precipitation. A particular attention is paid to sulphuric acid, a substance with a strong affinity for water vapour. We will discuss new results on the climatic effect of this water cycle perturbation. The alteration of droplets and crystals spectra due to the presence of sulphates will also be examined.

Wednesday / Mercredi p.m. Room/Salle 209
Session 3

Middle Atmosphere Observations of Chemistry 1 / Observations chimiques dans l'atmosphère moyen 1

Chair/Président: William E. Ward

The Composition and Photodissociative Flux Measurement as Flown on the NASA ER-2 High-Altitude Research Aircraft

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York University, CRESS

M.J. Prather
University of California, Department of Geosciences

A version of the AES SunPhotoSpectrometer, which was flown with Canadian Astronaut Steve MacLean during STS-52, has been designed to make measurements of the horizontal spectral flux, limb brightness and Earth-surface reflectivity from the NASA ER-2 research aircraft. The instrument was flown as part of the photochemical payload used for the Stratospheric Photochemistry, Aerosol and Dynamics Expedition (SPADE) of the NASA High Speed Research Program and it will accompany the Airborne Southern Hemisphere Ozone Experiment to the Antarctic next year. The spectrophotometer is based on a 1024-element, randomly-addressable Reticon photodiode array. Some aspects of the design and the performance of the instrument during SPADE will be presented.

Model Simulations of Heterogeneous Reactions in Sulfate Aerosol and PSC Particles: A Sensitivity Study

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York University

Field and laboratory measurements and model simulations confirm that the following heterogeneous reactions

$ClONO_2(gas) + HCl(solid)$ þ $Cl_2(gas) + HNO_3(solid)$
$HOCl(gas) + HCl(solid)$ þ $Cl_2(gas) + H_2O(solid)$
$ClONO_2(gas) + H2O(solid)$ þ $HOCl(gas) + HNO_3(solid)$
$N2O_5(gas) + H2O(solid)$ þ $2HNO_3(solid)$

$N220_5(gas) + HCl(solid)$ þ $CIN02(gas) + HN0_3(solid)$
are likely to be involved in the processing of polar stratospheric air on ice and NAT ($HN0_303H_20$) crystals to produce high levels of CIO which can catalytically destroy ozone leading to the formation of the ozone hole. Hydrolysis of $N20_5$ and $CION0_2$ also can occur on the ubiquitous stratospheric aerosol and these reactions primarily affect mid-latitude ozone. However, recent laboratory data has demonstrated that first two reactions can also process gas phase species on the sulfate aerosol at temperatures above 1-he NAT formation threshold. thus increasing activation of inactive chlorines such as HCI and $CION0_2$ to more active forms of $CIO_x = CI + CIO + 2CI_20_2 + CI_2$.

A new box model of the atmosphere has been developed which includes all mentioned heterogeneous reactions in addition to a fairly complete suite of gas phase reactions. Simulations of the winter and spring conditions in the lower stratosphere in the polar and mid-latitude regions have been carried out. We have studied the model sensitivity to the following factors: sulfate aerosol loading, PSC supersaturation, the reactions of $CION0_2$ and HOCl with HCl in sulfate aerosol.

We have also investigated the impact of the relatively new laboratory data which indicate that the cross sections of $HN0_3$ decrease with decreasing temperatures at the wavelength edge 270-320 nm. This effect reduces NO_x formation due to photolysis of $JIN0_3$ and makes ozone more vulnerable to the catalytic destruction by chlorine species.

Speam-2 Measurements made during STS-52

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S.G. MacLean, and B. Tryggvason

Canadian Space Agency, Canadian Astronaut Program Office

The SunPhotoSpectrometer Earth Atmosphere Measurement (SPEAM-2) experiment was flown on the United States Space Shuttle Columbia during October, 1992 as part of a group of Canadian experiments referred to as CANEX-2. Measurements of the solar intensity were made through the orbiter side-hatch window at various wavelengths in the visible and near-ultraviolet during a sunrise terminator crossing. The miniature, hand-held photodiode array spectrometer which was developed for the flight will be described and the data collected during STS-52 will be presented. The success of the experiment points the way toward the use of small instruments to make accurate, but inexpensive, observations of the composition of the upper atmosphere.

Differences in Upper Tropospheric Ozone, No_x, and No_x/No_y Between Mid-Latitude and Tropical Air Masses

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A J Weinheimer
National Center for Atmospheric Research, Boulder, CO

Two of the DC-8 flights during the second Arctic Airborne Stratospheric Expedition (AASE II) were between California and Tahiti. The flight to Tahiti took place on January 28 1991, and the return flight occurred the following day. The altitude of the DC-8 was mostly between 10 and 12 km. Both flights recorded extremely sharp, simultaneous changes in ozone, total reactive nitrogen (NO_y), fraction of NO_y as NO_x (NO_x = NO + NO_2), humidity, and several other variables at about 20þ N. There have been many other indications that "pristine" tropical air is much lower in concentrations of ozone and other tropospheric pollutants than mid-latitude air. These flights are somewhat unique however in the number of simultaneous measurements that were made, and the fact that they occurred at a higher altitude than most previous flights. In addition to putting the flights in a meteorological context, a chemical model will be used to investigate the reasons for the changes in the observed NO_x/NO_y ratio at the transition between the two air masses.

Wednesday / Mercredi p.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 4

Aviation Meteorology Algorithm Development / Algorithme de développement pour la météorologie de l'aviation

Chair/Président: Ken MacDonald

Climatological Study to Determine Microburst Occurrence, Frequency of Occurrence, and Location in Canada

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Low level wind shear, specifically the hazardous form of wind shear known as microbursts, has been recognized as a danger to aviation that has caused a number of air transportation accidents world wide over the past two decades. Their existence, frequency of occurrence, and potential threat in Canada has always been suspected, but never scientifically confirmed. This study, performed for Transport Canada's Transportation Development Centre, was an effort to establish a climatology of days with possible microburst events on a country-wide basis. As there have been no special measurement systems or networks established for microburst detection in Canada, there are no such measurements to rely on. All that is available are the climatological databases of standard hourly surface meteorological observations and twice daily radiosonde soundings. With this limited database, the approach taken was: i) to examine the intensive field experiments that have been carried out previously in the United States by the FAA, NCAR, and various university groups studying microbursts, ii) to identify the meteorological parameters indicating the presence (or absence) of this phenomenon that can be found in or derived from the available standard meteorological observations, and then iii) to relate these parameters to similar situations that may exist in Canada and establish their frequency of occurrence.

Analyses showed that simultaneous occurrences of trends for several standard surface meteorological parameters often suggest, to a high level of significance, the unlikelihood of a microburst occurring. Applying these same relationships to the Canadian database showed overall annual maxima for relative frequencies of potential microburst occurrence in south central Alberta and the west coast of British Columbia. The regional weather offices of Environment Canada were also surveyed for historical cases of suspected microburst events.

Verification of the "Gust" Algorithm using Doppler Radar Data

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Transport Canada is under-taking a climatological study to determine the frequency and location of microburst occurrence in Canada. Specifically, our objective is to derive a microburst climatology for the Montreal area using a "gust" algorithm applied to data archived by the J. Stewart Marshall Radar Observatory (MRO) of McGill University. This algorithm, based solely on radar reflectivity data, has already been successfully used by local forecasters for the past 3 summers in assessing

the strength of surface winds associated with thunderstorms. Based on the cloud top penetrative downdraft mechanism, it estimates the maximum surface wind speed W from the vertically integrated liquid water content, VIL, and the thunderstorm echo top, ET, from the relation $W = (c_1 VIL - c_2 ET^2)^{1/2}$ where c_1 and c_2 are two appropriate constants. The recent Dopplerization of the MRO radar enables us to attempt a verification of this algorithm by searching for signatures that are associated with strong downdrafts, namely low-level divergence, convergence and rotation at mid levels and descending reflectivity cores. Cases have been selected from the summer of 1993 where damaging surface winds have been reported. We will confirm whether the current temporal (5 minutes) and spatial (1 km) resolution of our Doppler data is sufficient to identify these phenomena. A better verification is expected for this summer 1994 when we anticipate temporal and spatial resolutions of 2.5 minutes and 0.5 kilometres respectively.

Wet Microbursts: A Forecasting Approach

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Centre Météorologique du Québec
Environment Canada

Gilles Fournier
Transport Canada

Aldo Bellon
McGill University

Severe wet microbursts pose a danger for both the aviation community and the public at large. The presentation will deal briefly with the morphology of wet microburst thunderstorm cells The forecast approach is based on both environmental conditions which research results indicate, favour such microbursts as well a radar reflectivity algorithm which was given the name "GUST".

Recent research results indicate that a wet microburst-pron environment is characterized by the presence of low-level moisture capped by a mid-level dry layer. It is possible to differential between a wet microburst situation, and a day with thunderstorm but no microbursts in terms of the vertical profile of the equivalent potential temperature (0e).

Case studies show the two types of storm structures can result i wet microburst activity the classical supercell type of storm an the "pulse-storm". A supercell generally develops in strong buoyancy energy and moderately to strong wind-shear conditions. Radar reflectivities for this category of storm indicate strong returns at mid-levels and a typical overhang signature. However wet microbursts have also been known to occur with "pulse-storms" which occur in moderately buoyant conditions with vertical wind shears varying from light to moderate. Radar reflectivities an visual observations suggest only a benign thunderstorm.

The GUST algorithm is based on the relative distribution of liquid water within the thunderstorm and uses both the vertically integrated liquid water content (VIL), as well as the radar echo top of a storm. Both these parameters can be derived fro volumetric radar information. The algorithm appears to discriminate wet microburst producing storms of both the supercellular and the "Pulse-storm" type.

Real-time Estimation of Atmospheric Turbulence Severity from In-Situ Aircraft Measurements

Larry B. Corman

National Center for Atmospheric Research
Research Applications Program
Boulder, CO

The quality of atmospheric turbulence detection and forecast information for the operational meteorology and aviation communities is directly linked to the quality of real-time measurements. Currently, the only direct data are subjective, qualitative, and intermittent pilot reports. This paper describes techniques, suitable for real-time application on commercial transport aircraft, to generate quantitative and comprehensive turbulence measurements. These algorithms build on standard methods used in the analysis of aircraft response to turbulence, but are specifically designed to address the limitations of the available on-board data and computational resources.

Development of a New Low-level Turbulence Analysis and Forecasting Index

Capt David I. Knapp (USAF), Robert Dumais and
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U.S. Army Research Laboratory
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Improving the accuracy of low-level turbulence forecasts emphasize the use of gridded data fields and high resolution terrain data to derive realistic localized horizontal and vertical wind flow patterns. Output from mesoscale models can provide forecasters the opportunity to use high resolution data to detect the subtle features in low-level wind fields which lead to turbulence occurrence. This study is designed to develop and verify an objective low-level turbulence analysis and forecasting index.

The Turbulence Index (TI) is the product of horizontal deformation and the sum of vertical wind shear plus convergence. It has been proven to be an effective tool at upper levels in the vicinity of jet stream maxima, and has been adapted for use in lower-levels. The TI is calculated using grid point wind data from the Higher Order Turbulence Model for Atmospheric Circulations (HOTMAC). Verification is being accomplished using data centered on daily 00 UTC RAOB times for cases occurring from February to April 1993 in mesoscale regions surrounding Denver, CO, Chicago, IL, and Huntsville, AL. Areas of index-derived turbulence and intensities are verified with pilot reports from 22 UTC to 02 UTC for each case studied. For the Huntsville region, the TI performs best in the layer from 1000-4000 feet above ground level with a turbulence occurrence Probability of Detection of .73 and a False Alarm Ratio of just .06.

In an effort to further refine the TI, its terms were separated into independent parts and statistically evaluated using multivariate linear regression techniques. A new Regression Turbulence Index (RTI) has been derived for the Huntsville region and compared to the TI, relating both to reported turbulence intensity. Correlation coefficients as high as .73 for the RTI exceeded those for the TI in all lower levels studied. Results to be presented will include similar calculations for the Chicago and Denver regions.

Wednesday / Mercredi p.m. Room/Salle 224
Session 4

Climate - Change or variation / Climat - Changement ou variation

Chair/Président: Bill Pugsley

Canadian Temperature Trends and Extremes and the Relationship to Large-scale Atmospheric Circulation

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An overview of annual and seasonal, national and regional, surface temperature trends in Canada over the past 100 years is given. The temperature data used were extracted from the Historical Canadian Climate Database (HCCD) of Atmospheric Environment Service. Climate stations were selected on the basis of spatial distribution, length of record, data continuity, homogeneity assessments and other factors. The HCCD was assembled to provide climate researchers access to a dataset that has been rigorously quality controlled, assessed for homogeneity and adjusted to be suitable for use in regional scale analyses.

There has been an increase in Canadian national mean temperature of approximately 1.0þC over the past century. This has been about twice the magnitude of the warming in the northern hemispheric over the same period. The nature of this warming is similar to that of the hemispheric record with a warming from the late 1890s to the 1940s, followed by a cooling into the 1970s, and then a resumption of a warming to the present. Regionally, the most striking contrast is the strong warming trend in the Mackenzie District of the western Canadian sub-Arctic of about 1.7þC and the cooling trend over the Arctic Mountain and Fiord region of the extreme northeastern Canadian Arctic of about 0.6þC since the late 1940s.

Regional temperature departures for individual seasons show considerable variability and extreme events are derived from rankings of HCCD data. The differences in the large-scale atmospheric circulation (50-kPa heights) during extremely warm and extremely cold regional conditions are illustrated and discussed. Also discussed is the extreme cold summer of 1992 and the cold winter of 1994 and their relationship to the large-scale atmospheric circulation.

The Ocean As A Source for Rapid Interglacial Climate Fluctuations

Andrew J. Weaver

School of Earth & Ocean Sciences, University of Victoria

Recent remarkable findings in Greenland ice core data have suggested that the climate of the last (Eemian) interglacial was not as stable as that of our present (Holocene) interglacial. Rapid transitions between warm and cold periods were found to occur over a period of several decades. The North Atlantic climate during the Eemian period was further shown to be characterized by three states: one significantly warmer than today; one similar to today and one significantly colder than today. While there is some concern as to the reliability of the ice core data corresponding to the latter half of the Eemian, it is suggested that the "conveyor" for North Atlantic deep water formation has three distinct modes of operation, consistent with the existence of the three Eemian climatic states. This suggestion is based on the results from an idealized global ocean model driven by quasi-realistic winds, freshwater fluxes, and sea-surface temperatures. It is further shown that rapid transitions between the modes can be excited through the addition of a simple random forcing to the mean freshwater flux forcing field. The model results suggest that a source for the observed, but controversial, Eemian climate variability may well lie in the dynamics of the ocean's thermohaline circulation which responds to an enhanced hydrological cycle associated with the warmer mean Eemian climate. The implications of these new findings to the current public policy debate regarding the *action* or *adaptation* to increasing greenhouse gases is also discussed.

Is the Global Climate System At A State of Self-Organized Criticality?

Michael R. Gipp

Department of Geology, University of Toronto

Recent work on ice cores suggests that global climate fluctuates rapidly between several metastable states, apparently

through changes in thermohaline circulation patterns. These changes in climatic state are also recognized in the deep-marine record as abrupt changes in the amplitude and phase of the first derivative of the þ^{18}O record (a proxy for the rate of global ice growth), which result because the relationship between the rate of ice growth and the insolation at high northern latitudes changes at the same time as thermohaline circulation patterns. The palaeoclimate record is thus "encrypted", and understanding it is difficult, because different parts of the record have been "encoded" in different ways.

In theory, the amount of information, or entropy, in the "encrypted" ice volume signal should be greater than that of the insolation signal. However, the opposite is the case, suggesting that the timing of climatic state changes is also related to insolation. Analysis of the timing of the climatic state changes suggests that the global climate system may have reached a state of "self-organized criticality". Small perturbations are propagated on all possible time and length scales. The concept of selforganized criticality may serve as a test for global climate models, and as a framework for the organization of global observations.

Implications of global climate at the critical state are: 1) the climate system may be represented by a number of interconnected elements, each of which may change state, and may induce one or more neighbours to also change state. 2) Climate will never reach equilibrium, but will episodically change from one metastable state to the next. 3) Dramatic changes in climate may be triggered by very small perturbations in critical parameters, such as atmospheric CO_2. 4) It will be impossible to predict the level of CO_2 required to produce these changes, because the behaviour of any part of the system is dependent on the history of the entire system. 5) The IPCC predictions of increases of 2.5þ in global temperature over the next 100 years may be dwarfed by local changes in temperature.

Are Linear Regressions Adequately Describing Temperature Trends in Climate Change Analyses?

Roger Pocklington[1], Richard Morgan[2], Kenneth Drinkwater[1]

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In many presentations of temperature change in global, hemispherical and regional climate analyses,linear regressions have been used to show that temperatures have risen significantly during the past 100 years in some regions and in the order of 0.3-0.6þC globally. However, due to the high variability in annual mean temperature data many of these linear trends are not statistically significant.

If instead of linears temperature normals (30 year means) are used, updating these normals every 5 years,temperature change in a number of regions show a curvilinear distribution which correlates with the data base with a far higher degree of significance than the corresponding linear.

Plots of normals indicate a secular sinusoidal trend upward during the early part of this century which reached a maximum in the mid-century decades and, thereafter, has been in a cooling phase.

Two anomalously, warm years in the last decade appear to have arrested this trend but whether this is a statistically induced temporary aberration only time will tell.

Some Dynamical Consequences of Greenhouse Gas Warming

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Aspects of climate warming are studied in terms of the differences in the equilibrium climates simulated for the current or

lxCO2 case and for the new equilibrium climate that results with twice that amount of CO2. The thermodynamic aspects of simulated climate change are usually given the most attention and the statistical significance of the simulated temperature change is certainly very much higher than that of the other surface (and upper air) variables. The dynamical consequences of greenhouse gas warming, although less pronounced, are also of interest.

Although doubling CO2 directly and indirectly affects the radiative forcing of the system, the change in overall forcing is remarkably small and hence the change in atmospheric energy transport is also small. In other words, the atmosphere's dynamics operate in a modified fashion in the 2xCO2 case since the forcing and poleward energy transport remain essentially the same while the thermodynamic structure of the atmosphere differs considerably. The nature of the modifications to the flow structures that allows this to occur is described.

Wednesday / Mercredi p.m. Room/Salle 209
Session 4

Middle Atmosphere Observations of Chemistry 2/ Observations chimiques dans l'atmosphère moyen 2

Chair/Président: Wayne F.J. Evans

The Spatial Pattern of Ozone Depletion in 1993 from TOMS Data

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In 1993, the ozone layer was thinner than ever observed previously. TOMS data has been analyzed with a GADS GIS system in order to investigate the spatial pattern of this depletion. The ozone thicknesses were measured by the Total Ozone Mapping Spectrometer on the Nimbus-7 and Meteor-3 satellites. In 1991, the ozone layer was close to the long term average since Arctic depletion was small that year. In the methodology employed, the average ozone thickness for the first week of each month from September 1992 to August 1991 was differenced with the ozone from the corresponding period from September 1990 to August 1991 OVCT latitudes in the northern hemisphere greater than 30 deg north. The maximum difference was in February; the ozone layer was depleted by 15% in February 1993 relative to February 1991. The depletion lessened in the following months to 6% by August 1993. This depletion occurred in a cap over the entire northern hemisphere from about 40 N to the pole.

Scanning Radiometer Imaging of the OH Nightglow

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University of Western Ontario

UWOSCR, The University of Western Ontario Scanning Radiometer, was originally designed to study small-scale structure in the OH nightglow. Its instantaneous field-of-view of 1þ affords a spatial resolution of 1.5 km at 86 km, the nominal height of the OH layer. The instrument scans a 16þ X 16þ area of the zenith sky in one minute. The detector is a thermoelectrically-cooled InGaAs diode with a silicon window, allowing detection of the near-infrared OH bands 7-4, 8-5, 2-0, 3-1, 4-2 and 5-3. Operation is unattended, under control of a computer-based ephemeris, so that the data base is interrupted only by inclement weather. This has extended the value of the instrument to investigation of longer period structures of tidal and

planetary scale.

UWOSCR-I, the prototype, has been in intermittent operation since the second quarter of 1991 at UWO's Delaware Observatory and on campaign as part of ANLC/ALOHA 93. UWOSCR-II has been in continuous operation since August 1991 at l'Observatoire de Haute Provence, France and UWOSCR-III was in operation at the Polar Observatory, Eureka N.W.T. during the past two winters. We summarize these observations and demonstrate the value of the instrument for investigation of atmospheric dynamics.

The Observation of Polar Mesospheric Clouds by the WINDII Instrument on UARS

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Polar Mesospheric Clouds (PMCs) are usually observed from the ground in late twilight in summer at high latitudes as noctilucent clouds. They can also be observed from space in daytime at high sun angles. In addition to the Michelson interferometer, the WINDII instrument on the UARS satellite has an imaging CCD camera with several filter channels. In each of these channels, images of scattered sunlight from the earth's atmosphere can be measured in the daytime at a spatial resolution of 1 km by 5 km. The presence of noctilucent clouds is indicated in many July profiles in the northern hemisphere from 82 to 85 km. The clouds were observed from 54 N to 72 N in summer, 1992 and 1993. The presence of noctilucent clouds is also indicated in many January profiles in the southern hemisphere from 82 to 85 km where the clouds were observed from 55 S to 72 S. Temperatures derived from Rayleigh scattered sunlight (from WINDII) in the vicinity of the clouds are extremely cold, sometimes below 150 K about 1 km above the clouds. Limb viewing camera images at 1 km by 2 km spatial resolution are also shown. Backscatter ratio altitude plots of the clouds indicate that they are very sharp, often with a vertical structure of less than 1 km. The occurrence of clouds was mapped from January 6 to February 4, 1994 in the southern hemisphere. For comparison, the occurrence of PMCs in the northern hemisphere are shown on maps for each day from July 9 to August 6, 1993; in general, the clouds occur in a cap from 60 N to the pole.

Planetary Scale Oxygen Greenline Emission and Dynamical Features Observed in January, 1993 with the WIND Imaging Interferometer on UARS

W.E. Ward, D. Y. Wang, B. H. Solheim, G. G. Shepherd

From the 20th to the 30th of January 1993, the Wind Imaging Interferometer on UARS observed the O(^{1}S) emission exclusively. This provided an opportunity for time series of emission rate and horizontal wind from a single emission to be acquired. This period of time proved to be quite active dynamically with a large amplitude two day wave being detected. In addition a stationary pattern in the intensity of the O(^{1}S) nightglow emission rate was observed (this emission originates from the 90 to 100 km region and is due to the recombination of atomic oxygen). The intensity of the maxima tend to occur at longitudes of 100 East and 100 West in the northern hemisphere and show a two day modulation. At the present time it is hypothesized that the stationary emission rate features are the result of influences from below, although an exact mechanism hasn't been identified. The temporal modulation of these features is thought to be due to the two clay wave. In this paper, WINDII data from this period are presented and these features discussed.

ODIN: A Satellite for Stratospheric and Mesospheric Studies

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ODIN is a Swedish/Canadian/French/Finnish small satellite mission with both astronomy and aeronomic objectives. The aeronomic objectives largely focus on stratospheric and mesosphenc chemistry and dynamics. The satellite instrumentation will include a sub-millimetre radiometer (<600 GHz), an optical spectrograph that operates over the wavelength range 300-800 nm and an imager at 1270 nm. The wavelength range selected for the spectrograph allows examination of trace atmospheric constituents such as OClO at 340 mn, NO_2 near 400 run, O_3 in the range from 400 to 700 nm (Chappuis Band), O_2 at 763 m-n, O_4 near 6M nm and aerosols at 700 nm over the altitude range from 12 to 90 km. The satellite is scheduled for launch in late 1997 and will be placed in a sun-synchronous orbit with the ascending node at approximately 18:00 local time. The objectives of the ODIN mission and the capabilities of the ODIN remote sensing instruments will be described.

Wednesday / Mercredi p.m. Room/Salle 232
Session 4

Sea Ice / Glace océanique

Chair/Président: Dave Mudry

Under-Ice Characteristics in the Northeast Water Polynya: Preliminary Results from Summer 1993 Fieldwork

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Preliminary data taken under the ice during the Polarstern cruise ARK-IX/3 to the Northeast Water polynya (NEW) in the summer of 1993 are discussed. Two ice barriers delimit the NEW to the north and south. A northward flow of 0.08 m/s was measured beneath the southern barrier, consistent with previous authors. The northern ice barrier is underflowed by a 0.06 m/s southward current at 27.5 m. This barrier inhibits ice advection from the Arctic Ocean, and is therefore critical to the ice-free conditions found in the NEW. An ARGOS-tracked ice floe with suspended instruments is used to show the spatial variability of the T-S characteristics of the NEW and of the East Greenland Current. The observed motion was consistent with the presence of an anti-cyclonic gyre in the NEW, and possible near-inertial tides on the continental shelf in the NEW.

A Coupled Ice-Ocean Model for the Labrador Pack Ice

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B2Y 4A2

A coupled ice-ocean model has been developed to simulate the distribution and velocity field of the pack ice off the Labrador and Newfoundland coast. The goal is to use the model for short-term operational ice forecast. On several-day time scales, the ice motion is predominantly wind driven, hence the dynamics of the upper ocean and ice-ocean coupling play the most important role in the ice movement. The thermodynamics of the ice and the oceanic mixed-layer are not considered in the present version of the model.

The model domain is a rectangle covering the Labrador Sea and the Grand Bank. The sea-ice part of the coupled model is Hibler's ice model. The ocean model is a diagnostic baroclinic ocean model with a given density field (Levitus winter data). The sea surface elevation along the boundaries is taken from that of ocean general circulation models. The ocean is spun up from a stationary state to a steady state in 15 days. This steady state is used as the initial condition for the ocean in the time integration of the model. The sea-ice is coupled to the ocean by an Ekamn layer which has a stress and depth dependent eddy coefficient. A quadratic drag law is applied to compute the stress between the bottom of the ice and the top of the Ekamn layer.

The model was run for up to 15 days using ECMWF's 6-hourly 10m winds as the input forcing field. The results were compared with available ice/ocean data in 1992, which included daily ice condition charts produced by Ice Centre Environment Canada, ice drifter data, ice velocity maps derived from sequential AVHRR images and moored current meter data.

Preliminary Results from a Climate Simulation made with the Canadian Middle Atmosphere

Stephen Beagley and Jean de Grandpre

Dep't of Earth and Atmospheric Science, York University

John Fyfe and Norman McFarlane

Canadian Centre for Climate Modelling and Analysis, University of Victoria

The Canadian Middle Atmosphere model is currently being developed as a global atmospheric general circulation model which fully resolves the region between the surface and the mesopause. A preliminary, but nearly state of the art version of this model has been constructed from an upwardly extended version of the third generation Canadian Climate Centre AGCM. A multi-year simulation has recently been completed with this model. A brief description of this model is provided and selected results from this simulation are presented and compared where possible with observed climatic data.

Sea Ice Monitoring and Modeling Site (SIMMS) - 1993

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In the high Arctic, the spring transition season is marked by a sharp increase in cloud cover at a time when incoming solar radiation is increasing and snow-covered sea ice is beginning to melt. This begins a complicated feedback process between surface albedo, cloud cover, and radiative and conductive fluxes near the snow/ice surface which lead into the summer

season. The tiping of this transition is controlled by changes in solar radiation and the larger scale atmospheric circulation. For the past four spring seasons, the SIMMS field program has been carried out on the sea ice off Resolute Bay, NWT (74 45N, 94 50W) to monitor this critical transition period.

The consolidation of a large multiyear floe in Resolute Passage in the spring of 1993 was particularly fortuitous and allowed detailed measurements of the differences in physical properties and conductive and radiative fluxes between first-year and multiyear sea ice. This presentation will concentrate on the differences in energy and momentum measurements carried out at two 10-metre towers on typical first year and multi-year ice. Since as much as 50% of the sea ice cover over the Arctic Basin is multi-year ice, these results should be useful in improving Global Circulation Modelling of the Arctic through improved parameterization of arctic sea ice processes.

On the Source of Sea-ice Cover Anomalies in the Arctic Basin

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In the late 1960's, an anomalously large quantity of ice was advected southward into the Iceland Sea, producing very low salinity water in this region. We refer to this as the Great Ice and Salinity Anomaly (GISA). Some authors argue that this variation in ice transport out of the Arctic basin is due to the presence of local wind anomalies (Dickson et al, (1988)) or Arctic wind anomalies (Walsh and Chapman, (1990)), whereas others (see Mysak et al, (1990)) suggest that the ice cover anomalies may be partly due to a large fresh water input from north American river runoff in the Arctic basin. The latter process results in an increase in the areal sea-ice extent in the
Beaufort Sea and eventually, to an increase in sea-ice transport out of the Arctic basin by the Beaufort Gyre and Transpolar Drift Stream.

A simplified dynamic thermodynamic sea-ice model is presented. In this model the time-dependence is neglected in the momentum equation, which we argue is a valid approximation for two-weeks averaged wind forcing. Finally, preliminary results on the relative importance of wind and river runoff induced ice anomalies in the Arctic are presented.

Thursday/Jeudi a.m. Room/Salle Alumni aud. / Aud des Anciens

PLENARY SPEAKERS/ CONFÉRENCIER INVITÉS

SPECIAL SESSION ON AGRICULTURE AND FOREST METEOROLOGY
SESSSION SPÉCIALE sur l'AGRICULTURE et la MÉTÉOROLOGIE FORESTIÈRE
Dr. E.H. Hogg

Predicting climate change impacts on the western Canadian boreal forest

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Recent predictions indicate that the western Canadian boreal forest could experience relatively large future increases in mean temperature, coupled with reduced soil moisture during the growing season. The impact of a drier future climate is expected to be especially severe near the southern boundary of the boreal forest, where growth and distribution of tree species are already limited by moisture deficits.

An interdisciplinary approach is needed to characterize both 1) biological responses of the boreal forest to present and future climates and 2) feedbacks of the boreal forest on global and regional climatic processes. BOREAS (Boreal Ecosystem - Atmosphere Study) is a large, ongoing international field experiment in Saskatchewan and Manitoba that is focusing on processes governing the exchange Of CO_2, water vapour and energy between the boreal forest and the atmosphere. The experiment has a spatially hierarchical design that will allow both biological and physical processes to be scaled up, from small spatial scales (e.g., individual leaves and trees), to much larger scales (landscapes and the regional scale).

Most of the field research within BOREAS will span one or two growing seasons; thus the strongest contribution of BOREAS will be to improve our understanding of diurnal and seasonal processes. However, many of the ecological processes operating in the boreal forest operate over much longer time-scales. These include, for example, forest fire regimes, tree regeneration and growth, and the long-term development of forests and peatlands in response to climate. An overview of current climate change research being conducted by the Canadian Forest Service, on both short- and long-term processes, will be presented.

Thursday/Jeudi a.m. Room/Salle 224
Sesion 1
Aviation Meteorology Forecasting & Modelling 1 / Prédiction et modélisation de la météorologie de l'aviation 1

Chair/Président: Angèle Simard

The CMC Aviation Package

Gilles Desautels

Development Branch
Canadian Meteorological Centre

For about five years, the Canadian Meteorological Centre has been producing forecast charts of significant weather parameters for the aviation industry. These forecasts are based on the Regional model which has now a 50 km horizontal resolution with 25 sigma levels in the vertical. Model variables at all sigma levels as well as at pressure levels are used to generate the forecast aviation fields at every 6 hours out to 24 hours twice a day. The intent of the presentation is to bring an update on these products, which have undergone some modifications in the past recent months.

The aviation package includes forecast icing and icing level charts. Rime icing is forecast to be likely when the air temperature is between zero and minus 16 degrees Celsius, with sufficient moisture and upward vertical motion. The charts present forecast of moderate or greater icing occurrences and an indication of its intensity and heights where it is expected to occur. The freezing level is the height above mean sea level of the lowest level where the air temperature is zero Celsius.

The aviation package also includes forecast tropopause height and forecast of (high level) turbulence in the layer between 400 and 200 hPa. The tropopause height, as defined by the Word Meteorological Organisation (WMO), is calculated using all the sigma levels above 500 hPa. The turbulence is assessed using the maximum value of the deformation vertical shear index in the layer 400 to 200 hPa.

Charts of the forecast surface stress and of the forecast (low level) turbulence in the layer between 700 and 400 hPa are also part of the aviation package. The surface stress is used as an indication of the mechanical turbulence near the surface. The low level turbulence is based on the deformation vertical shear index like for the high level turbulence.

Finally the aviation package includes charts of forecast clouds. The clouds are diagnosed from the model relative humidity at different sigma levels. Cloud opacity of six tenths or more of sky cover is contoured with an indication of the base (ceiling) and top of the cloud layers.

Several improvements of the aviation package are envisaged. A new algorithm for icing is considered, as well as the usage of new model variables to assess the clouds.

Description and Verification of the Eta Model Post-Processor for Aviation Weather Forecasting

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The Aviation Weather Development Program (AWDP) of the Forecast Systems Laboratory (FSL) is being sponsored by the Federal Aviation Administration (FAA) to improve aviation weather services. An element of the program is the Aviation Gridded Forecast System (AGFS) which is an information system that will produce forecasts of aviation-impact-variables (AIVs). Turbulence and icing are two examples of AIVs that are specific to the aviation community. One component of the AGFS is the Eta model, a numerical weather prediction model developed at the National Meterological Center (NMC), Washington, D.C. Presently, we are developing an Eta model post-processor which produces forecasts of AIVs at specified forecast times.

The Eta post-processor includes forecasting algorithms for clear-air turbulence, icing, winds at anemometer level, temperature and dewpoint at shelter height, altimeter setting, precipitation type, precipitation amount, Visibility, cloud top, as well as, winds, geopotential height, temperature, dewpoint, and relative humidity at various levels in the atmosphere. These parameters were tested by two evaluation exercises conducted by the Verification Program within the Aviation Division of FSL. Evaluation Exercise 1 (E1) was conducted April 1 - 10, 1991, and Exercise 2 (E2) was conducted February 23 - March 10. 1992. The Eta model was run at FSL for E1 and at NMC for E2, with 31 levels in the vertical and with a 30-km horizontal resolution over a domain that includes the 48 contiguous United States. The output used in E2 was obtained from Eta model runs with initial fields for 0000 UTC and 6-hourly forecasts for a 36-h period. Furthermore, the AIVs comprising the post-processor were derived from the 6- hourly output and verified with the actual observations at several locations (including 20 selected cities) across the United States. As a result of these verification exercises, we have made improvements to the Eta post-processor, such as implementing the TKE, icing and fog forecasts, and improving the cloud scheme.

We will present a detailed description of the algorithms which make up the Eta post-processor and the results from the two evaluation exercises.

Progress in Developing the Aviation Gridded Forecast System

Lynn Sherretz

NOAA Forecast Systems Laboratory
Boulder, CO

This presentation will describe progress by the Forecast Systems Laboratory (FSL) of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) in developing the Aviation Gridded Forecast System (AGFS). It also will define the AGFS and explain its role in the U. S. Federal Aviation Administration's (FAA) Aviation Weather Development Program.

While the domain of the first version of the AGFS will be the continental United States, we believe AGFS technology will help Canada meet its future aviation needs.

The AGFS will generate the accurate, timely and site-specific meteorological information that National Weather Service (NWS) forecasters and the FAA Aviation Weather Products Generator will require to tailor decision-making products for aviation users. Information generated by the AGFS also will support automation of Air Traffic Control.

Initially, the AGFS will be implemented at the National Meteorological Center (NMC) to generate analyses and forecasts of aviation-impact variables (AIVS) from NMC's operational national-domain analysis systems and forecast models. (Icing potential, turbulence potential, ceiling height, and visibility are examples of AIVS.) Later, the AGFS may be implemented at Weather Forecast Offices (WFOS) to generate analyses of AIVs for WFO domains. Those analyses would benefit from observations that are unique to WFOs such as observations made by WSR-88D radars.

FSL is developing an experimental AGFS to define requirements and test concepts for the operational AGFS. The experimental AGFS consists of forecast tools to generate AIVS, next-generation processing methods to run those tools, and an interactive workstation to enable NWS forecasters to add value to AIVS.

AGFS developmental progress to date includes implementing the Rapid Update Cycle (RUC) at NMC, developing algorithms to generate AIVs from the RUC and NMC's Eta model, and implementing a meteorological workstation at the Center Weather Service Unit at the Denver Air Route Traffic Control Center. Drawing on observations made by wind profilers and automated reports from aircraft, the RUC will generate forecasts out to six hours every three hours.

Volcanic Ash Dispersion Prediction: Research and Development for Aviation Products at the Canadian Meteorological Centre

Réal D'Amours, Michel Jean, René Servranckx, Joseph-Pierre Toviessi and Serge Trudel

Environmental Emergency Response Division
Canadian Meteorological Centre
Environment Canada
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Volcanic ash is a major aircraft safety hazard that has resulted in some close calls over the recent years. Once released, the ash plume can drift over great distances and cause disruptions to air traffic sometimes even thousands of kilometres away from the volcano. This was the case in September 1992 following the eruption of Mount Spurr (Alaska). Given the immediate threat posed by volcanic ash, predicting its movement and dispersion in the atmosphere is an important challenge. The Canadian Meteorological Centre applies the **C**anadian **E**mergency **R**esponse **M**odel (**CANERM**) to this task.

CANERM is a complex Eulerian 3-D transport, dispersion and deposition model. It operates on a polar stereographic grid and can be executed on the Northern and Southern Hemispheres. **CANERM** uses 11 levels in the vertical with horizontal grids of 150 kilometres, 50 and 25 kilometres. It can be executed in hindcast mode by using a sequence of objective analyses or in forecast mode by using numerical weather prediction forecasts in real time. A forecast for a 72 hour simulation is produced in less than one hour. The Canadian Meteorological Centre is currently developing graphical products that could be used to display predictions of the model's volcanic ash plumes for aviation interests.

The presentation will consist of a brief description of **CANERM**. We will then present some of the development work being conducted at the Canadian Meteorological Centre in the area of volcanic ash dispersion and transport. Forthcoming improvements to the model and examples of graphical products for aviation interests will be presented. Results will be shown, along with satellite imagery verification, for Mount Spurr's eruption of September 1992.

Thursday/Jeudi a.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 1

Climate & Agricultural Yields / Climat et production agricole

Chair/Président: J.D. Boisvert

Quantifying Effect of Late Summer Hail on Corn Production

L.M. Dwyer, D.W. Stewart, L. Evenson, B.L. Ma

Agriculture Canada, Centre for Land and Biological Resources Research, CEF, Ottawa

Hail is a relatively common, but unpredictable, weather phenomenon in Canada, but estimation of production loss is hindered by lack of an unaffected control for comparison. A hail storm 28 August 1990 resulted in extensive leaf shredding followed by complete corn senescence within two days of the storm. An ongoing field experiment to compare the growth and yield of nine hybrids with maturities ranging from 2350 to 2800 corn heat units (CHU) and planting dates of 30 April, 16 May and 29 May provided a range in growth stages from milk stage to full dent at the time of the hail

storm. A method of analysis was developed using above-ground dry matter accumulation at tasselling as a pre-hail indicator of production potential to calculate the reduction in harvest dry matter and grain yield resulting from the hail storm. The reduction in harvest dry matter and in grain yield was linearly related to the CHU required to reach physiological maturity at the time of the hail storm ($P<0.10$). Late maturity hybrids were most affected by the hail storm and contributed most to these regressions ($P=0.01$ and $P=0.02$ for harvest dry matter and grain yield, respectively). Harvest index was not affected by the hail storm ($P>0.10$).

Climatic Teleconnections from the Pacific Ocean to the North American Great Plains - Implications for Canadian Spring Wheat and U.S.A. Corn Yields

E.R. Gamett[1], J. Babb[2] and M.L. Khandekar[3]

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Large-scale atmospheric and oceanic circulation patterns and anomalies associated with El Nino/Southern Oscillation (ENSO) events have been shown to have a significant impact on seasonal weather over many parts of the world. ENSO events appear also to have a significant impact on world grain yields. Previous research has indicated that the warming of the sea surface in the equatorial eastern Pacific (El Nino) tends to favour Canadian spring wheat yields while sea surface cooling temperature in the same region (La Nina) mitigates against-spring wheat yields. It has been indicated that a significant negative statistical correlation exists between Indian monsoon rainfall levels and U.S.A. corn yields and also that surplus monsoons occur during La Nina conditions.

We have extended this study to investigate the impact of the Pacific North American (PNA) teleconnective index on temperature and precipitation anomalies over the Canadian spring wheat and U.S.A. corn growing areas. The PNA index is defined in terms of mid-tropospheric geopotential height anomalies at selected locations over the eastern half of the north Pacific Ocean, the Gulf of Alaska and Alberta. Preliminary analysis suggests that hottest (coolest) summers over the Canadian prairies and U.S.A. corn growing area are associated with a positive (negative) trend of the PNA index.

Implications of our study for foreshadowing Canadian spring wheat and U.S.A corn yields are discussed.

Long Term Trends and Variability of Simulated Spring Wheat Yields on the Canadian Prairies

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Weather has a relatively large effect on yields of spring wheat. Increases in concentrations of greenhouse gases may bring fundamental changes in climate and thus yields of all crops. Therefore to put these future changes in perspective, it is imperative that past trends be studied in detail. Changes in yields with time are due to weather and changes in non-weather factors, such as technology and soil properties. In this study a deterministic model was used to separate weather from non-weather influences and to quantify non-weather effects on spring wheat yields for the Canadian Prairies. These non-weather effects became relatively constant in the early 1980's. We generated yield records for the past 70 years setting the model at the 1980 level of technology and running the model using archived weather data for a number of locations in the three prairie provinces. Results indicated that

long term yield trends are small compared to annual variability. Trends over short periods, such as ten years, could be either negative or positive. There was some evidence of periodicity in these yield records. Standard deviations of yields for consecutive five-year periods showed no long term trends.

Evaluation of Weather Generators for Risk Assessment in Canada

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Many useful climate analyses have been based on normal climate conditions. There is a growing interest in assessing the affects of weather variability on environmental response. Soil erosion is an example of a process which may be dominated by extreme events rather than normal conditions. Climate generators have been developed to provide input data for simulation models to estimate erosion and the impact on crop growth. These climate generators have the potential to contribute to a number of applications such as land evaluation, sustainable land management and crop insurance where a measure of climate variability and risk is important. Long periods of climatic records are not always accessible and require large data bases if they are to be used for large area analysis. Climate generators can provide an indication of risk using a much smaller set of parameters provided it can be assumed that weather distributions follow some predetermined probability model. In this study, we assess the validity for Canadian conditions of the climate generator, CLIGEN, which was developed for water erosion prediction (WEPP) as well as the similar generator, WGEN, developed for assessing the impact of erosion on crops (EPIC). We will critically review the model assumptions. Observed data sets at selected sites across Canada will be used to parameterize the probability model and compare the statistical characteristics of observed and simulated sequences of data.

Thursday/Jeudi a.m. Room/Salle 209
Session 1

Cyclogenesis / Cyclogénèse

Chair/Président: R. Laprise

An Investigation of the Interaction between Slantwise Convection and Marine Cyclogenes

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A hydrostatic, primitive equation model is used to simulate an oceanic cyclone under idealized initial conditions. The model produces a realistic explosive cyclone with an intense bent-back warm front. The thermal gradient in the front exceeds 4K/50km, in agreement with recent observations. Convection was found to occur in the warm frontal zone. An adjustment of the stratification toward slantwise neutrality is noted in both the warm and the bent-back warm fronts after the explosively deepening phase. A dry slot occurs over the cyclone centre whose origin can be traced to the onset of

convective downdrafts in the early Stages of the cyclone.

The Potential Vorticity (PV) inversion technique due to Davis and Emanuel (1991) is used to quantify the contribution to the perturbation geopotential at 900, 500 and 300 mb from the low level PV anomalies (LPV), upper level PV anomalies (UPV), and the potential temperature anomaly at 1000 mb. It is found that during the mature stage, the positive LPV anomalies along the warm and bent-back warm fronts accounts for 40 % of the perturbation geopotential at 900 and 500 mb over the cyclone centre. The retrieved circulation indicates the presence of a small scale cyclonic vortex and intense cold advection in the bent-back warm frontal zone.

The contribution of the UPV anomaly is also significant, especially at the mid and upper troposphere. The underlying physical mechanism can be traced to an increase in vorticity advection in the middle troposphere associated with the formation of the bent-back warm front and its accompanying cold advection.

A comparison of a moist and a dry run indicates a smaller contribution of the 1000 mb potential temperature anomaly in the former case because of a reduction in the strength of the thermal anomaly from the convection induced cold advection in the bent-back warm front.

A Relationship between 1000-500mb Thickness Anomalies and Active Periods of Rapid Cyclogenesis during CASP II

Werner Wintels and John R. Gyakum

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Climatologies of cyclone activity over the North Atlantic basin and Northern Hemisphere 1000-500 mb thickness are presented to assess the representativeness of the large scale flow during the CASP II season (01Jan-15Mar 1992). Frequency fields of cyclone and rapid cyelogenesis events are constructed using a dataset derived from 00 and 12 GMT manual analyses. Cyclones follow a curved path from the Great Lakes across Sable Island and the Avalon Peninsula into the Greenland Sea. Rapid cyclogenesis maxima appear along the oceanic segment of this axis, a northward shift when compared to longer term climatologies. The thickness anomaly for this 75-day period shows a wave-3 pattern with amplitude of scale 10 dam. We find warm anomalies centered over Southern Saskatchewan, the North Sea, and Mongolia, with cold anomalies over Central Greenland, Northwestern Iran, and, the Central Pacific Ocean.

Active periods of rapid cyclogenesis are defined as time intervals for which daily bomb frequencies exceed a threshold value of 0.5. Compilations of data for active periods show:

- an increase in the amplitude of the wave-3 thickness pattern
- a large cold pool centered over Newfoundland and Labrador
- an enhanced baroclinic zone in the southern and eastern sector of the cold anomaly corresponding to the rapid cyclogenesis maxima

Current studies focus on a more rigorous statistical analysis of the anomalous thickness fields and producing quasigeostrophic diagnostics of bomb events during selected active periods.

Interaction of Convection with a Baroclinic Environment in Surface Cyclogenesis

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Considerable progress has been made in the recent years on the structure and evolution of rapidly deepening marine cyclones. However, little attention has been paid to the life cycles of extratropical cyclones during the growing season. These cyclones often spawn mesoscale convective systems (MCSs) and other severe weather events; they can also intensify rapidly in response to the tremendous amount of latent heat release associated with the MCSS. In this study, a 36-h simulation of an MCS that occurred during 10-12 June 1985 PRE-STORM and later evolved into a surface cyclone (Johnson and Hamilton 1988) is carried out to investigate the effects of moist convection on surface cyclogenesis. An improved version of the Penn State/NCAR mesoscale model (Anthes et al. 1987) with a fine-mesh length of 25 km is used for the present study. The model includes i) a two-way interactive nested-grid procedure (Zhang et al. 1986); ii) the Blackadar boundary-layer scheme (Zhang and Anthes 1982); iii) a modified version of the Fritsch-Chappell (1980) scheme with incorporation of moist downdrafts; and iv) an explicit moisture scheme containing prognostic equations for cloud water (ice) and rainwater (snow) (Zhang 1989). With the same version of the model, Zhang et al. (1989) have obtained a successful 21-h simulation of the life cycle of the squall system, as verified against detailed special network data (e.g., Johnson and Hamilton 1988).

The initial conditions of the simulation were characterized by a midlevel short-wave trough and a shallow surface front with little indication of cyclogenesis. The model reproduces the initiation of the squall line at nearly the right location 9 hours into the simulation. Then both the simulation and observations show the development of a pre-squall mesolow, a downdraft-induced mesohigh and distinct wake lows associated with the squall system (see Johnson and Hamilton 1988; Zhang et al. 1989). The system began to dissipate after 18 h into the simulation, as has also been observed. However, as the convective forcing decays, the wake lows merge into the presquall mesolow. Meanwhile, the vertical motion associated with the mesolows changes from descending to ascending, thus beginning the spin-up stage of a surface cyclone. The transformation of the MCS into a surface cyclone was well captured by the standard network and remarkably simulated by the model.

A series of sensitivity tests and diagnostic analyses have been performed. The results show that with the moist convection effects included, the model produces significant phase lag between the short wave and a thermal wave, thereby generating a favourable condition for surface cyclonic development. Specifically, the tremendous amount of latent heat release associated with the squall system deepens substantially the midlevel short wave and thus forces the wave to move with the MCS; its movement is determined by the interaction of convectively generated downdrafts with conditionally unstable conditions ahead of the trough axis. On the other hand, the propagation of the midlevel thermal wave is primarily governed by advective processes. In addition to the phase lag, moist convection also tends to enhance the large-scale baroclinity, providing a more favourable environment for surface cyclogenesis.

The Distribution and Variability of Sensible and Latent Heat Fluxes over the North Atlantic

G.W.K. Moore

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In support of the TOGA (Tropical Ocean - Global Atmosphere) experiment, the ECMWF has been producing high resolution (1.125 degree, 6 hourly) objectively analysed fields. There is now a nine year archive available for use by researchers in the atmospheric and oceanographic communities. This paper describes one such application of this important new data set. For the nine winters for which data exists, we used the diagnosed surface sensible and latent heat fluxes to derive mean and variance fields. The mean fields derived from this calculation agree in a qualitative manner with earlier mean fields derived from ship based observations. The ECMWF derived mean fluxes tend to be larger than reported earlier. The reason for this is not known but may be the result of systematic errors in the ship derived values. There are also differences that arise from the higher resolution of the new data. In particular, the ECMWF derived mean fields show a well defined region just south of Newfoundland where there is a marked minimum in both the sensible and latent heat flux. As will be shown, the existence of this minimum

is most likely related to the interaction of the Labrador and North Atlantic Currents.

A comparison of the mean fields with the climatological storm tracks over the North Atlantic shows a high degree of correlation. This supports the view that these fluxes are primarily the result of cold air outbreaks that arise from the passage of extra-tropical cyclones. As will be shown, the variances of both sensible and latent fluxes are of the same order as the corresponding mean values over much of the North Atlantic. It will be argued that this high degree of variability is consistent with the view that these fluxes are the result of a physical process, namely extra-tropical cyclogenesis, that is highly variable in both space and time. Several feedback loops by which the modifications to the atmosphere that arise from the magnitude and distribution of these fluxes can influence cyclogenesis will also be discussed.

Thursday/Jeudi a.m. Room/Salle 232
Session 1

Radar Meteorology / Météorologie des radars

Chair/Président: I. Zwadski

Raindrop Spectra and Updraught Determination by Combining Doppler Radar and Disdrometer

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A new radar scan designed for the vertically pointing mode of the University of Toronto's X-band Doppler radar was first used during phase II of the Canadian Atlantic Storms Program (CASP II). This scan consists of a mix of reflectivity factor, vertical velocity, spectral width, and Doppler velocity power spectrum measurements as a function of time and height Raindrop size spectra can be calculated from the power spectra using the Rayleigh scattering approximation. The power spectra, however, may be biased by the presence of vertical wind and by the inaccuracy of the radar measurements of the reflectivity factor. Data from a Joss-Waldvogel disdrometer, which was located at the radar site, is used to remove these biases prior to drop size spectrum calculation.

The reflectivity factor bias is manifested as a stretch or compression of the Doppler velocity power spectrum along the intensity axis. This effect is removed by multiplying the magnitude of each power spectral coefficient by a scale factor determined from a correlation between the reflectivity factors measured at the ground by the radar and the disdrometer. The presence of vertical wind results in a shift of the power spectrum along the velocity axis. The magnitude of this shift is deduced using a relationship characteristic of the rainfall type. This relationship ($Z = 507\ R^{1.44}$ for CASP 11 rain events between January 24 and March 1, 1992) is deter-mined solely from the disdrometer data. Once the biases have been removed, drop size spectra derived from radar measurements made near the surface are found to compare well with simultaneous measurements made by the disdrometer.

Long Term Radar Observations of the Melting Layer of Precipitation and their Interpretation

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600 hours of vertically pointing X-band radar data and 50 hours of UBF boundary layer wind profiler data were processed and analyzed to characterize quantitatively the structure and the causes of the radar signature from melting precipitation. Five classes of vertical profiles of reflectivity in rain were identified with three of them clearly having precipitation undergoing a transition between the solid and the liquid phase. Only one of them, albeit the most common, showed a radar bright band signature.

In-depth study of the bright band and its dependence on precipitation intensity reveals that the ratio of the bright band peak reflectivity to the rainfall reflectivity is constant at 8 dB below 0.5 mm/hr and then increases to reach 13 dB at 2.5 mm/hr and 16 dB at 5 mm/hr. The equivalent reflectivity factor of snow just above the melting layer is on average I dB to 2 dB below the reflectivity of rain just below the melting layer independently of precipitation intensity. The classical bright band explanation accounts for less than half of the observed enhancement; the difference could be explained by effects associated with the shape and density of melting snowflakes and, to a smaller extent, by precipitation growth in the melting layer, and aggregation in the early stages of the melting followed by breakup in the final stages. The bright band statistics were also significantly different for reflectivities in rain above 25 dBZ when observations were made with an X-band radar as opposed to the wind profiler because of the combination of attenuation in the melting layer and the fact that scattering from some of the large hydrometeors above and within the melting layer departs from the Rayleigh approximation usually used to compute reflectivity. The bright band is often capped by a thin and faint 'dark layer' which tends to be more evident at weak precipitation intensities.

Doppler Radar Signatures of Precipitation in Major Winter Snowstorms

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The Toronto Winter Storms Program was a pilot study by the University of Toronto in understanding wintertime precipitation occurring in the Toronto area. Four cases taken during January and February of 1991 in which the surface precipitation was entirely solid (snow or ice pellets) were examined.

The main means of investigating the storms was the X-band Doppler radar operating at the University of Toronto. Extended velocity-azimuth display (EVAD) analysis war. performed on the volume scan data to deduce the vertical profiles of the horizontal wind and the mean vertical air velocity. Periodically the radar was operated in a vertically pointing mode in order to collect the full Doppler spectral power density information. The first three moments were calculated directly to give vertical profiles of radar reflectivity, vertical velocity and spectral width.

Additional sources of data for the study included a radiosonde release at 0700 LST at the Atmospheric Environment Service located about 15 km north of the radar, Also, hourly surface observations were taken at the Toronto Island airport, located about 3 km south of the radar.

Overrunning by a warm, moist flow at mid levels, which is a characteristic feature in these major storms, will be documented, Also, the effect of Lake Ontario on the precipitation process will be discussed. Some criteria for aiding in the interpretation of the vertically pointing Doppler radar data in these types of situations will be presented. It is concluded that the potential to develop algorithms based on pattern recognition of radar data in wintertime events may be as promising as those developed for summer-time convection.

Characterizing the Evolution and Structure of Connective Cells with Radar Reflectivity Isosurfaces

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The evolution and structure of convective precipitation is analyzed with the University of Toronto X-Band Doppler radar via time-lapse volume scans. Four conical surfaces of reactivity are produced in the PPI mode between 17° and 62° elevation angle. The data along each ray are binned at 125 m intervals out to a maximum range of 9.125 km. The azimuthal spacing between each ray is 2° and the time required for each volume scan is 3.4 minutes. Reflectivity values are interpolated between each PPI surface to produce three dimensional reflectivity isosurfaces. These isosurfaces define the precipitation cells whose characteristics are then studied over several consecutive volume scans.

As an illustration of our methodology, we present an animation of an evolving thunderstorm observed on 4 November 1990 in Penang, Malaysia. The highly structured detail evident in this animation emphasizes that a vertically pointing radar cannot describe the evolution of precipitation since the horizontal and vertical motions of precipitation parcels cannot be discerned (e.g. the vertical growth of a quasi-stationary convective cell could have the same A-scope signature in time as a horizontally advected tower of convection). It is hoped that our present studies of convective systems in the Toronto area will provide information for local short range forecasting and will also reveal some similarities and differences between evolving tropical and extra-tropical thunderstorms.

Thursday/Jeudi a.m. Room/Salle 224
Session 2

Aviation Meteorology Forecasting & Modelling 2 / Prédiction et modélisation de la météorologie de l'aviation 2

Chair/Président: Richard Verret

Terminal Forecasting using Observations from an Automatic Weather Station

Bill Maynard

Newfoundland Weather Centre

Atmospheric Environment Service
Gander, Newfoundland

The Newfoundland Weather Centre has been issuing aerodrome forecasts for Churchill Falls, Labrador using observations from a READAC (Remote Environmental Automatic Data Acquisition Concept) station in conjunction with a remote video system for the past year. During this period data has been collected on the reliability and utility of these observations. Moreover, an expertise has been developed in regards to integrating READAC observations into an aviation forecast program.

This experience will be reviewed from an operational forecasting point of view. The manner in which uncertainties in the observations are handled in real time will be discussed. In particular, the utility of the remote video camera system will be presented. Furthermore, strategies that can be used to improve the quality of forecasts based on READAC observations will be shown.

SHORT - A Statistical Forecast Technique for Preparation of Aviation Terminal Forecasts

L. J. Wilson

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Using a dataset of up to 30 years of hourly aviation observations (SA's), a statistical short range forecast technique has been developed and tested. The method is designed to produce forecasts of weather elements of importance to aviation operations, wind direction and speed, cloud amounts and ceiling, visibility, and weather and obstructions to vision, for 2, 4, 6, and 8 hours in advance. The forecast technique is developed and tuned individually for each station, and provides output in the form of both probabilities and -suggested categories. The category thresholds am selected according to their significance to aviation operations. Longer projection times are also possible. skill against climatology has been demonstrated for forecasts out to 12 hours.

Another feature of the forecasts is that the qualifier "vrbl" is simulated in the forecasts by allowing two categories of ceiling and visibility to be chosen whenever a "toss-up" situation occurs in the probability forecasts.

The forecasts can be initialized using only the latest two hourly observations; NWP output Is not required. The forecast system runs on a PC in its latest format, producing forecasts in less than 1 0 seconds. The PC version requires data input by hand, but this could be easily automated with a connection to the data network. In addition to functioning as a guide to forecasting trends in an FT, the system can be used to answer "what if" questions by inputting slightly different "hypothetical" observations.

Forecasts from SHORT have been shown to outperform persistence at all forecast ranges. In the presentation, the characteristics of the technique will be summarized, and examples of forecasts shown. A diskette-based PC demo version will be available at the Congress.

ITWS Gridded Analysis[1]

F. Wesley Wilson Jr. and Rodney E. Cole

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[1] The work described has been sponsored by the Federal Aviation Administration. The U.S. government assumes no liability for its contents or use thereof.

Massachusetts Institute of Technology
Lincoln Laboratory

The ITWS gridded analysis system combines data from the Mesoscale Analysis and Prediction System (MAPS) with observations from diverse terminal-area sensors to provide gridded state-of-the-atmosphere variables: wind, temperature, pressure, and humidity. The winds product will be developed first, since wind information is used directly by aviation. It is an important factor in support of several other ITWS products, and a quality product is possible, based on the high resolution wind information, which is provided by Doppler radars.

There are several aviation weather products that depend on this gridded analysis system. First, the gridded horizontal winds and temperature fields are directly used as the winds and temperature fields for the Terminal Air Traffic Control Automation-Center Traffic Advisory System (TATCA-CTAS) system. This high-resolution winds analysis is also used as the background for the Runway Winds predictions and Wake Vortex Advisory products. Short-term gridded winds nowcasts, up to 30 minutes, are being investigated. The full gridded analysis is the backdrop for the development of storm evolution and ceiling and visibility products. In the end-state, some of this information may be provided by the Aviation Gridded Forecast System.

In 1992, the first prototype terminal-area winds analysis system was tested at Orlando International Airport. Successful field operations from August 17 until September 25 featured the first real-time analysis combining TDWR[2] and NEXRAD[3] data. An improved system was demonstrated in 1993. The new analysis system, which we call Optimal Estimation, is a natural combination of Optimal Interpolation and multiple Doppler analysis.

Storm Motion Algorithm for the Terminal Doppler Weather

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This paper describes a Correlation based algorithm for estimating the movement of radar echoes of convective storms. This algorithm is incorporated in the Terminal Doppler Weather Radar (TDWR) system (Turnbull et al), deployed by Raytheon Company for the Federal Aviation Administration (FAA). This system provides automatic detection of microbursts (Fujita, 1985) and low-level wind shear. Another major function of TDWR is to improve air traffic management through forecasts of wind shifts, precipitation and other weather hazards.

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[2] Terminal Doppler Weather Radar

[3] Next Generation Weather Radar (WSR-88D)

The Storm Motion algorithm examines time sequenced images of radar reflectivity data. For each pair of time-adjacent images, a crosscorrelation method is used to detect and measure "inter-image" storm motion. The resulting motion vectors (expressed in displacement and/or velocity) are smoothed to improve temporal continuity, As a final step, storm motion information is united with the reflectivity image to produce two types of output product: storm motion vectors (showing direction and storm speed) co-located with significant reflectivity cells, and an image translation which explicitly shows the expected storm locations at a future times of 5, 10, 15 and 20 minutes. The algorithm consists of several parts, These are: Generate weather image, Filter weather Tmage, Determine valid analysis points, Generate global vector, Generate local vectors, Estimate motion, Depict storm, Generate storm product, and Display storm product. The following is a description of each of these functions.

Data preprocessing

The generate weather image function preprocesses the time sequenced sixlevel precipitation product and conditions it for the storm motion algorithm. Specifically, it eliminates data where it is estimated that significant attenuation has occurred and all data below an adaptable threshold. It also converts the data to floating point representation for determination of correlation coefficients. The filter weather image function uses a median filter to smooth the current precipitation product (current weather image) to provide spatial continuity.

The determine valid analysis points function guards against random correlation by determining if the current weather image has any weather data suitable for motion detection. it determines a global analysis point, and a set of local analysis points for image cross-correlation. A local analysis point represents the intersection of grid lines placed over the current weather image. The local correlation box typically has a side-length equals to twice the distance between two adjacent analysis points. The current weather image is considered valid (i.e. suitable for cross-correlation) if it has at least one valid local analysis point.

Correlation Processing

The determine global vector function uses a cross-correlation algorithm on two precipitation images to calculate a global motion vector. it also produces a motion constraint map which represents the most likely local.weather motion. The same motion constraint map is used at each analysis point. The local correlation uses this map for faster and'more reliable determination of motion vectors.

The determine local vectors function produces a motion vector for each grid point on the current weather image. It uses a cross-correlation algorithm on all valid analysis points (on the grid), and interpolates valid motion vectors to all other grid points. Next the motion vectors are filtered to provide temporal continuity. The motion vectors are propagated in the absence of valid current weather image.

Display Processing

The next stop in the algorithm is to identify the locations for the display of the motion vectors. The Depict storm function determines the local reflectivity maximums in the data. The Generate storm function uses these the reflectivity maximum locations to determine where to place the motion vector. The motion vectors are generated by interpolating valid motion vectors to the selected storm center locations.

Thursday/Jeudi a.m. Room/Salle 209
Session 2

Climate Variability and Interaction / Variation et interaction du climat

Chair/Président: L. Mysak

Sea Surface Temperature Anomalies and the Simulated Cyclone Climatology

Steven J. Lambert

Canadian Centre for Climate Modelling and Analysis Victoria, B.C.

Six independent ten-year simulations using the CCC General Circulation model were caried out forced with observed monthly varying sea-surface temperatures. The cyclone climatolies were extracted and compared the the coresponding observed cyclone climatology.

On the Interactions between Synoptic Scale Eddies and the PNA Teleconnection Patterns

M.Klasa, J. Derome and J. Sheng

Department of Atmospheric and Oceanic Sciences and Centre for Climate and Global Change Research, McGill University

The barotropic and baroclinic interactions between the monthly mean Pacific/North American (PNA) anomaly pattern and the synoptic scale eddies are investigated. The study is based on 23 winters of NMC tropospheric data. The eddy vorticity forcing of the PNA fluctuations is calculated at the 250, 550 and 850 hPa levels. The vorticity forcing is represented in terms of monthly mean geopotential tendencies which are found to be spatially in phase with the PNA anomalies throughout the troposphere. Eddy thermal forcing (displayed as monthly mean temperature tendencies) is calculated at the 400 and 700 hPa levels. These temperature tendencies are found to be spatially out of phase with the PNA temperature anomalies at the two levels. The strongest vorticity forcing is in the upper troposphere with a characteristic time scale of about 6 to 10 days. The largest thermal forcing is found in the lower troposphere with about the same forcing time scale. In order to verify how the eddy forcing is affecting the structure of the PNA pattern, calculations of the atmospheric response to the forcing are under way. This is being performed by applying the eddy forcing at the five levels to a linear steady-state model with a non-zonal basic state.

Sea-Ice, Polar Amplification and Arctic Climate Warming

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From increasing greenhouse gases, all global climate models (GCM) predict warming of the Earth's surface and of the lower atmosphere. In polar regions and particularly in the Arctic, sea-ice cover is a major factor for regional warming. As an example, in a double CO_2 scenario the Canadian model (CCC/GCMii) calculates a reduction of about 66 % of the total mass of sea-ice. A reduction of sea-ice cover and thickness implies a surplus of solar energy storage into the ocean during late spring and summer. Consequently a warmer sea-surface temperature (SST) anomaly is formed and the energy returned to the atmosphere during the cold season. For a double CO_2 scenario, the CCC/GCMii produces a 12 to 15K warming over the Arctic ocean during January, while the global mean warming is only 3.5K. During the last 15 years a global warming has emerged. Although it is not yet statistically significant in its amplitude, it is in remarkable agreement with the CO_2 warming pattern. The main exception being the Arctic ocean where no amplification is yet apparent.

The response to a transient increase of greenhouse gases may explain in part the substantial difference between observations and models in the high Arctic. A series of diagnostics and simulations is carried out to determine the sensitivity of Arctic sea-ice to warm anomaly from external forcing like that of greenhouse gases. The hypothesis to verify is that an onset threshold of radiative forcing is required to activate the multi-annual sea-ice-temperature feedback. A weak forcing results in a small temperature anomaly where the heat storage is exhausted during the current year and does not compound into the following years. On the other hand, a double CO_2 forcing is sufficiently strong to activate the retreat of multi-annual sea-ice and allow the winter climate to drift to a much warmer condition by compound effect. This study uses the new FIZ-C version of the CCC/GCMii to investigate the ice sensitivity and pave the way to a future major experiment of transient CO_2 climate simulation.

Multivariate Analyses of Accumulation in Ice Sheets: Implications for Global Change

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Charles R. Bentley, Geophysical and Polar Research Center
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Madison, Wisconsin

The annual rate of net mass accumulation at the surface in the Antarctic and Greenland ice sheets is determined for grid-point locations 100 km apart from emissivity compilations based on Nimbus-5 ESMR and Nimbus-7 THIR data and applying hyperbolic functions developed specifically for each ice sheet. These data are used to define multivariate models which include latitude, surface elevation regionally updated by ERS-1 radar altimeter data, surface temperatures (THIR), and mean annual shortest distance to open ocean determined from sea ice concentration distributions derived from Nimbus-5 ESMR and Nimbus-7 SMMR data. The models are used to estimate expected

changes in the surface temperature and accumulation rate of the ice sheets on the basis of predicted sea surface temperature increases in the subpolar seas as well as potential changes in sea ice extent. The results provide new inputs for dynamic models in which atmospheric water vapor, as well as sensible and latent heat transports, may be considered. They also provide an estimate of the potential short-term variations in the contribution of the ice sheets to sea level change.

Thursday/Jeudi a.m. Room/Salle Alumni Aud./ Aud. des Anciens
Session 2

Forest and Agricultural Climatology / Climatologie des forêts et de l'agriculture

Chair/Président: B. Amiro

Estimating the Probability of Break-Even Yields for Continuous Wheat on the Canadian Prairies

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Research Branch, Agriculture and Agri-Food Canada, Ottawa

Most agricultural production in the Canadian prairie region is based on dryland cropping. Wheat production depends to a large extent on moisture available to the crop during the growing season, i.e., the amount of plant available water stored in the soil at seeding plus the growing season rainfall. Research has shown that yields of spring wheat are closely related to crop water use or actual evapotranspiration. Empirical yield relationships have been formulated for each of the major soil zones (Brown, Dark Brown, Black and Grey) of the prairie region.

In this study growing season evapotranspiration was estimated yearly using weather data for 30 yrs. (1956-1985) for each of 250 Agroecological Resource Areas (ARA) of the prairie region as input into the Versatile Soil Moisture Budget (VSMB) model. Results were combined with the empirical crop yield models to estimate the probability of obtaining economic break-even yields in each ARA. Break-even yields are those necessary to recover production costs and were estimated using recent data on prices and costs of production for continuous wheat in each of the major soil zones.

The probability of obtaining current break-even yields with continuous spring wheat was less than 20% in the Brown soil zone, increasing up to 60% in the Dark Brown zone and varying from 61 to 100% in the Black and Grey zones, with higher probabilities in ARA's with clay textured soils. The effect of changing economic conditions on the probability of obtaining break-even yields are also estimated.

Simulation of Soil Water Variations for Potato Crop

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Crop growth models are becoming increasingly used. They offer the possibility to assess the effects of water management on crop yield, water requirements, nutrient leaching and pollution control. In this study, we compared

the hydrological components of two crop growth models: 1) SUBSTOR, which is the potato version of CERES-type models, and 2) SWACROP, that was developed in the Netherlands for assessing the effect of water management on potato yield. SUBSTOR uses a conceptual soil water balance model, whereas SWACROP solves, by finite differences, the one-dimensional Richard's equation. Two years of soil water content data have been used to assess these two models. Data from 1992 were collected under non-irrigated conditions, and for 1993, irrigated and non-irrigated plots were set-up. For 1993, there were no differences in yield between irrigated and non-irrigated plots. Since many soil variables are required by the models, sensitivity analyses have been performed to identify which variables should be measured in priority. Various methods for determining reference and crop evapotranspiration were also investigated to evaluate their effect on soil water content.

Results of this research can be used to determine reference longterm effect of water management on yield of potato crop.

Evaluation of SAR for Soil Moisture Monitoring in Agriculture

J.B. Boisvert, H.J. Qwyn and H. Geng

Synthetic aperture radar (SAR) imagery is, among other things, a remote sensing way to measure soil moisture. Mapping of soil moisture from the grey level of an image is a feasible task but several factors can interfere and then, must be taken into account. The most important ones are crop cover, incidence angle and roughness. But once these factors have been controlled or assessed, the information can be used for several purposes such as monitoring, initialization and validation of regional soil moisture models, rainfall spatial distribution, estimation of water supplies in spring and fall, detection of field soil moisture spatial variability, enhancement of field drainage problems. This presentation will show a case of successful soil moisture mapping. The potential of RADARSAT for soil moisture monitoring will be evaluate, based on the actual knowledge and applications developed and tested from airborne SAR and ERS-1. The limiting factors will be enhanced and solutions will be suggested.

Estimation of Photosynthetically Active Radiation Absorbed by the Vegetation from Space

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Zhanqing Li
Canada Centre for Remote Sensing, Ottawa, Ontario

Knowing the amount of photosynthetically active radiation (PAR) absorbed by the vegetation is useful for agriculture, forestry and climate studies. This value can be used to estimate the growth rate of plants and the $C0_2$ uptake by the canopy in photosynthetic process. Although this value can be obtained from ground measurements, only satellites provide the temporal and spatial coverage for the global monitoring of absorbed PAR. On the basis of radiative transfer modelling in the atmosphere and inside canopy, we are proposing a method that uses the data collected by space-borne multichannel sensors (such as AVHHR) to estimate the amount-of PAR absorbed by the vegetation canopy. It takes advantage of the facts that the PAR spectral region (400 to 700 nm) coincides with the atmospheric window and that absorptivity of vegetation covers is closely related to the greenness of the vegetation. The absorption of visible light by the plants can thus be related to some vegetation index. This method can be applied regardless of the sky condition as long as a few observations on cloudless days are available every month. It is also fairly robust to change in atmospheric constituents, vegetation types and ground characteristics.

Thursday/Jeudi a.m. Room/Salle 232
Session 2

Weather Forecasting-1 / Prédictions météorologiques-1

Chair/Président: P. Merilees

Cloud Cover Parameterization in a Large-Scale Atmospheric Model

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The study addresses the problem of predicting cloud cover and its radiative impact in a large-scale atmospheric model. A convective and stratiform condensation scheme including cloud water content as a predictive variable is implemented in the Canadian global spectral model. An important aspect of the scheme is that the cloud amount estimation is a part of the condensation scheme and it is a key element in the sub-grid scale stratiform condensation parameterization. The cloud cover from the scheme is verified quantitatively using satellite data. The dependence of the grid-scale relative humidity threshold on the horizontal and vertical resolutions is examined. Possibility of parameterizing stratiform clouds as vertically sub-grid clouds and its verification are investigated. It is shown that the total cloud cover is better estimated as the sum of separate estimates of convective and stratiform cloudiness within the framework of the condensation processes parameterized in the model. The convective cloud cover is found to be very important to the radiative budget. An improvement in the model forecast, hydrological balance and cloudiness prediction is noticed when the stratiform relative humidity threshold decreases with height. The study also presents a new 3-dimensional view of the cloudiness estimated by the original scheme and provides a simple vertical and horizontal sub-grid scale cloud cover parameterization. Vertically sub-grid stratiform clouds combined with horizontally sub-grid convective clouds provide a remarkable improvement in the estimation of total cloud cover.

A Non-hydrostatic Variable-resolution Global Model of the Atmosphere

Jean Coté, Sylvie Gravel, Michel Roch, Alain Patoine and Andrew Staniforth

Recherche en prévision numérique and Centre météorologique canadien
Service de l'environnement atmosphérique

The goal of this work is to develop an efficient model to meet all actual and foreseeable operational requirements for Canada. These presently include short-range regional forecasting, medium-range global forecasting. and data assimilation. In the future they may include nowcasting at the mesoscale, and dynamic extended range forecasting on monthly or seasonal scale.

The main idea behind this thrust is that the finite-element method permits variable resolution in a natural way, and a focusing of resolution over an area of interest. This offers an efficient and simple solution to the nesting problem: the planetary waves are adequately resolved outside the high-resolution subdomain (which resolves mesoscale disturbances), and there is no abrupt change of resolution across an internal boundary since the resolution is varied smoothly in the outer part of the domain. There is also an obvious practical Advantage inasmuch as there is only one

model to maintain instead of the usual two (viz a global model for medium-range forecasting and a limited area model for regional forecasting).

The model employs the primitive (u-v) form of the equations and a two-time-level semi-implicit semi-Lagrangian discrecization. The model formulation is non-hydrostatic with a pressure-type hybrid vertical coordinate.

Polar Lows in the Labrador Sea: A Case Study

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University of Toronto

S. Sathiyamoorthy

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During the past twenty years, it has become apparent that intense and rapidly developing mesoscale vortices are often observed north of the primary Polar Front - the boundary between the cold polar air and the warm tropical air. These vortices, known as polar lows, occur primarily over the high latitude oceans and are of interest for a variety of reasons. Their initial growth and organization appear to be baroclinic in origin - yet the time and length scales associated with them are significantly shorter than is predicted by conventional instability theory. Their small size and rapid development make them particularly difficult to forecast. One also often observes strong surface fluxes of heat and moisture to be associated with these vortices. Indeed, their rapid development can for the most part be attributed to the convective activity driven by these fluxes. It is unclear as to what effect the same fluxes have on the ocean.

Polar lows were first identified in the Norwegian Sea and research has naturally tended to focus on those that develop in this area. In the past several years, it has become evident that they also commonly develop other areas as well. In this paper, we will describe our analysis of a polar low event that occurred in the Labrador Sea during the winter of 1992. As there are unfortunately no in-situ observations of this event, we will rely on satellite data as well as the high resolution objective analysis from the ECMWF to document the environment in which the low developed and the structure of the low itself.

Diagnosing Extra-Tropical Development Through the Zwack-Okossi Equation

Pierre Bourgouin (AES) and Peter Zwack (UQAM)

Extra-tropical cyclones are of prime importance for weather forecasting and, for this reason, have been thoroughly studied. This presentation will use an innovative way (Zwack and St-James 1994) for diagnosing the impact of different forcings on cyclone development that are based on the Zwack-Okossi development equation, the omega equation and a divergence equation. Numerical tools based on these equations have been developed at UQAM which can be used to calculate the individual contributions to development for each forcing: vorticity advection, the laplacian of temperature advection, the laplacian of latent heat release, the laplacian of sensible heat transfer, and, finally, orography. The diagnostics are obtained using data from a numerical weather prediction model (REF) simulation by D-L. Zhang of McGill University of a CASPII explosively developing cyclone.

Thursday/Jeudi p.m. Session 3 Room/Salle 233

Atmospheric Dynamics-2 /Dynamique de l'atmosphère-2

Chair/Président: M. Beland

Effects of Variable Wind Shear on a Diabatically Driven Mesoscale Circulation

G.W. Reuter and O. Jacobsen

We examine the response of stably stratified air flow to a slab symmetric diabatic forcing associated long-lasting precipitation bands. The steady-state linearized Boussinesq equations are used to model the diagnostic relationship between the vertical motion field, the heating source, and the ambient flow. The basic-state flow is assumed to be horizontally uniform and nonrotating, but the static stability and wind varies in the vertical.

For typical atmospheric stratification and a moving heating source associated with a cloud band, the Taylor-Goldstein equation is solved numerically. The numerical results show that the crossband wind shear tilts the updraft core and broadens it. As the magnitude of the shear is increased, the circulation becomes stronger. The details of the wind profile are also important in determining the intensity and structure of the circulation. When the wind profile indicates a convex bulge (i.e. the low-level shear is weaker than the upper-level shear), the circulation becomes slightly weaker in comparison to the linear wind profile. Conversely, the circulation becomes stronger when the wind profile has concave shape. Increasing the concave bulge tends to enhance the circulation but not in a monotonic fashion. This non-monotonic relation between the vertical motion and the parabolic windprofile is interpreted in terms of kinetic energy changes of parcels that interchange their altitudes.

Large Amplitude IGW Excitation by Atmospheric Jets

B. R. Sutherland and W. R. Peltier
Department of Physics, University of Toronto

More than being an interesting problem in its own right, it is now apparent that an understanding of the mechanisms by which internal gravity waves (IGW) are generated or absorbed in unstable or stable stratified parallel flow is crucial for the appropriate parametrization of "drag" in general circulation models. In many of the excitation mechanisms that have been proposed, IGW are assumed to develop through what are necessarily nonlinear processes. Indeed, as pointed out by McIntyre and Weissman (1978), any linearly unstable disturbance which penetrates into a region of constant N^2 and mean horizontal velocity is apparently trapped and it is therefore generally believed that a nonlinear analysis is necessary to assess the effectiveness of any instability as a radiator of internal waves. Recently, however, Sutherland and Peltier (1994) have performed nonlinear simulations in two dimensions of the evolution of jet and shear flow in stratified fluid such that the background density variation is reduced in the region of strong shear. These simulations demonstrate the possibility for IGW radiation which is capable of vertically transporting a significant fraction of the horizontal momentum initially associated with the mean-flow. Furthermore, in Sutherland et al. (1994) a penetration condition is derived on the basis of linear theory which successfully predicts under which circumstances such a basic state may radiate large amplitude IGW. The important question is of course whether such a radiation mechanism is realizable in the Earth's atmosphere. To this end we have examined the vertical profiles of horizontal velocity and N^2 taken from observations upstream of the Rocky mountains near Boulder, Colorado. Upon the observed mean-flow we superimpose a perturbation which is representative of a local acceleration of the tropospheric jet due to a supposed transient large-scale forcing which destabilizes the mean-flow in the region of reduced N^2. In nonlinear simulations employing these initial conditions, IGW are continuously generated until the mean-flow

stabilizes. In this time (about two hours in real time units) the flux of momentum into the stratosphere is approximately ten percent of the momentum associated with the initial basic state below the tropopause. We suggest on this basis that the reason why the atmospheric general circulation models overpredict the strength of the mid-latitude jet streams is that they do not resolve this emission mechanism. The conventional explanation, however, is that such models fail to explicitly resolve the drag due to wave absorption.

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The Numerical Formulation of MC2 and its Validation on the Classical Mountain Wave Problem

René Laprise, Philippe Héreil[1], Hélène Rivals[1], Robert Benoit[2], Michel Giguère, Michel Desgagné[2], Yves Chartier[2] and Guy Bergeron

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A Mesoscale Compressible Community (MC2) model is currently developed by a group of scientists of CCRM, the Cooperative Centre for Research in Mesometeorology, a research group formed by McGill and UQAM Universities with RPN as industrial partner. MC2 is developed with the aim of serving as a general purpose tool to be made available for mesoscale research in Canada. Already two Physics parameterization packages have being implemented in MC2-: the RPN Physics for application to fine-scale short-range forecasting by R. Benoit at RPN, and the CCC GCM-II Physics for application to regional climate modelling by R. Laprise at UQAM; other packages suitable for different applications are being developed elsewhere too.

MC2 evolved form a research model developed by the late André Robert. This model was designed to be a versatile model, numerically stable and efficient, using state-of-the-art semi-implicit semi-Lagrangian algorithms for solving the non-hydrostatic Euler equations. In this presentation, the dynamical and numerical framework of MC2 will be reviewed, with special attention devoted to the so-called "long timesteps" singularity of stationary forced disturbances, and the fidelity with which mountain waves can be simulated with the MC2 model. Some preliminary results of 3-D simulations of mountain disturbances produced by MC2 will also be presented.

Vertical Propagation of Linear Mountain Waves in Atmospheres with Varying Damping Coefficients

Hélène Côté and René Laprise

Département de physique, Université du Québec à Montréal

This study is on partial internal reflections of mountain waves that result from abrupt variations in a damping term applied to the wave field. This work complements that of Klemp and Lilly (JAS 1975) who studied the effect of

abrupt changes in static stability. In that study, discontinuities in the refractive index induced partial internal reflections of the waves which led to amplification of the low-level winds. The wave saturation hypothesis, widely used in gravity-wave drag parametrizations, involves dissipative mechanisms which act to reduce the wave amplitude. Such dissipation does not exist in a linear model, but it can be parameterized by adding a damping term to the equations. The results we present were obtained by time-integrating a two-dimensional non-hydrostatic linear model simulating mountain waves. Numerical and analytical solutions will be compared for different layer configurations where damping is applied.

Empirical Normal Mode Analysis of the Atmospheric Variability

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The theory of empirical normal modes (ENM) [Brunet, 1994, JAS] was first used to analyze 24 winters of the NMC dataset. An ENM analysis permits the empirical reconstruction of the excited normal modes in a time series as well as their respective variances and phase speed relationship, when the system is linear and non-dissipative. This approach enables quantitative and qualitative discussions of the wave mechanisms present in real or numerically simulated shear flows.

The ENM approach has been used to diagnose a hemispheric shallow water model in order to study the method's sensitivity. Long integrations with random topographic forcing of a polar vortex have been performed for different resolutions, time samplings, dataset dimensions and nonlinear regimes. A measure of predictability is obtained with an e-folding time for each observed Rossby waves. This shows two significant distinct peaks in the nonlinear regime variance, with the most predictable in the slow variability spectrum. This result has practical importance for the predictive skill atmospheric flow and will be discussed.

An ENM analysis of a 10 year AMIP integration of the Canadian semi-lagrangian global spectral forecast model (T63 with 23 vertical levels and prescribed SST and sea ice) will be shown. The analysis will focus in the winter polar vortex wave dynamics in the Northern Hemisphere.

Thursday/Jeudi p.m. Session 3 — Room/Salle:224

Aviation Meteorology Forecasting & Modelling 3
Modélisation de la météorologie de l'aviation 3

Chair/Président: Carr McLeod

Microphysical Study of the Conditions for Presence of Supercooled Water within Precipitation and the Coupling with Radar Data

Wanda Szyrmer
Université du Québec à Montréal

I. Zawadzki and F. Turcotte
McGill University

The supercooled cloud water content is a key parameter for the aircraft icing and for the development of precipitation. The production of supercooled water in clouds is possible only in sufficiently strong updraft so as to maintain the saturation with respect to water while the presence of solid precipitation depletes the moisture and the cloud contents. The generation of moisture excess during the air uplift must exceed the rate of vapour deposition on snow and the rate of snow riming. Thus, assuming the steady state and neglecting advection terms, the threshold value of the snow content compatible with the presence of the supercooled cloud can be calculated for a given vertical motion and temperature and pressure conditions.

These threshold values were determined using a microphysical bulk parameterization. The values found analytically are compared with the output of a high resolution 3-dimensional kinematic cloud model with a full microphysical scheme. The winds driving the development of hydrometeores are obtained by a 3D wind retrieval technique applied to single Doppler radar data. In this way a potentially operational method for detection of icing conditions is suggested.

Aircraft Verification of the Icing, Cloud and Freezing Level Forecasts from the CMC Aviation Forecast Model

Stewart G. Cober, George A. Isaac and Andre Tremblay.

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During the Second Canadian Atlantic Storms Program, 39 research flights were made into a variety of weather systems over the North Atlantic ocean. This provided a unique opportunity to study the accuracy of components of the aviation forecasts, by comparing model predictions to in situ aircraft measurements of cloud microphysics. Comparisons between aircraft measurements and forecasts of low cloud, middle cloud, freezing level and rime icing regions are summarized and strengths and weaknesses of the aviation forecast are discussed.

In general, the freezing level forecast was quite accurate, with the aircraft measurements and model predictions agreeing within 1 kft. Forecasts of rime icing regions were significantly overestimated by the model, primarily because the model failed to .account for the glaciation of clouds. The success of the low cloud and middle cloud forecasts depended on how well developed and wide spread the associated synoptic scale features were.

On the Forecasting of Supercooled Clouds

Andre Tremblay[1], Anna Glazer[1], Wanda Szyrmer[2], George A. Isaac[1] and Isztar Zawadzki[3]

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The presence of supercooled cloud water in the atmosphere is a major hazard for aircraft operation and has caused a significant number of aviation disasters. Accurate forecasting of regions of potential icing is crucial for flight planning and poscs a challenging problem to the meteorologist. To address this issue we will discuss the results of cloud microphysics simulations, mesoscale numerical integrations and the analysis of aircraft data collected during two research flights from the Second Canadian Atlantic Storms Program (CASP II). Based on cloud microphysics simulations, a technique to forecast supercooled cloud events within mesoscale simulations is suggested. This procedure is coupled with Lhe explicit predictive cloud water scheme of Sundqvist to produce aircraft icing forecasts with the Canadian Regional Finite Element model. The procedure is validated from a comparison with in situ airborne measurements from CASP II data. As an illustration for the application of this procedure, constant pressure maps showing regions of cloud ice, supercooled cloud water and cloud water are presented.

Towards the Improvement of Aviation Forecasting: The Validation of a Scheme for Mesoscale Prediction of Cloud and Precipitation Types from In Situ CASP II Aircraft Measurements and SSMI Observations

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Meteorological conditions associated with winter extratropical cyclones typically produce a rich variety of cloud and precipitation types. It is not uncommon to observe within these storms precipitation in the forms of snow, ice pellets, rain, freezing rain, freezing drizzle or a mixture of these. Supercooled liquid water associated with such clouds and precipitation can represent a significant hazard to aircraft. The available cloud and precipitation physics presently included in the Canadian Meteorological Centre forecast models are not sufficiently sophisticated to allow forecasts of areas of freezing rain, freezing drizzle and supercooled clouds with a satisfactory accuracy. To address this issue we suggest a technique to distinguish ice, liquid and supercooled water in the atmosphere. The scheme is coupled with the predictive cloud water scheme available in the Canadian Regional Finite Element model. Results are compared with in situ aircraft measurements collected during CASP II and with satellite SSMI data. Potential applications to improve the forecasting of cloud and precipitation types will be discussed.

Short Term Forecasting To Support Aircraft Ground Anti-icing Activities in Canada

*Michael Leduc, George Isaac, Paul Joe, Norman Donaldson, Bruno de Lorenzis, Brian Sheppard**

Cloud Physics Research Division

**Measurement Technology Division*

Ice and snow accumulating on aircraft while they are on the ground is as serious a problem as in-cloud icing. There have been numerous crashes related to this factor in recent years. Airport operations are severely hampered in

freezing and frozen precipitation conditions. Guidelines require that aircraft wing and control surfaces be completely free of ice and snow at takeoff. Accumulations of as little as a few tenths of a millimetre can cause serious degradation in aircraft performance during take off. Fluids have been developed which can de-ice and maintain these ice free conditions for short periods of time. However this time period, referred to as holdover time (typically from a few to tens of minutes), is strongly dependent on weather conditions. in particular, the rate of water equivalent precipitation falling during this holdover time is critical. Of course the accumulation of snow and ice on the runway is another serious problem.

Measuring and forecasting frozen or freezing precipitation to the accuracy of tenths of millimetre; over a few minutes, and over an area the size of an airport, is a totally different problem from the typical synoptic scale precipitation forecast. instruments are needed which can measure precipitation to a very fine scale. Techniques are needed which can distinguish short term variations in precipitation rate and phase.

As part of Transport Canada's Dryden Commission Implementation Plan, Environment Canada is undertaking three projects related to the ground icing program: 1- Assessment of present nowcasting schemes; 2- Investigation of current instrumentation related to icing: 3- Development of a prototype observing and nowcasting scheme. This paper will highlight the ongoing activities related to these projects.

Thursday/Jeudi p.m. Session 3 — Room/Salle: ALUMNI AUDITORIUM
AUDITORIUM des ANCIENS

Boundary Layer Meteorology/ Météorologie de la couche limite

Chair/Président: T.J. Gillespie

Multiscale Distributions of Flux Intensities Above and Within a Forest Canopy

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Turbulent fluxes above a rough surface are highly intermittent. A number of researchers have attempted to conditionally sample the most intense flux events and average them in some fashion to obtain characteristics of some typical coherent structure.

A new approach will be shown which makes use of the wavelet transform. Measurements from above and within a deciduous forest, under various stability conditions, are analyzed. Rather than begin with a search for 'coherent structures', a distribution of flux event intensities at each scale is obtained. Momentum and heat fluxes are considered. The effects of increased mixing efficiency at certain scales are seen near the canopy top. As well, normalized results for momentum flux show remarkable consistency between various stability conditions.

Flux Patterns and Coincidence of Turbulent Structures in Regional Energy and Gas Exchange over Agricultural Areas

C. Mitic[1], P.H. Schuepp[1], P.L. Desjardins[2] and J.I. MacPherson[3]

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Tying near-surface exchange processes to surface characteristics in spatially varying ecosystems is often difficult. Observations from low flying aircraft, flying a 44-line grid pattern over a 15 km x 16.5 km area of irrigated and non-irrigated agriculture land in Southern California, permitted the mapping of surface source (or sink) strength distributions, consistent with independently observed maps of greenness and surface temperature. The spatial distribution of coherent structures responsible for the transport of sensible heat, moisture, $C0_2$ and ozone was also mapped, as well as the mutual, spatial coincidence of these localized structures. Analysis of co-location of these structures helps to elucidate the relative importance of surface and boundary layer characteristics as driving forces for these exchange processes. Flux associations between moisture, heat, $C0_2$ and ozone varies with crop type and surface moisture conditions. With increasing emphasis on the definition of regional balances for energy and gases from realistic agricultural and forest systems (in particular greenhouse gases and ozone as an environmental hazard) there is a growing need for-optimum resolution of surface source distributions from airborne observations. The California data, obtained over surfaces with clearly defined surface heterogeneities, serve as an almost ideal data set to test the reliability of such techniques which will be applied to other ecosystems such as the BOREAS forest sites.

Multifractal Characterization of Aircraft-Based Measurements in a Turbulent Field

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The highly variable and Intermittent nature of gas fluxes resulting from turbulence over a vegetated surface Introduces great difficulties in the accurate quantification of estimates of those fluxes. The primary consequence of this intermittency is that repeated sampling in time over the same terrain will not reveal the same structure content, and hence will not produce the same flux estimates. Thus, limited repeated sampling can produce a distribution of flux estimates with a variance wide enough to prevent a meaningful estimate of the corresponding mew. The typical method of characterizing a fluctuating signal in a turbulent boundary layer is decomposition of the signal Into a mean and a fluctuating component; the length of time series required to accurately estimate the mean of the signal is then dependent on the correlation structure of the fluctuations. The presence of long correlations (i.e. variability on long wavelengths) In the signal makes estimation of the mean and higher-order moments extremely difficult, often necessitating prohibitively long time series. An alternative "multifractal" framework (in which the statistics of the signal are expressed in terms of the parameters α and C_1, and the codimension function c(y)), exists if the signal represents a cascade process exhibiting the following properties: 1) scaling symmetry, 2) a quantity conserved by the cascade, and 3) localness in Fourier space. Several techniques have been developed under this framework to estimate exponents characterizing the different statistical moments of the signal. This method offers a great deal more flexibility than the standard statistical approach to data analysis. The c(y) function describes the number of extreme events, or singularities, that are likely to be present on a given time series, and thus can be used to estimate the sample length required to guarantee convergence of desired moments. Furthermore, exponents from separate samples of the same variability can be combined under this framework to improve the statistical accuracy of the parameter estimates. Thus multiple passes over the same terrain may be used to improve knowledge of the relevant statistical quantities, in contrast to the traditional requirement that samples be exceedingly long. This approach will therefore have profound implications for both future sampling strategies and data analysis.

The Atmosphere Model to Assess the Safe Disposal of Canadian Nuclear Fuel Waste

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Canada's Nuclear Fuel Waste Management Program is researching a concept for disposal of immobilized nuclear fuel waste in a vault mined deep in stable plutonic rock. Far into the future, when protective barriers are eventually breached, radionuclides carried by groundwater may migrate from the vault to the biosphere. Here we describe the pathways through which radionuclides may move to the atmosphere from contaminated terrestrial and aquatic surfaces. We consider surface water and soil as primary sources of radionuclide fluxes to the atmosphere, and consider the processes of suspension and local dispersion. Some radionuclides may be attached to contaminated suspended particulate matter, whereas others are mobile as gases. The model considers natural phenomena such as wind erosion of soil, forest fires, gaseous emissions from soil, and bubble bursting at lake surfaces. We also model anthropogenic processes such as wood burning for energy and calculate radionuclide concentrations in both outdoor and indoor air. The model combines a variety of techniques including mass-loading concepts, flux density estimates, and parameterized dispersion models. The model is probabilistic: transport is modelled using simple mass transfer equations and variability is incorporated by distributing values for parameters. We describe the transfer equations, selection of parameter values, and the relative importance of various pathways.

Source Strength Determination of Trace (Greenhouse) Gases from Agriculture using the Diffusion Equation

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Agriculture has been identified as one of the major contributors of greenhouse gases (GHG), in particular CO_2, CH_4 and N_2O. The closed chamber method is the current mode of measuring trace gas flux from a surface source. However, enclosing an area from the natural environment immediately alters the micrometeorology and therefore the biology of that area, thus affecting the flux. An alternative, non-obstructive approach is based downwind, above-surface observations of concentration or flux, under the prevailing atmospheric conditions, from which the source strength can be estimated through the diffusion equation. Current developments are particularly promising for microscale experiments in the field, where the effect of various management techniques on the release of GHGs is being tested. Field tests on 2 m x 2 m and 4 m x 4 m plots were conducted to test this approach. Sulphur hexaflouride (SF_6) was released as a tracer gas from various configurations of surface sources, and vacuum pumps. were used to sample simultaneously in the crosswind and vertical direction at a given downwind distance from the source(s) to determine the distribution of the diffusing scalar. Observations served as a test of the relationship between source strength and sampled concentration, calculated on the basis of the diffusion equation. The application has been extended to methane, which was simultaneously released in some of the experiments. Ultimately, these studies should lead to a better definition of the potential of above-surface gas sampling (whether by tower or aircraft) to detect GHG source strength and configuration from agricultural systems at various scales.

Thursday/Jeudi p.m. Session 3 Room/Salle: 209

Climate Variability and Interaction 2/ Variation et Interaction du climat 2

Chair/Président: L. Mysak

On the Modification of the High and Low-frequency Eddies during ENSO Years: An Observational Study

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Department of Atmospheric and Oceanic Sciences
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A 24-year NMC data set was used to study the interannual variation of the extratropical atmospheric fluctuations. Significant differences were found in the winter seasonal mean flow, the low-frequency eddies and the synoptic-scale transients between El Niño years and non-El Niño years. In the El Niño winters, the Aleutian low in the North Pacific deepens and is accompanied by an enhanced PNA pattern. The low-frequency eddy activity is reduced in North Pacific and the high-frequency baroclinic waves are shifted east and south of their normal position in the Pacific.

The weak low-frequency activity during El Niño winters results from two processes. Firstly, less kinetic energy is supplied to the low-frequency eddies from the large-scale seasonal mean flow because of its modified structure. Secondly, the strong seasonal mean Aleutian low tends to keep the baroclinic synoptic-scale eddies moving along its southern side, causing only a weak interaction with the low-frequency eddies in the Northern Pacific, and thus less synoptic-scale eddy forcing.

Cyclone Frequencies over Northern Canada and the Northern Atlantic

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A decadal feedback loop proposed by Mysak, Marsden and Power relates cyclogenesis over the Iceland Sea and the Irminger Basin to precipitation and runoff in northern Canada. To examine this, a data bank consisting of monthly cyclone frequencies over parts of: Northern Pacific, Northern Atlantic and North America for the period 1950 to 1989 has been compiled. The cyclone frequency data is compared with other data, such as precipitation, pressure and SST data. Results for the McKenzie basin show that cyclones tend to come in from the west and northwest, originating in the Pacific. This indicates that the feedback loop has to be revised, taking into account cyclogenesis in the Northern Pacific and possible teleconnections between the Northern Atlantic and the Northern Pacific.

Varability and the North Atlantic Oscillation

G.W.K. Moore

Department of Physics
University of Toronto

It has been known for many years that when winter temperatures over the Canadian Arctic and Greenland are anomalously cold, Northern Europe typically experiences anomalously mild winters and vice versa. Walker and Bliss termed this temperature seesaw, the North Atlantic Oscillation (NAO). It is now understood that the NAO is related to the intensity of the Icelandic Low. Indeed a useful index for the NAO can be defined as the difference between the sea-level pressure anomalies at Iceland and the Azores. When the temperatures in the Canadian Arctic are anomalously low (high) and those in Northern Europe are anomalously high (low), this index is positive (negative).

In the literature it is conventional to assume that winter mean data is sufficient to characterize the NAO, that is one supposes that conditions in a given winter are sufficiently similar that one can characterize that winter by a single value of the NAO index. With this assumption, one can show that the oscillation has a period of some 5 to 10 years. Such a well-defined temperature and pressure oscillation in the atmosphere clearly is of great importance in furthering our understanding of the natural variability in the climate system. However, the assumption upon which thus result is based has not been rigorously tested. As will be shown in this paper, a new analysis of the 50 year NMC objectively analysed sea-level pressure data set shows that there is considerable variability of the NAO index within a given winter. Indeed on monthly time scales, there is essentially no correlation between the value of the index in successive winter months. As will be argued, this relaxation in the definition of the NAO allows one to show that it is merely a manifestation of the low-frequency variability in the mid-latitude storm tracks.

Midlatitude Atmosphere-Ocean Interactions: Observed

Shiling Peng[1] and John Fyfe[2]

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The impact of *tropical* sea surface temperature (SST) anomalies on atmospheric variability has been studied intensively. By contrast, the impact of *midlatitude* SST anomalies on atmospheric variability has obtained much less scrutiny. In this vein several studies in the last decade have employed General Circulation Models (GCMS) to simulate the winter atmospheric response to prescribed SST anomalies and have in many ways contradicted similar observational studies. A recent study by Peng et. al. (1993) has gone some distance toward reconciling these model and observational studies by demonstrating that the atmospheric response, both simulated and observed, to a midlatitude positive SST anomaly in the Atlantic depends not only on the position and intensity of the SST anomaly but also on the prevailing climatological flow. Here we expand on the study of Peng et. al. (1993) by discussing the impact of positive and negative SST anomalies in North Atlantic and North Pacific using SST and sea level pressure observations from 1930-1987. Comparisons will be made between the earlier studies as well as with the companion GCM study by John Fyfe and Shiling Peng.

Midlatitude Atmosphere-Ocean Interactions: Simulated

John Fyfe[1] and Shiling Peng[2]

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The impact of *tropical* sea surface temperature (SST) anomalies on atmospheric variability has been studied intensively, By contrast. the impact of *midlatitude* SST anomalies on atmospheric variability has obtained much less scrutiny. Here we attempt to partly rectify this situation with a study involving a sixty year integration of the CCC General Circulation Model (GCM) forced with observed monthly mean sea surface temperatures (SSTs). Using this integration, as well as ten year control experiment wherein no SST anomalies have been prescribed (so that the oceans evolve through ten identical annual cycles), we obtain the dominant modes of simulated atmospheric variability associated with midlatitude SST anomalies. The analysis tools used include principal component analyses, cross-correlation techniques and compositing procedures. Comparisons will be made between the earlier GCM studies as well as with the companion observational study by Shiling Peng and John Fyfe.

Thursday/Jeudi p.m. Session 3 Room/Salle 232

Operational Oceanography/ Océanographie Opérationnelle

Chair/Président: Keith Thompson

Electromagnetic Fields Induced by Ocean Currents

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Ocean currents induce electromagnetic fields. Analytical and numerical solutions using a governing induction equation, are presented for the electric and magnetic fields induced by realistic ocean current systems.

The potential for using geomagnetic observations in ocean and climate studies is discussed. Also discussed are the possible systematic effects of the large-scale circulation on the observed magnetic field, and the possible role of the poleward transport of conductivity in generating large-scale magnetic fields.

Lateral Intrusive Mixing - New Discoveries on an Old Front

Barry Ruddick and David Walsh

Dalhousie University

Thermohaline interleaving is often observed in regions of the ocean with compensating lateral gradients of heat and salt. The cross-frontal advective fluxes of heat, salt and other dissolved substances associated with interleaving are important in a variety of situations, from shelf-break fronts to deep-ocean fronts, as well as in the mixing of ocean eddies. We hope to be able to predict these fluxes in the near future. In this talk we present some recent discoveries relating to the dynamical processes which drive double-diffusive interleaving.

CTD profiles from the intrusive region of a Mediterranean salt lens reveal that deviations from the smoothed T-S curve ("spice deviations") are correlated with perturbations in density. where the water column is stratified in the diffusive sense (i.e., warm salty below cool fresh), warm saline intrusions slope downward as they propagate outward, and are found to be anomalously heavy. In the finger-stratified region, they slope upward and are light. We demonstrate how this correlation is consistent with the postulated dynamics of double-diffusive intrusions, is consistent

with the findings of a numerical model of intrusions, and with the findings of laboratory models. The magnitude of the observed density perturbation gives valuable clues about the buoyancy forces driving the intrusions, and hence about the frictional forces which check the lateral speed of advance.

A Near Real-Time Physical Oceanographic Analysis System

Doug Bancroft

Meteorology and Oceanography
Maritime Forces Pacific Headquarters

Oceanographic analyses are performed by Maritime Forces Pacific (MARPAC) Meteorology and Oceanography (METOC) Centre, in near real-time. The principal result of this analysis is an ocean feature description, or "nowcast", that is used to predict the performance of acoustic systems.

Early subjective "hand" analysis methods designed in the 1960s remained largely unchanged up to 1987. There was a requirement to enhance the quality and flexibility of these analyses, and provide for direct output of physical oceanographic fields to acoustic models. This required the integration of observations into an objective analysis (OA) program, coupled with a sophisticated visual display of both observational data and the OA results. Finally, there was a long standing requirement for forecasting oceanographic fields, vice simply nowcasting.

The Ocean Work Station (OWS) project was jointly funded by DND and DFO to meet these requirements, and was conducted as follows:

a. **Phase I.** research methodology for OA, and define Phase II approach. October-December 1992;

b. **Phase II** Implement an OA system with visualisation tools and export filters to acoustic models. January-March 1993;

c. **Phase II.5** Upgrade the Phase II OWS based on experience, e.g. assimilation of satellite AVHRR data, enhance widgets, provide for bathymetry visualisation simultaneously with other processed fields. August-December 1993;

d. **Phase III** Examine the "way ahead" for implementing a forecast model. October 1993-March 1994; and

e. **Phase IV** Implement a forecast model. Planned for April 1994.

The OWS runs on a HP 9000/730 workstation, using UNIX, X-windows and MOTIF. The RSI IDL visualisation program is used for graphics display. The system is capable of displaying raw and processed three dimensional geo-referenced data, including horizontal or vertical slices, and contour plots. Extensive use has been made of colour, interactive steering, and volume cuts. Procedures are available to display several two dimensional fields including difference fields, and other comparison and manipulation tools. Contours can be masked based on the error estimate.

The OA system employed by the OWS was initially implemented with a simple Gaussian correlation function, with a user-chosen length scale. It employs a trial field based on either climatology (Levitus), a previously calculated field (i.e. persistence), or fitted basis functions. The anomaly field has been assumed to be isotropic and homogeneous. This will be re-examined, particularly in the case of coastal analysis. Three dimensional OA is accomplished by using a "stack" of two dimensional OAs at user defined depth intervals.

The completed Phase II.5 OWS should be available for a "hands-on" demonstrations at various times throughout the Congress, and will be exhibited as a poster sessions.

The results of Phase III will be presented, as well as the proposed "way ahead" for operational oceanographic forecasting in Phase IV.

Collaboration with other groups interested in routine oceanographic forecasts of the Northeast Pacific is welcomed.

The Institute of Ocean Sciences Bulletin Board Service

Howard Freeland, Robin Brown, John Wallace and Bob Wilson

Inst. of Ocean Sciences, D.F.O.

In 1992 and 1993 the coast of British Columbia came under the influence of two El Nino events in as many years. Both of these climate anomalies had a direct and obvious impact on the fisheries around the coast of British Columbia. This obvious relationship increased demand within the B.C. fishing industry for oceanographic information. In response to that demand we, at the Institute of Ocean Sciences, decided to experiment with the electronic supply of information to the fishing community.

This talk will outline the experience gained at IOS running a Bulletin Board Service. We will outline the structure and philosophy of the BBS, sources of data and analyses, access to the BBS, who is using it, and why, and the prospects for cost recovery, etc. The talk will include a sample download of information from the BBS, an operation that can be carried out from a vessel at sea.

Use of the IOS BBS requires a PC computer with a terminal emulator and modem. To view PCX graphics files we recommend the Paintbrush program in Windows 3.0, or better. The terminal emulator should be set for 8 data bits, no parity and 1 stop bit, and the phone number is (604)-363-6385. We do not recommend attempting to download graphics files with a modem slower than 2400 baud.

Satellites, Oceanography and Society

David Halpern

Earth and Space Sciences Division
Jet Propulsion Laboratory
California Institute of Technology

Oceanography is a relatively young science, although the surface of the ocean has always concerned us in regards to trade and transportation, search and rescue, warfare human exploration, and recreation. The first attempt to systematically examine the global ocean below the surface was made by H.M.S Challenger in 1872-1876. The oceans cover 71% of the earth, and many large areas await to have a first-order description. That the surface of Venus is better mapped than the bottom of the ocean is a remarkable testament to the satellite-engineering establishment and to the opaqueness of the ocean. Recently, interest in the ocean has included non-military and non-transportation societal issues associated with daily-to-centennial time scales. Three examples are 1-Week ("medium range") weather forecasts (atmospheric blocking and frontal systems), seasonal-to-interannual climate forecasts (El Nino and La Nino), and decadal-to-centennial global change forecasts (global warming caused by greenhouse gases). For medium-range weather forecasts, knowledge of sea surface temperature is important. For seasonal-to-interannual climate forecasts, temperature and current within the upper 300-500 m and surface winds are important variables. For decadal-to-centennial global-change predictions of sea level and atmospheric temperature and precipitation, we require information about euphotic-zone biomass and thermohaline and flow characteristics throughout, the ocean basins. The influence of ocean dynamics upon the atmosphere, terrestrial ecosystem, and ocean fishery will be described. Satellites, by their frequent coverage of the global ocean, have already reduced the uncertainties associated with global ocean measurements, especially for sea surface temperature, sea surface height, surface wind components, near-surface

layer biomass, and near-surface current. Some factors limiting accuracy will be discussed. For seasonal-to-centennial forecasts relevant to society, subsurface oceanographic knowledge must be attained. It is a tenet of faith that satellite measurements in association with coupled ocean-atmosphere general circulation models (GCM) will propagate information on ocean dynamics from the sea surface into the ocean interior. Results from a coupled ocean-atmosphere GCM will be described.

Thursday/Jeudi p.m. Session 4 Room/Salle: 224

Aviation Meteorology Information Systems
Systèmes d'information pour la météorologie de l'aviation

Chair/Président: Howard Posluns

Current and Future Issues Related to the Provision of Meteorological Service for International Air Navigation

Olli M. Turpeinen

International Civil Aviation Organization (ICAO)
Air Navigation Bureau, Meteorology (MET) Section

This paper discusses the role of aeronautical meteorology within the International Civil Aviation Organization (ICAO). In view of the 50th anniversary of the Convention on International Civil Aviation (Chicago 1944) being celebrated in 1994, a brief retrospective will be provided. Most emphasis, however, will be placed on the future challenges facing international aeronautical meteorology. In particular, the following four issues in which research efforts are being devoted will be highlighted:

Automation of forecasting of critical en-route parameters. Automation of the production of the world area forecast system (WAFS) *significant weather forecasts* is one of the goals of this research. To achieve this, it will be essential for the world area forecast centres to be able to infer en-route weather parameters important to aviation, such as icing and turbulence from forecast model variables. Moreover, work is needed to validate and improve models used for tracking the dispersion of volcanic ash clouds.

Development of algorithms to measure turbulence and icing. An increasing number of aircraft will report meteorological data, initially wind and temperature values, using the automated air-ground data link, which will be implemented within the future air navigation system of ICAO. In this context, it is foreseen that turbulence and humidity will also be reported. However, the method to measure and report turbulence has still to be developed. In regard to icing, it is unlikely that any dedicated sensors will be installed on aircraft at this stage. Therefore, ways to infer aircraft icing from the humidity (and the temperature) data have to be developed.

Improvements in the provision of information on hazardous weather phenomena in the terminal area. In this context, issues related to mesoscale phenomena, such as wind shear, especially microbursts, will be discussed. The role of Doppler radars and automated real-time uplink of this data to aircraft will be emphasized.

Automatic weather observing systems (AWOS). Accommodation of AWOS into the meteorological observing practices will be addressed.

Prospects for Future Aircraft Weather Information Systems

J.E. Jordan and D.L. Marcotte

Flight Research Laboratory
National Research Council

Delivery of weather information and images to the aircraft cockpit is becoming technically feasible and should be operationally viable by the year 2000. To expedite this technology, the Flight Research Laboratory of the National Research Council is undertaking research and development in this area and examining different options for the delivery of aviation weather products to the cockpit. This work complements an existing collaborative research program in atmospheric sensing with the Atmospheric Environment Service using the NRC Convair 580 aircraft research facility.

One project recently undertaken is the development of a direct-receive weather satellite imaging system for the aircraft to support mesoscale storm measurements such as the Beaufort Arctic Storms Experiment (BASE). The first phase will utilize APT imagery received from polar weather satellites on 137.5 MHz VHF using PC-based components including receiver, adapter and software, as well as a specially-designed low profile microstrip antenna for airborne use. One aspect of this work will focus on the use of direct-receive imagery in aircraft operations during the experiment. Future plans could also investigate the use of high resolution (HRPT) imagery.

A second area of interest is digital communications technology which is the key to the delivery of aviation weather information to the aircraft cockpit. Various aspects of this technology are examined including types of data links, data compression schemes and aircraft computing and display technology. Though there have been advances in all these areas, satellite communications holds the most potential for aircraft use. A number of existing and proposed worldwide satellite communications schemes are examined and compared to terrestrial-based digital HF radio. Image compression methods based on lossless and lossy techniques are surveyed including LZW, JPEG and fractal compression along with image encoding including TIFF, GIF and "run length" coding. Finally, the technology used in the "glass cockpit" is reviewed. It is noted that a data communications link to an aircraft can be used in reverse to transmit weather observations to a central data assimilation and forecast facility. It is our intention to explore the use of these technologies using our aircraft as a "flying testbed". We would welcome future collaboration with the meteorology and aviation communities in this project.

A Graphical Interface for Aviation Weather Guidance Display (Scribe/Aviation)

R. Verret

Development Branch
Canadian Meteorological Centre

G. B. Jelley and D. K. Clark

CFFC Trenton
8 Wing CFB Trenton

In a joint project with Canadian Forces Forecast Centre (CFFC) Trenton, the Canadian Meteorological Centre (CMC) has developed a graphical interface to display element guidances relevant to aviation terminal forecasts. The interface is an adaptation of the one used in the interactive system for composition of meteorological forecasts (SCRIBE), under development at CMC, for public type of forecasts.

The interface is capable of displaying cloud amount, type and height from simply accessed tool boxes and menus. Precipitation type and visibility are also displayed, as well as, wind direction and speed, surface temperature and probability of precipitation. There is also provision to include warnings and remarks which may be significant to aviation. Some level of artificial intelligence is built into the system, in the sense that it will not allow the display of forbidden parameter combinations. It will also stack the cloud layers in the vertical according to cloud types and cloud heights, regardless of the order in which they were manually selected on the screen. The interface is also capable of managing different combinations of I'main" conditions with "variable" (VRBL), "occasional" (OCNL) and

"risk" (RISK) conditions.

At present, only the precipitation type, surface temperature, wind direction, wind speed and probability of precipitation can be initially loaded using Regional model guidances. All other elements must be inputted manually.

CFFC Trenton uses the interface to help generate an aviation weather guidances package that is site specific. The guidance is then downloaded to the remote site (YBG - Bagotville), where the official terminal forecast is prepared and issued locally by suitably trained staff.

The functionalities of the interface will be presented, as well as results on the utility of the system in the preparation of the terminal forecast for Bagotville.

Automated Surface Observations New Tools - New Challenges

Phil Clark

National Weather Service
WSFO Omaha, NE

Automated observation systems will be the foundation of the national observation network for the United States by the turn of the century. They will provide a true continual weather watch with minute-by-minute observations 24 hours a day. This will create a wealth of data for pilots and meteorologists and make an unprecedented Impact on the aviation industry and weather forecasting.

Sensor and computer technology has allowed this move Into fully automated observations. New automated systems, like the Automated Surface Observation System (ASOS), can quantify the more subjective elements provided only by human observers In the past Unfortunately this step Into the more subjective elements, such as the amount of sky cover, type of weather, visibility and some obstructions to vision, has brought to light the perceptual differences between the human and the machine.

Because of these perceptual differences forecasters and pilots must understand how automated systems respond to various weather conditions. Already pilots and tower personnel have questioned the accuracy of the Sensor Equivalent Visibility. Pilot reports provide evidence that the cloud coverage reported by the sensors and the pilot do not always match. It is also difficult to confidently Interpret the diversity of cloud heights and layers reported by automated sensors.

My presentation will focus on those elements that pose the greatest perceptual difficulties. I will provide basic explanations of their occurrence and the keys to match system response to human perception. I will also explore alternate techniques to evaluate the wealth of new data that forecasters and researchers have yet to fully appreciate.

An Assessment of Voice PIREPS in Aviation Related Weather Research

Barry Schwartz
NOAA/ERL/FSL
Boulder, CO USA

In the United States, the Federal Aviation Administration (FAA) is currently funding various agencies and private corporations to develop new and improved techniques to forecast in-flight turbulence and icing. Observations of turbulence and icing are needed to develop and validate these products. With the exception of the scientist who can access a research-quality database from a special field project, many developers are attempting to use observations of turbulence and icing from voice transmitted pilot weather reports (PIREPS) which at the current time is the only

source of these observations. Unfortunately, the PIREP reporting network in the U.S. was never designed to be used as a research-quality database. Therefore it is prudent that the user of these data understand the characteristics of the data that limit their use for quantitative studies.

This paper will present an analysis of PIREPS data archived at the Forecast Systems Laboratory (FSL) during 1993. Statistics containing the total number of PIREPS by season, geographic region, attitude, and time of the day will be presented. The analysis includes a look at the percentage of PIREPS that explicitly mention turbulence and/or icing intensity and how they relate to the total number of reports. It is tempting to interpret these statistics as a phenomenology for turbulence and icing, however, the statistics are only partially representative of the actual frequency and occurrence of the phenomena for two reasons. First, characteristics of the U.S. reporting system contaminate the statistics. Second, and more important, is the fact that the network only remotely senses the actual occurrence, duration, and areal coverage of the phenomena. Evaluation of the results suggest that these data are at best only marginally useful for quantitative aviation weather related research activities. A discussion of these problems along with suggestions for improving and standardizing PIREPS to make them more useful will be presented.

The U.S. National Meteorological Center Aircraft Data Base System 1994

Bradley Ballish and Raymond Crayton

Automation Division
National Meteorological Center
Washington DC 20233

Aircraft data is vital for analysis and forecast purposes. Considerable effort has been spent on improving the receipt, decoding, and quality control of aircraft data.

In December 1993, a new decoder was implemented into operations for aircraft data received on the Global Telecommunications System. This new decoder can successfully process a wide variety of properly and improperly formatted data. For reports at named locations or way-points, rather than at latitudes and longitudes, the decoder uses a global dictionary of way-points as well as the country code from the communications bulletin header to decide on the location of the data. A new global dictionary of way-points is received on a CD-ROM every 28 days from Defense Mapping Agency and the Federal Aviation Administration sends new points every 56 days on magnetic tape.

These aircraft data are subject to a variety of quality control systems. Conventional aircraft reports can be reviewed by a human analyst who can examine the output from a track-checking code, as well as looking at display maps and-an aircraft file that is sorted by the magnitude of wind increments relative to the model's forecast. With the help of these diagnostics the analyst can force data to be purged or kept for the analyses. In addition, all meteorological data including aircraft reports are then intercompared and quality-controlled by a software known as Optimal Interpolation Quality Control. Automated aircraft data currently are not subject to track-checking, but it appears that a new version of this software is needed as these reports can have various problems. Such automated reports that are observed to frequently have problems are put on a reject list.

The aircraft decoding and quality control system is monitored in various ways, which allows system improvement. In addition, feedback can be provided to airlines and data processing centers so that problems can be corrected.

Thursday/Jeudi p.m. Session 4 — Room/Salle 209

Climate Modelling/ Modélisation du climat

Chair/Président: C. Lin

FIZ-C a Fast-Portable Version of the CCC/GCM Climate Model Family

Jean-Pierre Blanchet and Daniel Therrien

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Montréal (Québec) H3C 3P8

During the last two years major efforts have been undertaken at UQAM to develop a regional versions of the CCC/GCM climate model. As part of this work, a one dimensional version (FIZ-C) of the complete GCM's physics has been made as a semi-prognostic climate model. Like its relatives MRC (Laprise, Caya) and FIZ-R (Goyette), this column model is driven by pre-calculated GCM's dynamics tendencies $\partial U/\partial t$, $\partial V/\partial t$, $\partial q/\partial t$, $\partial T\partial t$, $\partial \ln(p_s)/\partial t$) for its lateral boundary conditions, but it is fully independant to recalculate the whole GCM's physics. This scheme is designed to recalculate any geographical point of the globe for any time segment of the original GCM's runs. It permits accessing all computed variables, to examine each of the 125 GCM routines in great details, to analyse the interactions between processes, to improve the existing schemes and to develop new parameterization schemes. Because of its spatial limitation, FIZ-C is extremely efficient in CPU time (about 0.02% of GCM). For example, to compute one month of 2232 x 20 minutes time steps it takes about one minute on an HP file server, and on a simple IBM-PC (386) the simulated to real time ratio is about 2400:1 as compared to the typical 500:1 for a full grid calculation of GCM on a Cray computer. This means that the computer availability is not anymore a restriction for development of physical parameterization for GCM. The advantages of this approach are: portability of the code to almost any computer, on a local server and fast turnaround time with the chief advantage of sophisticated workstation's development tools and compatibility with the global GCM. FIZ-C may serve for teaching and training purpose, allowing to interrogate climate sensitivity to local changes in the environment. It can be useful for impact studies, environmental assessment and GCM experiment preparation.

UQAM Regional Climate Model: Diagnostics of a One Month Simulation

Daniel Caya, René Laprise, Michel Giguére et Guy Bergeron

Département de physique, Université du Québec à Montréal,

The primary tools for simulating climate are general circulation models (GCMs). These models include a complex physics package that represents the processes that are thought to be important in climate modelling. Unfortunately, such complexity needed to make a valuable simulation of the large-scale features of global atmospheric circulation, imposes a considerable load even on powerful super computer. Because of this important load, GCMs are limited to relative coarse spatial resolution which is a strong limitation for these models to be used for regional-scale climate study. A technique to overcome such a limitation, consists in nesting a high-resolution limited-area model in a GCM. This leads to a high-resolution regional climate model (RCM) having its boundary conditions supplied by the GCM. Such a RCM is currently under development at UQAM. The dynamics of this model is based on the Mesoscale Compressible Community (MC2) model developed by scientists from the Cooperative Centre for Research in Mesometeorology (CCRM) in Montréal while the physics is that of the second generation Canadian GCM.

Results from a month long integration of the RCM are presented. Boundary conditions for this integration were taken from archived climatic run data of the Canadian Climate Centre GCM. Diagnostics of primary meteorological fields from the RCM integration are compared with those from the GCM.

Spectral Analyses of Limited-Area Data Simulated by a Regional Climate Model

Sandra Turner and René Laprise

Atmospheric Physics, Physics Department, Université du Québec à Montréal

The atmosphere often behaves as a turbulent fluid which, at certain scales, exhibits homogeneity and isotropy properties. This feature results in the variance of atmospheric fields being distributed according to some power laws, and these can be used to validate models against observations. The Regional Climate Model currently under development at UQAM will be analysed in terms of its power spectra. Unprecedented high resolution will be achieved in climate mode through the use of a limited-area model nested within a general circulation model.

Introduction d'une orbite elliptique dans le modèle de circulation générale canadien

Bertrand Denis et Norman McFarlane

Canadian Centre for Climate
Modelling and Analysis

Afin de mieux représenter le flux radiatif solaire incident au sommet de l'atmosphére (S), l'orbite circulaire couramment utilisée dans le modéle de circulation générale du Canadian Centre for Climate Modelling and Analysis (CCCMA) a été remplacé par unc orbite elliptique. Bien que l'excentricité de cette orbite nouvelle soit faible, les variations de S qu'elle induit (+/- 3.5%) ont potentiellement un impact non négligeable sur le climat car c'est, par le fait mdme, la source premi@re d'énergie du systéme qui en est affectéc.

Les équations utilisées découlent de la toi des aires égates de Kepler et sont sollutionnées A l'aide d'une série numérique (Berger et Loutre, 1993). En plus de moduler la constants solaire en fonction de la distance terre-soleil, une orbite elliptique engendr-e aussi des saisons de longueurs inécales. Pour dvaluer l'impact que cette nouvelle orbite a sur le climat, les résultats de deux integrations de 10 ans sont comparées, soit une integration avec une orbite elliptique d'excentricité $\sum = .016724$ et I' autre avec une orbite circulaire ($\sum = 0.0$).

Le nouveau code informatique implanté pourra étre utilisé aisément pour simuler des climats d'époques antérieures A la notre oa 1'excentricité de l'orbite ter-restre était fort différente.

Ref:

McFarlane, N.A., G.J. Boer, J.-P. Blanchet et M. Lazare, 1992: The Canadian Climate Centre second generation general circulation model and its equilibrium climate, J. Climate, 5, 1013-1044.

Berger, A., et Loutre, M.F, 1993: Precession Eccentricity, Obliquity, Insolation and Palcoclimates, dans NATO ASI "Long Term Climatic Variation, Data and Modelling", Duplessy J.Cl. (ed.).

Parameterization of Dynamical Sub-grid Scale Processes in a Spectral GCM

J.N. Koshyk & G.J. Boer
Canadian Climate Centre,
Downsview, Ontario

The resolution of general circulation and other models is usually characterized by their grid spacing or spectral truncation. In all models, some representation or parameterization of the effects of unresolved scales on those explicitly resolved is required. Global atmospheric analyses from several sources are used to infer the dynamical effects of smaller horizontal scales on larger horizontal scales for the purpose of parameterizing these interactions in numerical models. The nonlinear interactions among scales are calculated in terms of a spectral decomposition on the sphere. An empirical spectral interaction function (EIF) is obtained from data which, when applied to larger scales (corresponding to resolved scales in a numerical model) reproduces the effects of small scales (corresponding to unresolved, sub-grid scales in a numerical model) on these larger scales in the observational data.

The BIF takes small negative values at low wavenumbers, implying that interactions with the unresolved scales provide

energy and enstrophy at these wavenumbers. It then becomes positive and increases sharply toward the truncation wavenumber. In this way, it qualitatively (but not quantitatively) resembles the function proposed by Leith, obtained in a very different fashion from two dimensional turbulence considerations. The EIF is height-dependent and differs from the hyperdiffusion often used in models and characterized by operators of the form V21, since the latter are inherently positive at all wavenumbers (i.e. dissipate energy and enstrophy at all scales).

The effect of the EIF on the simulated climate of the Canadian Climate Centre general circulation model (CCC GCN1) is investigated. A simulation with a restricted version of the function, for which the negative values axe set to zero, is also examined. As expected, the results obtained using the full empirical function show increased levels of kinetic energy at relatively small wavenumbers, where models have often been deficient. At wavenumbers near the truncation limit, spectral slopes of kinetic energy and enstrophy are somewhat shallower than expected from observational analyses.

Results from a Ten-year AMIP Integration Performed with the Canadian Global Spectral Forecast Model

Bernard Dugas and Harold Ritchie

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Along with many other global modelling centers, Recherche en prévision numérique (RPN) is participating in the Atmospheric Model Intercomparison Project (AMIP) which has been organized by the Program for Climate Model Diagnostics and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory. The basic purpose of AMIP is to undertake a systematic intercomparison and validation of the performance of global atmospheric models on seasonal and interannual time scales under as realistic conditions as possible. The decade 1979-1988 was selected as the AMIP test period for which PCMDI has supplied the sea-surface temperature and sea-ice dataset, which essentially provides a "perfect" ocean forcing. We present results from a first ten-year AMIP integration performed with the RPN spectral forecast model. This version is run in a semi-Lagrangian configuration with a T63 spectral resolution and 23 vertical levels. The model is otherwise nearly identical to the Canadian operational spectral forecast model. The standard intra-seasonal and inter-annual diagnostics of the model variability will be shown and compared with the relevant analysis-derived fields.

Thursday/Jeudi p.m. Session 4 — Room/Salle 232

Operational Oceanography/ Océanographie opérationnelle

Chair/Président: Keith Thompson

Mapping Circulation on the Outer Continental Shelf

Keith R. Thompson and David A. Griffin

Department of Oceanography
Dalhousie University

Subtidal currents on the outer Scotian Shelf are difficult to model. The problem stems from their short decorrelation

scales ($O(10km)$) and their sensitivity to forcing by the adjacent deep ocean and coastal trapped waves that propagate through the region.

As part of a project to track cod larvae in the field, we have developed an operational assimilative model for mapping flow on the outer continental shelf. In this talk I will briefly outline the dynamics upon which our model is based, and the main ideas behind the assimilation scheme. I will spend most of the talk on our assessment of the true predictive skill of the assimilation model, clearly an important question to address given that the model is "driven" by observations. I will also compare its predictive skill to that of simpler empirical schemes such as the use of the "nearest neighbour" and linear interpolation of nearby observations.

Summer currents in Queen Charlotte Sound, British Columbia

William Crawford, Michael Forman, Patrick Cummins

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We present evidence of previously unresolved oceanographic features in Queen Charlotte Sound and Hecate Strait using data collected in the summer of 1990 and interpreted using two different numerical simulations of currents. Features include a strong, prevailing southward flow along the southeast coast of the Queen Charlotte islands and a cold-water plume flowing to the open ocean from its origin in the shallows along the cast side of Hecate Strait. This plume is associated with thermal features which are regularly observed in late summer in these waters. A persistent outflow into the Pacific Ocean is.found within 20 km of Cape St. James at the southern tip of the Queen Charlotte Islands. Although observations and numerical situations here show strong residual tidal currents, these currents appear to form stationary eddies. The net outflow may be due to persistent density differences between Hecate Strait and the open ocean.

In central Hecate Strait, to the north of this outflow, prevailing along-strait currents are weak and there is an east-west interleaving of two water masses: warm water from the west side of the strait and cold water from the east side.

Forcing Field Assessment over Ocean Surface for Climatic Evolution of Ocean

M. Miyake

Air-Sea Research Ltd.

In the consideration of Global Change, the lack of historical data is always a major shortcoming in determining the climate-time evolution itself. The data to determine the forcing field or the field to verify climate is missing in the construction of a model (physics) to fill the gap of data to interpolate the time and space domain.

Therefore, for the design of the GLOBAL CLIMATE OBSERVATION SYSTEM, historical perspective and prioritized resource deployment is essential.

The very sparsely distributed radio sonde field where the temperature, humidity and wind profiles are used in constructing the global pressure height contours and its gradients is successfully used in assessing the potential vorticity field and its change.

Analogous consideration is needed in assessing the ocean dynamics and its forcing field.

Vertical Structure of Currents on the Northern Grand Bank: A View From A Bottom Mounted Acoustic Doppler Current Profiler

C.L. Tang and D.J. Belliveau

Bedford Institute of Oceanography
Department of Fisheries and Oceans
Dartmouth, N.S.
B2Y 4A2

Data obtained from a bottom mounted acoustic Doppler current profiler (ADCP) deployed on the northern Grand Bank for 70 days from mid-March to early July of 1990 were used to study the vertical structure of the currents. Good data were obtained from seventy percent of the water column sampled by the instrument. Only data near the sea surface were contaminated by the side lobes of the acoustic signals, and data close to the sea bottom had large errors, possibly caused by the extended transducer ringing due to a protective cover. To determine the vertical current structure In different frequency band, a rotary spectral analysis and empirical orthogonal function analysis were performed. The results show that the tidal and low-frequency (2 to 12 days) currents are predominantly barotropic with no significant change int he vertical structure over the mooring period. The low-frequency currents had a stronger clockwise component than counterclockwise component. The asymmetry of the rotary motion is attributed to more frequent storms passage to the north of the ADCP site than to the south of the site. The Inertial motion has no baratropic mode. The current structure is a two-layer flow with currents of similar magnitudes but opposite directions in the two layers. Such a structure suggests direct forcing by moving storms. The time change of the structure over the mooring period is consistent with this hypothesis.

Thursday/Jeudi p.m. Session 4 — Room/Salle: Alumni Aud. / Aud. des Anciens

Tropospheric Ozone/ Ozone de la troposphère

Chair/Président: L. Dwyer

Niveaux d'ozone et lien avec les facteurs météorologiques au site forestier de Duchesnay. Bilan 1988 - 1991

Alain Robichaud

Ministère des Ressources naturelles
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Dans le cadre d'un projet de recherche forestière visant à étudier l'impact des stress environnementaux sur les écosystèmes forestiers, quatre contaminants atmosphériques gazeux, soit le monoxyde et le dioxyde d'azote (NO, NO_2) le dioxyde de soufre (SO_2) et l'ozone (0_3), ont été échantillonnés en continue, à la station forestière de Duchesnay, au cours de la période 1988 à 1991. La station de mesure est localisée en milieu forestier, à environ 35 kilomètres au nord-ouest de l'agglomération urbaine de Québec. Les résultats démontrent que les oxydes d'azote et de soufre ne sont présents qu'en trés faibles concentrations; le monoxyde d'azote présentant les plus faibles concentrations. Par contre, l'ozone, le contaminant observé en plus forte concentration, atteint des niveaux susceptibles d'endommager la végétation. Les indices deposition calculés à Duchesnay pour ce polluant semble indiquer un impact significatif sur la croissance des végétaux lorsque les résultats sont comparés à certaines études effectuées en conditions contrôlées. Par ailleurs, les analyses présentées montrent qu'il existe une forte association

entre les moyennes estivales d'ozone (ler avril - 30 septembre), la fréquence de dépassements de la norme horaire provinciale et le type de situation météorologique. Ceci suggère que les fluctuations d'ozone sont déterminées largement par les variations météorologiques et que le transport à longue distance est le phénomène dominant dans l'apparition d'épisodes par l'ozone à Duchesnay. La production photochimique locale ne joue aucun rôle apparent dans l'occurrence de ces épisodes. Dans l'ensemble, les résultats obtenus sont plutôt consistants avec un concept de réservoir troposphérique d'ozone; les concentrations maximales au niveau du sol sont atteintes lorsqu'il y a rabattement au sol des contaminants présents dans ce réservoir.

The Climatology of Regional Ozone Episodes in Eastern North America during 1980 to 1992

J.D. Fuentes[1], T.F. Dann[1], D. Yap[2], P. Summers[1] and D Ord[1]

[1]Environment Canada
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During the summer, eastern North America frequently experiences regional episodes of elevated ground-level ozone concentrations. An ozone episode is defined as the simultaneous occurrence at several monitoring stations, covering a spatial extent of several hundreds km^2, of ozone concentrations exceeding the Canadian 1 -h average maximum acceptable objective of 82 parts per billion (ppb) for several consecutive hours on each of one or more successive days. Peak 1 -h ozone concentrations during episodes can reach up to 200 ppb at some Canadian sites, with maximum recorded values at some U.S. stations of approximately 300 ppb. The Canadian region most seriously and frequently affected by ozone episodes is southern Ontario and Quebec; Southern New Brunswick and Nova Scotia are affected to a lesser extent. Analyses of 13 years of ozone data for eastern North America reveal two distinct ozone episode types. Episodes affecting southern Ontario and Quebec typically originate in central U.S. south of the Great Lakes. Their associated air masses progressively move northeasterly, with the ozone-rich plumes travelling along the most abundant ozone precursor source regions in the U.S. These episodes are primarily associated with slowly moving anticyclonic systems and within warm sectors of cyclonic systems which favour relatively cloud-free air masses, warm air temperatures and south or southwesterly flows. These flow patterns place southern Ontario downwind of U.S. source regions of ozone and its precursors. The second ozone episode type starts to develop in areas just west and intensify east of the Appalachian mountains. The ozone-rich plumes travel along the eastern seaboard of the US and into Atlantic Canada. The latter episodes often occur under the influence of warm sectors of cyclonic systems moving south of the Great Lakes, and tend to last fewer days compared to the former episode type. In southern Ontario and Quebec most episodes (60%) last only one day, but on rare occasions they can persist up to 8 successive days. On average episodes last 4 consecutive hours in Canada, but they persist longer in the U.S. The spatial distribution of ozone concentration and the diurnal variation at selected monitoring sites will be presented. Details of the climatology of ozone episodes and the associated synoptic class stratifications will be presented.

Caractérisation des concentrations d'ozone troposphdrique dans la région de Montréal

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Nous avons pour but de découvrir une signature illustrant la différence entre le comportement des concentrations d'ozone observées à certains sites urbains et ruraux. Ces signatures serviront à déterminer le rayon d'action de l'activité urbaine sur les concentrations rurales d'ozone. Pour ce faire, nous disposons de donndes estivales moyennes (moyennes horaires) de concentrations d'ozone échantillonndes à toutes les heures. Ces données de surface

proviennent de stations de mesures situées sur l'île de Montréal et à la campagne. L'analyse spectrale, appliquée à ces sdries temporelles de concentrations d'ozone troposphdrique, est faite à l'aide de transformées discrétes de Fourier. De plus, diverses analyses statistiques viennent compiéter la caractérisation des concentrations urbaines et rurales typiques. Des résultats préliminaires seront présentés pour chaque type de sites.

Separating Chemical Contribution from Surface Deposition of Airborne Ozone Fluxes in the San Joaquin Valley of California

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The airborne near-surface ozone fluxes were found complex, due to the combined contributions from both surface deposition and atmospheric chemistry, over the surfaces of recently-cultivated bare soil, newly-cut hay, city and near highway in the San Joaquin Valley of California (California Ozone Deposition Experiment, 1991). This study explored a simple partitioning scheme by estimating the ozone surface deposition from a regression of mean ozone flux as a function of greenness and evapotranspiration over optimally-irrigated vegetative surfaces, under the assumption that flux residuals are caused by atmospheric chemistry. Subtracting the estimated ozone surface-uptake from the airborne flux measurements, the atmospheric chemical contributions over the study areas are estimated. The estimated chemical contributions over the surfaces of recently-cultivated bare soil, newly-cut hay, city and near highway are found more significant than the surface deposition in many cases, dominated primarily by ozone destruction. The analysis chemical reactions suggest% that NO surpluses over the requirement of the photostationary state above these areas are mainly responsible for the ozone destruction. These NO surpluses are believed to be linked to the strong NO emissions from the surfaces.

Isoprene and Monoterpenes Within and above a Deciduous Forest

D. Wang, J.D. Fuentes, G. den Hartog, R.H. Neumann, T.F. Dann and K.J. Puckett

Environment Canada

Plants release hydrocarbon compounds into the atmosphere in significant amounts. Some hydrocarbons can contribute to oxidant formation in the lower troposphere. Therefore, it is important to characterize their source and understand their spatial and temporal distribution. Measurements taken at a deciduous forest in Camp Borden, Ontario during the 1993 growing sea-son revealed that isoprene and the monoterpenes of ∝-pinene and 6-pinene were the most abundant phytogenic chemical species in the ambient air. Prior to leaf-bud break during spring, ambient concentrations above the forest were barely above instrurnent detection limit but progressively increased with growing season. Peak isoprene concentrations reached nearly 10 parts per billion (ppbv) during mid-,growing season while maximum monoterpene concentrations attained close to 2 ppbv. Both isoprene and monoterpene concentrations exhibited discernible and marked diurnal variations. Isoprene concentratios were highest during mid-afternoon, which coincided with maximum solar radiation and ambient temperature levels. and lowest during nighttime. Conversely, monoterpenes reached minimum and maximum concentrations during mid-afternoon and evening, respectively. Maximum monoterpene emissions normally occur throughout the day, with maximum emissions supposedly happening during mid-day. Thus the mid-day, measured minimum ambient monoterpene concentrations likely resulted due to photochemical destruction, and high nighttime values arose as a consequence of less chemical sink and increased

atmospheric stability and hence less diffusion. Significant isoprene concentration gradients existed between the forest crown and two canopy heights above the ground. Gradient measurements indicated that canopy isoprene fluxes can be reliably estimated using gradient diffusion and similarity theory (Gillespie et al. 1994). Isoprene emissions were measured by enclosing branches of aspen trees using gas exchange systems and gas chromatography. Isoprene emissions depended on foliage ontogeny, tree species and environmental factors such as foliage temperature and intercepted photosynthetically active radiation. For instance, young (< 1 month old) aspen leaves released approximately 100 times less isoprene than mature (> 3 months old) leaves.

Gradient-based Measurements of Isoprene Fluxes above a Forest Compared with Simultaneous Branch Measurements in a Cuvette

T.J. Gillespie and S. Lin
University of Guelph

J. Fuentes, G. den Hartog, H. Neumann & D. Wang
Environment Canada

H. Niki
York University.

Biogenic volatile organic compounds (VOCS) emitted by vegetation are involved in tropospheric ozone formation. Therefore, knowledge of source strengths of biogenic VOC emissions, relative to anthropogenic sources, is essential to assess strategies for curtailing tropospheric ozone in the Windsor-Quebec corridor. Total canopy emission of isoprene (C5H8), which is released by several common tree species and participates strongly in the formation of ozone in the presence of NOx, was estimated by a flux-gradient technique. Emissions of isoprene from portions of branches of high-emitting species in the forest were simultaneously observed with a cuvette technique.

Isoprene samples were collected in stainless steel canisters over half-hour periods at the 25 m and 35 m levels above a mainly deciduous forest of canopy height 20 m at Borden, Ontario. Exchange coefficients (K) for the 25-35 m layer were computed from micrometeorological data taken on the same tower, and the isoprene flux (FI) was calculated from:

FI = K (CI25 - CI35), where CI is the isoprene concentration.

A strong diurnal trend was observed in the data, with no detectable emissions in the dark and maximum mid-day emissions near 0.4 g m-2 s-1.

Another estimate of total canopy isoprene emissions can be computed by combining the cuvette data with knowledge of the light and temperature profiles through the tree canopy, and the species composition of the forest. Such a method has the advantage of allowing emission estimates at various times and locations to be made from microclimatic data. This presentation will include a comparison of these two methods for estimating voc fluxes from the forest.

Thursday/Jeudi p.m. Session 4 — Room/Salle: 233

Weather Forecasting 2 / Prédictions météorologiques 2

Chair/Président: R. Milo

Meteorological Operations at the Canadian Meteorological Centre

Thursday/Jeudi p.m.

Rick Jones

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At the Canadian Meteorological Centre a set of operational runs are executed daily on a host of computers including the NEC SX3-44 and several front end UNIX computers. Output from these runs consists of bulletins and charts which are distributed through the national communication system, and GRIB files which are binary messages of model grid points that are sent to many offices via a WAN.

The presentation will consist of a brief description of the computers in place and of the operational runs and models that are currently run. There will be a description of the model output that is currently available. Finally there will be mention of future plans for the improvement to the operational runs.

Recent Developments with the Operational Regional Forecast System

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On 3 November 1991 a new higher-resolution version of the regional forecast system was implemented into operations by CMC. The changes include modifications to the regional data assimilation system and to the regional finite-element (RFE) forecast model. The main features of the new version of the RFE model include an increase in resolution from 100 km to 50 km and to 25 sigma levels in the vertical. The new RFE model also includes an improved physics package, notably for condensation and radiation processes. An overview of this new version of the operational system and some typical performance statistics and case studies will be reviewed at the conference.

The presentation will also highlight the current work underway to develop even higher-resolution version of the regional forecast system. In order to further improve the regional numerical guidance, work is in progress to set up an experimental mesoscale operational run (25 km) with the RFF model where the high-resolution window of the model could focus on a particular Canadian region each day on a "storm-of-the-day" basis. This experimental run would also serve to test more advanced parameterization schemes (predictive cloud water content, mesoscale convection scheme,...). Results from this experimental run will be presented.

A Framework for Operational Forecast Verification

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Development Branch
Canadian Meteorological Centre

N. Bargerie and C. Le Bot

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Most forecast verification systems are faced with the problem a defining the truth against which the operational forecasts are going to be verified. A new system has been designed at the Canadian Meteorological Centre to solve that specific problem for the verification of public forecasts. All available surface observations, synoptic, hourly and supplementary aviation observations are used to create a truth file at a set of stations. The truth file is basically a matrix which includes all observed weather elements with a time resolution of one hour, taking into account the special observations produced at non standard times. The weather elements are cross-checked between themselves to validate the observations and thus create the truth. For instance, the temperature observations available at each hour, are cross-referenced against the maximum/minimum temperatures reported in the synoptic observations, to establish the true maximum/minimum temperatures on a local time window and to identify inverse temperature trends. Similar treatment is done to assess occurrences of precipitation. It will be possible in the future to combine in space and time the truth matrices created at the stations to create verifying matrices valid over an area, that can be matched with regional forecasts.

on the other hand, a similar set of matrices are generated from the forecasts. In order to do so, the forecasts must be in a format that can be easily processed by the system such as the format used internally within interactive computer forecast generation systems. The forecast matrices and the truth matrices can then be compared and the validity and skill of the forecasts assessed.

The verification system is flexible enough to be used to verify specific events, or events that meet specific threshold criteria. It can verify any weather element that can be forecast and observed. It can provide answers to the management question of how good the forecasts are at the national or regional levels. It can also help to find ways to improve the forecasts within a regional office and on an individual basis. A graphical interface will be developed so that the verification system can be used efficiently to answer the meteorologists' needs.

The design of the system will be explained and examples of national verification results will be presented.

Combining Lightning and Radar Data to Study Quasistationary Thunderstorms

Stephen Clodman

Atmospheric Environment Service
Downsview, Ontario

We have identified a type of quasistationary thunderstorm, quite common near the southern Great Lakes, which can produce very high lightning flash density and rainfall (450 mm in one case). Lightning and upper air data were used to describe these storms and to propose forecast rules. Our new study adds radar data at both high and low levels. We hypothesize that the causes of strong cloud growth, electrical charge separation, and rainfall are closely linked, and therefore the lightning and radar signals of the storm are close together in time and place. To test this, the locations and start-end times of several of these storms are measured by lightning detector, rain gauge, and radar, and then compared. Also the formation of these storms seems to be linked to convergence lines formed by lake winds, among other causes. The storms tend to start in particular places near the lakes when there is evidence of lake breezes or other lake winds. This study gives a demonstration for Canadian use of the techniques of combining lightning and rainfall data in thunderstorm study.

Helicity

G. Desautels and R. Verret

Development Branch
Canadian Meteorological Centre

Thursday/Jeudi p.m.

M. Leduc
Ontario Weather Centre

In the Summer 1993 the Canadian Meteorological Centre has added forecast helicity charts in the operational Summer Severe weather package. The interest in helicity came from studies done in the United States which established a relationship between the magnitude of the helicity and the intensity of the tornadic activity. Studies have also established that helicity as a forecast parameter has meaning only when thunderstorms are present or are expected to develop. On average, an increase in helicity begins to develop in the afternoon and reaches a maximum in the evening.

The helicity in the Summer Severe Weather package is calculated from the Regional model forecast wind vertical profile or hodograph over a layer extending from the surface up to the nearest sigma level at or above 3 km above the ground according to the following equation:

$$H = \Sigma(U_{n+1}Vn - UnVn+1) + \Delta V \bullet Cx - \Delta U \bullet CY$$

where H is the helicity, U_n and V_n are the u- and components of the wind on the sigma level n, ΔU and ΔV are the u- and v- component of the wind shear over the layer and C_x and C_Y are the storm motion vector components. The summation is done over the sigma levels in the column.

The calculation uses the wind forecasts at all the sigma levels in the layer. The calculated helicity is normalized over the depth of the column. The storm motion vector is estimated by using 75 percent of the mean wind speed in the layer from 850 to 300 hPa and by adjusting the direction of the mean wind 30 degrees to the right. Total wind speed and u- and v- components are averaged separately, and the averaged u- and v- components are used solely to derive an average wind direction for the layer.

In one instance, the Ontario Weather Centre used the helicity chart as one important element amongst others in the decision of issuing a Tornado warning that verified correctly. This case study will be presented.

Ageostrophic Circulations and their Impact on Cyclone Development

Pierre Bourgouin (AES) and Peter Zwack (UQAM)

At the synoptic and meso-alpha scales, the atmosphere is generally in a state of "balance". For a uniform, steady-state pressure gradient, this balanced state is geostrophic. Since the pressure gradient varies both in space and time, the balanced state, although close to, is not geostrophic. This presentation will show how it is possible to isolate the ageostrophic winds produced by various processes related to temporal and spatial variations of the wind and the pressure gradient: vorticity and thermal advection, latent heat release, sensible heat transfer, etc. The effects of these circulations on different meteorological fields will be also assessed. Finally, the impact of the ageostrophic circulations produced by jet-streaks on developping cyclones will be discussed.

Friday/Vendredi a.m. Session 1&2 Room/Salle: 209

Geophysical Fluid Dynamics / Dynamique des fluides géophysiques

Chair/Président: P.Taylor

Stability Characteristics for Isolated and Coupled Fronts over a Sloping Bottom

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We apply a recently developed theory (Swaters, *Phil. Trans R. Soc. Lond.* A 345, 295-325, 1993) describing the dynamics of surface intensified flows with large amplitude isopycnal deflections to the problem of determining the baroclinic instability characteristics of isolated and coupled fronts over a sloping bottom.

A Hamiltonian Weak-Wave Model for Shallow-Water Flow

Theodore G. Shepherd

Department of Physics, University of Toronto

The problem of small Rossby number vortical motion interacting with weak gravity waves is a fundamental one in geophysical fluid dynamics, encompassing such issues as nonlinear geostrophic adjustment and unbalanced (fast) instability of balanced flows. The simplest dynamical model that includes the relevant effects is shallow-water flow. However, the shallow-water equations have a number of features which make theoretical analysis difficult. To overcome this, an approximate model is sought which is the minimal model admitting both linear gravity waves and nonlinear vortical motion.

In making such an approximation, the Hamiltonian structure of the model should be retained if possible because it reflects the underlying symmetries of the problem, which are connected to such important conservation laws as energy, momentum, and potential vorticity. To this end, a systematic Hamiltonian derivation of a minimal weak-wave model is presented, based on three assumptions: (i) small Rossby number; (ii) a timescale separation between the vortical and the gravity-wave (divergent) motion; (iii) the amplitude of the gravity-wave motion is much smaller than that of the vortical motion. The resulting model has a quadratic Hamiltonian, and appears to be the simplest Hamiltonian system allowing vortical/gravity-wave interactions.

Slaving Principles and Balanced Dynamics for Stratified Flows

Oxino Bokhove

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The quasi-geostrophic equations are the best-known example of balanced equations, based on the approximate

balance between the Coriolis force and the pressure gradient. They are devoid of high-frequency waves and describe the slow-time behaviour of large-scale flows in the atmosphere and oceans in the extratropical troposphere. Their limited accuracy has stimulated the search for more accurate balanced models. Warn et al. (1994) have shown that the conventional Rossby-number expansion breaks down, but that this breakdown can be circumvented through a systematic, modified perturbation procedure based on a slaving principle.

The slaving principle entails that the "fast" variables associated with the fast modes of the system are assumed to be dependent on variables that have a 'slow" component in the linearized case. Hence, the tendency or predictive equations for the fast variables become diagnostic or "superbalance" equations. The resulting slaving manifold may be approximated by an asymptotic series expansion of the fast variables. Alternatively, approximate solutions of the superbalance equations can be obtained by iteration. The leading-order balanced models in a Rossby-number expansion always lead to the quasi-geostropic equations. Higher order balanced models for nearly geostrophic flows based on the slaving principle will be derived for stratified flows and compared with other higher-order balanced models.

Warn. T., Bokhove, O., Shepherd, T.G. and Valbs, G. 1994 Rossby-number expansions, slaving principles, and balance dynamics. Manuscript available from the authors.

Rossby-Number Expansions, Slaving Principles and Balance Dynamics

T. Warn

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It is argued that the conventional Rossby-number expansion for rapidly rotating fluid systems is secular for all but the simplest flows, in the sense that higher order terms in the expansion grow exponentially on average, and that at moderate values of the Rossby number the expansion is, at best, useful only for times of the order of the doubling times of the instabilities of the underlying quasi-geostrophic dynamics. Similar arguments apply to a wide class of problems involving a small parameter and sufficiently complex zeroth order dynamics.

A modified procedure, which Involves expanding only the fast modes of the system, is proposed and used to construct higher order balance approximations of the shallow water equations. The procedure, which is systematic and capable. at least in principle, of being carried to any order, is a special case of the bounded derivative method for which the balance equations involve only linear inversions. There is a large class of reduced systems associated with various choices for the slow variables. but the simplest one appears to be that based on potential vorticity.

Piecewise Linear Flow Profiles In Quasigeostrophic Stability Theory

Murray D. MacKay and G.W. Kent Moore

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Piecewise linear flow profiles have been used in studies of hydrodynamic stability for more than 100 years. Such profiles can considerably simplify mathematical analysis and much insight into the dynamics of continuous flows has been gained by their employ. The approach is to solve the appropriate governing equation (eg. Rayleigh, Taylor-Goldstein etc.) separately in layers and to match solutions at interfaces by asserting continuity of pressure (a dynamic constraint) and normal velocity (a kinematic constraint). Generally solutions are simple analytic functions and a straightforward dispersion relation results.

The method dates back to Kelvin's (1871) classic analysis of a stratified shear layer, and since then numerous authors have taken this approach. Nevertheless, there are well known problems with Kelvin's method that occasionally arise: in particular, discrepancies in the stability characteristics of piecewise linear flow profiles and the continuous profiles they are supposed to represent. These generally manifest themselves as the generation of spurious modes, or the failure to produce all of the unstable modes.

Given the long history and relative success of broken flow profiles in hydrodynamics, it is not surprising that some authors have tried to adapt their use to the problem of atmospheric baroclinic instability . This is typically accomplished by suitably modifying the Eady problem; ie. by solving the quasigeostrophic potential vorticity equation in layers and matching solutions at interfaces. Such an approach, however, violates the assumptions under which the equation was derived and is thus formally disallowed. This fact, while not new, is apparently not discussed in the literature. The purpose of this talk is to clarify which flow profiles are allowable in Q.G. stability theory, and to discuss any discrepancies in results for these profiles with some common piecewise linear profiles.

Wave-Activity and Stability Diagnostics for Semi-geostrophic Theory

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We derive semi-geostrophic (SG) pseudomomentum and pseudoenergy invariants and use them to obtain the following:

(i) a wave, mean-flow interaction theorem consisting of generalized Eliassen-Palm flux diagnostics, an elliptic equation for the stream function tendency, and a non-acceleration theorem, all analogous to their quasi-geostrophic (QG) forms;

(ii) a finite-amplitude local flux law for the pseudomomentum, and a small-amplitude flux law for the pseudoenergy, both of which obey the group-velocity property in the WKB limit;

(iii) linear and nonlinear generalized Charney-Stern theorems for perturbations to parallel flows, based on the pseudomomentum; and

(iv) a linear stability theorem for perturbations to steady flows, analogous to the QG form of Arnold's (1966) "First Theorem.

We also show, using the method of Ehassen (1983) and Magnusdottir and Schubert (1990) that

(v) the linear Charney-Stern theorem of (iii) can be generalized to apply to zonal flows along zonal topography of arbitrary amplitude relative to the scale height.

The second-order invariants are constructed using a variational principle in a similar manner to the QC calculations, as found in McIntyre and Shepherd (1987). Such an approach is possible when the equations of motion under the geostrophic momentum approximation axe transformed to isentropic and geostrophic coordinates (IGC), in which vertical and geostrophic advection terms are no longer explicit. The invariants arise naturally from the symmetries of the Hamiltonian structure of SG (Salmon 1985, Roulstone and Norbury 1993). We avoid use of the so-called "massless layer' approach to the modelling of isentropic gradients at the lower boundary, preferring instead explicitly to incorporate boundary contributions in the wave activity and stability diagnostics. This way the analogy with quasi-geostrophy is most transparent.

The results hold for both the f-plane, Boussinesq form of SG, as found in Hoskins (1975), as well as the b-plane, compressible system of Magnusdottir and Schubert (1990). In the limit of small Rossby number, the diagnostics reduce to their respective QG forms. Novel features particular to SG include tilting effects on Rossby wave propagation due to thermal wind terms in (i) and (ii), and apparently unnoticed lateral boundary stability criteria in (iii) and (v). It is hoped that the diagnostics, in particular their b-plane form, will prove useful in analysing synoptic to large-scale flow regimes where QG scaling is no longer valid but where slow motion nonetheless dominates.

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Assessment of the Interactions between the Slow Transients and the Synoptic-Scale Eddies in a T32 General Circulation Model

Jian Sheng

Canadian Climate Centre, Victoria, B.C.

The interactions between low-frequency transients and synoptic-scale eddies are investigated for the Northern Hemisphere winter. The analysis is performed on a 10-year integration of the Canadian Climate Centre general circulation model (CCC GCM). The model has ten vertical levels and a T32 horizontal resolution. Observed SST for 1978-1987 is specified as the bottom boundary, condition. To facilitate comparisons, an identical calculation is performed on the observed data prepared by ECMWF for the same period.

The observed mean height tendency due to the vorticity flux of the synoptic-scale eddies shows a dipole structure in both Pacific and Atlantic sectors. These patterns, oriented in the northwest-southeast direction, tend to enhance the westerlies in the eastern Pacific and eastern Atlantic and extend the jets eastward, if other forcing can be neglected.

Height tendency calculated from the CCC GCM compares well with the observations in terms of spatial distribution but the amplitude accounts only one half of that calculated from the ECMWF data. The standard deviation of the low-frequency height field is also well simulated by the model, except the amplitude is roughly 30% weaker. High values of low-frequency activities are located along the 55N latitude, with centres of maximum in the eastern Pacific, eastern Atlantic and the Hudson Bay.

To determine the phase relationship between the slow transients and the synoptic-scale eddy forcing, the lag correlation coefficients between the low-pass filtered height field and the height tendency due to the synoptic-scale eddy forcing have been calculated. A positive time lag is defined as that the phase of the forcing is leading that of the height. The maximum positive correlation appears at positive one-day lag in observed case and at zero lag in simulated. The very small time lags indicate that the slow transients and their synoptic scale forcing are almost in phase with each other. The geographic distributions of the observed and simulated correlations are also very similar: a zone of positively correlated area in the midlatitudes, between 40N and 60N, and maximum values found in the eastern Pacific and eastern Atlantic. The model calculation seems to show a slightly stronger correlation and better defined regional centres.

Friday/Vendredi a.m. Session 1&2 Room/Salle:232

Remote Sensing / Télédétection

Chair/Président:Pierre Larouche

Quality Analysis of the SRB Data: An Intercomparison of Two Satellite-based Products

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Surface radiation budget (SRB) is important for climate studies. Unfortunately, large differences exist among the state-of-art estimates of the SRB that are obtained from surface observation, satellite estimation and GCM simulation, The maximum discrepancy is about ten times the radiative effect of doubling CO_2! In order to provide the modellers with a creditable data set of the SRB, quality analysis of two satellite-based products is conducted. One is developed from the Earth Radiation Budget Experiment (ERBE) data using the algorithm of Li et al (referred to as ERBE/SRB). The other is the WCRP SRB product that is generated by applying the algorithm of Pinker and Laszlo to the ISCCP data (referred to as ISCCP/SRB). The global annual means of surface net solar radiation obtained from the two products differ by more than 10 Wm_{-2}. Regional differences range from 30 to more than 100 Wm_{-2}. In principle, the differences arise from input data and algorithm. To separate the two contributions, the algorithm of Li is applied to the ISCCP data. The resulting SRB data are subtracted from both the ERBE/SRB and the ISCCP/SRB data. The former differences are solely due to the use of different input data, whereas the latter differences mainly result from different algorithms. It is found that large regional differences are mainly associated with one of the input parameters, namely, planetary albedo. Most of the differences in planetary albedo between ERBE and ISCCP can be attributed to the problems associated with angular and spectral corrections for the ISCCP data. On the other hand, use of different algorithms leads to systematic discrepancies. Comparison of the two algorithms reveals that the systematic discrepancies can be accounted for by different methods used to compute water vapour absorption, The algorithm of Pinker and Laszlo employs the Lacis and Hansen parameterization which is proven to significantly underestimate water vapour absorption.

Bidirectional Dependencies of AVHRR Reflectance at Channel 1 and 2 over Land Surfaces

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AVHRR data have been widely employed for meteorological and environmental studies. For most applications, it is required that the measurements be independent of viewing geometry. The objective of this study is (1) to examine the bidirectional reflectance distribution (BRD) of the visible and near infrared AVHRR measurements made over a variety of land types; and (2) to establish some BRD functions (BRDF) to account for the angular dependency. To do so, a AVHRR data set of 3 years produced from the U.S. Geological Survey (USGS) is obtained. The data used include daily 1-km reflectance measurements at channel I and 2 made over 57 sites (20 X 20 km_2 for each site) in the United States and Canada from 1990 through 1992. Uniform sites representing barren, grassland, deciduous and coniferous forest, and cropland are selected. As the study is restricted to clear sides, a screening technique is applied to remove clouds. Observed top-of-atmosphere reflectance is analyzed as functions of viewing angles for different types of surfaces. Extensive analysis of the BRD for whole growing season indicates that BRD depends on wavelength band, land cover type, solar zenith angle, and vegetation growing condition which could be accounted for by a vegetation index. The BRDF should therefore be developed as a function of these variables for a specific land cover type at each channel.

Observational Evidence of Average 3-D Cloud Effects From Satellite Measurements Over Ocean

N. Loeb and R. Davies

McGill University

Despite many theoretical and observational studies that show the need to consider three-dimensional radiative transfer in the analysis of individual cloud scenes, the conventional approach in dealing with cloud radiative properties in radiation budget calculations, GCM's, and even in satellite retrievals is to use one-dimensional, plane parallel radiative transfer models. This is justifiable only if the three-dimensional nature of clouds turns out to be relatively unimportant when averaged over many actual cloud scenes.

We test this assumption by comparing the angular dependence in satellite-derived observations of the radiation field with plane parallel calculations on a statistical basis. The observations used consist of a full year of pixel-level data (S-8) from Earth Radiation Budget Satellite (ERBS) scanner measurements over ocean between 30 S and 30 N. Comparisons between the average mean observed and plane parallel radiance fields as well as the underlying frequency distributions are performed. In order to examine the effect of cloud type on the analysis, further comparisons are carried out by considering only observations from regions where clouds tend to be predominantly stratiform or cumuliform in nature.

Results show that even when averaging over a large number of samples, 3-D cloud effects still have a significant influence on the radiation field which is cloud type dependent. The implications of these results for cloud radiative modeling in GCM's and remote sensing of cloud properties will be discussed.

Remote Sensing of Phytoplankton Pigments in the Gulf of St. Lawrence, Canada: Spatial and Temporal Variability

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An analysis of 87 Coastal Zone Colour Scanner images of the Gulf of St. Lawrence (GSL), allowed the identification of phytoplankton pigments (Chlorophyll a and Phaeophytin) spatio-temporal patterns. The images were taken during the three open water seasons (1979-81). The image processing included: 1) the radiometric corrections, 2) the pigments calculations, and 3) the geometric corrections. Corrections for aerosol scattering was done using an iterative approach by selecting interactively the optimum Angstrom coefficient for each of the three visible channels. Results show the presence of a bloom occurring in the spring (April-May), and fall (August-September) seasons, while lower pigment values are found in the summer (June-July). Principal Component Analysis (PCA) for the three seasons confirms the presence of mesoscale spatial patterns in the GSL. The spring bloom is stronger in the northwestern and estuarine regions. Moderate pigment concentrations are found in the Magdalen Islands shelf, and the Northeastern GSL is characterised by low values. During the fall season, a second bloom is observed, principally in the western-central regions. Interchange of surface water with the Atlantic Ocean seems to occur through the Cabot Strait. The observed spatial distribution of pigments appears to be linked with known physical processes. The Gaspe Current is the region with the highest pigment concentration. High values are also found in the northwestern region, which correspond to a wind induced upwelling area. The northeastern regions are generally thought of as a downwelling region which could explain the low pigment concentrations found, though, occasionally high pigment values are detected in this area and may be important to the regional biological productivity. The results agree with previous shipboard observations, and suggest a non homogeneity of the biological system. The phytoplankton pigments seasonal cycle appears to change in relation to the local physical characteristics and nutrients disponsibility. These results can now be used as a basis to plan the next remote sensing studies on the phytoplankton pigments in the GSL using SeaWIFS data.

Observation of Gyre Circulation in the Labrador Sea from Geosat altimetry

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The Geosat altimeter data from about 60 repeat cycles of the Exact Repeat Mission (ERM) over the period November 1986 to September 1989 have been analyzed to show the annual basin-scale features of gyre circulation in the Labrador Sea. Complex emperical orthogonal function (CEOF) analysis is used to extract spatial and temporal patterns of altimetric sea-surface height anomalies. The analysis revealed that the first eigenmode had an annual variation of ≈ 3 cm amplitudes increasing shoreward. Its phase patterns indicated positive heights in winter/spring propagating southeastward at approximately 17 cm s^{-1} on the western side. On the eastern side the phase propagated northwestward at about 7 cm s^{-1}. Harmonic analysis of the across-track sea-surface slopes on the western side shows the annual cycles of amplitudes of $\approx 2.5 \times 10^{-7}$ ascending in winter/spring and descending in summer/fall toward the Labrador coast, consistently with the CEOF results.

The annual cycle of the across-track sea-surface slopes on the western Labrador Sea is consistent with the available current meter data. Nevertheless, the observed altimetric features from the altimetric height anomalies cannot be detected from those produced by a wind-driven barotropic model, implying that they might not be excited by wind stress. Finally, the observed long-wavelength propagating waves on the western side are identified as the lowest vertical mode of topographic Rossby waves, and thought to be generated by surface buoyancy flux.

Intelligent Information Processing for Electromagnetic Sensing of the Environment

Simon Haykin

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Typically, electromagnetic sensing of the environment involves the use of rather expensive pieces of microwave hardware. For example, the primary sensor may be a weather Doppler radar designed to identify the evolution of a severe storm. Such an application may also involve the use of human observations and inputs from other auxiliary sensors. The key question is how best to fully exploit the information gathered from the primary sensor and other auxiliary data. The answer lies in the use of intelligent information processing, the important attributes of which may be summarized as follows:

- Nonlinearity
- Adaptivity
- Information preservation
- Robustness
- Fault tolerance
- Attentional mechanism
- Multisensor fusion

In this paper we expand on these issues, and also identify the roles of computing tools such as neural networks, fuzzy logic, symbolic processing, and genetic algorithms in the implementation of an intelligent information processing system applied to the electromagnetic sensing of the environment.

Friday/Vendredi a.m. Session 1&2 Room/Salle:224

Weather Forecasting-3 / Prédictions météorologiques-3

Chair/Président: S. Gravel

Numerical Simulation of Extreme Sea-states Associated with Recent Intense Storms in the Canadian Atlantic

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During the last five years, the Canadian Atlantic experienced several intense weather storms which generated extreme sea-states with estimated maximum wave heights of 15m or more at several locations in the Scotian Shelf and the Grand Banks region. Noteworthy among these storms were the Grand Banks storm of January 1991, the Halloween storm of October 1991 and the "Storm of the Century" of March 1993. These intense storms produced hazardous wind and wave conditions during their passage in the Canadian Atlantic.

This paper discusses numerical simulation of sea-states associated with some of these storms using an operational ocean wave model called CSOWM (Canadian Spectral Ocean Wave Model). The CSOWM operates on two separate grids, one covering the northwest Atlantic and the other covering the northeast Pacific. For both these grids a nested fine grid is designed covering the nearshore regions of the Canadian Atlantic as well as the

Canadian Pacific. The computer code of the CSOWM is designed with several optional packages like coarse grid or coarse plus fine grid, deep-water physics or deep plus shallow-water physics and a first generation or a third generation source-term algorithm.

The paper presents some of the simulation results of the extreme sea-states associated with these storms. The results are further discussed in terms of the wave model physics and the accuracy of the wind fields that drive the model.

Description of the Weather Network Database

Pierre Dionne

MétéoMédia/The Weather Network

MétéoMédia/The Weather Network has developed a database system to process meteorological "spot-time forecasts. Each forecast consist of a "weather or sky" element, a 6-hour probability of precipitation and specific-time temperature, wind speed and direction. Depending on the period of the day the forecasts will range from 6 to 36 hours ahead. At each working session, the meteorologist will forecast for four periods: morning, afternoon, evening and overnight. For the first three periods, the forecaster will overwrite the forecasts done at the previous session. For the last period, he will overwrite a forecast produced from model output statistics.

To avoid typing mistakes, a warning will tell the meteorologist if some forecast values are out of predetermined limits. The system will eventually be updated to tell the meteorologist if he forecasts record values. The purely statistical and man-made forecasts are both archived, this allow us to do verification and comparison of both forecasts.

The forecasts are used to generate maps shown on T.V. and simple-text faxsheet used by radio announcer. The whole system is relatively efficient. It allow a team of four meteorologists per shift to provide forecasts for about 150 stations.

The Weather Network also archive weather observations and weather-related data such as road conditions. This allow to have a large dataset to study how weather and other phenomenons correlate.

Hot Air Balloon Forecast Program at St. Louis, Missouri

Joe Pedigo

Lead Forecaster
WSFO, St. Louis, MO

Hot air ballooning has become one of the fastest growing sports in the United States. Specific forecasts for hot air balloonists have been made for the St. Louis area since July 3, 1991. Detailed forecasts are prepared twice daily by staff members at the National Weather Service. This information is broadcast ten times daily by the Flight Service Station on the FAA's Telephone Information Briefing Service. This recorded message, updated hourly, includes the latest surface observations, surface wind forecasts, geostrophic wind, boundary layer and upper level wind forecasts, radar information, and an outlook for the next flying period (i.e. "near sunset today, near sunrise tomorrow"), within the forecast area of responsibility.

The Hot Air Balloon Forecast has become the most popular product the Flight Service issues, averaging 2000 to 2500 requests per month year-round. Since hot air balloonists are so vulnerable to meso and microscale weather phenomena, the National Weather Service uses the latest computer outputs, wind profiler, and a host of WSR-88D Doppler radar products (e.g. VAD wind profile) to construct site-specific forecast products which are far superior to the current aviation terminal forecasts.

This report will focus on the Hot Air Balloon program at WSFO
St. Louis. The overview will include: 1)..a verification of forecasts completed during 1992 and the first half of 1993, 2) ..how other NWS offices could participate in developing a similar program, and 3)..provide directions on how the National Weather Service and FAA's Flight Service could improve the joint venture of supplying state-of-the-art information for the balloonists and the general aviation community across the nation.

Precipitation Type Forecasting

G. Desautels and R. Verret

Development Branch
Canadian Meteorological Centre

Four different algorithms for dynamic precipitation type forecasting are being examined. All these algorithms use forecast parameters from the 50 km resolution Regional model, with 25 sigma levels in the vertical. The winter months of 1994 have been selected for the test period. There are five possible precipitation types that can be forecast with the algorithms considered: rain, rain and snow mixed, freezing rain, ice pellets and snow. Only the grid points where the instantaneous model precipitation rate is above a specific threshold value are considered for display. The precipitation type forecast at a station is generated by assigning the calculated precipitation type at the nearest grid point.

Koclas's algorithm, which is currently operational at the Canadian Meteorological Centre, identifies the number of times that the forecast vertical temperature profile crosses the zero degree Celsius line on the tephigram. The precipitation type is assessed from the application of criteria on the forecast surface temperature and the thicknesses of each warm (above zero Celsius) and cold (below zero Celsius) layers.

Bourgouin's algorithm uses criteria which depend on the structure of the forecast temperature profile and on the amount of energy in each warm or cold layer to asses if the solid precipitation will melt in the warm layers of if the liquid precipitation will freeze in the cold layers.

Baldwin-Contorno's algorithm requires a dew point spread of less than two degrees before estimating the precipitation type. Similarly to Bourgouin's algorithm, it takes into account the energy of the warm and cold layers, but calculated with respect to the wet bulb temperature.

Ramer's algorithm requires a relative humidity of 90 percent or more to define a layer in which precipitation is originating. The precipitation in each warm or cold layer is then examined with respect to the wet bulb temperature and the thickness of the layer to estimate the cumulative percentage of the precipitation that should be solid. The total value of this cumulative percentage is used to identify the precipitation type.

Case studies will be presented. Preliminary results indicate that there is generally little differences between the forecasts generated from these algorithms, except in the critical areas where the precipitation is changing from liquid to solid.

SCRIBE

R. Verret, G. Babin, D. Vigneux, J. Marcoux, J. Boulais, R. Parent, S. Payer

Development Branch
Canadian Meteorological Centre

SCRIBE is an interactive system for composition of meteorological forecasts. It can generate plain language public forecast bulletins from weather element matrices available at a set of stations or sample points. The matrices are prepared at a threehour time resolution. Upon reception of the matrices, the knowledge base system processes the data to extract the ideas or concepts hidden behind the digital guidances. The knowledge base system works through a domain space of rules to generate the concepts which are the results of a semantic numerical analysis of the weather element matrices content. The concepts follow standards of codification that provides a simpler way to display the content of the weather element matrices on the graphical interface for editing rather than displaying the raw numbers. Once the editing task is complete at the interface level, the modified concept file is quality controlled before being fed to the knowledge base system again to generate the plain language bulletin.

The knowledge base system uses approximately 550 rules to generate the concepts. It can produce more than 40 precipitation concepts (rain, rain heavy at times ...), including three types of concepts applicable to thunderstorms (risk, possibility, a few) at up to three levels at the same time (ex.: rain and snow possibly mixed with ice pellets). It can also produce two types of concepts applicable to precipitation accumulation (liquid and frozen), six classes of probability of precipitation concepts, 13 sky cover concepts (11 stationary states and two evolving states), 14 classes of wind speed with eight directions, two types of visibility concepts (blowing snow and fog) and ten types of maximum/minimum temperature concepts.

The knowledge base system uses approximately 850 rules to generate the plain language bulletins. Forward chaining is normally used to query the rules although backward chaining is also possible depending on the problem to be solved. The knowledge base system creates a basic sentence structure that can be matched into different structures representing different semantics expressing the same content, following a case base reasoning approach.

SCRIBE is being expanded to generate agriculture and marine forecasts. The capabilities of the system will be demonstrated including the capability of generating different bulletin formats for the same forecast. The adaptation of the graphical interface for marine forecasts is complete and will also be demonstrated.

Meteorological Performance of the Canadian Global Spectral Forecast Model

Christiane Beaudoin and Harold Ritchie

Recherche en prévision numérique

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In June 1993 the horizontal resolution of the global spectral model used for data assimilation and medium range forecasts at the Canadian Meteorological Centre (CMC) was increased from a triangular 79-wave (T79) truncation to a T119 truncation. At the same time significant modifications were introduced in the physical parameterizations:

a Kuo-type scheme for deep convection, a new parameterization for shallow convection, more sophisticated solar and infrared radiation schemes, and a new convective cloud cover parameterization. In this presentation we will review the recent meteorological performance of the global forecasting system, including conventional scores, in order to assess the impact of this implementation and to compare with forecasts produced by other centres. Experimental ten-day forecasts have also been produced routinely with this version of the model. We will examine the evolution of the forecast errors as a function of forecast length (from day 1 to day 10) in terms of conventional scores, as well as the recently available "anomaly correlation coefficient". Further improvements to this model are also currently being tested for a future implementation. Latest results will be presented at the Congress.

DERF Experiments with the Canadian Global Spectral Forecast Model

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The possibility of using numerical models for long range forecasting at the Canadian Meteorological Centre first arose with the implementation of the global analysis and forecast system in 1991. A team has been formed to work specifically on Dynamic Extended Range Forecasts (DERF). The first objective was to evaluate if long range runs (monthly to seasonal) of the operational forecast model can demonstrate any skill. Preliminary results based on integrations for 1992 will be presented. The year 1992 was chosen mainly because its summer (i.e. the months of June, July and August) was abnormal for Canada, with below normal temperatures registered during the whole season. It was hoped that a signal of this magnitude could be detected by the model.

The configuration used is the same as the operational global forecast model, with the following modifications: horizontal resolution reduced to spectral T63; slightly upgraded vertical resolution to 23 levels; physical parameterization that includes variation of solar input during the integration and a more realistic balance between infrared and solar radiation at the model top; and sea surface temperatures and ice cover that vary during the course of the integration so that the anomalies observed during the month prior to the integration are applied to the climatology of the forecast month. Comparisons of geopotential heights, i.e. monthly means of analyses versus forecasts, demonstrate skill in the troposphere, and indicate a definite improvement over climatology.

Wednesday/Mercredi 1500-1600

AFFICHES/POSTERS- AGRICULTURE AND FORESTRY/AGRICULTURE et FORÊTS

Development of Relaxed Eddy-Accumulation Systems for Measuring Herbicide Volatilization After Field Application

E. Pattey[1], P. Rochette[1], R.L. Desjardins[1], and A.J. Cessna[2]

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The relaxed eddy-accumulation (REA) technique is a relatively new technique used to measure trace gas fluxes. It expresses the covariance of the vertical wind speed (W) with the trace gas concentration as the product of an empirical coefficient A, the standard deviation of W and the difference in the mean concentration of the trace gas associated with updrafts and downdrafts. Its accuracy was recently evaluated as being excellent using CO_2 fluxes measured by the eddy-correlation technique as a reference. The REA system for agrochemical flux measurements is designed to accumulate air samples associated with updrafts and downdrafts at a constant flow rate in two traps for later analysis of the mean concentration. It avoids the need of a fast-response sensor for measuring the trace gas, required with the eddy correlation technique, by using fast- response valves. It requires only two samples to analyze per period compared to the 4-6 samples of the aerodynamic-gradient technique. Two REA systems have been developed. The first one uses polyurethane foam plugs (PUF) as a trapping medium with a 60 L min-1 flow rate. The second system is based on mini-tubes (MT) filled with Tenax-TA resin, which requires flow rates in the 100 mL min-1 range. The PUF medium needs to have extraction and concentration adjustment before gas chromatography (GC) analysis, while the MT support allows to analyze directly the entire sample by coupling a thermodesorption unit to the GC. The first experiment was carried out for four days in fall 1992, to measure the volatilization rates of triallate and trifluralin with both REA systems in order to determine if Tenax-TA could replace the traditional PUF medium. The herbicides were not soil-incorporated as recommended so that a wider range of volatilization rates could be studied. The flux pattern of both trapping systems was similar but the magnitude of the peaks was slightly different, due to adsorption/desorption along the inlet tubing wall in the MT measuring system. Cumulative fluxes agreed well for triallate (3%). For trifluralin, a higher cumulative flux of 22% was obtained with the MT measuring system. From this study, we concluded that the REA system using Tenax-TA medium was promising for measuring agrochemical fluxes but that it required an improved control system for minimizing adsorption/desorption along the inlet tubing wall, since the collected amounts of herbicides were much smaller than in the PUF medium. The second experiment was carried out during summer 1993, to measure volatilization rate of metribuzin and metolachlor incorporated into the soil and trapped in MT. The herbicide fluxes were about two orders of magnitude lower than those measured in the first experiment. The performance of the REA measuring system will be discussed.

Methane and Carbon Dioxide Fluxes From Poorly Drained Adjacent Cultivated and Forest Sites

R. Lessard, P. Rochette, E. Topp, E. Pattey and R.L. Desjardins
Centre for Land and Biological Resources Research Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6

Methane and carbon dioxide fluxes at the soil surface were measured from April to November 1992 in Ottawa, on adjacent cultivated (corn) and forest (temperate woodland) sites using closed chambers (ten chambers per site). The objectives were to quantify the spatial and temporal variability of gas exchange rates, and to determine the effects of soil temperature and moisture on the fluxes. On the forest soil, rates of CO_2 emissions and CH_4 uptake ranged from 2.27 to 14.82 g m^{-2} d^{-1} and 0.04 to 1.10 mg m^{-2} d^{-1}, respectively. On the cultivated soil, the measured CO_2 fluxes varied from 0.27 to 7.07 g m^{-2} d^{-1} while methane uptake ranged from 0 to 0.13 mg m^{-2} d^{-1}. There was a positive correlation between soil surface CO_2 fluxes and soil temperature for the forest (R^2 = 0.74, s(Y) = 1.77 g m^{-2} d^{-1}) and the cultivated (R^2 = 0.48, s(Y) = 1.10 g m^{-2} d^{-1}) sites. Temperature had little effect on methane uptake by the forest soil suggesting that gas diffusion was rate limiting. This was further substantiated by the observation that methane uptake showed a strong negative correlation with soil water content (R^2 = 0. 79, s(Y) = 0.12 mg m^{-2} d^{-1}). The spatial variability for methane uptake in the forest soil was found to be much larger than that previously observed for soil carbon dioxide production but is lower than that reported for nitrous oxide production. For fluxes larger than 0. 15 mg m^{-2} d^{-1}, the number of sites necessary to estimate the average flux with a precision of 10% (α = 0.05) ranged from 7 to 452.

Computer-Based Quality Control Checks for Autostation Data

Henry Hayhoe, Douglas Balchin, David McAndrew and John Wereschuk

CLBRR, Agriculture Canada, Ottawa, Ontario

Monitoring meteorological variables and soil temperatures at remote field locations using an electronic data logger can provide valuable detailed information in real-time. Unfortunately, experience has shown that automated systems can produce large amounts of totally erroneous data. These errors may go unnoticed when the data is used in near real-time computer models for farm management decision support. Traditionally, data has been recorded manually, which has provided for some quality checking. This meant that at least totally unrealistic values would be expected to be identified and checked. It is important to build into automated data collection systems some computer-based checks which indicate to potential users that the data is questionable. This is especially true for near real-time applications. More detailed quality control and data massaging would be appropriate if the data were to be incorporated in a climate archives. In this presentation we will give examples of soil temperature data collected at remote field locations to illustrate the types of errors which can occur and the checks used to identify them. Flags which identify data that failed a test are stored with the data in a FOXPRO data base and can be made available with the data. Computer counts of flags on a daily or hourly basis can be used to map areas of questionable data in a data base.

Radiation Use Efficiency in Soybean (Glycine max (L) Merr.)

P. Rochette, R.L. Desjardins, E. Pattey and R. Lessard

Centre for Land and Biological Resources Research, Research Branch, Agriculture Canada

Plant growth is directly related to the fraction of carbon fixed by photosynthesis that is converted into phytomass. We report here the results of a study aiming at the estimation of the net CO2 exchange rates (Fc,c) of a soybean crop over the growing season. Hourly values of Fc,c were estimated based on eddy correlation measurements of CO2 fluxes above the canopy, on chamber measurements of CO2 fluxes at the soil surface and on the assumption that the root respiration can be computed as a fraction of daily photosynthesis. Mean daytime Fc,c varied between 0.67 and 0.83 mg m^{-2} s^{-1} for a leaf area index (LAI) greater than 1, with a maximum hourly value of 1.48 mg m^{-2} s^{-1}. Absolute mean nighttime Fc,c were usually less than 20% of daytime values. Hourly Fc,c varied non-linearly with intercepted photosynthetically active radiation (IPAR). Daytime totals of Fc,c were calculated by summing up hourly values estimated using non-linear relationships to verify if deviations from linearity for the instantaneous

canopy fluxes result in a non-linear component in daily accumulation. Daily estimates of Fc,c obtained from the non-linear equation varied curvilinearly with IPAR. Moreover, the use of a linear equation induced an average bias of +1.17 g m-2 d-1, caused by the more frequent occurrence of low IPAR values during daytime. The accuracy of the Fc,c estimates was evaluated by comparing the radiation-use efficiency calculated using Fc,c estimates with radiation-use efficiency calculated using phytomass accumulation. The agreement between the two approaches was within 10% for LAI>2 but calculated Fc,c overestimated radiation-use efficiency based on phytomass accumulation for smaller LAI.

Soil Temperature Profiles under Conventional and Conservation Tillage from Latitude 45°N to Latitude 55°N

B.L. Ma, L.M. Dwyer, H.N. Hayhoe, D. McAndrew

Agriculture Canada, CEF, Ottawa, Ontario and Vegreville, Alberta

Soil temperature varies with latitude, method of tillage and soil type. In this study, soil profile (5, 20, 50, 100, 150 cm) temperatures were measured on similar soils at Ottawa, Ontario and Vegreville, Alberta under conventional and conservation tillage. They were compared for five different periods, corresponding approximately to spring pre-planting, emergence/vegetative growth, grain fill, post-harvest, and over-winter. Soil temperature differences between conventional and conservation tillage were evident at the 5-cm and 20-cm depths. Conservation tillage tended to reduce the diurnal amplitude in soil temperature at 5 and 20 cm depths, particularly during the early growing season. Soil temperature at 50, 100 and 150 cm depths showed negligible diurnal fluctuation. The lag between an increase or a decrease in air temperature and reflection of this change in soil temperature increased, and sensitivity of soil temperature to the magnitude of the air temperature change decreased, with soil depth. As a result, the amplitude of seasonal soil temperature fluctuations decreased with soil depth. Soil profile temperatures were compared between Ottawa and Vegreville, and implications for root growth and water and nutrient uptake at the different latitudes were considered.

L'Écoulement turbulent simulé d'une forêt en laboratoire

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[3]Valeur généralement retrouvée pour l'écoulement de l'air de la forêt.

La présence d'une forêt produit, dans l'atmosphère au-dessus, des phénomènes intermittents turbulents que l'on appelle Structures Cohérentes. Les transports induits par celles-ci, de la quantité de mouvement, de la chaleur, de l'humidité, du CO2 , vers le sol, ou vice versa, sont de l'ordre de 80%. Elles sont présentes environs 20% du temps. La modélisation numérique de l'atmosphère utilise maintenant des grilles plus fines qui deviennent donc plus sensibles aux conditions de surface. Commne une forêt est rarement homogène sur de très grandes étendues, il devient important de comprendre le phénomène sous différentes conditions de densité pour permettre une modélisation fidèle à la réalité. Pour ce faire, nous avons utilisé l'environnement partfaitement controlé d'un tunnel hydraulique et d'une maquette de cylindre qui nous permet d'étudier les structures cohérentes sans avoir les interferences d'une météo changeante d'une véritable forêt et les inconvénients de déplacer tout le matériel d'une forêt à une autre. La maquette utilisée nous donne une bonne représentation d'un écoulement de l'air dune forêt. La turbulence géndrée se dissipe selon la pente spectrate de -5/3 que l'on retrouve dans la nature. Les paramètres de Uh /u* ≅ 3.0 (entre 2.5 et 5)[3], zo/h ≅ 0.08 (0.01 à 0.2)[3] et d/h ≅ 0.8 (0.7±0.1)[3] sont respectés. Les structures cohérentes générées sont trés sensibles à la densité des diverses maquettes. L'intensité de celles-ci décroît selon l'accroissement de la densité. Les paramètre de d, zo, u*, h seront donc les termes impor=ts pour la modélisation des structures cohérentes dans la turbulence de la couche limite.

Wednesday/Mercredi 1500-1600

AFFICHES/POSTERS- AVIATION METEOROLOGY/ MÉTÉOROLOGIE DE L'AVIATION

Terminal Doppler Weather Radar Program status and System Characteristics

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The Terminal Doppler Weather Radar (TDWR) system, now being deployed by Raytheon Company for the Federal Aviation Administration (FAA)[1], provides automatic detection of microbursts and low-level wind shear. Microburst-induced wind shear can result in a sudden, large change in airspeed which has had a disastrous effect on aircraft performance during take off or landing. The National Transportation Safety Board (NTSB) has reported that between 1975 and 1985 there were 149 aircraft accidents, which resulted in more than 450 fatalities - all attributed to wind shear. The second major function of TDWR is to improve air traffic management through forecasts of wind shifts, precipitation and other weather hazards.

The TDWR System generates meteorological base data and windshear products and, through the timely detection and reporting of hazardous wind shear, automatically prepares warning messages for air traffic controllers to relay to pilots. These data are displayed to air traffic controllers in easy to interpret graphic and alphanumeric products. The radar collects low altitude meteorological data and performs reliably in the terminal area environment characterized by natural and man-made ground clutter. The TDWR design specifically addresses the extraction of weather information in the presence of radar returns from severe ground clutter.

The fully coherent, high-sensitivity/high-resolution design ensures the generation of high-quality meteorological data, refractivity, velocity and spectrum width, which are critical for the automatic, low false-alarm operation of the microburst and wind shear processing algorithms.

The program status, and system characteristics in the areas of: operating frequency, ground clutter suppression, system stability, antenna sidelobes, sensitivity, and reliability, are presented

[1]Contract ATFA01-89-C-00002

Spectral Sensing of Meteorological Parameters: Description of a Method and Results

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Electromagnetic waves provide very powerful means for observing and measuring certain properties of the atmosphere. As a complement to standard meteorological sensors and radiosondes, quantitative measurements of atmospheric state parameters can be made remotely using both actives (lidar, radar) or passive techniques (UV, visible, IR and microwave radiometers). These techniques have many inherent advantages over immersion measurements. They can provide the volume integration of the variable being measured and thus is more representative of a region than are point measurements. In many cases, the instrument does not have to be located directly in the region of interest. Observation can be made in 3-D and in real time and finally the instrument can be controlled automatically and data processed continuously. In recent years remote sensing has greatly extended the ability to observe the earth atmosphere. In meteorology, the many possible applications have not been exhausted and further development seems very promising.

At the Defence Research Establishment Valcartier, a new method for the passive remote sensing of atmospheric temperature and humidity profiles is currently under development, This method is based on the spectral measurement of the IR radiation emitted by the atmosphere itself. The resulting emission spectrum is strongly modulated by atmospheric state parameters. When measured at a sufficiently high resolution and over a wide spectral range the emission spectrum can be properly inverted to retrieve temperature and humidity profiles and possibly information on clouds and aerosols. Prior to the implementation of this technique into an operational system, there are important issues that remain to be investigated experimentally. With this intention, DREV has acquired a ground-based spectrometer system referred to as the Double Beam Interferometer Bounder (DBIS). This sounder can accurately measure the atmospheric emission with a high resolving power of approximately 5000 spectral elements in the IR region from 3 to 20 pm. The purpose of this paper is to describe both theoretical and practical aspects of the DREV sensing method and to report recent results. After a review of the basic concepts involved in remote sensing, the experimental methodology developed for the spectral measurements of the atmosphere is presented. Then the inversion method for the retrieval of temperature and humidity profiles is described and results are compared to corresponding radiosonde data. Finally, a simple and computationaly fast technique for temperature profiling in the boundary layer below 500 m is proposed.

Measurement of Extinction Coefficient in Fog, Rain and Snow using Forward Scatter Meters

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Forward scatter meters (FSM) are used to determine the extinction coefficient of fog or haze by measuring the light scattered from a beam of near infrared light in the angular range of approximately 20° to 50°. The visibility can be derived from the extinction using Koschmeider's law. Commercially available FSMs are usually calibrated against a transmissometer to give the extinction during fog, conditions. By comparing FSM extinction measurements to transmissometer derived extinction we show that multiple scattering effects may be significant when calibrating a FSM. The amplitude of the angular scattering function of rain and snow is quite different than that of fog in the FSM measurement range, therefore measurement of extinction during precipitation episodes requires calibration factors different from that used for fog. We derive the calibration constants required to give the correct extinction during rain and snow and show that they give more accurate extinction values through comparison with transmissometers.

On the use of Atmospheric Wind-profiler Radars in Aircraft Fightpath Planning

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A VHF atmospheric windprofiler has recently been completed at the University of Western Ontario in London, Canada. This instrument can measure atmospheric wind velocities in the altitude range between 2 and 9 km with a temporal resolution of 5 minutes, and an altitude resolution better than 0.5 km, in all weather conditions, including clear air and cloudy. It can run unattended. It can also measure the strengths of atmospheric turbulence in the same height region with similar resolution.

As such, radars of this type are ideally suited for use in the aviation industry. In this presentation, the potential of using several of these instruments at strategic locations as an aid to flight planning is investigated. The Detailed knowledge of the turbulence and wind fields afforded by these instruments can be applied to avoid regions of severe turbulence and flight paths can be planned which enable aircraft to achieve wind-assisted passage and thereby reduce fuel costs. These and other potential advantages of such radars will be outlined.

A Quasi Operational Implementation of a Three Dimensional Wind Retrieval Algorithm from Single Doppler Radar Observations

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J.S. Marshall Radar Observatory, McGill University

A variational method for the retrieval of a three dimensional wind field from single Doppler radar observations was developed . The constraining numerical model is comprised of the conservation equation for reflectivity, the continuity equation and a quasi-steady state for the wind field. The method minimizes a cost function defined as the difference between the observations of radial velocity and the corresponding model variables, plus the residuals of the conservation equation for reflectivity. The continuity equation is used as a strong constraint while the conservation equation for reflectivity is used as a weak constraint.

An implementation of the above variational method in a Silicon Graphics Indigo system consists of a number of parallel processes which collect the McGill Radar volumetric reflectivity and Doppler observations from the front end Doppler processor and prepare a stack of CAPP is at user selected spatial resolution. The user can then select a

subarea from these CAPPIs (in real time or from tape archives) and display the retrieved 3-D wind field in the subarea at selected height levels. This software package gives the user various choices regarding the model variables and constraints as well as the height levels for the 3-D wind retrieval. The main objectives of this package are to provide 3-D wind field in a semi-operational mode and to enable us to understand and study the variational algorithms in various meteorological situations. We believe that this system will be of considerable use in aviational meteorology.

FTA2 Operational Evaluation of the Sky Condition Reports from Two Automatic Weather Reporting Systems (AUTO) for the Production of Terminal Forecasts

Doug Dixon

Canadian Forces Forecast Centre
Edmonton, Alberta

Two auto stations, a Canadian READAC and American VAIS, were deployed to Wiarton, Ontario for the period January through July 1993. The information obtained from the sky condition reports produced by the AUTO stations were evaluated and compared to the reports issued by the stations' weather observers.

The original FTA study, published in October 1991, reported on a user evaluation of the weather conditions reported by two READAC stations deployed in Wiarton and North Bay, Ontario. The major discrepancy in the information sensed and reported by the READAC stations, was in the sky condition reports...primarily cloud heights during period of precipitation.

The results of this second evaluation show that both AUTO systems reported similar cloud heights to the observer's when there was no precipitation in the area. During periods of rain, READAC reported much lower cloud heights than the other two reports...frequently as low as zero. On other occasions, READAC was unable to determine a cloud deck during a continuous precipitation event, either rain or snow, and resorted to reporting a selection of scattered layers of cloud. VAIS appeared to be able to bore through the precipitation and provide a reasonable report on the overlying cloud deck.

This evaluation also demonstrates that the VAIS system is as sensitive as READAC for the detection and reporting of thin and less persistent cloud layers or elements. The ability of both systems to detect and report the amount of cloud cover was comparable. Also, both systems have a comparable ability to detect and report the amount of the sky covered by clouds.

The VAIS reports obtained during this test were judged in general as suitable information for the preparation of cloud height forecast, while the READAC reports were considered as being significantly deficient during periods of precipitation.

Active-Passive Radiolocation of Dangerous Centres in Thunderstorms

L. Kachurin and E. Lozowski

Department of Geography, Division of Meteorology
University of Alberta

Active-passive radiolocation of thunderstorm centres over a wide diapason of wavelengths is a new and intensively developing research and technical trend, through which one may obtain qualitatively new information on the electrical condition of clouds. In the pre-storm stage, the severity of the situation may be determined, as well as the potential danger for aircraft engines. During the thunderstorm stage, the location, timing and duration of lightning of various

scales may be determined. With data obtained in real time, space-time images may be constructed, and the tendency for thunderstorm process development may be precalculated.

Thunderstorms are a dangerous threat for aircraft engines and large industrial sites. The intensification of air transportation and the increase in aircraft size and speed have been accompanied by an increase in the number of flying accidents and catastrophes, caused by unexpected lightning strikes. There are also instances of spacecraft crashes, due to lightning strikes during their launch stage.

Icing and electrification of aircraft and the provocation by them of lightning in electrically non-active clouds are closely related dangerous phenomena.

Results of Verification of Conditional Terms in Terminal Forecasts Issued at WSFO Boise, ID

Les Colin

National Weather Service, Boise, ID, USA

Conditional terminal forecast terms "occasional", "chance", and "slight chance" are not currently evaluated by the U.S. National Weather Service (NWS) AFOS Era Verification (AEV) system. This omission has permitted forecasters to use conditional terms somewhat indiscriminately, which in turn has undermined the overall quality of the terminal forecasts. As a result policy changes have been made at the national level with the intention of discouraging and/or eliminating the use of conditional terms. At WSFO Boise an automated verification program was devised which can evaluate conditional ceiling and visibility forecasts, in addition to the prevailing forecasts addressed by AEV. Forecast categories and their respective weights are ranked in order of importance as follows: prevailing (7), occasional (4), chance (2), slight chance (1). Weighted credit for correctly forecast categories is awarded provided credit has not already been awarded for a higher category. Credit is deducted for all incorrectly forecast conditional categories. Forecast difficulty is evaluated as a function of both how variable and how low observed conditions are. Results for WSFO Boise are discussed. It is expected that verification scores for prevailing forecasts should improve as a result of the added effort required to score well on the conditional forecasts.

An Updated Climatology of Freezing Precipitation at Canadian Airports

R.A. Stuart

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Willowdale, Ontario

G.A. Isaac

Cloud Physics Research Division
Atmospheric Environment Service
Downsview, Ontario

Freezing precipitation is a significant hazard to aviation as well as other forms of transportation. Observations of freezing rain and freezing drizzle have been routinely recorded at airports across Canada for several years, and thirty year (1961-90) archives are now available for analysis. An examination of this archive showed that 137 observing sites in Canada had at least 10 years of record with 24 hourly observations per day in this 30 year period. Climate statistics of freezing precipitation at individual stations can be found in the Principal Station Analysis series of AES publications (AES, 1983-85), and more extensive statistics are contained in the Quicklimate software package (Stuart and Ranahan, 1991). However, national maps of these statistics are not as accessible as individual station

data, with the most recent map apparently being produced by MacKay and Thompson (1969).

In this talk, the results of a review of these 137 stations will be presented. This review will include national and regional maps of freezing precipitation occurence and duration as well as updated station statistics of freezing rain and freezing drizzle. A selection of results from a large variety of stratification exercizes will also be shown as time permits. The original study includes analyses of the frequency of occurence of freezing precipitation by precipitation type, geographical location, time of year, time of day and concurrent wind direction. Time permitting, we will also present a discussion of the persistence of freezing precipitation through analysis of duration statistics for various locations and times of year.

The results of this work will be useful in estimating the threat of freezing precipitation at Canadian airports, and in suggesting possible causes of its development and the prediction of its onset and duration.

A Climatological Assessment of Hazards Requiring Aircraft Ground De-Icing

R.A. Stuart

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G.A. Isaac

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This presentation will discuss the threat of precipitation icing to aircraft on or near the ground. Ice on the wings of an aircraft poses a threat to the lift capability of the aircraft, while ice on the ground is a hazard to aircraft either taking off or landing. In-cloud icing is also a threat to aircraft, but this hazard was considered beyond the scope of this work.

The severity of any icing hazard at the surface will depend upon a number of factors including the amount of and type precipitation involved, the number of hours in which precipitation is observed, the ambient temperature and humidity, and the temperature of the surface on which the ice accumulates, which is not necessarily equal to the air temperature. The hourly climate archive includes dry and wet bulb temperatures, relative humidity, and precipitation type. Precipitation amount is estimated in the corresponding daily climate archive.

In this study, the relative impact of the hazards requiring aircraft ground de-icing at 15 Canadian airports will be compared with airports in the United States and Europe. Hourly ice or snow accretion indices will be defined for frost, wet snow and freezing precipitation, and the occurrence of extreme values of these indices will be determined for each of the airports specified for examination.

A Comparison of ACARS Temperature and Wind Measurements with Radiosonde Data

Barry Schwartz

NOAA/ERL/Forecast Systems Laboratory
Boulder, CO

A comparison of wind and temperature measurements made by automatically-recording sensors aboard commercial

jetliners (ACARS) on takeoffs and landings with high resolution radiosonde data for the 1 February - 13 March 1992 (STORMFEST period) is presented. Data for temperature, wind direction, and wind speed were collected and segregated by the separation of the radiosonde and aircraft in both space and time for a reasonably sized time and space window. It is shown that there is little dependency on the difference of the two measurements due to the distance and time separation of the sensors. Thus, in a sense, the results presented in this study is a direct comparison of the two sensors measuring side by side and provides a partial assessment of the quality of ACARS observations. Indications are that the temperature measurements compare most closely followed by wind speed and wind direction. The results indicate that the comparison may also be illustrative of the mesoscale variability of temperature and wind measurements over the High Plains of Colorado. Questions regarding the reliability of the ACARS instrument during certain types of flight conditions are raised.

Aviation Applications for Lightning Data

John F. Canniff

U.S. Department of Transportation

Within the United States, there has been much interest recently in the use of network lightning data to locate thunderstorms and broadcast warnings to pilots as part of an automated weather message. After a few years of development, the Federal Aviation Administration (FAA) has begun implementation of a system that will append a lightning remark to an automated weather report.

The FAA is installing AWOS and ASOS systems at airports throughout the US. Both these automated weather systems require the capability to automatically detect and report thunderstorms. The FAA reviewed the capabilities of both lightning detection networks and stand-alone sensors, and selected the network approach.

Implementation is straightforward. Lightning strike data from the national network is transmitted to each of 20 ATC centers, where it is processed through an algorithm to identify which of the strikes fall within 30 NM of each AWOS/ASOS. Each minute, a message is sent to each AWOS/ASOS indicating the lightning remark to be added to the broadcast weather message. Strikes within 5 NM of the airport are reported as "LTG AT ARPT"; strikes between 5 and 10 NM as "LTG VCNTY"; strikes between 10 and 30 NM (with sector direction) as "LTG DSNT (sector)".

Modifications must be made both to the processors located at the centers and to the AWOS/ASOS systems before the lightning data can be implemented. The full system should be operational by 1997.

A prototype system will be demonstrated within Minnesota beginning May 1994. The state will contract to have network lightning data processed locally for dissemination through state-owned AWOS's. FAA is supporting Minnesota in their demonstration.

Recent studies would indicate that the performance of the automated lightning detection will be better than current manual observations of thunderstorms, under most circumstances. Data will be presented showing their relative performance characteristics.

Alternate - An Expert System for the Automated Production of Aerodrome Forecasts

Bruce Whiffen and Hugh Goodacre

Newfoundland Weather Centre
Atmospheric Weather Service
Gander, Newfoundland

The Newfoundland Weather Centre (NWC) has developed an expert system, now called Alternate, for the automated production of aerodrome forecasts (FT's). This package combines output of precipitation type and wind field at the aerodrome from the SCRIBE matrices of the Canadian Regional Finite Element (RFE) and Global models with the climatological range of expected ceiling and visibility values and presently reported surface observations. The FT's produced via this process yield routine frequencies of expected part periods, VRBL and OCNL conditions, and conform to the latest changes introduced by MANAIR.

Alternate has been tested on the aviation desk at NWC Forecasts for three twenty-four hour terminals: St. John's (YYT), Gander (YQX) and Stephenville (YJT), as well as a READAC (AWOS) site: Churchill Falls (ZUM), were produced at six-hour intervals over a one-month period. Aviation forecasters were asked to provide feedback on the FT's with particular attention to format, utility and accuracy and in comparison with those FT's produced operationally. No major deficiencies were noted during the teat. The most significant recommendations have already been implemented.

The climatological database will be expanded to incorporate all twenty-three aerodromes within Atlantic Region. The precipitation type and wind field derived from the nationally developed meteorological workstation - the Forecast Production Assistant, (PPA) - will also be utilized. Incorporation of other parameters, such as the observed and forecast air, sea and dew point temperatures (to enhance the forecast of stratus and advection fog) is also planned.

Wednesday/Mercredi 1500-1600

AFFICHES/POSTERS- METEOROLOGY / MÉTÉOROLOGIE

Global Gridded Datasets

Frank Keimig

University of Massachusetts at Amhurst
Department of Geology and Geography

Access to global gridded datasets has become relatively easy in recent years, but organizing and displaying, or visualizing, such data in a meaningful way requires a considerable amount of effort. To facilitate a better understanding of climatic conditions over the last 140 years, we have prepared a computer-based atlas which can be readily accessed by any user who has a PC, MAC or workstation with an 8-bit RGB color monitor (or better). The atlas is available on CD-ROM and through FTP client communication with Internet.

Several gridded data sets (surface temperature, precipitation, sea level pressure, and 500 millibar heights) have been converted into continuous-tone color anomaly maps. The data have been expressed as anomalies from reference period means (or as percentages, in the case of precipitation). By color-coding the anomalies and displaying all four maps for a given time period simultaneously, the links between the general circulation and anomalies of temperature and precipitation are more easily recognized. The atlas therefore has applications in both research and teaching.

All data have been processed to produce monthly, seasonal and annual maps as GIF (Graphics Interchange Format) images using 1024 x 822 pixels and 256 colors. Each GIF image represents the data with color contours and shading on world and hemispheric maps. Three types of images have been produced, one using a cylindrical equidistant

projection, the second a polar orthographic projection (displaying both North and South polar projections), and the third a location map of the actual data points. All images display maps of temperature, precipitation, pressure, and heights for an individual month, season, or year (where data exist).

The Ozone Layer and UV Radiation: Impacts on the Biosphere and Humans

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The decline of the atmospheric ozone layer is generally linked with global warming as an impending global environmental change. Unlike global warming, the impacts of ozone depiction are not only projections into the future but are upon us now. The action of man-made chemicals into the ozone layer have been active in reducing the global ozone layer for several years. In addition, recent eruptions of Mt. Pinatubo and other volcanoes have introduced other ozone-destroying chemicals into the stratosphere The result has been a more rapid decline in upper atmospheric ozone concentrations than previously expected with global ozone levels the lowest on record in 1992. Preliminary reports for 1993 expect even lower ozone levels. Recent research has shown that the reduction in the ozone layer and concurrent increase in ultraviolet radiation will have major consequences to life on earth and human health and welfare This paper reviews the recent research into impacts of ultraviolet radiation on man and the biosphere and concludes that action to reduce the emissions of ozone-destroying compounds is not enough. Actions must also be taken to alter life styles in response to increased UV radiation.

Application of the Synthetic Dual-Doppler Technique to An Operational Weather Radar

B. Larochelle and G. Reuter

Geography Department, University of Alberta

The synthetic dual-Doppler technique (SDD) is a method whereby two sequential Doppler radar observations of a moving storm are matched to simulate simultaneous observations from two Doppler radars at different locations. The two radial wind fields thus obtained allow for the reconstruction of the horizontal wind field in the storm. In order to obtain useful results from the technique, the storm relative wind structure should remain quasi-steady between observations.

An investigation into the real-time use of this method with a limited scan Doppler weather radar is undertaken. A SDD analyzer, developed on a microcomputer, accepts input from the Carvel weather radar (Edmonton, Alberta), to provide a two dimensional wind field analysis. Cases examined include tornadic storms and a gust front. In addition, sensitivity tests are done on the SDD method using simulated wind fields. The importance of storm steadiness, the effect of turbulence within the storm, and the sensitivity to storm position matching are thus examined. Finally, a related technique is described and tested wherein only one Doppler observation is used, but is limited to storms with band symmetry.

Although the limited Doppler scan of the Carvel radar imparts severe restrictions on the SDD technique, useful information can be obtained for case studies of severe summer storms and gust fronts. The SDD analysis is found to be very sensitive to the storm advection vector, and quite reliant on the quasi-steady assumption. By allowing for interactive fine-tuning of storm positions at run-time, it is shown that the advection sensitivity problem can be minimized, giving some merit to the notion of using the SDD technique for real-time severe weather forecasting.

Aspects of Local- and Regional-scale Climatologies in the Canadian Arctic Islands: Coastal Effect at AES Eureka, Ellesmere Island

David E. Atkinson

Department of Geography, University of Ottawa

The area encompassed by the arctic forms a large part of North America. Further understanding of arctic climate will enhance understanding of climatological patterns in other regions. As well, increasing interest has been directed towards the arctic regions in light of "global warming" scenarios that suggest the earliest manifestations of a temperature increase would be found there.

A significant obstacle impeding more detailed understanding is a lack of data for the high arctic, a region that is almost the size of Europe. The emphasis of this project is to refine aspects of arctic climatology by incorporating a 20 year dataset of meteorological observations that has not been previously analyzed: the data gathered by the Polar Continental Shelf Project (PCSP). This data set includes temperature, wind, weather and cloud obserations as recorded, usually twice per day, by the field parties PCSP has supported. The PCSP data set will be able to fill important gaps in knowledge, which will be explored in this project.

This presentation represents preliminary results from a few of the PCSP stations. The extent of influence exerted by the ocean upon meteorological parameters (wind, temperature) during the summer months (June, July, August) will be analyzed by contrasting observations from AES Eureka with PCSP stations located progressively farther inland.

Numerical Investigation of Regional Climate with FIZR, a Physically Based Interpolator: Results of a One-Month Simulation

Stéphane Goyette and René Laprise

Département de Physique, Université du Québec à Montréal

FIZR provides a physically based framework for regional climate studies. That framework can be applied to various climate problems such as topography-induced precipitations and potentially all kinds of historical events including CO_2 doubling scenario. We have developed FIZR in order to interpolate low-resolution GCM datasets onto an arbitrary high-resolution regional grid. FIZR is designed as a numerical model where precomputed atmospheric $<<$Dynamics$>>$ is combined with recomputed high-resolution subgrid-scale parameterized $<<$Physics$>>$. This combination is then integrated in a prognostic mode over a limited domain of interest. The present work addresses the question of regional climate prediction by combining precomputed Canadian Climate Centre (CCC) GCM atmospheric Dynamics with recomputed CCC GCM subgrid-scale parameterized Physics. To illustrate the potential of the FIZR approach, preliminary results of a one-month simulation performed with FIZR is compared with a CCC GCM T32 integration, both with prescribed SST. FIZR is presently running with a spatial resolution of 0.5° (roughly 45 km), 10 levels in the vertical, and a 20 min. timestep.

Differential Reflectivity and Phase Distributions as Functions of Fall Speed

Vytas Kezys and Simon Haykin

CRL, McMaster University

The IPIX radar at McMaster University has been used to develop a novel technique for deriving differential

polarimetric properties of Precipitation as a function of fall speed. The technique involves coherent, polarimetric measurements of rain at moderate elevation angles (e.g. 30 degrees). At these angles, the distribution of fall speeds is reflected in the Doppler spectrum. As well, the oblateness of drops imparts a differential reflectivity and phase on the polarimetric radar return. As oblateness and fall speed are related through drop size, one would expect that the differential polarimetric distributions would behave as a function of Doppler velocity.

Full spectral processing is performed on both like polarizations. Deriving accurate estimates of the differential polarimetric properties as a function of Doppler velocity (as opposed to total properties averaged over the range of fall speeds) requires a large number of independent samples. This is achieved through the use of frequency agility and very high pulse rates.

The differential reflectivity and phase distributions were clearly evident under conditions of moderate and heavy rain. The measured results are compared to Mie scattering theory. The technique has potential applicability for the remote sensing of drop size distributions as well as separating propagation and backscatter components of differential polarimetric returns.

Tangent Linear Semi-Lagrangian Modeling

Richard Ménard

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The validity of linearization of a semi-Langrangian algorithm is examined. It is found that for finite amplitude perturbations, there is no guarantee of strict linearization when a piecewise interpolative scheme is used. A ratio test is introduced for a dual purpose of diagnosing consistency of tangent linear models and for diagnosing errors that arise in utilizing non stricly valid tangent linear models. It is found that errors in tangent linear semi-Langrangian algorithm utilizing a piecewise interpolative scheme depends on the first noncontinuous derivative in the interpolating function. Errors produced with linear, cubicspline and, Fourier interpolation are examined.

A Hydraulic Model of Gap Winds in Howe Sound, British Columbia

Peter L. Jackson and John Tucker

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The University of Western Ontario
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Gap winds in western North American coastal fjords are the shallow, often very strong seaward flow of air which occurs when arctic anticyclones move southward against the interior side of the coast mountain barrier. This synoptic scale configuration creates strong low level horizontal pressure gradients oriented down the fjords which result in gap wind flow through them. Results from wind and pressure data, as well as 3D numerical modelling suggest that gap wind flow is analogous to hydraulic channel flow -- with phenomena such as supercritical flow and hydraulic jumps apparent. The resemblance between gap winds and the hydraulic flow of water in a channel has been exploited by creation of a hydraulic atmospheric numerical model which successfully simulates gap winds. The hydraulic model, and its X11 based graphical user interface, will be demonstrated.

Healthy Living with Sunshine

TG Medlicott[1], HS Campbell[2], E Murphy[3]

[1]Prairie and Northern Region
Environment Canada

[2]Cancer Prevention Program
Alberta Cancer Board

[3]Alberta and NWT Division
Canadian Cancer Society

A healthy environment supports a healthy population. Nowhere is this more critical than in protecting the ozone layer. Environment Canada's research has shown that depletion of the ozone layer causes increased levels of ultraviolet radiation (UVR). If this continues it will result in loss of plant species, disruption of marine life food chains and damage to natural ecosystems. On the health side, increased risks of cataracts, skin cancers and malignant melanoma are expected. Traditional public education has heightened awareness, but left the public overwhelmed, confused and feeling powerless. A new approach to public education was undertaken by a partnership between the Alberta Cancer Board, the Canadian Cancer Society and Environment Canada.

An educational program has been developed which combines the environmental and health sciences into a single presentation which is delivered via state of the art computer technology. Aimed at parents and caregivers, this interactive multi-media computer system engages users in an active learning experience where they can choose topics which interest them. In the environment section there are four choices: 1) the ozone layer, 2) effects of UVR on plants, animals and ecosystems, 3) the Montreal Protocol, and 4) the UV Index™. The health section covers 1) the body's reaction to UVR, 2) protection, 3) risk factors for skin damage, 4) early detection, and 5) children. Learning is enhanced by the use of "what-if" scenarios, demonstrations (e.g. users see what happens to the skin with sun exposure), comparisons (users see differences in the UV Index™ levels in different locations), "test yourself" quizzes before and after each topic, and personalized feedback.

The interactive system will be set up in the poster display area where conference participants can explore the program. An oral presentation will describe how the organizations collaborated to produce this innovative educational program.

A Numerical Model of Turbulent Air Flow over Water Waves with Nonuniform Surface Roughness

P.Y. Li, Dapeng Xu and Peter A. Taylor

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A numerical model (NLMSFD (Xu and Taylor 1992)) is proposed for the turbulent air flow over a train of water waves of small amplitude. The flow is considered as aerodynamically rough, and the surface roughness z_0 is allowed to vary with position along the wave. This is to try to model the effect of shorter gravity and capillary waves which could be generated by a nonlinear transfer of energy from the dominant wave and are steepest just forward of the crest (Longuet-Higgins 1969; Keller and Wright 1975). The turbulence closure schemes adopted to close the momentum equations are E-xz, q^2l level (Mellor and Yamada 1982), and LRR (Launder, Reece and Rodi 1975). Variable z_0 is introduced into the program by making use of the concept of a 'constant-flux' or 'wall' layer

close to the surface. With the form used when z_0 varies, the predicted fractional rate of energy input per radian advance in phase, Zeta, due to the working of the surface normal stresses is shown to be larger than for z_0 constant within the main generation region. The predicted values of Zeta could be increased by a factor of three to four. This brings Zeta more into line with the field measurements.

Tethersonde Profiling of 0_3 and $N0_2$ during PACIFIC '93 - Lower Fraser Valley, British Columbia

D.G. Steyn[1], I.G. McKendry[1], D.R. Hastie[2], J. Pisano[2]

[1]Atmospheric Science Programme, Department of Geography, University of British Columbia
[2]Centre for Atmos. Chem., York University

An intensive field campaign was conducted in the Lower Fraser Valley, British Columbia during the summer of 1993 in order to investigate various aspects of the photochemical smog problem in the valley and to provide initialisation and validation data for photochemical modelling. Vertical profiling of 0_3 and $N0_2$ (as well as other meteorological variables) up to 1 km AGL was conducted at two sites in the Pitt Lake area using tethersondes. Profiles generally reflect the daytime formation of 0_3 downwind of Greater Vancouver within a relatively shallow planetary boundary layer. Evidence is also presented of high concentrations in elevated stable layers. Local thermo-topographic circulations appear to be critical in determining both the horizontal and vertical distribution of pollutants in the region and may contribute to recirculation of pollutants. In particular, pollutants appear to be transported up tributary valleys of the Lower Fraser Valley during the day and possibly out of the valleys in nocturnal katabatic flows.

Climatology of the St-Lawrence River and the Gulf

Marc Besner and Gilles Morneau

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Ville St-Laurent (Quebec)

The purpose of this study is to characterize the climate of the St-Lawrence river and the gulf by different statistical approaches. The observations taken by a network of 25 weather stations along the coasts, several ship reports and one meteorological buoy will be used.

The proposed method is to compare the simultaneous measurements of a land station to those from ships located inside a given marine area and to compute statistical relationships between the two sites. The meteorological elements being analysed are the wind, the air temperature, the visibility and humidity. When we apply the computed relationships to the complete database of hourly observations of the land network, comprising several years of continuous data, we obtain a new, derived database valid for the 20 selected marine sectors. The derived wind field is used as input to a wave generation model to build a wave climatology for each sector.

Finally, the complete climatology obtained from the derived databases will be compared to the climatology obtained by other methods.

Climatologie du fleuve et du golfe Saint-Laurent

L'objet de ce travail est la caractérisation climatologique du fleuve et du golfe Saint-Laurent par différentes approches statistiques. Pour y parvenir, les mesures d'un réseau de 25 stations météorologiques localisées le long des côtes ont

été utilisées ainsi que celles provenant de différents navires et d'une bouée météorologique.

L'approche proposée consiste à comparer de façon statistique les mesures simultanées d'une station terrestre avec celles provenant des rapports de navires à l'intérieur d'un secteur maritime donné. Les paramètres météorologiques analysés sont le vent, la température de l'air, la visibilité et l'humidité. En appliquant les relations trouvées sur les données des stations terrestres, pour lesquelles il existe des observations horaires complètes couvrant plusieurs années, vingt (20) secteurs maritimes ont été caractérisés par une base de données synthétiques représentant les différents paramètres météorologiques. Également, les vents horaires générés sont utilisés comme données de base à un modèle de génération de vagues afin d'en évaluer la climatologie.

Finalement, la climatologie obtenue de la base de données dérivée sera comparée à celle obtenue par d'autres méthodes.

Evaluation and Modification of the STAR Procedure for Canadian Conditions

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The STAR (STability ARray) procedure is frequently used to classify atmospheric stability from routine meteorological observations. A number of studies have shown that stability classes deducted by STAR are poorly correlated with classes derived from more direct turbulence indicators. Previously, attempts have been made to modify the procedure to improve its performance in urban areas, at high latitudes and over the sea. In this paper, we evaluate and modify the procedure for Canadian conditions, paying particular attention to the effects of snow-covered ground.

The performance of the STAR procedure was evaluated at four sites across eastern and central Canada by comparing the STAR-derived classes with those predicted by ∂_θ, the standard deviation in wind direction. The procedure performed poorly at all sites, identifying the correct class less than one time in three, and severely underestimating (overestimating) the frequency of occurrence of very unstable (stable) conditions. The procedure was modified to take account of snow by comparing winter sensible heat fluxes over snow-free and snow-covered ground, but no real improvement in performance was achieved. Further modifications were made empirically by using the ∂_θ data to determine the most likely stability class for each combination of insolation and wind speed considered in the STAR procedure. The revised method showed some increase in predictive skill. but remained unsatisfactory in several aspects. Deficiencies inherent in the STAR approach appear to limit the extent to which routine data can reflect the prevailing atmospheric stability, particularly at complex sites. More reliable dispersion estimates can be obtained directly from ∂_θ data generated through on-site monitoring programs.

The present method for deducing stability class from vertical temperature gradient was also evaluated, but was found to be unreliable. The lack of any significant correlation between temperature, gradient and ∂_θ prevents this method from being improved.

Applications of Information Theory in Assessing Past Global Climate Change

Michael R. Gipp

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The mathematical relationship between ice volume and insolation at some high northern latitude is considered to

consist of linear and nonlinear components, with the linear components dominating. The picture has been complicated by recent work on ice cores, which suggests that global climate fluctuates rapidly between several metastable states, apparently through changes in thermohaline circulation patterns. Global change is thus effected by reorganization of heat and precipitation, resulting in large local variations in climate. The changes in climatic state would be expected to result in changes to the linear and nonlinear components of the ice volume-insolation relation.

Changes in climatic state may thus be recognized in the deep-marine record as abrupt changes in the amplitude and phase of the first derivative of the $a_{18}O$ record (a proxy for rate of ice growth). The paleoclimate record may be described as "encrypted", because applying different mathematical expressions over different intervals of the record is analogous to the encryption of information using polyalphabetic keys. Codebreaking is difficult, because different parts of the message are encrypted using different codes. Cryptanalysts have devised a function, known as the index of coincidence, which can be related to the number of codes used in the encryption. The index of coincidence for the ice growth proxy differs considerably from that for the isolation record. Since the isolation is presumedly not encrypted, it follows that the ice growth record is. These conclusions provide evidence in support of the hypothesis of global climate change by sudden changes in thermohaline circulation.

Using Divergence Damping to Eliminate the Spurious Semi-Lagrangian Resonance

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Recently Rivest *et al.* (to appear in *Mon. Wea. Rev.*) clearly identified a spurious resonant response in semi-Lagrangian discretizations for stationary solutions, such as those forced by orography, and recommended using a second-order accurate off-centering of the semi-implicit scheme as one acceptable solution to this problem. We are examining the use of divergence damping as an alternate way to eliminate this resonance. A linear analysis of the shallow water equations shows that divergence damping formally eliminates the spurious semi-Lagrangian resonance for stationary solutions. A second-order accurate (Crank Nicholson) treatment can be incorporated easily and cheaply in spectral models, in a generalized formulation which is readily rendered very scale selective.

Tests have been performed using a slightly modified version of the Canadian global spectral forecast model that is used for global data assimilation and medium range forecasts at the Canadian Meteorological Centre. The modifications are to increase the timestep from the operational value of 30 minutes to 45 minutes (in order to provoke the resonance which is not present in the operational model), and to remove the physical parameterizations (so as not to obscure the response to this numerical problem). For a case in which there is a strong flow across the Rockies, unrealistic detail over Montana exhibits symptoms of the resonant behaviour and can be removed by reducing the timestep to the operational value of 30 minutes, or by removing the mountains. It can also be eliminated by introducing divergence damping, removing the problem over Montana without changing the forecast significantly elsewhere.

A systematic series of experiments is in progress with a shallow water spectral model in order to determine the relative effectiveness of this approach compared to first-order off-centering.

Proposition of a Workstation Demonstration for CMOS in Ottawa

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The Canadian Meteorological Centre (CMC) has developed operational tools using workstation technology to deal with numerical forecasting. These applications include animation, overlaying of meteorological fields with satellite imagery and observational data, graphical editing and other applications. Applications will be demonstrated using a workstation.

Semi-Lagrangian Transport of Humidity in the Canadian General Circulation Model

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Recently, a research group in numerical climate modelling was created with the goal of developing a Middle Atmosphere Model (MAM). Representing a consortium of several Canadian universities and the Canadian Climate Centre of the Atmospheric Environment Service of Canada, the MAM Project has as its main objective the development of a general circulation model of the atmosphere that includes all relevant processes of the stratosphere and the mesosphere, in addition to those of the troposphere. In such a model, the accuracy of the transport of the several tracers is highly sensitive to the numerical method in use, whether those tracers are active or passive. The transport (or advection) of tropospheric humidity, in particular, must be done with great precision, given the complexity, of its interactions between model dynamical and physical processes. We propose here a comparison between a semi-Lagrangian advection scheme of water vapour and a spectral scheme, in order to assess their respective impacts on model climatology, and hence verify our hypothesis that the semi-Lagrangian approach be superior because of its desirable weak numerical dispersion and diffusion.

The Cloud Population Spectrum and its Representation in Large-scale Models.

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Cumulus convection occurs over a very wide range of scales, ranging from scales typically varying with the PBL depth (-1 km) to mesoscale cloud clusters. The latter are in large part responsible for the large-scale vertical mass flux, and are generally unresolved in large-scale climate models. As clouds are a significant component of the deep vertical transport in the atmosphere (not to mention the global radiation budget,) the transport properties of clouds am of vital importance to global climate models.

The present paper considers the spectrum of cloud populations and shows that it can be divided into two. Smaller clouds tend to transport momentum and the thermodynamic fields downgradient and thereby do satisfy a mixing-length hypothesis. However deep cumulus convection shows a tendency to organize itself into clusters, and therefore the transport in this portion of the spectrum is upgradient. This division of the spectrum is demonstrated using previous

studies of mesoscale cloud cluster formation in the tropics.

The implications for global models are diverse. The parameterization of subgrid processes generally assumes a separation of scales between the parameterized processes and resolved processes. At current model resolutions (-100 km) the upgradient portion of the convective spectrum is generally transferring energy into the resolved portion of the spectrum thus calling into question the hypothesis of scale separation. A more general approach taking into account the sub-grid spectrum may be required, and such an approach is developed here.

Further, a very simple modification of an existing scheme for convection parameterization in climate models is suggested, based upon the division of the spectrum into deep and shallow clouds. This scheme is applied to studies of radon transport in the troposphere.

The Use of High-Density Aircraft Observations at CMC

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Canadian Meteorological Centre
Satellite and Analysis Division

In order to take full advantage of the rapidly increasing number of high-density aircraft observations, namely AMDARS and ACARS, we have developed a revised aircraft data selection scheme and tested the sensitivity of the analysis and the forecast to these new data. Aircraft data are first clustered in the horizontal at about the resolution of the analysis grid (approx. 100 km). For each cluster, one report (closest to the analysis time) is then chosen for each analysis level in the vertical. We will show the impact of these new data onthe newly-revised three-dimensional analysis system. Results from the CMC global SEF and regional EFR models will also be presented.

Warm Fronts Within Canadian Winter Storms: Weather Conditions, Precipitation, and Mesoscale Structure

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Warm fronts are typically a critical aspect of winter storms over Canada. Several aspects of these features have been studied with the use of special observations made during CASP II. First, the passage of a warm front is typically linked with the organized evolution of many parameters including visibility, cloud base height, blowing snow, wind shear, accretion as well as the type and amount of precipitation. Depictions of typical situations have been developed. Second, combined aircraft and Doppler radar investigations have been made within some of these situations in order to characterize the lower troposphere. The 0°C isotherm on the lower surface of the freezing precipitation inversion is typically very irregular (which may mean that it is a region of gravity wave formation) but is closely linked with the warm frontal surface itself. Associated radar profiles can lead to occurrences of multiple "radar bright bands". Third, the detailed structure of the fronts aloft have been investigated with aircraft in-situ measurements. The frontal surfaces with strong convergence and wind shear often coincide with 0oC and have rain on one side and snow on the other. Diabatic effects associated with precipitation phase changes contribute to this phenomenon. And, finally, non-hydrostatic modeling studies have been conducted in order to better understand the complex linkages between precipitation and frontal development in these warm frontal situations.

Wednesday/Mercredi 1500-1600

AFFICHES/POSTERS- MIDDLE ATMOSPHERE WORKSHOP / ATMOSPHÈRE MOYEN ATELIER

Similarities and Difference between the Initial Purple Crow Lidar Density and Temperature Measurements, Other Measurements and Some Models

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The University of Western Ontario
London, Ontario, Canada

The University of Western Ontario's Purple Crow Lidar (PCL) is beginning a measurement program of density and the temperature of the middle atmosphere. The long-term goal of the PCL is to routinely measure temperature and density from the troposphere to the thermosphere to search for signatures associated with an enhanced Greenhouse effect due to anthropogenic activity. Reliable long term measurements require a thorough understanding of the lidar system's behaviour. One measure of lidar performance is the product of transmitter power with receiver area. The PCL has a performance factor of 64 WM^2, which is a significant increase over other present Rayleigh systems. Such a high performance factor puts high demands on many components of the system that must be adequately addressed before the measurement can be interpreted as a physical quantities. This paper will focus on the "truthing" of the PCL by comparison of average measurements during summer and winter with established empirical models.

Tidal/Gravity Wave Interaction and their influence on the Large Scale Dynamics of the Middle Atmosphere - Model Results

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In this paper the effect of tides on the propagation and breaking of internal gravity waves is examined in the context of two simplified models of the middle atmosphere.

First, an idealized tidal wind field superimposed on a typical wintertime climatological zonal mean wind is used in conjunction with a Lindzen-like gravity wave drag (GWD) parameterization scheme. The time mean GWD is found to be very sensitive to the vertical structure of the tide with long wavelength tides permitting a considerable enhancement of the drag in the mesosphere and lower thermosphere. In addition, the use of a localized source of gravity waves is shown to result in the generation of non-migrating components of the GWD forcing.

Next the effects of tidal/gravity wave interactions are examined in a more realistic context using a global quasi-geostrophic dynamical model. Tidal wind and temperature fields are prescribed a priori using the Forbes 1982 tidal

model and an orographic gravity wave drag scheme is employed. The influence of the tidal wind fields on the location and strength of the gravity wave drag is strongest in the mesosphere and lower thermosphere where the tidal winds are of the same order as the zonal mean component. At mid and low latitudes the differences between the case without tides present are largest and occur as a result of the filtering effects of the shorter vertical wavelength diurnal tide. At more polar latitudes where the longer wavelength semidiurnal tide dominates, a slight increase in drag occurs. The interaction between the tidal wind fields and the localized orographic gravity wave momentum flux has important consequences for the in situ generation of planetary scale disturbances. In particular, the amplification of stationary planetary wavenumber one is enhanced by the presence of tides.

Modelling Tropospheric Ozone Using A Global 3-D Chemical Transport Model

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Department of Earth and Atmospheric Sciences
York University

Analysis of tropospheric ozone soundings suggest that northern hemisphere ozone may be increasing while that of the southern hemisphere remains stationary. However, our knowledge of the ozone budget in the troposphere is still rudimentary and the relative roles of stratospheric and photochemical sources remain uncertain. Thus we have been developing a global 3-D chemical transport model (CTM) of the troposphere and lower stratosphere to investigate this problem. Currently there are 12 vertical levels which uses sigma coordinates going up to about 10 mb. Transport uses the spectral method at R15 resolution but this will be changed in the near future to a semi-Langarangian method. Horizontal resolution corresponds to about 500km. To solve the continuity equation the model uses an operator-splitting technique, allowing transport and chemistry operators to be applied at different time intervals. The chemical operator is applied less frequently than the dynamical operator which has a 30 minute time step. Species with a short lifetime are treated locally, and not transported. The boundary layer is modelled with a parameterized emission and deposition scheme. Forty chemical species are included, comprising O_2, HO_2, NO_2, CO, methane, ethane, propane, ethene, alkenes(C_2) and their oxidation products. Products such as the radicals, organic peroxides (C_2), organic acids and aldehydes with similar chemistry are treated as generic species. The model has been run for 100 days, driven by dynamical data from the NCAR middle atmosphere model but will also be run using objectively analysed data from the Canadian Meteorological Centre. We will present some of the
output from the model run some of which indicate the impact of ozone export from north America and the importance of long range transport of PAN and CO.

Lidar Measurements of Stratospheric Ozone and Aerosol in Toronto and in the Canadian Arctic

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Dept of Physics and Astronomy, York University

Since March 1991, before the eruption of Mt. Pintubo, lidar measurements of the stratospheric aerosol layer over Toronto have been routinely conducted. In addition, during Feb-Mar 1993 and Nov-Mar 1993/94, lidar measurements

of stratospheric aerosol and Ozone have been conducted in the Canadian Arctic at a facility located at Eureka, N.W.T (80 N, 86 W). The observatory at Eureka is part of the primary Canadian station in the Network for Detection of Stratospheric Change (N.D.S.C.). Measurements made at Toronto are presented and discussed as well as compared to the results of Mie calculations based on Sonde data. In particular, the observed evolution of the aerosol optical depth will be presented. Also, results from Eureka will be presented for Feb-Mar 1993 and initial results will be presented for the 1993/94 season.

Variability of the Upper St. Lawrence Estuary Frontal Region from Remote Sensing Data

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Centre d'Applications et de Recherche en Télédétection
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Ministère des Pêches et des Océans
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Mont-Job, QC
G5H 3Z4

A set of 6 Landsat images were used to evaluate the spatial variability of the density front located in the Upper St. Lawrence estuary. The data used consisted of Landsat 5 thermal imagery having a ground resolution of 120 metres thus allowing precise geographic location of the features of interest. The images were radiometrically corrected using an algorithm developed with in-situ measurements made at the time of data acquisition for two of the sampling dates. These images were then geographically corrected using ground control points visible on each image. Even with such a limited data set it is apparent that the tide is the main factor controlling the location of the front. However, other factors such as wind, freshwater runoff and bathymetric features also play a role leading to a high complexity of the surface temperature field. These results will be used to validate a high resolution three-dimensional numerical model being developed for the St. Lawrence estuary.

Observing Ocean Dynamics with HF Radar

Jim Helbig

Northwest Atlantic Fisheries Centre

A robust algorithm for HP radar radial velocity data is described that yields not only vector currents but also the differential kinematic properties of divergence, vorticity, shear and normal distortion rates. This algorithm was applied to two weeks of CODAR data was obtained in Conception Bay, Newfoundland, and the computed surface circulation is compared with vertical sections of currents measured contemporaneously with an acoustic doppler current profiler. The comparison suggests that the CODAR derived field is at times decoupled from the flow a few metres deeper. The vorticity balance is also estimated and corroborates the contention that the CODAR derived fields are dynamically valid, but are sometimes characteristic of the near surface only. The response of the surface layer to wind forcing is discussed as are the occurrence of eddies.

Wednesday/Mercredi 1500-1600

Oceanographic WorkStation Demonstration

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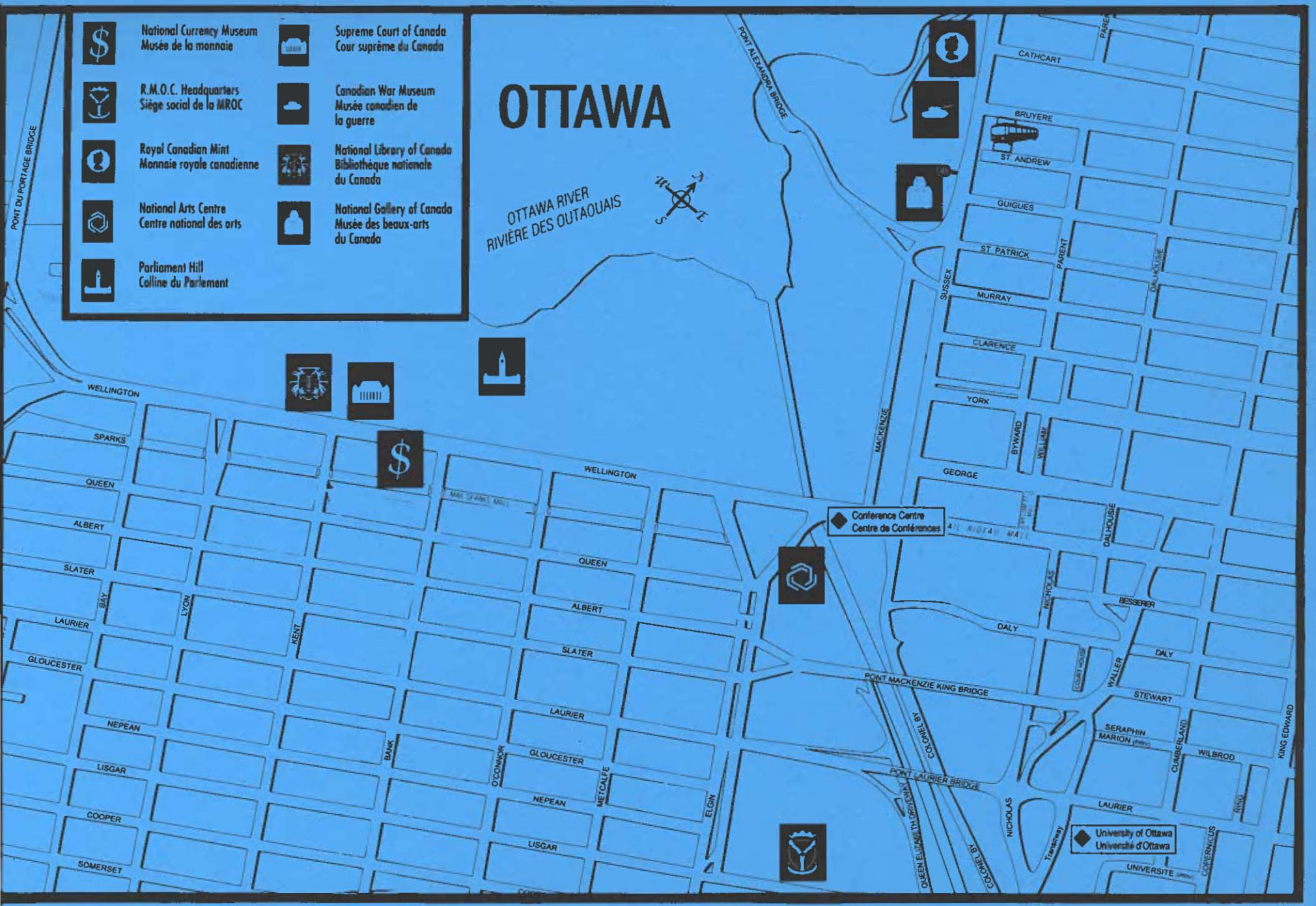
DFO and DND have jointly developed an Oceanographic Work Station (OWS) for the analysis and visualisation of two and three dimensional oceanographic data. A working OWS will be on display during the poster session, along with a number of selected outputs from near real time analysis from the Northeastern Pacific. Congress participants are invited to take the OWS for a "test drive". Project staff will be available to allow individuals to try the various analysis tools. In particular, the three dimensional viewing system should be of interest. Extensive use has been made of colour, volume cuts, and two dimensional slices.


National Currency Museum
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Siège social de la MROC
Royal Canadian Mint
Monnaie royale canadienne
National Arts Centre
Centre national des arts
Parliament Hill
Colline du Parlement
Supreme Court of Canada
Cour suprême du Canada
Canadian War Museum
Musée canadien de la guerre
National Library of Canada
Bibliothèque nationale du Canada
National Gallery of Canada
Musée des beaux-arts du Canada
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OTTAWA RIVER
RIVIÈRE DES OUTAOUAIS
PONT DU PORTAGE BRIDGE
PONT ALEXANDRA BRIDGE
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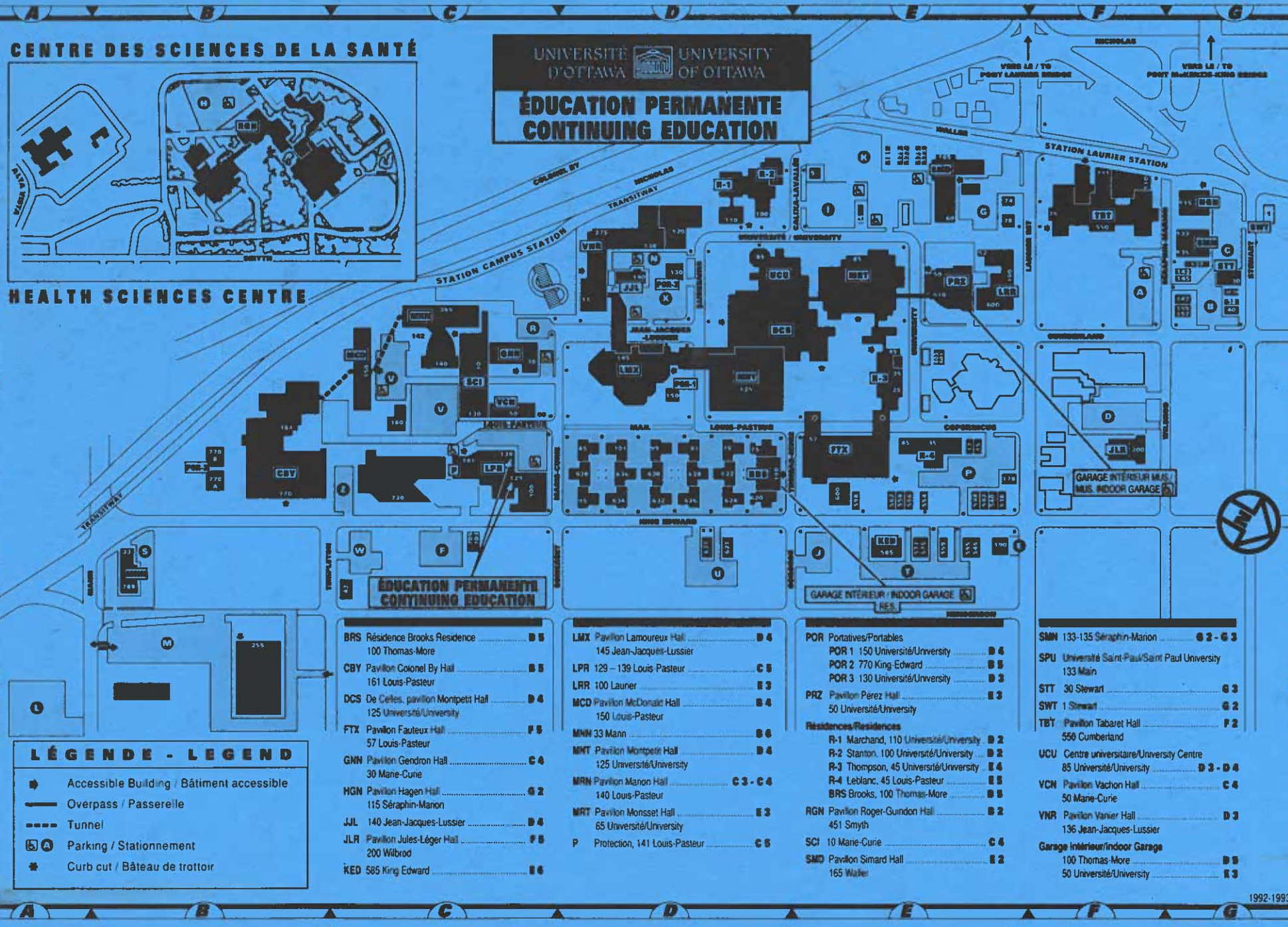
SERAPHIN MARION
QUEEN ELIZABETH DRIVEWAY
Transitway
UNIVERSITE
COPERNICUS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TRANSITWAY
NICHOLAS
COLONEL BY
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LÉGENDE - LEGEND
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Overpass / Passerelle
Tunnel
Parking / Stationnement
Curb cut / Bâteau de trottoir
BRS Résidence Brooks Residence ..... B 5
100 Thomas-More
CBY Pavillon Colonel By Hall ..... B 5
161 Louis-Pasteur
DCS De Celles, pavillon Montpetit Hall ..... B 4
125 Université/University
FTX Pavillon Fauteux Hall ..... F 5
57 Louis-Pasteur
GNN Pavillon Gendron Hall ..... C 4
30 Marie-Curie
HGN Pavillon Hagen Hall ..... G 2
115 Séraphin-Marion
JJL 140 Jean-Jacques-Lussier ..... B 4
JLR Pavillon Jules-Léger Hall ..... F 5
200 Wilbrod
KED 585 King Edward ..... E 6
LMX Pavillon Lamoureux Hall ..... B 4
145 Jean-Jacques-Lussier
LPR 129 – 139 Louis Pasteur ..... C 5
LRR 100 Laurier ..... E 3
MCD Pavillon McDonald Hall ..... B 4
150 Louis-Pasteur
MHN 33 Mann ..... B 6
MNT Pavillon Montpetit Hall ..... B 4
125 Université/University
MRN Pavillon Manon Hall ..... C 3 - C 4
140 Louis-Pasteur
MRT Pavillon Monsset Hall ..... E 3
65 Université/University
P Protection, 141 Louis-Pasteur ..... C 5
POR Portatives/Portables
POR 1 150 Université/University ..... B 4
POR 2 770 King-Edward ..... B 5
POR 3 130 Université/University ..... B 3
PRZ Pavillon Pérez Hall ..... E 3
50 Université/University
Résidences/Residences
R-1 Marchand, 110 Université/University ..... B 2
R-2 Stanton, 100 Université/University ..... B 2
R-3 Thompson, 45 Université/University ..... E 4
R-4 Leblanc, 45 Louis-Pasteur ..... E 5
BRS Brooks, 100 Thomas-More ..... B 5
RGN Pavillon Roger-Guindon Hall ..... B 2
451 Smyth
SCI 10 Marie-Curie ..... C 4
SMD Pavillon Simard Hall ..... E 2
165 Waller
SMN 133-135 Séraphin-Marion ..... G 2 - G 3
SPU Université Saint-Paul/Saint Paul University
133 Main
STT 30 Stewart ..... G 3
SWT 1 Stewart ..... G 2
TBT Pavillon Tabaret Hall ..... F 2
556 Cumberland
UCU Centre universitaire/University Centre
85 Université/University ..... D 3 - D 4
VCN Pavillon Vachon Hall ..... C 4
50 Marie-Curie
VNR Pavillon Vanier Hall ..... D 3
136 Jean-Jacques-Lussier
Garage intérieur/Indoor Garage
100 Thomas-More ..... B 5
50 Université/University ..... E 3
1992-1993