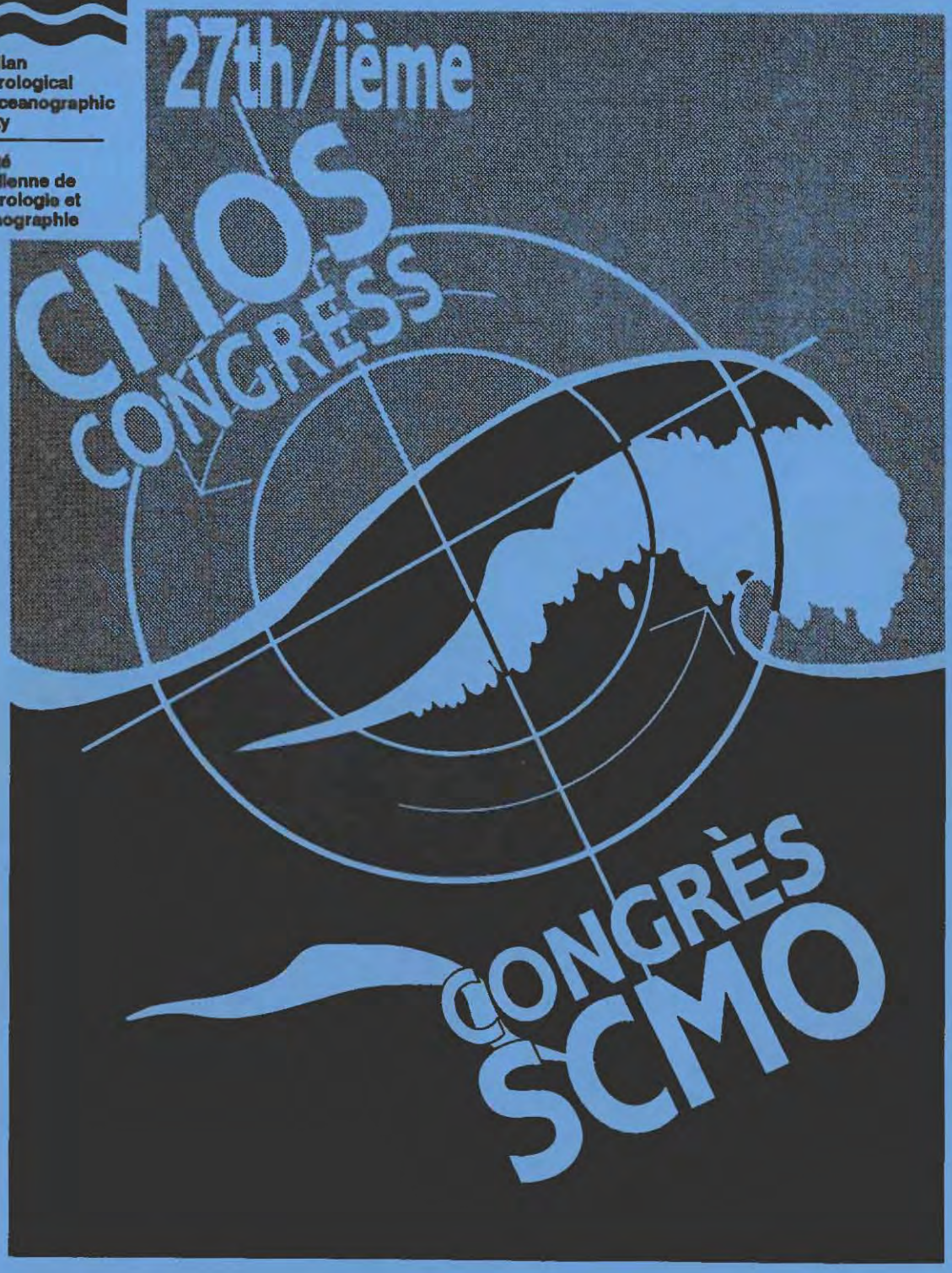
Canadian Meteorological and Oceanographic Society

Société Canadienne de Météorologie et Océanographie



UNIVERSITY OF NEW BRUNSWICK
FREDERICTON, NB CANADA

JUNE 8-11, 1993
8-11 JUIN, 1993

WELCOME TO FREDERICTON AND U.N.B.

The University of New Brunswick welcomes delegates to the 27th Annual CMOS Congress. Here are some notes to help get you familiar with the facilities we will use.

ACCOMMODATION

There is an airport shuttle service to the University and downtown hotels (TRIUS Taxi, cost $6.00). We have a block of rooms at the Lord Beaverbrook Hotel and the Sheraton Inn. UNB is about a 20 minute walk away from the Lord Beaverbrook; turn left on Queen for 1 1/2 blocks, right onto University Avenue and straight ahead to UNB. The Sheraton Inn is a little too far away to walk (≈ $4.50 by taxi).

UNB Residence: Tibbits Hall has been reserved for CMOS delegates. You can register at the Residence Administration Office at any time (open 24 hours a day, 7 days a week). If you are arriving on Monday, someone from the Residence Office will be at the CMOS Registration Desk from 12 noon to 8 pm, and then again on Tuesday morning from 8 am to noon. Visa and Master Card are accepted for residence fees only.

FINDING YOUR WAY AROUND

The buildings we will use are close together, in the west-centre portion of the campus (see map on back cover). Scientific sessions and most committee meetings be in Tilley Hall. We will use rooms 102 and 125 on the ground floor, 205 on the second floor, and 303 on the third. These rooms are on the west side of the building close to a central stairway.

Coffee, posters, exhibits, social events, and some committee meetings are scheduled for the Student Union Building (SUB).

MEALS

Delegates will find the Garden Square Cafeteria in the SUB most convenient for their meals. The Cafeteria is open from 7 am to 11:30 pm, offering full course meals, a short order section, a deli and a bakery.

BIENVENUE À FREDERICTON ET À L'U.N.-B.

L'Université du Nouveau-Brunswick souhaite la bienvenue à tous les délégués (es) du 27 ième congrès annuel du CMOS. Les informations suivantes vous aideront à vous familiarisez avec les facilitées que nous utiliserons.

HEBERGEMENT

Il y a un service de navettes entre l'aéroport, l'université et les hôtels du centre-ville (les taxis TRIUS coûtent ≈ $6.00). Nous avons des chambres de réservées aux hôtels Lord Beaverbrook et le Sheraton Inn. L'université est à environ 20 minutes de marche de l'hôtel Lord Beaverbrook; tourner à gauche sur la rue Queen et suivre cette rue pour un pâté de maison et demie, tourner ensuite à droite sur University Avenue qui vous mènera tout droit à l'université. Le Sheraton Inn est situé un peu trop loin de l'université pour être facilement accessible à pieds (≈$4.50 par taxi).

Résidence de l'U.N.-B.: La résidence Tibbits Hall à été réservée à l'intention des délégués (es) du CMOS. Vous pouvez vous inscrire au bureau d'administration de la résidence en tout temps (ouvert 24 heures par jour, 7 jours par semaine). Une personne du bureau des résidences sera également à votre disposition au bureau d'inscription du CMOS de midi à 20 heures le lundi et de 8 heures à midi le mardi matin. Les cartes de crédit, Visa et Mastercard, seront acceptées uniquement pour payer les frais d'hébergement à la résidence.

COMMENT VOUS RETROUVER

Tous les édifices que nous utiliserons sont situés à proximité les uns des autres dans la portion ouest - centre du campus (se référer à la carte au dos de la couverture). Les présentations scientifiques et la plupart des réunions du comité auront lieu à Tilley Hall. Nous utiliserons la salle 102 et 125 sur le premier étage, la salle 205 sur le deuxième étage et la salle 303 sur le troisième étage. Ces salles sont toutes situées du côté ouest de l'édifice à proximité des escaliers centrals.

Café, affiches murales, évènements sociaux et quelques réunions de comité auront lieu au Student Union Building (SUB).

REPAS

La caféteria le "Garden square" situé au SUB conviendra à la majorité des délégués (es). La cafétéria est ouverte de 7 heures à 23 heures 30. On peut s'y procurer des repas complets et on y retrouve également une section pour des repas légers, une charcuterie et une boulangerie.

Co-Editors: D.A. Daugharty, Faculty of Forestry, University of New Brunswick
and
J.W. Loder, Bedford Institute of Oceanography

Technical Editor: A. Armstrong, Faculty of Forestry, University of New Brunswick

Editorial Assistants: M. Burhoe, Bedford Institute of Oceanography
D. Lewis, Faculty of Forestry, University of New Brunswick
F. Forrester, Faculty of Forestry, University of New Brunswick

1993

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TABLE OF CONTENTS
TABLE DES MATIÈRES

Come to the 28th Annual CMOS Congress
to be held in the beautiful Nation's Capital

Ottawa, Ontario

May 30 to June 3, 1994

Theme -- "Science: addressing the issues"

Scientific Program Committee

Geoff Holland
Telephone: (613) 990-0298
Fax: (613) 990-5510

Local Arrangements Committee

Mike Hawkes
Telephone: (613) 996-3661
Fax: (613) 995-4197

Please contact the Local Arrangements Committee regarding general inquiries and the Scientific Program Committee for special sessions, workshops, etc. Exhibitors, please contact John Falkingham at (613) 996-4552 to reserve your prime floor space.

Rserve your time **NOW** and hope to see you in Ottawa next May during the tulip festival.

Vous êtes invités au 28e Congrès de la SCMO
qui aura lieu dans la magnifique Région de la capitale nationale

Ottawa, Ontario

du 30 mai au 3 juin 1994

Thème -- "Science: des solutions aux problèmes"

Comité du programme scientifique

Geoff Holland
Telephone: (613) 990-0298
Fax: (613) 990-5510

Comité local d'organisation

Mike Hawkes
Telephone: (613) 996-3661
Fax: (613) 995-4197

Prière de contacter le Comité local d'organisation pour les reseignements d'ordre général et le Comité du programme scientifique pour les sessions spéciales et les ateliers de travail, etc. Pour les exhibits, contactez John Falkingham à (613) 996-4552 pour réserver votre place de choix d'exposition.

Inscrivez **MAINTENANT** le Congrès d'Ottawa à votre agenda dans l'espoir de vous voir lors du festival des tulipes d'Ottawa le mois de mai prochain.

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 in Rm 102 start the program each day, and on Thursday afternoon; after these sessions, a five minute break allows delegates to reach the 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 carefully observe the starting and ending times of breaks.The break on 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 the order of presentation of papers. Abstracts for poster papers are included in their appropriate session, and time for an oral précis has been included.

REGISTRATION DESK

The registration desk will be open throughout the Congress, and will function as an information centre after registration is complete. There will be a phone at the desk (453-5091) available for local and credit card calls, and there will be a message board where delegates can leave and receive messages; the message board will also be used to post last minute program changes.

SOCIAL FUNCTIONS

Monday: There will be an informal reception, with refreshments, in the Blue Lounge, starting at 7pm.

Tuesday: The Annual General Meeting will be held in Tilley Rm 125, at 8 pm.

Wednesday: The Patterson Medal, awarded by AES for distinguished service to meteorology in Canada, will be presented at a special luncheon to be held in the SUB Ballroom. Everyone is encouraged to attend: tickets can be purchased at the Registration Desk ($10.00).

The Public Lecture will be one of the most interesting talks you will ever hear. It will be given in Tilley, Rm 102 at 7 pm (abstract on page 3).

Thursday: The banquet will feature Atlantic salmon and fiddleheads (a New Brunswick specialty); reception at 7 pm, dinner at 7:30 in the SUB Ballroom.

QUELQUES INFORMATIONS UTILES AUX PARTICIPANTS

PROGRAMME SCIENTIFIQUE

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

Des sessions plénières dans la salle 102 (Tilley Hall) débutent chaque programme journalier. Une session plénière aura également lieu jeudi après-midi. Après chaque session plénière, une intermission de 5 minutes est planifiée afin de permettre aux délégués (es) de se rendrent aux sessions de leurs choix. 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 demandés (es) de respecter les heures à lesquelles débuteront et se termineront les intermissions. L'intermission de mercredi après-midi durera une heure afin de permettre aux délégués (es) de regarder les affiches murales et de s'entretenir avec leurs auteurs.

Les résumés contenu dans ce programme ont été imprimés d'après l'ordre des présentations. Les résumés pour les affiches murales sont listés dans la session appropriée et du temps pour un compte-rendu oral a été incorporé.

BUREAU D'INSCRIPTION

Le bureau d'inscription sera ouvert pendant toute la durée du congrès et sera utilisé comme centre d'informations dès que les inscriptions seront complétées. Il y aura un téléphone disponible au bureau d'inscription (453-5091) pour les appels locaux et les appels avec cartes de crédit. Il y aura également un tableau pour les messages où les délégués (es) pourront laisser ou reçevoir des messages; ce tableau sera également utilisé pour afficher les changements de programme de dernière minute.

FONCTIONS SOCIALES

Lundi: Il y aura une réception sans cérémonie, avec rafraîchissements, qui débutera à 19 heures dans le salon bleu.

Mardi: La réunion générale annuelle aura lieu dans la salle 125 de Tilley Hall à 20 heures.

Mercredi midi: La médaille Patterson, décernée par SEA pour service distingué à la météorologie au Canada, sera présentée lors d'un dîner special qui aura lieu à la salle de dance du SUB. Tous le monde est encouragé à y assister: les billets pourront être achetés au bureau d'inscription ($10.00).

La lecture publique sera un des plus intéressants discours que vous aurez jamais entendu. Elle sera donnée à Tilley Hall, salle 102 à 17 heures (résumé à la page 3).

Jeudi: Le banquet comprendra entre autres, du saumon de l'Atlantique et des crosses de fougères (une spécialité du Nouveau-Brunswick); la réception aura lieu à 19 heures et le souper débutera à 19 heures 30 dans la salle de dance du SUB.

Wednesday/Mercredi June/Juin 9

PUBLIC LECTURE
CONFÉRENCE PUBLIQUE

Time: 1900 Room/Salle: Tilley 102

THE COMET IMPACT THAT KILLED THE DINOSAURS

Alan R. Hildebrand

Dr. Alan R. Hildebrand graduated from the University of New Brunswick in 1977 with a B.Sc. in Geology. After working in the mineral exploration industry he returned to school at the University of Arizona to earn a Ph.D. in planetary sciences in 1992. Now with the Geological Survey of Canada, Alan is working on impact processes and the Cretaceous/Tertiary (K/T) boundary event. His dissertation work revealed that the K/T crater is buried on the Yucatán Peninsula of Mexico. The crater, which he named Chicxulub (Chick-shoo-loob), is ~ 180 km across and is one of the largest craters known on the Earth. Alan will discuss the clues which lead to the discovery of the Chicxulub crater and how this impact changed the Earth's environment. The atmospheric effects of this impact probably caused the extinction of the dinosaurs and many other forms of terrestrial life. The probability of recurrence of a disaster of this magnitude and lesser (but still deadly) impacts requires a measure of astronomical vigilance.

ACKNOWLEDGEMENTS
REMERCIEMENTS

The Congress organization 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.

Air Canada
Atmospheric Environment Service
Department of Fisheries and Oceans
Forest Protection Limited
University of New Brunswick

INVITED SPEAKERS
CONFÉRENCIERS INVITÉS

E.P.W. Attema, European Space Research and Technology Centre
Remote Sensing/Télédéction (Friday a.m.)

C. Banfield, Memorial University of Newfoundland
Casp II & Cyclones/ Programme Canadien d'Études des Tempétes Atlantique et Cyclones (Tuesday p.m.)

K.H. Brink, Woods Hole Oceanographic Institution
Oceanography of Seamounts/Océanographie des Monts Sous-Marins (Tuesday a.m.)

A.R. Hildebrand, Energy, Mines and Resources Canada
Public Lecture/Conférence Publique (Wednesday p.m.)

J. Imbrie, Brown University
Climate Modelling I - Long Time Scales/Modélisation du Climat I - Échelles sur de Longues Périodes (Tuesday a.m.)

K. Kranck, Bedford Institute of Oceanography (**)

A.J. Kreuger, Goddard Space Flight Center
Ozone and the Ultraviolet/L'Ozone et les Rayons UV (Thursday p.m.)

D.L. Mackas, Institute of Ocean Sciences
Physical-Biological Interactions in the Ocean/Interactions Physiques-Biologiques dans l'Océan (Thursday a.m.)

J. Mills, Atmospheric Environment Service
Modernizing Canada's Weather Service/La Modernisation des Service Météorologiques Canadiens (Thursday a.m.)

A.M. O'Toole, Atmospheric Environment Service
Ozone and the Ultraviolet/L'Ozone et les Rayons UV (Thursday p.m.)

J. Régnière, Forestry Canada
Forest and Agricultural Meteorology/Météorologie Forestière et Agricole (Wednesday a.m.)

B. Saltzman, Yale University
Climate Modelling I - Long Time Scales/Modélisdation du Climat I - Échelles sur de Longues Périodes (Tuesday a.m.)

L.D. Talley, Scripps Institute of Oceanography (*)
World Ocean Circulation Experiment - Expérience Concernant la Circulation Océanique Mondiale) (Wednesday p.m.)

D.W.R. Wallace, Brookhaven National Laboratory
Physical-Biological Interactions in the Ocean/Interactions Physiques-Biologiques dans l'Océan (Thursday a.m.)

E.F. Wood, Princeton University
Hydrologic Cycle I - Land Processes & Hydrologic Modelling/Cycle Hydrologique I Processus Terriens et Modélisation Hydrologique (Thursday a.m.)

(*) Sponsored by the Canadian National Committee of WOCE
(**) Sadly, Kate Kranck passed away on March 30, 1993

SCIENTIFIC PROGRAM COMMITTEE
COMITÉ DU PROGRAMME SCIENTIFIQUE

Chairman/Président
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D. Wortman,, Atmospheric Environment Service, Fredericton

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T.S. Murty, Institute of Ocean Sciences
D.G. Wright, Bedford Institue of Oceanography

EXHIBITORS
EXPOSANTS

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Enterprise Electronics Corp., Montreal, Quebec
Guildline Instruments, Smith Falls, Ontario
Seimac Limited, Dartmouth, Nova Scotia

CMOS COMMITTEE MEETINGS
RÉUNIONS DES COMITÉS DE LA SCMO

Committee/Comité	Day/ Jour	Time/ Heure	Room/ Salle	Building/ Pavillon
Climatological Bulletin/Bulletin Climatologique	Monday/ Lundi	1000	205	Tilley
Scientific/Scientifique	Monday/ Lundi	1000	303	Tilley
Accreditation/Accrédiation	Monday/ Lundi	1100	103	SUB
WOCE/ECOM	Monday/ Lundi	1100	125	Tilley
Education/Éducation	Monday/ Lundi	1400	205	Tilley
Editorial Board/Conseil du Rédaction	Monday/ Lundi	1500	103	SUB
Centre Chairs/Présidents des Centres	Monday/ Lundi	1600	303	Tilley
CMOS Executive Meeting/SCMO Conseil d'Administration	Monday/ Lundi	1600-1800 2000-	103	SUB
Annual General Meeting/Assemblée Générale Annuelle	Tuesday/ Mardi	2000	125	Tilley
CASP II/PCETA II	Wednesday/ Mercredi	2000	125	Tilley
Fisheries Oceanography/Océanog. des Pêches	Thursday/ Jeudi	1210	125	Tilley
Hydrology/Hydrologie	Thursday/ Jeudi	1630	303	Tilley

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
	JUNE 7	JUNE 8	JUNE 9	JUNE 10	JUNE 11
7:30 -		REGISTRATION			
0800-0835					REMOTE PLENARY
0820-0855			FOR. & AG. MET. PLENARY	PHYS.-BIOL. PLENARY	
0830-0845		OPENING			
0840-1020					REMOTE HYD. IV OZONE COASTAL OC.
0845-0955		CLIM. MODEL. PLENARY			
0900-1020			CLIM. MODEL. III FOR. & AG. MET. ATM. DYN. OC. SFCE WAVES	PHYS-BIOL WOCE MOD. WEA. SERV. HYD. I	
0955-1025		BREAK			
1020-1040					BREAK
1020-1050			BREAK	BREAK	
1025-1210		CLIM. MODEL. I CASP & CYC. SEAMOUNTS AEROS. & RAD.			
1040-1220					REMOTE CLOUD PHYS. OC. MIXING
1050-1210			CLIM. MODEL. III FOR. & AG. MET. ATM. DYN. COASTAL OC.	PHYS-BIOL MOD. WEA. SERV. HYD. I TRACERS	
1200 -	REGISTRATION				
1210-1340		LUNCH		LUNCH	
1210-1340			PATTERSON LUNCHEON		
1340-1415				OZONE PLENARY	
1340-1520		CLIM. MOD. II CASP & CYC. SEAMOUNTS PBL			
1340-1500			FOR. & AG. MET. HAZARDS ATM. MODEL. WOCE		
1420-1520				OZONE HYD. II MESO/TROP MET. CLIMATOLOGY	
1520-1550		BREAK		BREAK	
1500-1600			POSTER BREAK		
1550-1730		CLIM. MOD. II CASP & CYC. PBL TOPO. OC.			
1600-1740			HYD/MET FOR-AG HAZARDS ATM. MODEL. WOCE		
1550-1730				OZONE HYD. III MESO/TROP MET. COASTAL OC.	
	COMMITTEE MEETINGS				
	POSTER AND EXHIBITORS SET-UP TIME				
1900	ICE BREAKER	2000 ANN. GEN. MTG.	1900 PUBLIC LECTURE	1900 BANQUET	

Aeros. & Rad. - Aerosols and Radiation
Atm. Dyn. - Atmospheric Dynamics
Atm. Model. - Atmospheric Modelling
CASP & CYC. - Canadian Atlantic Storms Program II and Cyclones
Clim. Model. I - Long Time Scales
Clim. Model. II - Models and Observations
Clim. Model. III - Sea Ice
Climatology - Climatology and Impacts
Cloud Phys. - Cloud Physics and Chemistry
Coastal Oc. - Coastal Oceans
For & Ag. Met. - Forest and Agricultural Meteorology
Hazards
Hyd/Met. For-Ag. - Joint Session: Hydrology/Forest & Agricultural Meteorology
Hyd. I - Land Processes and Hydrologic Modelling
Hyd. II - Hydrologic Applications of Remote Sensing
Hyd. III - Hydrometeorological Processes
Hyd. IV - Variability in Hydrometeorological Patterns
Meso/Trop Met. - Mesoscale and Tropical Meteorology
Mod. Wea. Serv. - Modernizing Canada's Weather Services
Currents
Oc. Mixing - Ocean Mixing
Oc. Sfce Waves - Ocean Surface Waves
Ozone - Ozone and the Ultraviolet
PBL - Planetary Boundary Layer
Phys.-Biol. - Physical-Biological Interactions in the Ocean
Remote - Remote Sensing
Seamounts - Oceanography of Seamounts
Topo. Oc. - Topographic Influences on Ocean Currents
Tracers - Tracers in the Ocean
WOCE - World Ocean Circulation Experiment

LUNDI	MARDI	MERCREDI	JEUDI	VENDREDI
7 JUIN	8 JUIN	9 JUIN	10 JUIN	11 JUIN
	0730 - INSCRIPTION			
	0830-0845 BIENVENUE	0820-0855 PLÉNIÈRE MÉT. FOR. et AG.	0820-0855 PLÉNIÈRE INT. PHYS.-BIO.	0800-0835 PLÉNIÈRE TÉLÉDÉTECTION
	0845-0955 PLÉNIÈRE MODÉLISATION DU CLIMAT	0900-1020 MODÉL. CLIM. III MÉT. FOR. et AG. DYNAM. ATMOS. OC. CÔTIER	0900-1020 INT. PHYS.-BIO. ECOM MOD. SERV. MÉT. HYD. I	0840-1020 TÉLÉDÉTECTION HYD. IV OZONE OC. CÔTIER
	0955-1025 PAUSE	1020-1050 PAUSE	1020-1050 PAUSE	1020-1040 PAUSE
	1025-1210 MODÉL. CLIM. I PCETA et CYC. MONTS MARIN AÉROS. et RAY.	1050-1210 MODÉL. CLIM. III MÉT. FOR. et AG. DYNAM. ATMOS. ONDES SUP.	1050-1210 INT. PHYS.-BIO. MOD. SERV. MÉT. HYD. I TRACEURS	1040-1220 TÉLÉDÉTECTION PHY.CHIM. NUAG. MÉLANGE OC.
1200 - INSCRIPTION RÉUNIONS DES COMITÉS TEMPS DE MISE EN PLACE POUR EXPOSANTS	1210-1340 DÉJEUNER	1210-1340 DÉJEUNER PATTERSON	1210-1340 DÉJEUNER 1340-1415 PLÉNIÈRE OZONE	
	1340-1520 MODÉL. CLIM. II PCETA et CYC. MONTS MARIN C.L.P.	1340-1500 MÉT. FOR. et AG. PHÉN. DANGER. MODÉL. ATMOS. ECOM	1420-1520 OZONE HYD.II MÉT. MÉSO/TROP. CLIMAT et INCID.	
	1520-1550 PAUSE	1500-1600 AFFICHAGES	1520-1550 PAUSE	
	1550-1730 MODEL. CLIM. II PCETA et CYC. C.L.P. COUR. OC	1600-1740 HYD./MÉT. PHÉN. DANGER. MODÉL. ATMOS. ECOM	1550-1730 OZONE HYD.III MÉT. MÉSO/TROP. OC. CÔTIER	
1900 RÉCEPTION	2000 ASS. GÉN. ANN.	1900 CONF. PUBLIQUE	1900 BANQUET	

Aéros. et Ray. - Aérosols et Rayonnement
C.L.P. - Couche limite planétaire
Cour. Oc. - Influence topographique sur les courants océaniques
Dynam. Atmos. - Dynamique de l'atmosphère
Ecom - Éxperience concernant la circulation océanique mondiale
Hyd.I - Processus terriens et Modélisation hydrologique
Hyd. II - Applications hydrologiques de la télédétection
Hyd. III - Processus hydrométéorologiques
Hyd. IV - Variabilité des configurations hydrométéorologiques
Hyd./Mét. - Session conjoint: Hydrologie et Météorologie forestière et agricole
Int. Phys.-Bio. - Interactions physiques-biologiques dans l'océan
Mélange oc. - Mélange océanique
Mét. For. et Ag. - Météorologie forestière et agricole
Mét. Méso/Trop- Météorologie a la mésoéchelle et tropicale

Modél. Atmos. - Modélisation de l'atmosphère
Modél. Clim. I - Échelles sur de longues périodes
Modél. Clim. II - Modèles et Observations
Modél. Clim. III - Glace de mer
Mod. Serv. Mét. - La modernisation des services météorologiques canadiens
Monts Marins - Océanographie des monts sous-marins
Oc. Côtier - Océan côtier
Ondes Sup. - Ondes supérieures de l'océan
Ozone - L'ozone et les rayons UV
PCETA et CYC. - Programme canadien d'études des tempêtes atlantique II et Cyclones
Phén DANGER. - Les phénomènes dangereux au Canada
Phy. Chim. Nuag. - Physique et chimie des nuages
Télédétection
Traceurs - Les traceurs dans l'océan

0830-0845	WELCOMING REMARKS / MOTS DE BIENVENUE			
0845-0920 0920-0955	**PLENARY SESSION / SESSION PLÉNIÈRE** **CLIMATE MODELLING I - LONG TIME SCALES / MODÉLISATION DU CLIMAT I - ÉCHELLES SUR DE LONGUES PÉRIODES** **RM / SALLE 102** Geological perspectives on modern climate. J. Imbrie *(Invited)* A dynamical theory of the ice ages. B. Saltzman *(Invited)*			
0955-1025	HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE			
	CLIMATE MODELLING I - LONG TIME SCALES **MODÉLISATION DU CLIMAT I - ÉCHELLES SUR DE LONQUES PÉRIODES** **RM / SALLE 102**	**OCEANOGRAPHY OF SEAMOUNTS** **OCÉANOGRAPHIE DES MONTS SOUS-MARINS** **RM / SALLE 125**	**AEROSOLS AND RADIATION** **AÉROSOLS ET RAYONNEMENT** **RM / SALLE 205**	**CASP II & CYCLONES** **PROGRAMME CANADIEN D'ÉTUDES DES TEMPÊTES ATLANTIQUES II ET CYCLONES** **RM / SALLE 303**
	Chair/Président: D.G. Wright	Chair/Président: K. Juniper	Chair/Président: J.P. Blanchet	Chair/Président: O. Hertzman
1025-1045	Relationships between climate and ocean magnetism and the potential for using geomagnetic data as proxy for river discharge into the Arctic. R. H. Tyler and L.A. Mysak	The Fieberling Guyot program. K.H. Brink *(Invited)*	Direct radiative effects of aerosols in the lower atmosphere based on aircraft measurements. L. Moreau and H.G. Leighton	Doppler radar observations of a warm front. D.R. Hudak, R.E. Stewart, A.D. Thomson and R. List
1045-1105	Ocean circulation changes during Youger Dryas: evidence from modelling and data. D.G. Wright, T.F. Stocker and S. Lehman		Climatic effects of high volcanic aerosal loading. J. Jiang and W.F.J. Evans	Horizontal and tilting melting layers in CASP II storms. R.E. Stewart, R.W. Crawford and K.K. Szeto
1105-1125	Atmospheric radiocarbon as a measure for transient changes of the ocean's thermohaline circulation. T.F. Stocker, D.G. Wright and W.S. Broecker	Why is the top of Cobb Seamount such a popular place to live? V. Tunnicliffe and T. Parker	Response of the CCC third generation GCM to trpospheric aerosol. H.W. Barker and M. Lazare	On the development of freezing temperatures in Newfoundland. J.W. Strapp, R.A. Stuart and G.A. Isaac
1125-1145	Multiple equilibria of an asymmetric two-basin ocean model. T.M.C. Hughes and A.J. Weaver	Ocean circulation at and near a shallow seamount in the N.E. Pacific Ocean. H.J. Freeland	Assessment of the radiative and climatic effects of large smoke injections into the lower atmosphere. R.K.R. Vupputuri, J.P. Blanchet and K. Higuchi	Aircraft icing potential of East Coast winter storms. S. Cober, G. Isaac, J.W. Strapp and M. Patnoe
1145-1210	POSTER PRECISES: #'s 1, 2, 3	Relationship between phytoplankton production and the physical structure of the water column near Cobb Seamount, northeast Pacific. L. Comeau and A.F. Vézina	Model simulated cloud micro physics - radiation interaction in Arctic air mass formation. E. Girard and J.P. Blanchet	CASP II: Mesonet sampling in IOP 4 - the great freezing rain event. O. Hertzman
1210-1340	LUNCH / DÉJEUNER			

	CLIMATE MODELLING II MODELS & OBSERVATIONS MODÉLISATION DU CLIMAT II MODÈLES ET OBSERVATIONS RM / SALLE 102	OCEANOGRAPHY OF SEAMOUNTS OCÉANOGRAPHIE DES MONTS SOUS-MARIN RM / SALLE 125	PLANETARY BOUNDARY LAYER COUCHE LIMITE PLANÉTAIRE RM / SALLE 205	CASP II & CYCLONES PROGRAMME CANADIEN D'ÉTUDES DES TEMPÊTES ATLANTIQUE ET CYCLONES RM / SALLE 303
	Chair/Président: A.J. Weaver	Chair/Président: K. Juniper	Chair/Président: Y. Delage	Chair/Président: O. Hertzman
1340-1400	On the qualitative behaviour and non-oscillation of Stommel's thermohaline box model. L-Q. Zhang and B. Ruddick	Amplified currents at Cobb Seamount. D. Codiga and C.C. Eriksen	Turbulent boundary-layer flow over idealized topography: wind tunnel, high-order closure and LES studies. W. Gong, A Dornbrack, P.A. Taylor, K.W. Ayotte and D. Xu	Assessing the orographic component of surface precipitation over upland coastal areas. C. Banfield *(Invited)*
1400-1420	Convective adjustment and isopycnal mixing in an ocean general circulation model. W.A. Gough	Physical-biological coupling and control of phytoplankton growth at Cobb Seamount: an ecosystem approach. J.F. Dower	Large-scale simulation of the convective boundary layer over an inhomogeneous surface. S. Shen and M.Y. Leclerc	
1420-1440	A new approach in regional climate modelling: description of a thermodynamic, diagnostic and semi-prognostic numerical model: FIZR. S. Goyette and R. Laprisé	Perturbations physiques associées au mont sous-marin Cobb: impact sur le fonctionnement de la boucle microbienne. M. Bourgeois	Measuring vorticity in the surface layer: why bother? a new sensor, preliminary results? J. Wilson	Airborne surveys of the planetary boundary layer above the marginal ice zone. P. C. Smith and J.I. McPherson
1435-1455	On the différences between early and late winter atmospheric repsonse to the sea surface temperature anomolies in the northwest Atlantic. S. Peng, L.A. Mysak, H. Ritchie, J. Derome and B. Dugas	Turbulence measurements around Cobb Seamount. T. D. Mudge and R. Lueck	An investigation of flux-variance methods and universal functions applied to three land-use types in unstable conditions. J. Padro	Effects of winter storms on sea-ice over the Newfoundland Shelf. C.L. Tang
1455-1515	A C-grid ocean general circulation model. W. Xu, C. Lin and A. Robert	An investigation of Lagrangian eddy formation over seamounts. J. Shore		Verification of 3, 4 and 5-day prognostic charts during CASP II. A.G. Earle
1515-1545	HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE			
		TOPO. INFLUENCE ON OC. CURRENTS INFLUENCE TOPOGRAPHIQUE SUR LES COURANTS OCÉANIQUES		
		Chair/Président: M.W. Stacey		Chair/Président: R.E. Stewart
1545-1605	Temperature trends at coastal stations on the periphery of the North Atlantic Ocean. M.R. Morgan, R. Pocklington and K. Drinkwater	Steady drift generated over mid-ocean ridges by oscillatory flow. S. Allen and D. Renouard	A model of stable, two-dimensional atmospheric boundary-layer flow over fixed, sinusoidal topography. L. Chan	A numerical model investigation of an explosively deepening winter storm during IOP4 of CASP II. Z. Huo, D.-L. Zhang, J. Gyakum and A. Staniforth
1605-1625	An evaluation of the potential impact of methane calthrate destabilization on future global warming. L.D.D. Harvey and Z. Huang	Perturbations of canyons on shelf currents and some properties of canyon waves. S. Chen	Modelling the diurnal temperature range in the planetary boundary layer. B. Crenna	Diagnosing surface development of extratropical cyclones: the impact of height of diabatic heating. J. St. James and P. Zwack
1625-1645	Greenhouse warming prediction by a simple energy balance climate model. K. Szilder and E.P. Lozowski	An acoustic Doppler current profiler estimate of the internal tide in Knight inlet, British Columbia. R. F. Marsden and K.C. Greenwood	A model for the correction of surface wind data for sheltering by upwind obstacles. P.A. Taylor and J.R. Salmon	Étude diagnostique d'une simulation d'un developpement cotier maritime a l'aide de l'equation de Zwack-Okossi. S. Desjardins and P. Zwack
1645-1705	Global upwelling - interannual variability and climate change. L. Xie and W.W. Hsieh	Numerical simulations of stratified tidal flow across Georges Bank: internal wave generation. K.G. Lamb	Drag parameterization and effective roughness lengths for complex terrain. D. Xu, K.W. Ayotte and P.A. Taylor	Satellite observations of precipitating sratocumulus clouds. P. Austin and R. Pincus
1705-1725		Internal solitions in the Canadian Archipelago. R.F. Marsden, R. G. Ingram and L. Legendre		The use of TOMS data in the study of mesoscale polar vortices. M.C. Reader and G.W.K. Moore
2000	ANNUAL GENERAL MEETING/ASSEMBLÉE GÉNÉRALE ANNUELLE RM/SALLE 125			

0820-0855	**PLENARY SESSION / SESSION PLÉNIÈRE** **FOREST AND AGRICULTURAL METEOROLOGY / MÉTÉOROLOGIE FORESTIÈRE ET AGICOLE** **RM / SALLE 102** BioSIM: A computer-based decision support tool for seasonal planning of pest management activities. J. Régnière *(Invited)*			
	FOREST & AGRICULTURAL METEOROLOGY **MÉTÉOROLOGIE FORESTIÈRE ET AGICOLE** **RM / SALLE 102**	**OCEAN SURFACE WAVES** **ONDES SUPÉRIEURES DE L' OCÉAN** **RM / SALLE 125**	**CLIMATE MODELLING III** **SEA ICE** **MODÉLISATION DU CLIMAT III** **GLACE DE MER** **RM / SALLE 205**	**ATMOSPHERIC DYNAMICS** **DYNAMIQUE DE L' ATMOSPHÈRE** **RM / SALLE 303**
	Chair/Président: R.B.B. Dickison	Chair/Président: F.W. Dobson	Chair/Président: L.A. Mysak	Chair/Président: H.-R. Cho
0900-0920	Climatic teleconnections from the Pacific Ocean to the Canadian prairies - implications for spring wheat yields. E.R. Garnett, J. Babb and M.L. Khandekar	Wave energy input into water waves. P.Y. Lin and D. Xu	Interannual variability of Arctic sea ice using a coupled sea ice-ocean model. D.M. Holland, L.A. Mysak and J.M. Oberhuber	Thermal forcing of slow transients by the synoptic scale eddies in the atmosphere. H. Lin and J. Derome
0920-0940	Evaluation aérienne et prévision des indices Canadiens forêt-météo. L. Pouliot	The performance of the Canadian spectral ocean wave model CSOWM. M. Khandekar and R. Lalbeharry	A box model of the Greenland Sea, Norwegian Sea and Arctic Ocean. D.Y. Robitaille and L.A. Mysak	On the interactions between synoptic scale eddies and the PNA teleconnection pattern. M. Klasa, J. Derome and J. Sheng
0940-1000	Comparison of pesticide spray deposition model results with operational measurements. T.C. Farrell and B.L. Beattie	Wind stress from wave slopes using Phillips' equilibrium theory. B.-A. Juszko, R.F. Marsden and S.R. Waddell	Modelling interannual ice variability in the Gulf of St. Lawrence. B. DeTracey and R.G. Ingram	Potential vorticity dynamics in an atmospheric GCM. J. Koshyk
1000-1020	POSTER PRECISES: #'s 4, 5	Sensitivity study of an interactive graphical wind and wave analysis system. B. Dawson	Simulation of the Arctic ice cover using a multi-level model. G.M. Flato	Leaky modons. G.E. Swaters
1020-1050	**HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE**			
		COASTAL OCEAN **OCÉAN CÔTIER**		
		Chair/Président: P.C. Smith		
1050-1110	Modelling the spatial variations of wind velocity and wet deposition of acidic ions on Roundtop Mountain, Quebec. J.L. Walmsley, H.A. Bridgman and R.S. Schemenauer	Rotation-limited-flux: application to Hecate Strait, British Columbia. C.G. Hannah and W.R. Crawford	The relationship between large scale circulation and the climate at Resolute Bay, NWT. T. Agnew, J. Knox and A. Silis	General circulation modeling of stratospheric interannual variability. K.P. Hamilton
1110-1130	Calculating total annual amounts of SO2 absorbed by spruce forests in the vicinity of an elevated SO2 source. C.P.-A. Bourque and P.A. Arp	A diagnostic, variable-resolution model for the tidal and estuarine circulation in eastern Juan de Fuca Strait and the southern Strait of Georgia. M.G.G. Foreman, R.F. Henry and R.A. Walters	Stochastic excitation of decadal variability in the Greenland Sea ice cover. G.M. Flato and G. Holloway	Daily radiative entropy variations from the Earth Radiation Budget Experiment. G.B. Lesins and H. Jiang
1130-1150	Analysis of levels of gas pollutants and dry depositions at a forest research site near Quebec City: 1988-1991. A. Robichaud	Outflow at Cape St. James in Hecate Strait, British Columbia. W.R. Crawford and M.M. Foreman	The parameterization of the conductive heat flow through a seasonal snow and sea ice volume. T.N. Papakyriakou, D.G. Barber and E.F. LeDrew	Forecasting polar lows in the Labrador Sea. D. Hanley and O. Hertzman
1150-1210	Smoke ventilation forecast at Pacific Weather Centre: accuracy and climatology. B. Snyder	The influence of wind and Scotian Shelf inflow on the circulation around Georges Bank. D.A. Greenberg, J.W. Loder and Y. Shen POSTER PRECIS (1205-1210): # 8	POSTER PRECISES: #'s 6, 7	Momentum budget for atmospheric orographic flows using observations of the PYREX field experiment. R. Benoit
1210-1340	**PATTERSON LUNCHEON / DÉJEUNER PATTERSON**			

	WORLD OCEAN CIRCULATION EXPERIMENT EXPÉRIENCE CONCERNANT LA CIRCULATION OCÉANIQUE MONDIALE (ECOM) RM / SALLE 102	ATMOSPHERIC MODELLING MODÉLISATION DE L' ATMOSPHÈRE RM / SALLE 125	FOREST & AGRICULTURAL METEOROLOGY MÉTÉOROLOGIE FORESTIÈRE ET AGRICOLE RM / SALLE 205	HAZARDS LES PHÉNOMÈNES DANGEREUX RM / SALLE 303
	Chair/Président: B.R. Ruddick	Chair/Président: R. Benoit	Chair/Président: R.B.B. Dickison	Chair/Président: T.S. Murty
1340-1400	Deep and intermediate circulation in the tropical Pacific - WOCE observations. L.D. Talley *(Invited)*	Reducing the Gaussian grid in spectral forecast models: advantages and impact on weather forecasting. E. Yakimiw and H. Ritchie	A candidate joint velocity probability distribution function for canopy turbulence. S. Du and J. Wilson	Canadian hazards from wind: assessing and reducing the risks. A.G. Davenport
1400-1420		Meteorological performance of higher resolution versions of the Canadian global spectral forecast model. H. Ritchie, C. Beaudoin and M. Tanguay	Analysis of turbulent structures above a forest canopy using the wavelet transform. B.J. Turner and M.Y. Leclerc	The International Decade for Natural Disaster Reduction - a progress report. J.P. Bruce
1420-1440	The effect of thermodynamic sea ice on the stability and variability of the thermohaline circulation. S. Zhang, C.A. Lin and R.J. Greatbatch	Global balance of the heat and moisture budgets in the Canadian Spectral Model. C. Girard and B. Bilodeau	Pressure fluctuations and coherent motions inside a forest. Y. Zhuang	Environment Canada's approach to the IDNDR. A. Szlazak
1440-1500	Development of a global steady-state finite-element barotropic model. P.G. Myers and A.J. Weaver	POSTER PRECISES: #'s 9, 10	An algorithm for predicting fog water input in the Maritime Provinces. X. Yin and P.A. Arp	Recent progress in the identification, classification and forecasting of summer severe weather. P. Joe *et al.*
1500-1600	HEALTH/POSTER BREAK / PAUSE SANTÉ/SEANCE D' AFFICHAGE BLUE LOUNGE			
			Hydrology/Forest & Agricultural Meteorology Hydrologie et Météorologie Forestière et Agricole	
		Chair/Président: H. Ritchie	Chair/Président: R. Soulis	
1600-1620	The steric component of sea level rise associated with enhanced greenhouse warming: a model study. K. Bryan and W.W. Hsieh	A compressible multi-scale modelling tool for the Canadian atmospheric research community: the MC2 model. R. Benoit, R. Laprise, Y. Chartier, M. Desgagné and M. Giguère	The response of the land surface heat and moisture balance to small-scale temperature and wetness inhomogeneity. Y. Guo and P.H. Schuepp	Oil spill: a major threat to the marine environment. M. El-Sabh
1620-1640	The mean circulation in the western North Atlantic diagnosed by the Mellor *et al* method. T.H. Reynaud, A.J. Weaver and R.J. Greatbatch	An intercomparison of CMC, ECMWF, and NMC operational analyses. S.J. Lambert	A comparison between summertime and wintertime eddy fluxes and profiles over and within a deciduous forest in southern Ontario. H.H. Neumann and G. denHartog	Oil spill modelling: a review of major oil spills in Canadian coastal waters. S. Venkatesh
1640-1700	Intense currents in the deep north-east Pacific Ocean. H.J. Freeland	The regional forecast system at CMC: implementation of a higher resolution version. A. Méthot and R. Hogue	On the need to determine local scale variations in evaporation rates. W.J. Stolte	The tsunami from the 1917 explosion in Halifax Harbour. D.A. Greenberg, T.S. Murty, A. Ruffman
1700-1720	Semi-Langrangian solutions to the three-dimensional advective-diffusion equation. S.K. Das	A numerical study of winter frontal precipitation systems. K.K. Szeto and R.E. Stewart	Modelling studies of gas fluxes from lakes and ponds. J. Kwan and P.A. Taylor	A severe thunderstorm climatology for Alberta. B.J. Paruk and S.R. Blackwell
1720-1740	The equatorial Kelvin wave in finite-difference models. M.K.F. Ng and W.W. Hsieh	Large scale transport studies: a radon and lead experiment. S.R. Beagley, J. de Grandpré, J.C. McConnell, N. McFarlane and R. Laprise		Panel Discussion
1900	PUBLIC LECTURE/CONFÉRENCE PUBLIQUE RM / SALLE 102			

0820-0855	**PLENARY SESSION / SESSION PLÉNIÈRE** **PHYSICAL-BIOLOGICAL INTERACTIONS IN THE OCEAN / INTERACTIONS PHYSIQUES-BIOLOGIQUES DANS L'OCÉAN** **RM 102** Physics-biology interactions: roles of mesoscale and small scale motions in plankton ecology. D.L. Mackas *(Invited)*			
	HYDROLOGIC CYCLE I **LAND PROCESSES & HYDROLOGIC MODELLING** **CYCLE HYDROLOGIQUE I** **PROCESSUS TERRIENS ET MODÉLISATION HYDROLOGIQUE** **RM / SALLE 102**	**PHYSICAL-BIOLOGICAL INTERACTIONS IN THE OCEAN** **INTERACTIONS PHYSIQUES-BIOLOGIQUES DANS L'OCÉAN** **RM / SALLE 125**	**WORLD OCEAN CIRCULATION EXPERIMENT** **EXPÉRIENCE CONCERNANT LA CIRCULATION OCÉANIQUE MONDIALE** **RM / SALLE 205**	**MODERNIZING CANADA'S WEATHER SERVICE** **LA MODERNISATION DES SERVICES MÉTÉOROLOGIQUES CANADIENS** **RM / SALLE 303**
	Chair/Président: R.G. Lawford	Chair/Président: F.H. Page	Chair/Président: W.W. Hsieh	Chairs/Présidents: F. MacNeill & K. MacDonald
0900-0920	Large-scale hydrologic modeling. E. Wood *(Invited)*	Juvenile Atlantic cod in the northern Gulf of St. Lawrence, Canada. R.G. Bradford and J.A. Gagné	Comparison of OSCURS model output to WOCE surface drifter tracks in the Northeast Pacific. G. Bakker, P.H. LeBlond and J. Ingraham Jr.	A foundation for the future. J. Mills *(Invited)*
0920-0940		The ontogeny of scallop life history stages in relation to the physical environment in the Quoddy region. S.M.C. Robinson and F.H. Page	Convection from an isolated source in a rotating stratified fluid. D. Brickman and D.E. Kelley	Modernization of weather services in New Brunswick. R. Lefebvre
0940-1000	Using the Canadian Land Surface Scheme (CLASS) in the CMC global forecast model. Y. Delage	Modelling the dispersal of sea scallop larvae on Georges Bank in autumn: the effects of mean advection, behaviour and larval origin. M.J. Tremblay, J.W. Loder, F.E. Werner, C.E. Naimie, D.R. Lynch, M.M. Sinclair and F.H. Page	The North Atlantic Tracer Release Experiment: a summary of the field program. N. Oakey, B. Ruddick, J. Burke and D. Walsh	Aviation terminal forecasts based on automated observations (FTAUTO). J. Anderson and B. Shannon
1000-1020	Stand-alone comparisons of land surface schemes. D. Verseghy	Computer simulations of the influence of ocean currents on the return migrations of Fraser River sockeye salmon: 1950-1990. K.A. Thomson, W.J. Ingraham, W.J. Healey, P.H. LeBlond, C. Groot, C.G. Healey and S.M. Hanlon-Thomson	A first look at microstructure measurements from the North Atlantic Tracer Release Experiment. J. Burke, B. Ruddick and N. Oakey	FTGEN - an automated FT production system. B. Whiffen
1020-1050	**HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE**			
			TRACERS IN THE OCEAN **LES TRACEURS DANS L'OCÉAN**	
	Chair/Président: D. Verseghy		Chair/Président: E.P. Jones	
1050-1110	Hydrological cycle in simple atmosphere-ocean models. D. Mercer	Seasonal and interannual variability of phytoplankton pigment concentrations in four eastern boundary current regions. A. Thomas, P.T. Strub, S. Lévesque, C. James	A suite of anthropogenic halocarbon tracer measurements in the Greenland and Norwegian Seas. D.W.R. Wallace, P. Schlosser, J. Bullister and J. Blindheim *(Invited)*	Transport Canada proposed R&D activities on atmospheric sensors and their integration for aviation meteorology. G. Fournier
1110-1130	An examination of the surface energy and water budgets of the CCC climate model. G.A. McBean and R.A.S. Hourston	Sources of variability in phytoplankton crop composition in spring. L.A. Hobson and V.A. Funk	POSTER PRECISES: #'s 13, 14	A knowledge base system to analyze and synthesize large amounts of meteorological data. R. Verret, G. Babin, D. Vigneux and R. Parent
1130-1150	Application of the U.B.C. watershed model to two climatically different watersheds. M.C. Quick, A. Loukas, R. Millar, D. Nixon and E. Wu	Overview of scientific progress of the Ocean Production Enhancement Network. P. LeBlond	Modification of halocline source waters during freezing on the Beaufort Sea shelf: evidence from oxygen isotopes and dissolved nutrients. H. Melling and R.M. Moore	The Significant Event Desk. P. Chadwick
1150-1210	Global Energy and Water Cycle Experiment (GEWEX). T. Krauss, R. Lawford and W. Nicholaichuk	POSTER PRECISES: #'s 11, 12	Atlantic water in the Arctic Ocean. B. Rudels, E.P. Jones and L.G. Anderson	A workstation for the AES Weather Service Office environment. K. Macdonald, D. Dueck, N. McLennan, M. Schaffer and A. MacAfee POSTER PRECISES (1200-1210): #'s 15, 16
1210-1340	**LUNCH / DÉJEUNER**			

1340-1415	**PLENARY SESSION / SESSION PLÉNIÈRE** **OZONE AND THE ULTRAVIOLET / L'OZONE ET LES RAYONS UV** **RM / SALLE 102** Total ozone changes since the eruption of Mount Pinatubo. A. Kreuger *(Invited)*			
	OZONE AND THE ULTRAVIOLET **L'OZONE ET LES RAYONS UV** **RM / SALLE 102**	**MESOSCALE AND TROPICAL METEOROLOGY** **MÉTÉOROLOGIE À LA MÉSOÉCHELLE ET TROPICALE** **RM / SALLE 125**	**CLIMATOLOGY AND IMPACTS** **CLIMATOLOGIE ET INCIDENCES** **RM / SALLE 205**	**HYDROLOGIC CYCLE II** **HYDROLOGIC APPLICATIONS OF REMOTE SENSING** **CYCLE HYDROLOGIQUE II** **APPLICATIONS HYDROLOGIQUES DE LA TÉLÉDÉTECTION** **RM / SALLE 303**
	Chair/Président: W.F.J. Evans	Chair/Président: G.B. Lesins	Chair/Président: R. Lefebvre	Chair/Président: T. Krauss
1420-1440	Ozone watch and UV index: environmental information to the public. A.M. OToole *(Invited)*	Kelvin wave-CISK and the Madden-Julian oscillations of the equatorial troposphere. H.-R. Cho	On the application of airport visibilities to distances over 25 km. R.A. Stuart and R.M. Hoff	Canada and the GPCP Algorithm Intercomparison Programme. W.D. Hogg and P.J. King
1440-1500		Principal oscillation pattern analysis of observed and simulated tropical summertime synoptic scale disturbance. J. Fyfe	Defining the synoptic seasons in southwestern Ontario. K.C. Heidorn POSTER PRECIS (1455-1500): #17	Estimating aereal snow water equivalent of Northwest Territories using passive microwave data. T.Y. Gan
1500-1520	Measurement and forecasting of ultraviolet radiation and sunburn time over southern Ontario. W.F.J. Evans	A numerical model study of the mesoscale organization of tropical convection: squall line initiation in GATE Phase III. V. Balaji, G.P. Klaassen and J.-L. Redelsperger	Weather and health: can it ever be in Canada? D.A. Bourque and J.L. Bart	Operational water surface temperature mapping using AVHRR data. E. Milewska, H. Le, N. Bussieres and B.W. Wannamaker
1520-1550	**HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE**			
			COASTAL OCEAN **OCÉAN CÔTIER**	**HYDROLOGIC CLCLE III** **HYDROMETEOROLOGICAL PROCESSES** **CYCLE HYDROLOGIQUE III** **PROCESSUS HYDROMÉTÉOROLOGIQUES**
			Chair/Président: D.A. Greenberg	Chair/Président: R.F. Hopkinson
1550-1610	Statistical total ozone analyses and forecasts for Canada. L.J. Wilson and M. Vallée	The transatlantic fate of hurricanes and tropical storms. J.L. Walmsley	Wave- and wind-driven flow on the continental shelf. Z. Xu and A.J. Bowen	Moisture budget computations of evapotranspiration from sequential radiosondes. G.S. Strong
1610-1630	An evaluation UV index forecast. P. Dionne	Breaking internal gravity waves. G.P. Klaassen and L.J. Sonmor	Circulation on the Scotian Shelf forced by mesoscale variability in the wind field. J. Sheng and K.R. Thompson	Relationships between precipitation and atmospheric circulation for British Columbia. G.A. McBean and R.A.S. Hourston
1630-1650	The potential impact of a major volcanic eruption on global climate, stratospheric ozone and surface UV-B radiation. R.K.R. Vupputuri and K. Higuchi	A thermodynamic approach to atmospheric energetics. M. Mills and G.B. Lesins	Shelf circulation and four dimensional data assimilation. D. Griffin and K. Thompson	Meeting of Hydrology Special Interest Group
1650-1710	Stratospheric ozone variations, are they important to studies of marine climatology? B.J. Topliss	A meso-scale precipitation index based on moist symmetric instability: results for central Alberta. G. Reuter and N. Aktary	Prediction of storm surges in Newfoundland. M. McCrady	
1710-1730	Case study of making the green choice between ozone depleting and global warming technologies. J.D. Reid	Mesoscale potential vorticity analysis of a cold front. Z. Peng and O. Hertzman	Optimal estimation of eddy-viscosity for a quasi-three-dimentional numerical tidal and storm surge model. S.K. Das and R.W. Lardner	
1900	**BANQUET / BANQUET SUB BALLROOM**			

0800-0835	**PLENARY SESSION / SESSION PLÉNIÈRE** **REMOTE SENSING / TÉLÉDÉTECTION** **RM / SALLE 102** The first European Remote Sensing Satelite ERS-1: development, data products and applications. E.P.W. Attema *(Invited)*			
	REMOTE SENSING **TÉLÉDÉCTION** **RM / SALLE 102**	**OZONE AND THE ULTRAVIOLET** **L'OZONE ET LES RAYONS UV** **RM / SALLE 125**	**COASTAL OCEAN** **OCÉAN CÔTIER** **RM / SALLE 205**	**HYDROLOGIC CYCLE IV - VARIABILITY IN HYDROMETEOROLOGICAL PATTERNS** **CYCLE HYDROLOGIQUE IV - VARIABILITÉ DES CONFIGURATIONS HYDROMÉTÉOROLOGIQUES** **RM / SALLE 303**
	Chair/Président: F.W. Dobson	Chair/Président: J. McConnell	Chair/Président: C.L. Tang	Chair/Président: D.A. Daugharty
0840-0900	AVHRR satellite observations of the intensification of the shelf break current during an upwelling event off Vancouver Island. G.C. Staples and W.W. Hsieh	METOZ: the generation of ozone and ultraviolet radiation maps from meteorological data. L.R. Poulin and W.F.J. Evans	Residual currents in a three-dimensional baroclinic model at the central Strait of Georgia, B.C. S.G. Marinone, J. Fyfe and S. Pond	Inter-hemispheric comparisons of hydroclimatic patterns along the western coasts of the Americas. R.G. Lawford
0900-0920	Radar and infrared measurements of a thermal feature made under varying atmospheric conditions. B.J. Topliss, T.H. Guymer and A. Viola	The synoptic climatology of surface ozone in rural southern Ontario. K.C. Heidorn	A numerical model of the circulation in Knight Inlet, British Columbia. M. Stacey and S. Pond	Recent observed trends and modelled historical interannual variability in Canadian snow cover. R.D. Brown and B.E. Goodison
0920-0940	Annual variation of sea surface slopes over the Scotian Shelf and Grand Banks from Geosat altimetry. G. Han, M. Ikeda and P.C. Smith	Suface ozone levels and trends in central and eastern Canada during 1980-91. J.D. Fuentes, T. Dann and S. Beauchamp	Numerical study of Hudson Bay summer ocean circulation: gyres, meanders, separations and coastal jets. J. Wang, L. A. Mysak and R.G. Ingram	Point PMP estimation over northern Saskatchewan. R.F. Hopkinson
0940-1000	A study on altimeter data assimilation to a two-layer Rossby wave model by adjoint method. L.Z. Cong and M. Ikeda	The Antarctic ozone hole in 1970 from IRIS. E. Paat and W.F.J. Evans	Upper ocean circulation model. J. Gan, R.G. Ingram, R.J. Greatbatch and P. Chen	
1000-1020	Rainfall retrieval during GPCP/AIP-1: a pattern recognition approach using satellite data and CMC forecast model fields. C. Grassotti and L. Garand	Ozone depletion and development of enhanced C10 during the 1991-92 Arctic winter using a 3-D CTM. J. Kaminski, J.C. McConnell and E.M.J. Templeton	A numerical study on circulation in the Baie des Chaleurs. P. Chen and R.G. Ingram	
1020-1040	**HEALTH BREAK / PAUSE SANTÉ BLUE LOUNGE**			
		CLOUD PHYSICS & CHEMISTRY **PHYSIQUE ET CHIMIE DES NUAGES**	**OCEAN MIXING** **MÉLANGE OCÉANIQUE**	
		Chair/Président: H.G. Leighton	Chair/Président: K.G. Lamb	
1040-1100	An evaluation of sea surface wind measurements from two different satellites: SSM/I & ERS-1. N. Wagneur	The hydrometeorology of CANSAP and CAPMoN precipitation chemistry samplers. R.F. Hopkinson	Basin mixing in a tidally energetic fjord. S. Tinis and S. Pond	
1100-1120	Wind stress measurements during the ERS1 Cal-Val Experiment. R.J. Anderson, S.D. Smith and F.W. Dobson	Seasonal fog and precipitation chemistry at forested mountain sites in southern Quebec. R.S. Schemenauer, C.M. Banic and N. Urquizo	Turbulent mixing in solitons. N. Oakey and N. Cochrane	
1120-1140	Recent results from the Grand Banks ERS-1 SAR Wave Experiment. F.W. Dobson, S.D. Smith and P.W. Vachon	Collision rates of small droplets in weakly turbulent clouds. A.S. Koziol and H.G. Leighton	Turbulence and mixing in the Strait of Gibraltar. J.C. Wesson and M.C. Gregg	
1140-1200	The McGill Doppler radar facility. A. Singh, A. Kilambi, E. Ballantyne, A. Bellon, B. Katz and I. Zawadzki	Solar radiative transfer for wind sheared cumulus clouds. H.W. Barker	Modelling of double diffusive intrusions. D. Walsh and B.R. Ruddick	
1200-1220	Inference of energy and radiative fluxes within a snow covered sea ice volume from microwave scattering. D.G. Barber, T.N. Papakyriakou and E.F. LeDrew	Air quality simulations - how much bias and error can climate introduce? Z. Randonjic and J.W.S. Young		
	POSTER PRECIS (1220-1225): # 18			

ABSTRACTS/RÉSUMÉS

Tuesday/Mardi a.m. Room/Salle 102

CLIMATE MODELLING I: LONG TIME SCALES
MODÉLISATION DU CLIMAT I: ÉCHELLES SUR DE LONGUES PÉRIODES

Chair/Président: D.G. Wright, Bedford Institute of Oceanography

GEOLOGICAL PERSPECTIVES ON MODERN CLIMATE

J. Imbrie (Invited)
Department of Geological Sciences, Brown University, Providence RI 02912

Records of climate extending back several million years place the relatively warm, "interglacial" climate of the past 10,000 years in perspective. In this historical panorama we see long-term trends, step-like changes in regime, and quasi-periodic oscillations with wave lengths ranging from ~2,000 to ~100,000 years. For the past million years, the climatic narrative has been dominated by glaciation cycles with periods near 23,000, 41,000, and 100,000 years. Because changes in orbital geometry modulate the seasonal radiation cycle at periods which match these climatic cycles quite closely, the Milankovitch theory provides an unusual opportunity to investigate how the climate system responds to an external forcing function whose temporal and spatial structure can be calculated a priori. This paper will examine the sequence of responses in the North Atlantic area that led to the termination of the last major glaciation (Stage 2), and compare this pattern with sequences that led to the termination and onset of glaciations flanking the penultimate interglaciation (Stage 5e).

A DYNAMICAL THEORY OF THE ICE AGES

B. Saltzman (Invited)
Dept. of Geology and Geophysics, Yale University, New Haven, CT 06511, U.S.A.

It can be shown that, even in the most rapid periods of change, the geologically-inferred rates of growth and decay of the late Cenozoic ice sheets were too small to be calculable from traditional climate models (e.g., GCMs) given the uncertainties in representations of the fundamental fluxes of energy, momentum, and water in all forms. Thus, we approach the problem in a more inductive way by trying to formulate a physically plausible low-order dynamical system representing the net effects of these fluxes, that can account for the observed slow variability with a minimum number of adjustable parameters (rate constants) given the prescribed forcing due to earth-orbital variations. Such a dynamical model of the late Cenozoic (Plio-Pleistocene) climate and glacial variations has been constructed as an ongoing effort of a group that has included A. Sutera, A. Hansen, K. Maasch, and M. Verbitsky. The present version of this model includes the effects of free and forced variations of atmospheric carbon dioxide acting in concert with the known earth-orbital (Milankovitch) radiative changes to interactively produce changes in the global ice sheets, their underlying bedrock, and the deep ocean thermal state. We present here a review of this present model, illustrating its capability to account for the main features of the complex paleoclimatic record over the last 5 My. In particular,

both the major long-term regime changes and the more detailed behaviour over the late Pleistocene are deduced as a self-consistent solution, prescribing as external forcing only the orbitally-induced variations of summer insolation at high northern hemisphere latitudes and an assumed variations of the long-term balance between tectonic outgassing and weathering downdraw of carbon dioxide over this period.

RELATIONSHIPS BETWEEN CLIMATE AND OCEAN MAGNETISM AND THE POTENTIAL FOR USING GEOMAGNETIC DATA AS PROXY FOR RIVER DISCHARGE INTO THE ARCTIC

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Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, Que. H3A 2K6

We first explore the possibility that observed correlations between geomagnetic records and climate variables (such as surface temperature) may be due to large-scale ocean currents. The currents may simultaneously transport heat (affecting weather and climate) and induce large-scale magnetic fields measurable at land observatories. Since the induced magnetic fields also depend on the salinity and temperature of the water (via electrical conductivity) an intricate relationship may exist between climate, magnetism and ocean properties.

In a specific application, we explore the potential for using geomagnetic data as a proxy for Mackenzie River discharge. In the Arctic, we show that the ocean-induced magnetic fields can be expected to vary with changes in salinity and total transport. In the Canadian Arctic Archipelago both salinity and transport (and, hence, the induced magnetic fields) will be affected by variations in the Mackenzie runoff.

We present observations that show an apparent negative correlation between the Mackenzie runoff and variations in the horizontal component of magnetic observations from stations in the Canadian Archipelago. These observations suggest that increases in Mackenzie runoff may decrease the conductivity of the water and hence a decrease in the amplitude of ocean- induced magnetic variations.

OCEAN CIRCULATION CHANGES DURING YOUNGER DRYAS: EVIDENCE FROM MODELLING AND DATA

D.G. Wright[1], T.F. Stocker[2] and S. Lehman[3]
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[2]Lamont-Doherty Geological Observatory, Palisades, NY, U.S.A.
[3]Woods Hole Oceanographic Institution, Woods Hole, MA, U.S.A.

Warming at the termination of the last ice age was interrupted for a period of about 1000 years during which the climate around the North Atlantic appears to have returned to near glacial conditions. Broecker and colleagues have suggested that this event, known as the Younger Dryas, was due to a weakening or cessation of the overturning circulation in the Atlantic, triggered by fresh water discharge from melting ice sheets.

We begin by examining the response of a simple, coupled global ocean- atmosphere-sea ice model to meltwater discharge as estimated by Fairbanks (1989). Past studies have shown that relatively little freshwater input is required to collapse the present overturning circulation and a new equilibrium is established with reduced deep flow. Here we show that if the hydrological cycle of the initial state is modified such that there is a modest increase in the net surface water loss from the North Atlantic,

then a response more consistent with observations is obtained. Meltwater input still results in a fresh water cap over the northern North Atlantic which causes a shut-down of the overturning circulation. However, after the meltwater input decreases, this cap slowly erodes away and eventually the overturning circulation is abruptly re-established. A second, weaker meltwater pulse has relatively little climatic impact, consistent with observations. Sensitivity of these results to model parameters and assumptions will be discussed.

$\delta^{18}O$ records from sea sediments throughout the Atlantic show evidence of "overshoots" in this quantity both before and after the Younger Dryas event. One possible interpretation of this observation is that the first overshoot marks the initial intrusion of $\delta^{18}O$-depleted glacial meltwater into the deep ocean as the termination began. During Younger Dryas, when deep water formation was reduced, meltwater again accumulated in the surface layers of the North Atlantic and when the overturning resumed, it was rapidly folded into the deep ocean. If this interpretation is correct, then the observed variations in $\delta^{18}O$ provide additional evidence of major changes in the deep ocean circulation. We will use our model simulation to investigate what part of the observed variations in $\delta^{18}O$ can be realistically attributed to this effect.

ATMOSPHERIC RADIOCARBON AS A MEASURE FOR TRANSIENT CHANGES OF THE OCEAN'S THERMOHALINE CIRCULATION

T.F. Stocker[1], D.G. Wright[2], and W.S. Broecker[1]
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[2]Dept. of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S. B2Y 4A2

A coupled, latitude-depth, global ocean-ice-atmosphere model is presented which includes the balance of stable and decaying tracers. The model is used to address the question of cycling of radiocarbon in the climate system using the Younger Dryas event as an example.

First, modest modifications in the atmospheric branch of the hydrological cycle are invoked in order to tune the coupled model such that the transient response to meltwater perturbations closely resembles the Younger Dryas climate event. The evolution of atmospheric radiocarbon is then examined, and the influence of rapid change of the thermohaline circulation on the radiocarbon "clock" is quantified. A large-scale increase of convection in the global ocean, caused by either resumption of the conveyor belt circulation or formation of Antarctic Bottom Water after a period of collapse, lowers the atmospheric radiocarbon content and produces a "plateau" in the radiocarbon age. If the deep ocean reservoir has been decoupled from the surface long enough, the initiation of active convection can create a strong age plateau extending over a few hundred years. In the case of resumption of convection in the Southern Ocean, changes of the atmospheric radiocarbon concentration may appear unrelated to the evolution of climatically relevant variables such as the meridional heat transport. However, they provide important information on the long-term evolution of the ocean's thermohaline circulation.

MULTIPLE EQUILIBRIA OF AN ASYMMETRIC TWO-BASIN OCEAN MODEL

T.M.C. Hughes and A.J. Weaver
School of Earth and Ocean Sciences, University of Victoria, Victoria, B.C. V8W 2Y2

An ocean general circulation model is used to examine the influence of model geometry and surface buoyancy and wind stress forcing in producing the asymmetry of the present-day thermohaline

circulation. The model domain is a highly idealized Atlantic and Pacific, linked by a circumpolar ocean in the south, and the integrations are performed under mixed boundary conditions.

The model reproduces the tendency of the real ocean to favor a "Conveyor" type circulation with sinking at high northern latitudes in the Atlantic and upwelling in the North Pacific. A "Southern Sinking" equilibrium with thermohaline overturning only in the Antarctic is also possible. Under salinity and wind stress forcing analogous to the present-day climate, North Pacific deep sinking is not observed, ruling out the inverse conveyor and double northern sinking states. The magnitude of the thermohaline cell in the North Atlantic varies over a wide range between the different experiments; in contrast, the overturning in the Southern Ocean is fairly constant between runs but adopts one of several qualitatively different configurations. Experiments with different choices of surface buoyancy forcing indicate that the model bias is not solely dictated by the hydrological cycle since the conveyor belt is favoured even under a salt flux field with net precipitation over the North Atlantic. However, upon removing the wind stress forcing, a "Northern Sinking" equilibrium appears, and a number of runs designed to clarify how the wind stress forcing may control the buoyancy-driven circulation are described.

Poster No. 1

ESTABLISHING A GLOBAL DATABASE OF ABRUPT CLIMATE CHANGE OVER THE PAST 18,000 YEARS

Jin-qi Fang[1] and F.A. Street-Perrott[2]
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[2]School of Geography, University of Oxford, Oxford OX1 3TB, England

Closed lakes (lakes without natural outlets) act as rain gauges that provide a detailed record of past changes in climate. As early as 1979, Street and Grove established a global lake-level change database of the past 30,000 years and tried to extract climatic change information. Since then, the data bank was updated for several times. In 1991, using a similar method, the databases about Chinese lakes were developed by Fang. However, because of no raw data in these earlier versions of databases, it is impossible to improve them so that it can be used for different research objectives and produce high time-resolution information, e.g., abrupt climatic change information. In 1992, we worked together to establish a new data base. An outline on the data base structure has come out. All raw data related to the lakes, sampling, and lake-level changes will be stored into the Raw Data Bank. Research Data Bank will be easy to work out by different researchers on their research objectives. Now financial support to input data into the data bank is being sought with the support of Prof. Robert Gilbert in the Queen's University.

Poster No. 2

EFFECTS OF INCORPORATING TOPOGRAPHIC STRESS IN A GLOBAL OCEANIC GENERAL CIRCULATION MODEL

M. Eby and G. Holloway
Institute of Ocean Sciences, Sidney, British Columbia V8L 4B2

Topographic stress arises from the interaction of eddies with topography, generating pressure-slope correlations which may drive large scale ocean circulations. For ocean models with coarse resolution, hence not resolving eddies or resolving them inadequately, a representation of subgridscale effects is

required. We use the GFDL Modular Ocean Model to test a topographic stress parameterization which consists of modifying the viscosity term to provide a tendency toward a maximum entropy configuration. Inclusion of topographic stress forces poleward eastern boundary undercurrents, strengthens equatorward tendencies in deep western boundary currents, sustains a deep Alaska Stream, and induces other changes. Although the influence of topographic stress is most clearly seen at depth, there are surface expressions including a reduction of implied air-surface heat flux near the separation of western boundary currents.

Poster No. 3
UQAM REGIONAL CLIMATE MODEL: PRELIMINARY RESULTS

D. Caya, R. Laprise and M. Giguère
Dépt. de physique, Université du Québec à Montréal, Montréal, H3C 3P8

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. Chemical composition of the atmosphere, complex radiation scheme, ground cover, topography, etc. are parts of what is to be included in the so-called physics of a climate model. Such complexity in actual GCMs is needed to make a valuable simulation of the large scale features of a global atmospheric circulation. However, a strong limitation to the use of these models for regional climate study is their coarse spatial resolution. A technique, used to overcome such a limitation, consists in the nesting of a high-resolution, limited-area model in the 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.

Typical integrations of limited-area nested models seldom extend beyond the 1 to 2 day range when used in forecast mode. This poster presents results from a 10-day long integration of the RCM. Boundary conditions are supplied to the RCM from archived CCC GCM climatic run data. These tests illustrate the potential of the nesting strategy for climate simulations.

Tuesday/Mardi a.m. Room/Salle 125

OCEANOGRAPHY OF SEAMOUNTS
OCÉANOGRAPHIE DES MONTS SOUS-MARINS

Chair/Président: K. Juniper, Université du Québec à Montréal

THE FIEBERLING GUYOT PROGRAM

K. H. Brink (Invited)
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

From late 1989 until late 1991, a group of primarily physical and biological oceanographers concentrated on oceanographic effects peculiar to large isolated topographic features in the ocean. The seamount chosen, Fieberling Guyot, is located in the Pacific Ocean at about 32.5 degrees latitude, west of San Diego. Its summit depth is at about 520m, well above the local abyssal plain depth of 4400m.

The field work consisted of a pilot year (1990) and a main field program (1991) that was distinguished by the deployment of a 9-element moored array and intensive survey work. The results presented represent the findings of many of the program's investigators, without whom this presentation could not be given.

Tentative results represent a pleasing mixture of anticipated findings and completely unexpected results. In the internal wave band, clear evidence was found for the hypothesized critical reflection of internal waves enhancing higher frequency currents at topographically selected locations. At lower frequencies, amplified diurnal tides and the associated rectified along-isobath currents dominate the flow structure immediately above the seamount. An unanticipated result is the strong evidence for vertically propagating near-inertial currents, apparently influenced by the vorticity associated with the mean around-seamount flow. While there were several interesting findings related to biological effects over the seamount, perhaps the most striking was the significantly enhanced population of seabirds over the feature, a result suggestive of near-surface effects despite the substantial depth of the seamount summit.

WHY IS THE TOP OF COBB SEAMOUNT SUCH A POPULAR PLACE TO LIVE?

V. Tunnicliffe and T. Parker
Earth & Ocean Sciences and Dept. of Biology, Univ. of Victoria, Victoria, B. C. V8W 2Y2

Submersible observations of the top 700 meters of Cobb Seamount record very high abundances of benthic organisms and fish, particularly around the pinnacle from 120 to 28m. An algal field carpets the top while scallops, anemones, sea squirts and sponges leave little basalt exposed on the seamount sides. We examine the constituents of this community available from photographs and a few dredges. Most originate from the coastal northwest but not all the "parent community" is represented. Invertebrates with both long-lived planktonic larvae and brooded larvae are present. Photographs from the 1960's suggest the assemblage is relatively stable. We invoke the exposed open-ocean nature of the habitat to explain absence of some shallower species: they may recruit but cannot survive. These invertebrates can maintain self-seeding populations by virtue of the circulation gyre around the seamount. While offshore counter currents can bring some recruits, rafting on kelp may be a major transit agent. Three species of rockfishes were abundant and the juveniles formed large, dense schools above the pinnacle. The high biomass in both invertebrates and vertebrates attests to a high productivity in the water column.

OCEAN CIRCULATION AT AND NEAR A SHALLOW SEAMOUNT IN THE N.E. PACIFIC OCEAN

H.J. Freeland
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This paper describes describes the velocity field over and around Cobb Seamount, a shallow seamount near the junction of the subarctic current and the California Current in the N.E. Pacific Ocean. The background flow field is examined using surface drifters deployed as part of the WOCE Surface Velocity Program and kindly made available by R. Thomson. The actual circulation at Cobb is examined using data from current meter deployments on three separate expeditions. The low-frequency flows indicate that a Taylor-Proudman cap, cone or column is a permanent feature of Cobb Seamount and that must result in an ageostrophic convergence of flow on the seamount. The convergence must have important implications for the trapping and retention of fish larvae in the vicinity of Cobb. Energetic flows at periods of about 21 hours can reliably be ascribed to seamount-trapped waves,

though it is not possible to verify that the observed distribution of energy at 21 hours fits the theoretical modal structures for such waves. At shorter periods it is observed that the internal wave field is amplified well above the energy levels expected by the GM76 spectrum.

RELATIONSHIP BETWEEN PHYTOPLANKTON PRODUCTION AND THE PHYSICAL STRUCTURE OF THE WATER COLUMN NEAR COBB SEAMOUNT, NORTHEAST PACIFIC

L. Comeau[1] and A. F. Vézina[2]
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[2]Dept. of Fisheries and Oceans, Institut Maurice-Lamontagne, Mont Joli, Que. G5H 3Z4

The objective of this study was to determine the impact of the Cobb Seamount (northeast Pacific) on total and new phytoplankton production. In August 1991, sampling was carried out along six 18 km spokes radiating outward from the summit of Cobb Seamount. Physical parameters and phytoplankton uptake of NO_3^- (new production) and CO_2 (total production) were measured at six different levels of incident light (50%, 25%, 10%, 6%, 1%, and 0.1%). The concentration of dissolved nutrients (NO_3^- and SiO_4^-) was generally high (> 1 µM) at all sampled depths. The spatial distribution of new or total production could not be related to the availability of dissolved nutrients. A three-dimensional statistical analysis of the spatial structure showed a coupling between the decreasing depth of temperature isolines and the decreasing depth of the chlorophyll *a* maxima toward the summit. The levels of both new and total production were generally high in the area surrounding the peak, suggesting stimulation of NO_3^- assimilation by an improvement in the light regime.

Tuesday/Mardi a.m. Room/Salle 205

AEROSOLS AND RADIATION
AEROSOLS ET RAYONNEMENT

Chair/Président: J.P. Blanchet, Universite du Quebec a Montreal

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DIRECT RADIATIVE EFFECTS OF AEROSOLS IN THE LOWER TROPOSPHERE BASED ON AIRCRAFT MEASUREMENTS

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Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, P.Q. H3A 2K6

It is now well established that aerosols, by scattering and absorbing solar radiation, affect the terrestrial heat engine. Depending on the overall reflectivity and absorptivity of the haze column and on the surface albedo, the net effect could be cooling or warming. Understanding of the influence of aerosols is handicapped by lack of data and by the fact that their composition and distribution is highly variable in space and time. For the same reasons, the incorporation of aerosols in climate models is usually rudimentary.

We have in-situ measurements of the vertical profile and size distribution of aerosols taken over several places in eastern Canada at different times of the year. These data have been incorporated in a simple multi-layer radiative transfer model to estimate the effects of the aerosols in the lower

troposphere on the local radiation budget. In some cases, the short-wave radiative forcing of aerosols is far from being negligible.

CLIMATIC EFFECTS OF HIGH VOLCANIC AEROSOL LOADING

J. Jiang[1] and W.F.J. Evans[2]
[1]CRESS, York University, Toronto, Ontario
[2]Environmental Resource Studies, Trent University, Peterborough, Ontario K9J 7B8

Temperature variations from the climatological mean may be due to the natural variability of the unperturbed system, but part of the variability may also be accounted for in terms of volcanic activity. We have examined the effects of high volcanic aerosol loading on global radiation by using the MODTRAN radiation program. Model calculations at 44° N and 78° W show the effects of volcanic aerosols as follows: (1) Global radiation decreases by up to 33.7 W/m^2. Global radiation increases by up to 25% before sunset; (2) Average transmittance changes from 10 to over 30%. The transmittance increases are larger when close to sunset; (3) Integrated thermal radiance changes by 0.1 W/m^2. Using these results, a Surface Energy Balance Model (SEBM) has been used to predict a surface temperature cooling ΔT of 2.0°C. In order to compare this result with the observational data, 10 years of meteorological (Toronto Airport) daily mean temperature records have been collected. These 10 year mean temperatures (1980-1990) have been compared with the mean temperatures of 1992 at Pearson airport. A cooling of $\Delta T \sim 1.8$°C indicates a possible signal of the 1991 Pinatubo eruption. We also collected meteorological temperature data at 64° N, 67° W. A larger surface cooling signal of $\Delta T \sim 2.1$°C has been found. This higher latitude station is closer to the "sunset" situation.

RESPONSE OF THE CCC THIRD GENERATION GCM TO TROPOSPHERIC AEROSOL

H.W. Barker and M. Lazare
Canadian Climate Centre, Downsview, Ontario M3H 5T4

Currently, most general circulation climate models (GCMs) do not account for background tropospheric aerosols. Several studies, however, suggest that in some regions attenuation of solar radiation by tropospheric aerosols rivals that due to water vapour. Results of this study elucidate the impact of including background tropospheric aerosols on the latest version of the CCC-GCM. Two types of aerosols were included: a moderately absorbing one over land and an almost purely scattering one over oceans. Globally averaged optical thicknesses were 0.125 and 0.08 (at 0.55 μm radiation) over land and ocean respectively with maximum values at the equator decreasing linearly with latitude poleward. The aerosols were assumed to be evenly distributed throughout the planetary boundary layer. Note that these aerosols did not interact on a microphysical level with water and ice clouds. Since the aerosols were assumed to be clouds but not in cloud droplets, the continental aerosols do, however, enhance solar absorption inside clouds. On a globally averaged basis, the inclusion of aerosols leads to reduced solar absorption at the surface by approximately 7 Wm^{-2} and increased atmospheric absorption by about 4 Wm^{-2}. Globally averaged screen temperature was reduced by approximately 0.5^{oC} (which compares favourably with previous estimates) but larger local anomalies were observed. At the time of writing this abstract, analysis had just commenced. Results will be expanded upon much by the time of presentation.

ASSESSMENT OF THE RADIATIVE AND CLIMATIC EFFECTS OF LARGE SMOKE INJECTIONS INTO THE LOWER ATMOSPHERE

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[3]Atmospheric Environment Service, Downsview, Ontario M3H 5T4

A coupled 1-D radiative-convective-photochemical diffusion model which takes into account the wavelength-dependence of the interaction between the smoke aerosols and solar radiation is used to investigate the possible radiative and climatic effects of large smoke injections into the lower atmosphere due to sources such as oil and forest fires. The 1-D experiments were carried out using five levels of smoke concentrations with optical depths ranging between 0.006 to 5. The results indicate that the absorption of solar radiation by soot aerosols with optical thicknesses greater than 1 would lead to cooling near the ground, resulting in a strong increase of thermal stability in the smoke polluted atmosphere. At lower smoke optical depths the results support the concept of threshold smoke loading, below which the soot aerosols would lead to slight warming rather than cooling near the ground. Also will be discussed are the implications of higher levels of CO and NO_x in the smoke polluted atmosphere to the changes in the vertical ozone distribution.

MODEL SIMULATED CLOUD MICRO PHYSICS - RADIATION INTERACTION IN ARCTIC AIR MASS FORMATION

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Qué. H3C 3P8

The rate of air mass transformation from maritime to continental polar air depends on the water vapour removal through precipitation processes. In turn, the reduction of atmospheric water vapour reduces the greenhouse effect and enhances cooling of the surface and lower atmosphere. To investigate the role of microphysical processes in the air mass modification, a detailed column model is developed. It accounts for gas to particles conversion, formation of CCN and ICN, aerosol growth by condensation, coagulation, activation, freezing and gravitational sedimentation. The aerosol/droplet/crystal spectra are simulated from 0.001 to 500 μm with a multi-level column of the lower troposphere (7 km). The purpose of the model is to investigate the influence on the properties of aerosols in the air mass transformation. In particular the acidification of condensation particles may alter the water flux and in turn the atmospheric temperature.

Tuesday/Mardi a.m. Room/Salle 303

CANADIAN ATLANTIC STORMS PROGRAM II AND CYCLONES I
PROGRAMME CANADIEN D'ÉTUDES DES TEMPÊTES ATLANTIQUES II ET CYCLONES

Chair/Président: O. Hertzman, Dalhousie University

DOPPLER RADAR OBSERVATIONS OF A WARM FRONT

D.R. Hudak[1], R.E. Stewart[1], A.D. Thomson[2] and R. List[2]
[1]Cloud Physics Research,Atmospheric Environment Service, Downsview, Ontario M3H 5T4
[2]Department of Physics, University of Toronto, Toronto, Ontario

The University of Toronto operated an X-band Doppler radar during CASP II at Torbay, Newfoundland. Normal operating procedure, repeated every 10 min, involved volume scans and RHIs on selected azimuths to document the storm morphology, precipitation intensity, and wind field information. The range resolution was 250 m out to a maximum range of 18.25 km. This scanning strategy was interrupted periodically to operate the radar in a vertically pointing mode to collect the full Doppler spectral power density information. In this mode the vertical resolution was increased to 125 m. The range bins were stepped through sequentially from 0.25 km to echo top, recording the full Doppler spectrum. This cycle was repeated usually from three to five times before returning to the regular scanning mode.

Data taken from a cloud system ahead of a warm front associated with a rapidly deepening storm that was crossing Newfoundland will be discussed. Volume Velocity Processing of the volume scan data was used to document the kinematic properties of the system. Vertical profiles of the first three moments of the Doppler spectrum were used to characterize its microphysical structure. A research aircraft flying horizontal transits over the radar provided further measurements of cloud properties. This information was combined with the temperature sounding data and detailed surface precipitation type observations, both taken at the radar site. As a result, a qualitative assessment of the relative importance of the main microphysical processes leading to the diversity of precipitation types can be made.

HORIZONTAL AND TILTING MELTING LAYERS IN CASP II STORMS

R.E. Stewart, R.W. Crawford and K.K. Szeto
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

It has been known for some time that horizontal melting layers are a critical feature of many storms but few observations of these have ever been reported. In addition, such layers tilt down to the surface in many winter storms so that snow falls to their north and rain to their south. However, there has only been one study of the nature of such tilting layers. Within CASP II, nine vertical ascents were made through horizontal melting layers and nine horizontal passes were made through tilting melting layers. The vertical profiles exhibit extensive variations of microphysical characteristics and winds over a range of melting layer depths. The horizontal passes illustrate that the width of the tilting melting region varies dramatically from a few hundred meters to 10s of kilometers. It was also generally characterized by strong dynamic variations and preliminary results indicate that it was sometimes subjected to frontogenetic forcing partially attributable to precipitation phase changes. As shown

through such observations as well as through numerical simulations, the key attributes and consequences of horizontal and tilting melting layers will be discussed.

ON THE DEVELOPMENT OF FREEZING TEMPERATURES IN NEWFOUNDLAND

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It is commonly accepted that freezing precipitation requires that ice particles fall through a warm air mass resulting in complete or partial melting of the ice, with subsequent re-freezing of these liquid particles upon striking a surface with a temperature below 0°C. However, during over 150 hours of storm cloud studies in Newfoundland during CASP II, investigators observed freezing precipitation at the surface when no upper level warming layer was present. This would suggest that such cases of freezing precipitation developed from a "warm rain" process in which rain drops grew through condensation and coalescence. The ice phase could not have participated in the growth process since this would have resulted in the freezing of the particles before they reached the surface.

A climatological study of 30 years of surface and upper air observations was carried out for two Newfoundland locations and one continental station to determine how frequently and under what conditions freezing precipitation was observed without a warm layer aloft. Preliminary results from climatological records suggest that freezing drizzle is frequently observed at the ground when all upper air temperatures are less than 0°C. The results of this study will be presented along with a detailed case study of this phenomenon from CASP II using observations from the NRC Convair 580 aircraft.

AIRCRAFT ICING POTENTIAL OF EAST COAST WINTER STORMS

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The aircraft icing potential of East Coast Winter Storms was investigated during the CASP II field project. The primary objective was to investigate and characterize the cloud microphysics associated with aircraft icing encounters. Icing research was a cooperative effort between the Atmospheric Environment Service, National Research Council, Boeing Commercial Airplane Group and Airbus Industrie with additional funding provided by the National Search and Rescue Secretariat.

During the project, over 1000 icing patches were encountered with an instrumented Convair 580 research aircraft. A patch was defined as greater than 500 meters of continuous liquid water content greater than 0.03 g m^{-3}. A statistical analysis of temperature, droplet median volume diameter, liquid water content and liquid water path was used to characterize the icing patches. The results are compared to the icing envelopes of the Federal Aviation Administration, and to previous icing measurements of East Coast storms. In general, icing severity was well within the safety envelopes, although three severe icing events were documented. The most extreme icing was associated with patches of supercooled drizzle droplets.

CASP II: MESONET SAMPLING IN IOP 4 - THE GREAT FREEZING RAIN EVENT

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During CASP II a mesonet of 10 m towers was deployed on the Avalon Peninsula of Newfoundland. During the strong storm of IOP 4 (January 31-February 1, 1992) the mesonet delineated well the evolution of the low level onshore flow which contributed to the long-lived freezing rain event, one of the primary aspects of this storm in the region.

The prolonged period of freezing rain was characterized by winds which backed towards the northeast with time. The surface air temperatures increased during the event despite apparent cold advection in the low levels. The increase is postulated to be associated with the falling precipitation.

The thermodynamic structure of the precipitation features in the storm just east of the Avalon peninsula was sampled with the Convair 580 aircraft during the period 21 Z Feb 1 - 00 Z Feb. 2. The analysis of the data from this flight is continuing.

Tuesday/Mardi p.m. Room/Salle 102

CLIMATE MODELLING II: MODELS AND OBSERVATIONS
MODÉLISATION DU CLIMAT II: MODÈLES ET OBSERVATIONS

Chair/Président: A.J. Weaver, University of Victoria

ON THE QUALITATIVE BEHAVIOUR AND NON-OSCILLATION OF STOMMEL'S THERMOHALINE BOX MODEL

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Stommel's [1961] 2-box model of thermohaline circulation is generalized to incorporate either mixed or Newtonian thermal and saline boundary conditions. We assume a rate of exchange flow that depends in a possibly nonlinear fashion upon the density difference, and set a condition on the maximum rate of decrease (not increase) of flow with increasing density difference. If the saline adjustment time is larger than the thermal, then we find:
(1)The model can not exhibit self-driven oscillations.
(2)There is one and only one stable 'saline' equilibrium state corresponding to evaporation-driven sinking.
(3)'Thermal' equilibrium states corresponding to sinking in cooling zones may or may not exist. If they do, they come in pairs, one saddle and one stable node or spiral. A 'wiggly' flow law may lead to more than one such pair.

Thus Stommel's original qualitative picture is found to hold generally, with multiple stable equilibria and non-oscillation being the key model results.

CONVECTIVE ADJUSTMENT AND ISOPYCNAL MIXING IN AN OCEAN GENERAL CIRCULATION MODEL

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The role that an explicit convective adjustment scheme plays in an isopycnal ocean general circulation model is examined. A series of equilibrium and cooling experiments are performed using an isopycnal mixing parameterization with and without an explicit convective adjustment scheme. All cases perform in virtually an identical fashion indicating that the inclusion of an explicit convective adjustment scheme is unimportant. This confirms the contention that much of the convection found in a lateral mixing model arises as a result of destabilization caused by the mixing parameterization itself.

In the adjustment to the new equilibrium in the cooling experiments, all cases show a secondary peak in the number of statically unstable points after 200 years. This is attributed to the flushing of cold bottom water as a result of the intensification of the meridional flow. The timescale of this secondary peak is found to be a function of the magnitude of the cooling anomaly and the surface restoring timescale.

A NEW APPROACH IN REGIONAL CLIMATE MODELLING: DESCRIPTION OF A THERMODYNAMIC, DIAGNOSTIC AND SEMI-PROGNOSTIC NUMERICAL MODEL: FIZR

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Atmospheric general circulation models (GCMs) coupled to simple ocean and sea-ice models have been used over the past years to simulate, with the help of supercomputer resources, current global climate and global climatic changes. Despite differences in physics parameterization schemes, horizontal resolution and numerical methods in fluid dynamics, contemporary second-generation GCMs agree well on global climate and on the direction of the doubled-CO_2 induced global climatic changes. However, these models still show much disagreement in regional features underneath the large-scale patterns of precipitation, soil moisture, cloud cover, etc. Since there is much uncertainty associated with the GCMs' ability to project regional-scale features mainly because of their low spatial resolution, and today's computer resources being a strong limiting factor, indirect methods are now the only practical means of obtaining regional-scale climatological data. Therefore a reliable source of large scale data being GCM grid outputs, one possible approach to produce regional-scale climatic projections is to limit the domain of study over which high horizontal resolution is required.

Following on these considerations, the present work seeks to address the question of regional climate prodiction by combining precomputed Canadian Climate Centre (CCC) GCM atmospheric circulation (Dynamics) with recomputed CCC GCM subgrid-scale parameterized processes (Physics). The combination (Dynamics + Physics) is then integrated in a prognostic mode on a high horizontal resolution grid of an arbitrary chosen area over the earth. The methodology arises from the premise that most of the "small scale" variability, i.e., variability produced by phenomena operating at scales below the current GCM spatial resolution, is mostly the result of the "Physics" processes rather than "Dynamics". Furthermore, our approach takes advantage of our confidence in the large-scale climatic simulation carried out by the CCC GCM. Then, the fine scale interpolated Dynamics coupled with high-resolution Physics calculation would produce a high resolution regional climate forecast centred on the Physics driving hypothesis. Hence, this model named FIZR would provide a framework for regional climate impact studies applied to problems including CO doubling scenario and potentially all kinds of historical events.

ON THE DIFFERENCES BETWEEN EARLY AND LATE WINTER ATMOSPHERIC RESPONSE TO THE SEA SURFACE TEMPERATURE ANOMALIES IN THE NORTHWEST ATLANTIC

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To assess the winter atmospheric response to the sea surface temperature (SST) anomalies in the northwest Atlantic (40-60°N, 30-60°W), a model simulation study has been conducted using the global spectral model at RPN with T42 horizontal resolution. Results from six 50-day integrations with prescribed positive SST anomalies initialized from independent November analyses and similarly, four runs initialized from January analyses, have been examined in comparison with their control runs. It is found from these experiments that the atmospheric responses to the imposed positive SST anomalies are significantly different in the November and January simulations. Positive geopotential height differences (warm minus control runs) in the northern North Atlantic downstream of the warm SST area are observed in the November cases and negative ones in the January cases. Diagnostic analyses of these experiments demonstrate that in the November runs, the surface heating from the warm SST cannot be balanced by the horizontal advection and penetrates deeply into the atmosphere up to the 200mb level. In the January runs, however, the low - level heating can be effectively offset by the strong horizontal cold advection. Results from these diagnostic analyses will be presented. In addition, a comparison between the model results and results from a data analysis of 50-year (1930-79) records of SST and SLP will be presented.

A C-GRID OCEAN GENERAL CIRCULATION MODEL

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We describe the formulation and verification of an ocean circulation model formulated using the Arakawa C-grid. The C-grid has been shown to give more accurate results than the B-grid in geostrophic adjustment and linear convection. We include in the model a semi-implicit treatment of the Coriolis term, and a small scale dissipative term which depends on the horizontal divergence. The latter reduces the noise in the vertical motion field. The model is formulated with β-plane geometry and temperature is the only state variable.

The verification experiments are performed using idealized wind and temperature surface forcings in an ocean basin with a comparable size as the North Atlantic. We compare the results obtained at coarse horizontal resolution with those of other models. The surface heat flux, northward heat transport and thermohaline circulation are all simulated well. Results with different forms of frictional parameterization are also discussed. An eventual goal is to use the model for eddy-resolving experiments; some preliminary results will be shown.

TEMPERATURE TRENDS AT COASTAL STATIONS ON THE PERIPHERY OF THE NORTH ATLANTIC OCEAN

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Annual mean air temperatures at coastal stations in Eastern Canada, from Nova Scotia to Baffin Island, reached maximum warming in the early 1950s. Since then, a cooling trend has prevailed with recent temperatures being close to the long-term average.

Temperatures at other coastal stations bordering the North Atlantic — in Greenland, Iceland, the Norwegian Sea area and around the British Isles — show similar trends. However, the strength of the cooling increases poleward and appears to be centred in the Greenland Sea area, where some stations are close to, or at, their lowest temperature normals this century. Moreover, there is little evidence of any winter warming taking place.

Temperature trends at coastal stations, around the periphery of the North Atlantic, in general, appear to be more closely related to off-shore sea temperature trends rather than the overall warming taking place in the Northern Hemisphere.

AN EVALUATION OF THE POTENTIAL IMPACT OF METHANE CLATHRATE DESTABILIZATION ON FUTURE GLOBAL WARMING

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Future global warming due to anthropogenic emissions of greenhouse gases has the potential to destabilize methane clathrates, which are found in permafrost regions and in continental shelf sediments worldwide, resulting in the release of methane gas. Since methane is a strong greenhouse gas, this could produce a potentially important positive feedback. Here, a series of one-dimensional models of the vertical, coupled heat transfer and methane destabilization process is used to estimate rates of methane destabilization and release to the atmosphere accompanying global warming. Different one-dimensional columns are used to represent continental shelf sediments of various shelf depth-temperature combinations in each of several latitude zones. The potential amount of methane clathrate in each column is estimated from 1°X 1° data for: shelf depth, shelf-water interface temperature, sediment thermal conductivity, geothermal heat flux, and organic matter content. The first four parameters serve to determine the volume of the methane clathrate stable region, while organic matter content is used as a proxy for the probability of finding methane clathrate. Any region that would have been unstable for methane clathrate during the peak of the last glaciation is assumed to contain no methane clathrate today. A single column is used to represent all terrestrial permafrost regions.

Scenarios of anthropogenic CO_2 and CH_4 emission are used to drive a simple model of the carbon cycle, yielding scenarios of CO_2 and CH_4 concentration increase. These increases in turn drive a one dimensional (globally averaged case) or two-dimensional (latitudinally resolved case) coupled atmosphere-ocean climate model. The temperature changes as a function of time, ocean depth, and (for the latitudinally-resolved case) latitude are used as upper boundary conditions to drive the heat transfer/methane clathrate release models. Methane release from clathrate destabilization is added to the assumed anthropogenic CH_4 emission, leading to increases in both CH_4 and CO_2 concentration. Based on a wide variety of parameter input assumptions and anthropogenic emission scenarios, it

appears that methane clathrate destabilization will increase global warming by, at most, 25-30% compared to the case without clathrate destabilization. For many assumptions and/or scenarios, however, the positive feedback is much weaker.

GREENHOUSE WARMING PREDICTION BY A SIMPLE ENERGY BALANCE CLIMATE MODEL

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A new simple time-dependent atmosphere-ocean energy balance climate model has been used to examine the influence of an increase in the carbon dioxide concentration in the atmosphere on climate change. Three essential climate feedbacks are considered: water vapour, snow-ice albedo, and cloud feedbacks. The study focuses on the influence of the cloud feedback which is divided into three components: cloud water content, cloud altitude and cloud amount feedback. The model shows that the cloud water content and cloud altitude feedback could lead to the formation of a new warm stable equilibrium as a result of increasing carbon dioxide in the atmosphere. After an initial gradual increase, the global surface temperature can rapidly rise in the model reaching values approximately 14 K warmer than the present value. The model also suggests that without additional greenhouse forcing the cloud amount feedback may lead to free oscillations with a period of several years. If weak annual solar forcing is imposed, the climate system's oscillations can become chaotic.

GLOBAL UPWELLING - INTERANNUAL VARIABILITY AND CLIMATE CHANGE

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Using the COADS monthly wind stress data (1950-1988) to calculate the global distribution of wind-induced upwelling, we studied the interannual variability and climatic change of global upwelling. EOF analysis showed that the dominant first mode in the Pacific Ocean was due to the El Nino-Southern Oscillation (ENSO). This mode also revealed that ENSO induced upwelling/downwelling occurred far away from the well known equatorial regions. Besides ENSO, longer term decadal scale variations were found in global upwelling, the most notable of which was the meridional shifting of the equatorial upwelling band. There was also an interesting interaction between ENSO with the decadal variations -- the ENSO warm events tended to cancel out the effects of the decadal variations.

Strong climatic trends were found in the equatorial and coastal regions, with a maximum value of 3 cm/day/year, obtained near the equator at 120°W. The subpolar, the equatorial and the coastal regions west of continents tended to have increasing upwelling trends, whereas the subtropical regions and the southern hemisphere tended to have decreasing upwelling trends (or intensifying downwelling trends).

SIMULATION OF NUTRIENT CYCLING IN THE NORTH ATLANTIC USING A PLANETARY GEOSTROPHIC OCEAN MODEL

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We use a 3-dimensional spherical planetary geostrophic ocean circulation model to simulate nutrient transport in the North Atlantic ocean. The physical model has an idealized box geometry of 60^0 latitude and 60^0 longitude, with a horizontal resolution of 2^0, and 15 vertical levels. Annual mean forcing of wind stress, surface temperature and salinity is used. The nutrient model is based on the conservation of total nitrate (organic and inorganic). To simulate net nutrient uptake in the euphotic zone (new production), surface nitrate concentrations are relaxed to their observed values. The euphotic zone is taken to be the upper 2 levels of the model.

Martin et al. (1987, *Deep Sea Research 34*, 267-285) suggested that there are two mechanisms for the transport of nitrate in the North Atlantic: a shallow cell coincident with the Gulf Stream recirculation gyre, and the overturning meridional cell associated with the formation of North Atlantic deep water. The nutrient circulation pattern simulated by the model is described. In particular, the hypothesized role of the horizontal circulation and overturning meridional cell in the nutrient transport is examined.

Tuesday/Mardi p.m. Room/Salle 125

OCEANOGRAPHY OF SEAMOUNTS
OCÉANOGRAPHIE DES MONTS SOUS-MARINS

Chair/Président: K. Juniper, Université du Québec à Montréal

AMPLIFIED CURRENTS AT COBB SEAMOUNT

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Cobb seamount (46.75 N, 130.81 W) rises from a 32 km diameter base 2800 m deep to a main summit terrace 100-300 m deep and 9-10 km wide. Presently underway analyses of bathymetric, hydrographic, and velocity data collected at Cobb during a 5-day R/V Thompson survey in October 1991 will be shown. A complete Hydrosweep mapping reveals topographic deviations from circular symmetry with typical roughness scales of order 1 km. In CTD "tow-yo" casts there is no evidence of isopycnal doming which would be associated with a Taylor cap. Density fine structure is extensive, with pycnostads common and 10-20 m in height. Velocity measurements extending to radius 7.5 km and depth 520 m were collected using a hull-mounted RDI 150-kHz Acoustic Doppler Current Profiler, with sampling designed to resolve diurnal, inertial and semidiurnal motions on scales of 20-50 m in the vertical and 1-2 km in the horizontal. Currents are typically of order 20 cm/s and highly variable with no single dominant frequency, and are likely a superposition of amplified tidal and near-inertial motions. A comparison of the subinertial component to stratified seamount-trapped waves and a dynamical description of any steady recirculation will be facilitated by a frequency decomposition of the velocity field.

PHYSICAL/BIOLOGICAL COUPLING AND CONTROL OF PHYTOPLANKTON GROWTH AT COBB SEAMOUNT: AN ECOSYSTEM APPROACH

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Standing stocks of phytoplankton over Cobb Seamount, 500km southwest of Vancouver Island, are typically 2-5 times higher than background levels. Three recent cruises to Cobb Seamount have shown that (i) upwelling (ii) existence of a closed anticyclonic circulation (*Taylor cone*) over the seamount summit and (iii) reduced grazing pressure from mesozooplankton combine to produce this local enhancement of phytoplankton biomass. The main effect of the upwelling is to shoal the pycnocline over Cobb, thereby increasing the average light level experienced by the phytoplankton. The recirculating current has been seen to persist for at least three weeks at a time and acts to retain phytoplankton biomass over the seamount. Results from a 1992 cruise show that this same recirculation retains fish larvae over Cobb Seamount, and that Taylor cone formation is important to recruitment success in the Cobb rockfish population. The observed reduction in mesozooplankton biomass over Cobb is likely due to predation by seamount-associated fish (*Sebastes* spp.). Preliminary results from a simple mathematical model (four trophic levels) of the surface mixed layer over Cobb also argue for a strong role for top-down control of phytoplankton production.

PERTURBATIONS PHYSIQUES ASSOCIÉES AU MONT SOUS-MARIN COBB: IMPACT SUR LE FONCTIONNEMENT DE LA BOUCLE MICROBIENNE

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Des études ont démontré l'influence de facteurs environnementaux tels la température ou l'enrichissement du milieu sur le fonctionnement de la boucle microbienne. L'incidence des perturbations hydrologiques reste mal documentée et son étude considère le domaine côtier. La présente étude se penche sur l'efficacité du transfert d'énergie du phytoplancton vers la boucle microbienne (bactérioplancton et flagellés) en relation avec les perturbations de la colonne d'eau associées au mont sous-marin Cobb (46°45'N 130°48'O), situé à 500 km de la côte ouest Canadienne. Ce type de milieu n'est pas soumis aux influences du domaine côtier et génère des perturbations quasi-permanentes qui facilitent l'échantillonnage. Avec les forts potentiels de pêche qu'ils représentent l'étude des monts sous-marins trouve un intérêt nouveau.

En août 1991, le mont sous-marin Cobb occasionnait une remontée des isohalines et des isothermes. L'activité du bactérioplancton et des flagellés mesurée sur le site a démontré que l'efficacité de la boucle microbienne décroît sous l'influence de ces perturbations alors que la production primaire est accrue. Les résultats laissent croire que ces conditions favorisent la sédimentation de la production primaire et la production de biomasse via la chaîne alimentaire classique plutôt que la regénération des éléments nutritifs par les populations de la boucle microbienne.

TURBULENCE MEASUREMENTS AROUND COBB SEAMOUNT

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Using the FLY II dissipation profiler, we took profiles of turbulence over and about Cobb Seamount. Some profiles over the shelf show the bottom boundary layer (BBL) to be homogeneous with the

strongest turbulence occurring at the bottom. Many other profiles show the BBL as a region of anomalously cold water and high temperature gradients, where the strongest turbulence occurs 5 - 20 m above the bottom. The cold water in the BBL is inconsistent with the down-slope Ekman pumping from the expected anticyclonic Taylor column. Outward from the shelf edge the most intense turbulence was at mid-depths (200 - 250 m) and was not associated with the bottom. There was also a systematic decrease in the turbulence with increasing distance from the seamount. By 7 km from the centre, the turbulence dropped to background levels.

We believe the intensified turbulence over and about the seamount is due to a combination of shear of the large scale circulation and internal wave breaking. The turbulence above the shelf is believed to be primarily due to interaction of the circulation with the various scales of the bottom. The anomalously cold water in the BBL over the shelf suggests there are no closed streamlines above the seamount and the expected Taylor column may not exist. However, internal waves may have advected the cold water up-slope. Turbulence at mid-depth outward from the shelf edge is unlikely to be remnants advected from the seamount. Internal wave breaking from intensification by reflection off the seamount is probably the cause. Intensification would be localized to the seamount and would explain the outward decrease in turbulence.

AN INVESTIGATION OF LAGRANGIAN EDDY FORMATION OVER SEAMOUNTS

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Seamounts and shallow banks are often associated with economically viable fishing grounds. It is believed that topographically forced circulation patterns result in the formation of nutrient trapping eddies over these banks which provide suitable living and growing conditions for some species of fish. As not all seamounts and banks support particle retention, it would be useful to know the principal forces behind the creation of these Lagrangian eddies. Recent research in the field indicates that interplay between the formation of Taylor columns (stationary columns of fluid trapped above a topographical perturbation), bottom friction, and stratification are the major factors behind the flow dynamics. A finite element model of Foreman and Walters has been applied to the study of particle trajectories and Lagrangian eddies over seamounts and banks.

Tuesday/Mardi p.m. Room/Salle 125

TOPOGRAPHIC INFLUENCES ON OCEAN CURRENTS
INFLUENCE TOPOGRAPHIQUE SUR LES COURANTS OCÉANIQUES

Chair/Président: M.W. Stacey, Royal Roads Military College

STEADY DRIFT GENERATED OVER MID-OCEAN RIDGES BY OSCILLATORY FLOW

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The mid-ocean ridges of the world's oceans are regions of plate spreading and local sources of new sea floor. Around hydrothermal vents associated with the ridges, a distinct and diverse biological

community exists. The question of how this community seeds new areas of hydrothermal venting many kilometers away raises questions as to the mean currents in the region.

Recent laboratory experiments conducted on the large rotating table at Grenoble have shown both along ridge and across ridge mean currents at the centre point of the ridge generated by oscillatory flow over the ridge. The pattern of the currents is a strong function of the rate of rotation of the table which governs the ratio of the baroclinic Rossby radius to the width and length of the ridge. Numerical simulations will be presented which give a more complete picture of the flow generated around the ridge and which show how the flow is determined by free and forced topographic waves trapped over the ridge. Weakly nonlinear wave theory will be used to identify the dominate resonance phenomena.

PERTURBATIONS OF CANYONS ON SHELF CURRENTS AND SOME PROPERTIES OF CANYON WAVES

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Perturbations of submarine canyons on shelf currents are studied using Rossby adjustment in a homogeneous fluid model. The canyon in the model is assumed to have a sloping bottom, vertical edges, to be infinitely long and on an f-plane. The analytical solutions show that the geostrophic velocity, the flux and the surface elevation are determined by 1). the ratio of the canyon depth to the shelf depth, 2). the width of the canyon and 3). the width of the shelf current. Two important parameters defined in the process of adjustment are -- the Canyon Flux Number and -- the phase/ group speed of long canyon waves.

A simple case is discussed as an example. If the canyon has a flat bottom and at the initial time the fluid is at rest but has a step-like discontinuous surface elevation along a certain line being perpendicular to the canyon, in the final geostrophic state the canyon will act as a complete barrier to the approaching flow which is asymmetrically diverted along the canyon in opposite directions. When a flow "goes through" a shelf-canyon system, a net flux is generated to the left (right) of the flow in the northern (southern) hemisphere.

Canyon waves existing in a shelf-canyon system are studied analytically with a homogeneous fluid model. An infinitely long, flat bottom canyon with vertical edges is chosen on an f-plane. The study demonstrates the existence of canyon waves, whose dispersion relation, phase/ group speed and surface elevation have been studied. Canyon waves are dispersive and propagate along one of the canyon edges in such direction that keeps the canyon (deep water portion) at its left (right) side in the northern (southern) hemisphere.

AN ACOUSTIC DOPPLER CURRENT PROFILER ESTIMATE OF THE INTERNAL TIDE IN KNIGHT INLET, BRITISH COLUMBIA

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Previous studies of Knight Inlet, British Columbia have revealed the presence of a strong internal M2 tide. Most of the energy was found to be in either the first or second dynamic modes. Due to a similarity in modal structure below 20m depth and inadequate sampling of the surface layer, objective estimates of the distribution of tidal energy and reflection coefficients, until now have been impossible

to obtain. During June and July, 1989, we executed an intense acoustic dopper current profiler(ADCP) sampling of the inlet. We use these results to show the existence of a strong semi-diurnal flow in the baroclinic field. It is proposed that the horizontal phase information inherent in the spatial sampling by the ADCP can be used to resolve the vertical sampling problem. Through a least squares fit of the data to a simple free wave propagation model of the inlet, we arrive at objective estimates of the distribution of M2 internal tide energy. The fitting procedure is found to be sensitive to fluctuations in the basin width. When an accurate estimate is incorporated into the fit, we arrive at net energy fluxes of 0.44×10^6 W toward the mouth of the inlet at Protection Point and 1.17×10^6 W toward the head of the inlet at Tomakstum Island. We show that these results do not display the degeneracy inherent in other estimates and that they are in agreement with a recent numerical model of the inlet by Stacey and Pond (1992).

NUMERICAL SIMULATIONS OF STRATIFIED TIDAL FLOW ACROSS GEORGES BANK: INTERNAL WAVE GENERATION

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Results of some initial, idealized numerical simulations of inviscid stratified flow across the northern edge of Georges Bank are presented. These simulations were carried out in order to develop an understanding of some of the complex internal wave phenomena observed in this location (Loder et al. 1992). The numerical model solves the fully nonlinear, non-hydrostatic, inviscid Boussinesq equations on an f-plane. The model is two dimensional, with spatial variation in the vertical and cross-bank directions only. The model topography and tidal strength are similar to observed values. The model successfully reproduces some observed features including the formation of a large depression and a hydraulic jump over the bank edge during off-bank flow and two on-bank propagating depressions every tidal period. An undular bore propagating away from the bank is in agreement with other observations (La Violette et al. 1990). Rotational effects are shown to the responsible for the formation of the second of the on-bank propagating depressions. Sensitivity of the results to the topographic slope, tidal strength, density, and model initialization are explored.

INTERNAL SOLITONS IN THE CANADIAN ARCHIPELAGO

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An acoustic Doppler current profiler detected numerous large amplitude events in the vertical velocity structure of the water column under land-fast ice Resolute Bay, North West Territory, Canada. This study focuses on a particularly distinct wave train of four internal solitons. The three dimensional velocity structure of each wavelet is examined with a two meter depth resolution and a two minute sampling interval. An integration of the vertical velocity field indicates a vertical migration of the isopycnals in agreement with a theoretical model by Benjamin. The Richardson number, calculated immediately below the pycnocline (ie. region of maximum density gradient and maximum static stability), indicates an environment suitable to promote mixing by Kelvin-Helmholtz instabilities. Based on the results, a nutrient supply mechanism is proposed to explain under-ice algae growth.

Tuesday/Mardi p.m. Room/Salle 205

PLANETARY BOUNDARY LAYER
COUCHE LIMITE PLANÉTAIRE

Chair/Président: Y. Delage, Atmospheric Environment Service, Dorval

TURBULENT BOUNDARY-LAYER FLOW OVER IDEALIZED TOPOGRAPHY: WIND TUNNEL, HIGH-ORDER CLOSURE AND LES STUDIES

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There have been many studies of turbulent boundary-layer flow over topography conducted over the years, some concerned with stably stratified flow and lee waves, but many focusing on the neutrally stratified boundary-layer. Flow over an infinite train of two dimensional sinusoidal waves (z_s = a Cos kx) serves as a canonical example of these flows and can assist in attempts to refine our understanding of turbulent flow over topography. In the present paper we will present wind tunnel measurements, high order closure model calculations and Large Eddy Simulation (LES) results for this flow.

In the wind tunnel experiments we obtained mean velocity profiles and turbulence statistics at various positions along the 11th wave (along a model with a total of 14 sinusoidal waves) for two cases with the same slope (ak = 0.5) but different surface roughness ($kz_0 = 3.1 \times 10^{-4}$ - relatively smooth and 4.2×10^{-3} - relatively rough). The flow over the smooth surface remains attached while in the rough case the flow separates. An additional complication arises in the smooth case where stable, secondary flows develop in the form of vortex pairs aligned with the flow. These are also obtained in the LES simulations of the wind tunnel flow. MSFD[1] and NLMSFD[2] results for the same case will also be discussed.

[1]Mixed Spectral Finite Difference model.
[2]Non-Linear MSFD model.

LARGE-SCALE SIMULATION OF THE CONVECTIVE BOUNDARY LAYER OVER AN INHOMOGENEOUS SURFACE

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Significant spatial inhomogeneities in surface properties constitute a common phenomenon over land. It is still unclear how these influence the turbulent structure of the overlying convective boundary layer and how its character differs from the natural random variability observed over more homogeneous surfaces.

A high resolution large-eddy simulation was performed to address this question. Surface heat flux variations are sinusoidal and two-dimensional, dividing the total domain into 'patches' of about 250

m. Wind speeds were 1 m/s. Results were compared against a simulation in which the total heat flux was preserved but distributed evenly over the domain.

The simulation reveals that when patches of strong heat flux are distributed over the domain ---hot spots--- their influence is significant and affects the lower half of the convective boundary layer, giving rise to small scale circulations of roughly the size of surface hot spots. Results from phase averages suggest that inhomogeneous heat fluxes influence the behaviour of the turbulence statistics, and in particular of the higher moments.

MEASURING VORTICITY IN THE SURFACE LAYER: WHY BOTHER? A NEW SENSOR, PRELIMINARY RESULTS?

J. Wilson
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When we see leaves or snowflakes swirling in the wind, we get a distinct impression of the scale and intensity of vorticity, and a feel for the "mixing". But despite the central role played by vorticity in both our visual concept and the theory of turbulence (viz. the energy cascade to smaller scales via vortex stretching), vorticity has rarely been measured in the atmospheric surface layer, and it largely remains to determine the magnitude and scaling of the vorticity components and their fluxes. Experimentation seems warranted, on the principle that it is often fruitful to study nature directly rather than limit one's field of view to models purporting to represent nature; and there is always the possibility that new knowledge of vorticity might contribute towards a better description of processes of practical interest, such as turbulent mixing.

This talk will view vorticity knowledge: Kolmogorov scaling, and the dynamical equations; vorticity production at boundaries; and available data on variances and fluxes near ground. A prototype ultrasonic vorticity sensor will be described, whose averaging area is of order 0.005 m^2, ten times smaller than the earlier devices of Ohtou *et al.* (1983); Bound. Layer Meteor. 27) and Koprov *et al.* (1988: BLM 42). And, if available, field data with the new sensor will be reported.

AN INVESTIGATION OF FLUX-VARIANCE METHODS AND UNIVERSAL FUNCTIONS APPLIED TO THREE LAND-USE TYPES IN UNSTABLE CONDITIONS

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Fluxes calculated from three flux-variance methods, which depend upon three different forms of the normalized standard deviation functions (referred to as universal functions) of the surface atmospheric stability have been tested and compared with measurements for temperature and water vapour. The flux measurements were made over a fully leafed deciduous forest, a leafless deciduous forest and over a wetland region during the summer. The first method (referred to as the variance method) allows for certain constants, which are associated with the universal functions, to vary with the land-use type and the scalar for which the flux is computed. The second method uses the universal function known as Tillman, which depends upon two constants and the third method, known as Wyngaard, is the simplest and depends upon one constant only. Flux estimates from the variance method yield the best agreement with the observations over the three land-use types and the Wyngaard method appears to yield estimates that are quite comparable to it. The measurements for the universal functions agree better with the Wyngaard function for temperature and better with the Tillman function for water

vapour, although both show some scatter. The simplest Wyngaard method is considered adequate for computing the fluxes of temperature and water vapour from their variances.

A MODEL OF STABLE, TWO-DIMENSIONAL ATMOSPHERIC BOUNDARY-LAYER FLOW OVER FIXED, SINUSOIDAL TOPOGRAPHY

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A model of stable, two-dimensional boundary-layer flow over gently-sloped topography is developed. The model implements a forward-time finite difference numerical scheme based on the time dependent equations of motion with a specified initial state along with given upper and lower boundary conditions until a steady state is reached. The boundary-layer is effectively infinite; the top is uniformly horizontal, and the bottom, which is the shape of the topographical surface, is given by $z_s = -a\cos(kx)$, where $k=2\pi/\lambda$ and λ is the wavelength, and has a maximum slope $ak < 0.5$. The lateral boundary condition is periodic with a period of λ. The stable stratification is described by a real, positive Monin-Obukhov length L_0 determined from the shear stress and vertical heat flux applied at the top of the boundary-layer. Two versions of the model are developed: in one, stability is a global condition and is described by a fixed parameter L_0 throughout the flow, while in the other, it is a variable flow quantity and is given by a function of position $L_0\Lambda(x,z)$. The model was initially tested with rigid lid upper boundary conditions. Various stabilities and surface amplitudes were considered in both model versions. Results show the streamlines are terrain-following near the surface decaying to flat horizontal at the top with no detectable phase shift in the intermediate levels. This absence of internal waves is consistent with solutions for geometrically similar, inviscid, density-stratified flows with no vertical motion at the upper boundary. In order to generate internal waves, we are applying wave-transmitting upper boundary conditions.

MODELLING THE DIURNAL TEMPERATURE RANGE IN THE PLANETARY BOUNDARY LAYER

B. Crenna
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Recent analyses of temperature trends indicate that the diurnal temperature range (DTR) has been decreasing over the past half century. At this point, it is unclear what mechanisms are most important in causing such changes to occur, and what role alterations in surface rather than large-scale forcings have played. In order to provide physical insight into the sensitivity of the DTR to changes in several controlling parameters, a set of one-dimensional, high-resolution planetary boundary layer models has been employed. The models incorporate the widely-used Mellor and Yamada turbulence closure schemes at several levels of complexity. Considerable attention is paid to resolving the near-surface layer.

Using the models, the sensitivity of the DTR to a "phase space" of possible forcing-change scenarios was investigated. Variables in this phase space included geostrophic wind speed, water vapour concentration, surface roughness, albedo, surface moisture availability, average cloud fraction and elevation, latitude and season, and carbon dioxide and aerosol concentrations. In addition, the model was run using from ten to four thousand grid points, to determine the effect of model resolution on the temperatures predicted, and comparisons were made between the results obtained by the different closure scheme levels.

A MODEL FOR THE CORRECTION OF SURFACE WIND DATA FOR SHELTERING BY UPWIND OBSTACLES

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Wakes behind 2D fences and 3D obstacles are reviewed with special emphasis on reduced mean wind speeds and sheltering effects. Based partly on Perera's study of wakes behind 2D fences, and assuming a Gaussian spread for wakes behind 3D obstacles, a shelter model is proposed and tested. The shelter produced depends on a wake moment coefficient, $\tilde{C}_h$, which appears to be significantly less for 3D obstacles than for 2D fences. The model (WEMOD) provides a simple basis on which to "correct" anemometer data for sheltering effects associated with upstream obstacles. Such corrections are an important step in the generation of improved surface wind climatologies and wind atlases.

As illustrations of the use of model we will show applications to the estimation of sheltering effects of buildings at Lethbridge Airport (Alberta, Canada) and the J.A. Fitzpatrick Nuclear Power Station (New York State, U.S.A.) on wind measurements at those sites.

DRAG PARAMETERIZATION AND EFFECTIVE ROUGHNESS LENGTHS FOR COMPLEX TERRAIN

D. Xu, K.W. Ayotte and P.A. Taylor
Department of Earth and Atmospheric Science, York University, North York, ON, M3J 1P3

NWP and Atmospheric Global Circulation Models generally use relatively simple specifications of the land surface roughness field. The Canadian Climate Centre (CCC) GCM has neutral drag coefficient and z_o fields based on Cressman's estimates. These include both vegetation and topographic contributions to z_o and lead to some anomalies relative to surface micrometeorological estimates. The Cressman approach emphasises the drag caused by topographic effects, especially over the Rockies, Andes and Himalayas. Now that the CCC GCM explicitly includes a gravity wave drag parameterization this emphasis is being reassessed.

Two separate issues are involved: one is the representation of areas of heterogeneous roughness (e.g. how do we parameterize a grid square containing a mix of forest, prairie and lake) while the other is how to account for the drag on sub-grid scale topography. Both issues will be briefly reviewed and a methodology for determining effective momentum roughness lengths from topographic and land use information (as available on standard 1:50,000 maps) will be presented.

Tuesday/Mardi p.m. Room/Salle 303

CANADIAN ATLANTIC STORMS PROGRAM II AND CYCLONES
PROGRAMME CANADIEN D'ÉTUDES DES TEMPÊTES ATLANTIQUES II ET CYCLONES

Chair/Président: O. Hertzman, Dalhousie University (1335-1515)
Chair/Président: R.E. Stewart, Atmospheric Environment Service (1545-1725)

ASSESSING THE OROGRAPHIC COMPONENT OF SURFACE PRECIPITATION OVER UPLAND COASTAL AREAS

C. Banfield (Invited)
Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X7

Determination of the extent of orographic influences over precipitation represents a significant challenge for the forecasting of individual storm precipitation magnitudes and their hydrological and human impacts. This presentation reviews progress made in the understanding of the processes whereby topography exerts an influence over precipitation intensity and duration in selected mid-latitude coastal environments. The contribution of orographic effects under different synoptic meteorological scenarios and terrain configurations will be examined. Over Atlantic Canada the diversity of coastal orientations and upland dimensions, together with the particular meteorological conditions accompanying coastal precipitation episodes, complicates the recognition of orographic influences. The role of orography in the production of local to meso-scale patterns in event precipitation will be examined for situations in eastern Newfoundland, including selected cases observed during the CASP II period.

AIRBORNE SURVEYS OF THE PLANETARY BOUNDARY LAYER ABOVE THE MARGINAL ICE ZONE

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During CASP II, a series of five flights of the NRC Convair-580 was conducted in the planetary boundary layer above the marginal ice zone (MIZ) on the Northeast Newfoundland Shelf with the primary goal of measuring the vertical fluxes of heat and momentum. A new under-wing pod configuration for the flux instrumentation required comprehensive testing prior to and during the project in order to insure the reliability of the measurements. The observed rms gust velocities are found to satisfy the empirical scaling laws for a weakly unstable boundary layer above the MIZ and the neutral drag coefficients are consistent with other MIZ measurements, as a function of ice concentration and type. Finally, the ice-water transects reveal qualitatively different behaviour of the momentum flux, depending upon the magnitude of the heat flux increment over the water. Some simple two-dimensional models are invoked in an effort to explain this effect.

EFFECTS OF WINTER STORMS ON SEA-ICE OVER THE NEWFOUNDLAND SHELF

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During a 23-day cruise on C.S.S. Hudson to the N.E. Newfoundland Shelf in March 1992 as part of the CASP II sea-ice programs, ice, oceanography and wind data were collected to study the response of the ice-ocean system to strong wind forcing. The data include CTD, current profiles from a moored ADCP, ice drift, wind at the ship, and current shear at a drifting ice station. A strong storm with wind speeds up to 40 ms occurred on March 26, and a weaker storm with a maximum wind speed of 25ms occurred on March 23. After the March 26 storm, the ice coverage decreased rapidly, especially in the Flemish Pass. The ice drift followed closely the winds. Over the one month period after the deployment, the ice drifted in the southeastward direction with a mean velocity of 0.15ms . The currents under the ice were measured by three S4 current meters suspended from the ice surface at 5m, 15m and 40m depths. The vertical structure of the currents exhibit an Ekman spiral during strong winds which is consistent with the theory of wind driven ice motion. By comparing the CTD data taken before and after the March 26 storm, mixed-layer deepening was evident in the open water areas, but the mixed-layer properties were not changed significantly in the ice covered areas. CTD sections across the ice zone show that water in the deep ocean is homogeneous as a result of winter convective mixing, but over the shelf the water is stratified. This suggests that there is continuous intrusion of the Labrador Sea water onto the shelf along the bottom. The intrusion can be a compensating flow of the offshore surface current forced by winds.

VERIFICATION OF 3, 4 AND 5-DAY PROGNOSTIC CHARTS DURING CASP II

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For the field program of Canadian Atlantic Storms Program II, (CASPII), January 15 to March 15, 1992, a forecast centre was set up in St. John's, Newfoundland to provide meteorological support to the project.

One duty of the centre was to provide guidance out to day-5. To assist forecasters in this task, NWP 3, 4, 5-day prognostic charts were available from three Centres, namely, Canadian Meteorological Centre (CMC), National Meteorological Centre (NMC) and European Centre for Medium-range Weather Forecasting (ECMWF).

The three numerical products are verified for the CASPII period. Of particular interest are the central pressures, positions, speed and rate of deepening of the more intense cyclones. As well the consistency between successive issues of the same model is evaluated.

Another area of interest is how well the day-3 portion of the 3,4,5-day charts follow from the 48-hr progs of CMC's RFE and Global and NMC's NGM models. This is examined.

A NUMERICAL MODEL INVESTIGATION OF AN EXPLOSIVELY DEEPENING WINTER STORM DURING IOP14 OF CASP II

Z. Huo[1], D-L. Zhang[1], J. Gyakum[1] and A. Staniforth[2]
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An improved high resolution version of the Canadian regional finite-element model (RFE) is used to simulate a case of explosively deepening storm that occurred during the Canadian Atlantic Storm Program II (CASP II). A 48h simulation is employed to examine the structure and evolution of the storm. A series of sensitivity experiments are conducted to provide a better understanding of the physical and thermodynamical processes that might be responsible for the rapid deepening, such as surface sensible and latent heat fluxes, latent heat release, condensation schemes, topography and sea ice etc. The model reproduces very well the intensity and position of the storm as verified against all available observations. In particular, the size and position of the "eye" seen on the satellite imagery are well reproduced. Analysis of the results confirm previous investigators' findings about the mesoscale structures of the explosive storm, such as upper-level jet streaks, the low-level jets ahead the cold and warm fronts and the warm core seclusion. The analysis of the model output also show that: (1) an amplifying upper tropospheric wave determines the initial development of the storm; (2) at the beginning of the most explosively deepening stage, an upper level jet streak acts in such a way that the transverse circulation associated with it focuses the upper-level divergence and midlevel ascent over the surface low; and (3) the latent heat release and surface fluxes of sensible and latent heat account for a relatively small portion of the rapid deepening.

DIAGNOSING SURFACE DEVELOPMENT OF EXTRATROPICAL CYCLONES: THE IMPACT OF HEIGHT OF DIABATIC HEATING

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During the past decades, many studies have shown the importance of diabatic heating in extratropical cyclones. An analytical study, where the atmosphere is simplified by assuming barotropic and frictionless motion, examined the impact of the height of diabatic heating. Using a semi-geostrophic version of the Zwack and Okossi development equation (MWR, 1986), the results showed that when diabatic heating is in the upper part of the troposphere the development is weaker but the vertical motion is stronger than when diabatic heating is near the surface..

Clearly, it would then be appropriate to examine these effects in the real atmosphere. In this paper we will present results from verification of the impact of the height of diabatic heating in a realistic atmosphere as simulated by the RFE model. These results may have important consequences for understanding the physics of polar lows and other diabatically driven systems.

ETUDE DIAGNOSTIQUE D'UNE SIMULATION D'UN DEVELOPPEMENT COTIER MARITIME A L'AIDE DE L'EQUATION DE ZWACK-OKOSSI

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Dans le but d'une meilleure compréhension de l'évolution de la structure des systèmes météorologiques extra-tropicaux tels en autres les cyclones, les anticyclones et les fronts, nous présentons un diagnostique du développement d'une simulation numérique du modèle EFR. Le diagnostique se fait à l'aide de l'équation de développement de Zwack-Okossi (MWR 1986) qui fut étendue jusqu'au nombre de Rossby de l'ordre de 0.3 puis vérifiée par Lupo et al. (MWR 1992) sur un réseau d'observations. Pour tenir compte du terme adiabatique, une modification est apportée à cette équation afin de mieux isoler la contribution de chaque forçage au développement et au mouvement vertical. Nous présentons ici les modifications de l'équation de même que les résultats du diagnostique pour un important développement Maritimes survenu dans la période du 5 au 7 décembre 1992 tel que simulé par le modèle EFR.

SATELLITE OBSERVATIONS OF PRECIPITATING STRATOCUMULUS CLOUDS

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[1]Atmospheric Sciences Programme, University of British, Vancouver, B.C. V6T 1Z2
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We present half-hourly geostationary satellite retrievals of cloud-top temperature and cloud optical depth for sub-tropical, precipitating stratocumulus layers in a Lagrangian reference frame advecting with the low-level wind. These observations show the drizzling clouds undergoing rapid transformations, in which they lose up to 40% of their liquid water over 30 to 60 minute intervals. We discuss error estimation for the optical depth retrievals using simultaneous measurements from the Landsat Terestrial Mapper, the NOAA 9 Advanced Very High Resolution Radiometer, an airborne multi-channel radiometer, and in-situ aircraft measurements, and estimate the impact of these large rainrates on the cloud dynamics and microphysics.

THE USE OF TOMS DATA IN THE STUDY OF MESOSCALE POLAR VORTICES

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We investigate the hypothesis that certain types of mesocale vortices in the polar air streams are associated with upper level disturbances. For this study we make use of the daily Total Ozone Mapping Spectrometer (TOMS) data. The 50 km resolution of this instrument is sufficiently small that one should be able to distinguish the presence of tropopause distortions and the resulting intrusion of ozone-rich stratospheric air that are associated with upper-level disturbances. Considering the relative scarcity of conventional meteorological information in the polar regions, the TOMS data provides a potentially useful tool for the study of such storms.

Preliminary results of an examination of 39 storms over Canadian and Scandinavian waters showed only 17 occurring in relatively featureless areas of the TOMS data. Of the remainder, 11 appeared to be in close association with mesoscale local maxima in the data and 11 accompanied extremely steep larger scale features. While the TOMS data showed much more structure in the spring months due

to the break up of the polar vortex, the fraction of storms associated with mesoscale "ozone highs" was approximately unchanged between fall and spring. The fraction of storms with relatively flat TOMS data was approximately three times higher in the months of October through December than in January through March, while those associated with large scale TOMS features were correspondingly enhanced in spring.

A more quantitative study of the value of TOMS data in the classification and characterization of these vortices, based on a much larger number of cases and including information from 500 mb charts where available, is underway. Along with further investigation of the apparent association between some mesoscale polar vortices and localized maxima in the TOMS data, we are also attempting to determine whether the seasonal variation in the fraction of storms near large scale TOMS features reflects some difference in storm generation mechanisms or just the large number of vortex fragments in spring.

Wednesday/Mercredi a.m. Room/Salle 102

FOREST AND AGRICULTURAL METEOROLOGY I
MÉTÉOROLOGIE FORESTIÈRE ET AGRICOLE

Chair/Président: R.B.B. Dickison, Atlantic Weather & Environmental Consultants Ltd.

BIOSIM: A COMPUTER-BASED DECISION SUPPORT TOOL FOR SEASONAL PLANNING OF PEST MANAGEMENT ACTIVITIES

J. Régnière (Invited)
Forestry Canada, Quebec Region, Sainte Foy, Québec G1V 4C7

Pest management activities in forestry, particularly monitoring risk assessment and pest control, involve considerable human and material resources. To optimize the deployment and use of these resources, plans must be developed which take into consideration the fact that the development of insects and plants is highly temperature-dependent. The planning task becomes rather daunting in geographically and topographically complex arenas.

BioSIM is a computer-software package being developed into a Seasonal Pest Management Decision-support tool. Although still in its infancy, BioSIM has met considerable interest in the Canadian forest pest-management circles, and is being used operationally in Quebec and New Brunswick. BioSIM is centered around two sets of activities: producing geographically-specific weather forecasts and predicting phenomenological events from these weather forecasts. Both activities involve (1) managing data bases, (2) running simulation models and (3) producing reports in a so-called user-friendly environment. The phenomenological simulation models handled by BioSIM all require daily minimum and maximum daily air temperatures as inputs. So the weather components of the BioSIM system were designed to provide the best possible time series of weather data for a given geographical location, based on the "nearest" sources of three types of information: real-time observations, 5-day forecasts, and long-term forecasts based on normals.

In this presentation, the weather-related components of BioSIM will be described, with a particular emphasis on geographical/altitudinal projection and the generation of long-term forecasts from normals. Application of BioSIM in topographically complex arenas with GIS technology will also be demonstrated.

CLIMATIC TELECONNECTIONS FROM THE PACIFIC OCEAN TO THE CANADIAN PRAIRIES - IMPLICATIONS FOR SPRING WHEAT YIELDS

E.R. Garnett[1], J. Babb[2] and M.L. Khandekar[3]
[1]Canadian Wheat Board, Winnipeg, Manitoba R3C 2P5
[2]Canadian Grain Commission, Winnipeg, Manitoba
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Large-scale atmospheric and oceanic circulations 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. The ENSO events are further found to have significant impact on world grain yields. Previous study (research) has indicated that the warming of the sea surface temperatures in the equatorial eastern Pacific (called El Nino) tends to favour Canadian spring wheat yields while the cooling of the sea surface temperature in the same region (called La Nina) mitigates spring wheat yields.

We have extended this study to investigate the impact of the Pacific North American (PNA) index on temperature and precipitation anomalies over the Canadian prairie provinces. The PNA indices 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 the Canadian west coast. Preliminary analysis suggests that hottest (coolest) summers over the Canadian prairies are associated with positive (negative) trend of the PNA index.

Implications of our study for foreshadowing grain yields over the Canadian prairies are discussed.

EVALUATION AÉRIENNE ET PRÉVISION DES INDICES CANADIENS FORÊT-MÉTÉO

L. Pouliot
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Les indices canadiens Forêt-Météo servent à évaluer l'inflammabilité et la sécheresse des forêts ainsi que les comportements des feux de forêt potentiels ou en cours. Nous savons que les indices sont des valeurs discontinues (d'une gamme de danger à l'autre) et que la distribution des valeurs d'indice n'est pas une distribution linéaire. Par conséquent, on ne peut traiter les indices par une simple arihmétique ou tenter d'interpoler entre deux valeurs. Dans cet ouvrage on revise brièvement les relations des paramètres météo, indices et feux de forêt. On souligne les niveaux de précision qui affectent les calculs d'inflammabilité des forêts et de comportements des incendies. On décrit la méthode d'évaluation et de prévision des indices Forêt-Météo par zone météo-forestière reliée aux incendies. Cette méthode spatiale est développée et utilisée par le Centre météorologique du Québec afin de fournir l'assistance météorologique demandée par les responsables de la protection des forêts contre le feu au Québec.

COMPARISON OF PESTICIDE SPRAY DEPOSITION MODEL RESULTS WITH OPERATIONAL MEASUREMENTS

T. C. Farrell[1] and B.L. Beattie[2]
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During July and August 1991, 6 operational pesticide spray events in Prince Edward Island were monitored for meteorological conditions and spray deposit on downwind receptors. Three of the cases involved aerial application of the pesticide "Bravo" (active ingredient: chlorothalonil) to potato plants by a Piper Pawnee aircraft flying approximately 3 metres above the field. The remaining three cases had spray applied from a height of one metre by a farm tractor.

Five of the cases were used as input into version 4.0.2 of the FSCBG (Forest Service Cramer Barry Grim) Aerial Spray Computer Model. This version incorporates both the far-wake FSCBG and near-wake AGDISP (Agricultural Dispersion) deposition models to predict the behaviour of spray material released through nozzles into the wake of a spray aircraft (either fixed-wind or helicopter). AGDISP solves for the effect of the aircraft wake on the behaviour of released spray using a Lagrangian approach. FSCBG solves for the effects of local meteorology, canopy interaction, and deposition after the spray is no longer influenced by the aircraft wake. Deposition from a number of spray swaths and droplet sizes is summed at various receptor positions.

In general, model results for infield receptors were fairly close to measured when accurate emission rates were known. However, the model depositions dropped off much more quickly downwind of the field than was seen from the sampler measurements. Different meteorological conditions encountered during each spray case changed the model results in and near the edge of the field, but not significantly further downwind.

The usefulness of this Model in predicting deposition from operational pesticide spraying is dependent on the accurate knowledge of sensitive input parameters.

Poster No. 4

DIRECTION NATIONALE DE LA MÉTÉOROLOGIE DU MALI, DIVISION AGROMÉTÉOROLOGIE

M.T. Traoré
Division Agrométéorologie, Direction nationale de la météorologie, Bamako, Mali

L'agrométéorologie étudie les relations existant entre les facteurs météorologiques, hydrologiques d'une part et les cultures, les pâturages, les arbres, les animaux d'autre part afin d'appliquer la connaissance de l'atmosphère à la pratique agricole.

Les activités agrométéorologiques au Mali, supervisées et coordonnées par la Division d'agrométéorologie sont menées en collaboration avec les services techniques du secteur rural.

Elles comportent deux volets essentiels:

1) Volet "assistance" chargé du suivi de la campagne agricole, en élaborant des informations agrométéorologiques (décadaires, mensuelles, conjoncturelles) en vue de contribuer à l'alerte précoce.

2) Volet "études et développement" chargé du suivi des champs et de l'élaboration des conseils et avis destinés aux paysans en vue d'une prise en compte des informations agrométéorologiques dans leurs activités culturales afin de minimiser les risques et d'augmenter la production agricole. Le volet s'occupe également des études et analyse d'autres paramètres agrométéorologiques indispensables à l'élaboration des avis et conseils.

Poster No. 5

SOIL TEMPERATURE DIFFERENCES IN ARTIFICAL GROWING MEDIA

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Temperatures were measured at a depth of 5 cm in nine different greenhouse growing medium formulations filling styroblock growing containers. The media combined one of three different peats with either vermiculite, perlite or no additive. All artificial media had a much higher porosity than mineral soils and water content differences were even more important in controlling thermal property and soil temperature differences. Afternoon soil temperatures generally had an inverse relationship with soil moisture. Hydraulic conductivity at actual water content, which includes the effects of both soil moisture and ease of water movement for evaporation, had a better correlation with both afternoon and mean daily temperature than did water content or heat capacity. Highest temperatures at night were observed in media with intermediate water contents. Soil temperature differences between media were greatest when water contents were low.

MODELLING THE SPATIAL VARIATIONS OF WIND VELOCITY AND WET DEPOSITION OF ACIDIC IONS ON ROUNDTOP MOUNTAIN, QUEBEC

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[2]Cloud Physics Research, Atmospheric Environment Service, Downsview, Ontario M3H 5T4

The MS-Micro/3 computer model for wind flow in complex terrain is applied to the Roundtop Mountain complex in southern Quebec for three cases: average conditions observed during the August 1987 Chemistry of High Elevation Fog (CHEF) measurement program; and conditions observed during two 24-h periods in August and September 1987. Spatial variations in wind speed and direction calculated from the model follow terrain features, with highest wind speeds on ridges and lowest in valleys. Model results at two sites on Roundtop Mountain are compared with observations. Although the model is designed for gentle terrain variations and steady-state meteorological conditions, the agreement with wind observations is good.

The wind fields produced by MS-Micro/3, were used in further calculations to obtain spatial distributions of $SO_4^{=}$, NO_3^{-}, and H^{+} deposition rates over Roundtop Mountain. Contributions due to fog deposition and precipitation were computed separately. Input parameters included cloud base

height, liquid water content (LWC), precipitation rate and ion concentrations in fog and precipitation, as observed at two CHEF sites. The spatial pattern of ion deposition from fogwater is strongly influenced by the terrain, largely because both wind speed and LWC tend to increase toward the tops of the ridges and the summits. Isopleths of ion deposition from precipitation broadly follow the terrain, but deviate in detail, mainly because of the effect of differing slopes built into the model. These variations in slope, together with the assumed increase of precipitation rate with altitude, are the dominant factors in precipitation deposition.

CALCULATING TOTAL ANNUAL AMOUNTS OF SO_2 ABSORBED BY SPRUCE FORESTS IN THE VICINITY OF AN ELEVATED SO_2 SOURCE

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Total annual amounts of SO_2 absorbed by forest canopies downwind from an elevated point source (a SO_2-emitting power generator north of Grand Lake in central New Brunswick), were examined by computer simulations and by measurements based on lead dioxide sulfation plates. The simulations involved modelling the release of SO_2 from the point source and subsequent plume, and the absorption of SO_2 by spruce forests downwind from the source. Daily amounts of absorbed SO_2 were calculated for downwind distances from 0 to 42 km, and for different weather conditions, including neutral conditions, and atmospheric transitions from stable to unstable conditions. Per hectare rates of SO_2 deposition and absorption were calculated from dawn to dusk with insolation, wind speed, turbulence, and canopy moisture, as main variables. Yearly influences of changing weather conditions on the SO_2 absorption pattern as affected by precipitation, atmospheric stability, wind speeds and directions were estimated by way of Monte Carlo simulations. These simulations were calibrated for the area surrounding the Grand Lake Power Generator. The predicted rates of canopy-absorbed SO_2 were similar to those obtained with the lead dioxide sulfation plates. Topography was revealed to be an important factor in modifying the actual SO_2 absorption rates. According to the calculations, the total annual amount of SO_2 absorbed within 42 km from the source should be about 2% of the total amount of SO_2 emitted from the source.

ANALYSIS OF LEVELS OF GAS POLLUTANTS AND DRY DEPOSITIONS AT A FOREST RESEARCH SITE NEAR QUEBEC CITY: 1988-1991

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Within the framework of a research project which has the goal of studying the impact of environmental stresses on forest ecosystems, four gas pollutants (O_3, SO_2, NO_2, NO) have been sampled on a routine basis at the forest research site of Duschenay (located 35 km NW of Quebec City) during the period 1988-1991. Results confirm that nitrogen oxides and sulphur dioxide concentrations are extremely low. However, ozone concentrations reach, at times, levels that can be potentially harmful to vegetation. For the latter pollutant, analyses presented show that there exists a strong association between the seasonal mean (April to September) and the frequency of existence of the provincial standard (80 ppb) with the type of meteorological situations. This suggests that fluctuations of ozone concentrations are largely determined by meteorological variations and confirm that long distance transport is the dominant phenomenon in the generation of ozone episodes at Duchesnay. Selected regression models for the maximum daily ozone are presented. The variability explained by the best model is 63% (R~0.79). It is also shown that the local photochemical production does not play a significant role during

ozone episodes at Duschenay. Finally, preliminary results of the annual and monthly dry deposition of gas pollutants calculated with a multiple resistance model using the data of 1991 are presented.

SMOKE VENTILATION FORECAST AT PACIFIC WEATHER CENTRE: ACCURACY AND CLIMATOLOGY

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At the Pacific Weather Centre in Vancouver, B.C. an operational smoke control, or ventilation forecast is prepared daily during the fire season from April to October. This forecast forms an integral part in the decision making process by local Forest Service Protection personnel for prescribed burning within Designated Smoke Sensitive Areas (DSSA) of the province.

The aim of this paper is to consider the utility of the ventilation forecast for smoke management purposes by examining the accuracy of the forecast Ventilation Index (VI) given actual afternoon values; and to present a climatology of values of VI for each month. Verification statistics will be generated for the 1991 and 1992 seasons for three forecast sites in B.C. where upper air soundings are taken. Results will look at specific categories of VI as well as categories adjusted for 'burn' versus 'no-burn' situations. Furthermore, it is hoped that this study will generate some impetus for improving the operational smoke ventilation forecast.

Wednesday/Mercredi a.m. Room/Salle 125

OCEAN SURFACE WAVES
ONDES SUPÉRIEURES DE L'OCÉAN

Chair/Président: F.W. Dobson, Bedford Institute of Oceanography

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WAVE ENERGY INPUT INTO WATER WAVES

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Turbulent airflow over a water-wave train of finite wave slope is studied numerically based on the nonlinear mixed spectral finite difference model of Xu and Taylor (1991). The wave surface is considered as aerodynamically rough. The turbulent closure scheme adopted is the *E-kz*. Fractional rate of energy input per radian advance in phase, ζ, and the phase change of pressure maximum from trough are estimated for various wave ages from this model. The results are compatible with Gent and Taylor's (1976) nonlinear model for finite wave slopes, and with Townsend's (1972) linear model for small wave slope. Results for small wave slope obtained by using the q^2l level 4 closure scheme developed by Mellor and Yamada (1982) are included for comparison.

The dependence of ζ on wave age has been examined and the impact of different closures will be discussed.

THE PERFORMANCE OF THE CANADIAN SPECTRAL OCEAN WAVE MODEL, CSOWM

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The CSOWM is Environment Canada's operational ocean wave model which has been implemented at the Canadian Meteorological Centre (CMC) in Montreal since January, 1991. The CSOWM is run twice daily and the model products, in the form of a 4-panel wave height charts with wave height contours and digital information of four other wave parameters, are disseminated across the country. The model is verified against available buoy measurements over two oceanic regions - northwest Atlantic and northeast Pacific - where model wave height charts are produced.

The present paper provides a brief description of the CSOWM followed by the performance of the model as measured in terms of standard error statistics of model generated parameters versus buoy measured parameters. The performance statistics are analyzed in the context of model physics.

WIND STRESS FROM WAVE SLOPES USING PHILLIPS' EQUILIBRIUM THEORY

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Wave amplitude and slope data were obtained from a WAVEC heave, pitch and roll buoy drifting in the Alaska gyre. A comparison of the slope spectrum to simultaneous wind stresses allowed us to estimate Phillips' (1985) proposed universal constant, β. Re-introducing this constant β into Phillips' spectrum and using measured slope spectral characteristics, a slope inferred wind stress was calculated which was shown to agree well with both the directly measured and model stresses thereby validating both Phillips' theory and Smith's (1988) boundary layer model. Any discrepancies with the model stresses were attributed to second-order wave-age effects. Toba's constant, α, was shown to increase with wave-age as a direct response to increasing directional spread of the roughness elements, due to wave-wave interaction. The roughness length, Z_0, non-dimensionalized by the sea RMS waveheight, was shown to decrease with wave-age in a manner consistent with Kitaigorodskii's (1970) functional form. Other relations, often discussed in the literature and based on regressions of observations taken in generally fetch-limited, shallow-water locations, although passing through our results for young wave-ages, could not be extended to older wave-ages in this open-ocean, fetch unlimited, deep water experiment.

SENSITIVITY STUDY OF AN INTERACTIVE GRAPHICAL WIND AND WAVE ANALYSIS SYSTEM

B. Dawson
Atmospheric Environment Service, Bedford, Nova Scotia B4A 1E5

The sensitivity of an interactive graphical wind and wave analysis system to successive levels of editing of input fields was studied. Wind and wave analyses resulting from each run of the system were compared to measured winds and wave heights from Canadian East Coast buoys.

The system is based on the FPA/KASSPR software developed by Meteorological Services Research Branch of Atmospheric Environment Service. It uses pressure, air and sea temperature data from a CMC (Canadian Meteorological Centre) model to produce wind fields, and subsequently, wave fields.

The study period ran from November 29, 1992 to January 22, 1993, and includes five storms with significant wave heights of 10 metres or more.

Simple editing of pressure centres can result in significant improvements, particularly where low pressure development is poorly forecast by the CMC model. Further editing of pressure and derived wind fields, although time consuming, can make additional improvements to the wave analyses.

Wednesday/Mercredi a.m. Room/Salle 125

COASTAL OCEAN
OCÉAN CÔTIER

Chair/Président: P.C. Smith, Bedford Institute of Oceanography

ROTATION-LIMITED-FLUX: APPLICATION TO HECATE STRAIT, BRITISH COLUMBIA

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Rotation-limited-flux is a conceptual model of the low frequency (time scales of days to weeks) fluctuations in sea straits. The model is a generalization of geostrophic control (Garrett and Toulany, 1982) and gives a first order account of the effect of Kelvin waves on the sea level and transport fluctuations in a sea strait. The model provides 1) a measure of the importance of the Earth's rotation in the along-strait dynamics and 2) a basis for separating the locally wind-driven response from the pressure-driven response in the sea level observations. The pressure-driven response is the response to sea level differences between the ends of the strait.

We use rotation-limited-flux to interpret the results of an empirical orthogonal function (EOF) analysis on wind, sub-surface pressure and current data gathered in Hecate Strait in 1983-84. The first two pressure modes represent forcing dominated by sea level differences and local winds respectively. The sea level forcing is attributed to the coastal set-up caused by the large scale meteorological forcing. The separation of the local and large scale forcing provides additional insights into the current and transport observations.

A DIAGNOSTIC, VARIABLE-RESOLUTION MODEL FOR THE TIDAL AND ESTUARINE CIRCULATION IN EASTERN JUAN DE FUCA STRAIT AND THE SOUTHERN STRAIT OF GEORGIA

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[2]U.S. Geological Survey, Tacoma, WA

A three-dimensional, finite element model is used to calculate the tidal and estuarine flows in eastern Juan de Fuca Strait and the southern Strait of Georgia. Two estuarine circulations are computed diagnostically from extensive salinity and temperature measurements taken in January and July 1968.

Eight constituents are included in the tidal calculations and the harmonics are compared with those from the Crean finite difference model, and those from historical tide gauge and current meter observations.

Model currents are found to reproduce the vertical profiles of current observations well, except in regions where internal tides exist. The pattern of tidal residual currents is found to have much more detail than previous coarser resolution models and numerous eddies are predicted around specific coastal and bathymetric features. The combined residual flow arising from tides and estuarine forcing is shown to retain some of these eddy structures while demonstrating the expected picture of seaward flow at the surface and inflow at depth.

OUTFLOW AT CAPE ST. JAMES IN HECATE STRAIT, B.C.

W.R. Crawford and M.G.G. Foreman
Dept. of Fisheries and Oceans, Institute of Ocean Sciences, Sidney, B.C. V8L 4B2

Near Cape St. James at the southern tip of the Queen Charlotte Islands in British Columbia, a strong narrow jet always flows to the southwest, into the Pacific Ocean from the south end of Hecate Strait. Our observations reveal a surface-intensified jet, within which warm surface waters are mixed with deeper colder water as the flow passes Cape St. James. The outflow of this jet is about 0.3 Sv, which is greater than the average flow through the entire width of Hecate Strait in summer. The return flow into Hecate Strait passes just offshore of this jet, creating a high shear region. The combination of mixing and return flow likely enhances the nutrient supply and biomass of this region. A finite-element model of the residual barotropic tidal currents shows a small intense eddy here but little outflow. We are conducting experiments with a three-dimensional finite-element model to examine the steady state baroclinic flow at the Cape, and to simulate the interaction of this steady flow with the M2 tidal current.

THE INFLUENCE OF WIND AND SCOTIAN SHELF INFLOW ON THE CIRCULATION AROUND GEORGES BANK

D.A. Greenberg, J.W. Loder and Y. Shen
Dept. of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S. B2Y 4A2

Earlier studies have shown the importance of tidal rectification, tidal mixing and the Gulf of Maine scale density distribution to the circulation around Georges Bank. In this paper we will show how the large scale wind fields and transport into the Gulf of Maine along the Scotian Shelf, both in a steady state and long period (greater than tidal period) oscillation can influence this circulation. Our principal tool in this investigation is a three dimensional, linear-harmonic finite element model covering the continental shelf from the Laurentian Channel to the Mid-Atlantic Bight. It also includes the adjacent deep sea areas with an artificial limit of 1200m in depth.

Poster No. 8

A NEAR REAL-TIME PHYSICAL OCEANOGRAPHIC ANALYSIS SYSTEM

D. Bancroft
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Periodic oceanographic analyses are performed by Maritime Forces Pacific (MARPAC) Meteorology and Oceanography (METOC) Centre, near real-time. The principal result of this analysis is an ocean feature description, or nowcast, that in turn is used to forecast the performance of naval acoustic detection systems. In pre-existing subjective procedures, oceanographic analysts use quality controlled XBT observations, combined with ship and buoy observations, coupled with satellite imagery when available, to subjectively construct products for end-users.

There was a requirement to enhance the quality of these analyses and to provide machine aids to both increase the flexibility of the nowcast, and allow for direct output of relevant physical oceanographic fields to operational acoustic models. This required the integration of observations into an objective analysis computer program, coupled with a sophisticated visual display of both observational data and the objective analysis results.

The system developed runs on a Hewlett-Packard 9000/730 series workstation, in an X-window/MOTIF graphical user interface. Graphics display is performed using Research Sytems Inc.'s IDL visualisation program. The software developed is capable of displaying raw and processed three dimensional geo-referenced data, including specified 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.

Ultimately it is desired to produce forecasts of oceanographic fields out to 144 hours. This will, in a subsequent project, be accomplished by using a three dimensional baroclinic oceanographic model, driven by boundary layer wind and temperature fields and surface wave fields provided by Canadian Meteorological Centre (CMC).

Wednesday/Mercredi a.m. Room/Salle 205

CLIMATE MODELLING III: SEA ICE
MODÉLISATION DU CLIMAT III: GLACE DE MER

Chair/Président: L.A. Mysak, McGill University

INTERANNUAL VARIABILITY OF ARCTIC SEA ICE USING A COUPLED SEA ICE-OCEAN MODEL

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[2]Meteoroligisches Institut der Universiq Hamburg, Hamburg, Germany

A coupled ice-ocean numerical model is used to study interannual variations in the Arctic ice-pack. The sea-ice component of the model includes both dynamics and thermodynamics based on Hibler and

Oberhuber respectively. The ocean component is a diabatic isopycnal ocean circulation model with prognostic temperature and salinity fields and realistic topography (Oberhuber). The models are coupled through an ocean mixed layer. The coupled model is forced using monthly atmospheric fields spanning several decades. The simulation of sea-ice thickness, concentration, and circulation is compared with observations. In particular, the model is used to hindcast the great ice and salinity anomaly of the 1960's.

A BOX MODEL OF THE GREENLAND SEA, NORWEGIAN SEA AND ARCTIC OCEAN

D.Y. Robitaille and L.A. Mysak
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A simple box model, first developed for the Weddell Sea (Martinson et al, 1981), is applied to four different Arctic regions connected together: the Greenland Sea, the Norwegian Sea, the Arctic Ocean, and the Greenland Gyre (in the western part of the Norwegian Sea). The model consists of a simple thermodynamic ice model covering two layers of water: a mixed layer and a deep layer. These two layers can, under specific conditions, mix together to create a state of active overturning. The system is forced by monthly atmospheric temperatures in the four regions.

The model predicts the ice thickness, the temperature of the water in the mixed layer, and its salinity for the four regions. Also determined are the water temperature and salinity for the deep layer in the Arctic Ocean. The convective state of one region, ie, whether it is in an active overturning state or not, is also obtained continuously.

These different output variables in the model compare favourably with observed data. The Arctic Ocean is characterized by continuous ice cover, the Greenland Sea and Greenland Gyre have winter ice cover only, and the Norwegian Sea region never forms an ice cover. Another feature of the model is the presence of a region of active overturning in the Greenland Gyre region. There overturning is generated at the beginning of the winter by salt rejections due to the formation of sea ice. This overturning state is then stopped at the end of the winter season by the production of freshwater due to sea ice melt.

MODELLING INTERANNUAL ICE VARIABILITY IN THE GULF OF ST. LAWRENCE

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The Gulf of St. Lawrence exhibits a large amount of interannual ice variability. The recent availability of a twenty-eight year areal ice extent data set has prompted a modelling study. An uncoupled modified Hibler model initialized by observed November water temperatures, and forced by monthly mean atmospheric data has been applied to the Gulf of St. Lawrence for the years 1969-1972, a period of extreme ice variability.

The interannual ice variability is the result of complex interactions and may not be simply related to changes in any one forcing variable.

SIMULATION OF THE ARCTIC ICE COVER USING A MULTI-LEVEL MODEL

G.M. Flato
Institute of Ocean Sciences, Sidney, British Columbia V8L 4B2

Large scale motion is responsible for the highly variable thickness of the Arctic ice cover, producing areas of open water or leads and deforming the pack into pressure ridges tens of meters thick. Although the ridging process is important in determining the overall ice budget and the response of the ice cover to climatic change, it is only crudely parameterized in the two-level sea ice models now beginning to be used in climate studies. A method of describing the large-scale dynamic and thermodynamic behavior of pack ice in terms of its thickness distribution (a probability density function of ice thickness) was developed by Thorndike et al. (*J. Geophys. Res.*, 80: 4501-4513, 1975) and allows a more complete parameterization of ridging. In the present work, this thickness distribution theory was extended by including ridged and level ice explicitly. Calculating ridged and level ice thickness distributions separately allows more insight into the formation, distribution, and evolution of ridged ice and enables more comprehensive comparison to observations.

This more general theory was incorporated into a large-scale sea ice model, termed the multi-level model (similar to that of Hibler, *Mon. Wea. Rev.*, 108: 1943-1973, 1980), and used to simulate the Arctic ice cover using observed atmospheric forcing from 1979-85. A 14 year spin-up, using two repetitions of this forcing, was required to allow the ridged ice statistics to reach a seasonal equilibrium. The results of this model were compared to various submarine and satellite observations to evaluate its performance. With the appropriate choice of parameters, the multi-level model produced thickness and ridge statistics in general agreement with observations, although there may be some bias in the large-scale thickness buildup pattern. In addition, a number of sensitivity studies were conducted to investigate various physical processes and their parameterization in the model. Of particular interest here were parameters describing the ridging process and the functional form of the so-called ridge redistributor. Finally, an idealized sensitivity study was performed to illustrate the response of the Arctic ice cover to atmospheric warming and the differences in the response predicted by the multi-level model and the more widely-used two-level model.

THE RELATIONSHIP BETWEEN LARGE SCALE CIRCULATION AND THE CLIMATE AT RESOLUTE BAY, NWT

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This study examines the 44 year record of monthly/seasonal averaged temperature and precipitation observations at Resolute Bay, NWT in conjunction with changes in large scale circulation patterns over the eastern Arctic and north Atlantic. Teleconnection patterns for the north Atlantic (the North Atlantic Oscillation) and the less known Baffin Island- West Atlantic Oscillation are used to explain about 60% of the variability in seasonal temperature at Resolute Bay.

STOCHASTIC EXCITATION OF DECADAL VARIABILITY IN THE GREENLAND SEA ICE COVER

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Decadal variations in North Atlantic surface salinity, most notably the great salinity anomaly of the 1970's, were postulated by Mysak et al. (*Clim. Dyn.*, 5:111-133, 1990) to result from a complex feedback cycle involving outflow of ice through Fram Strait, North Atlantic salinity, Arctic cyclogenisis, runoff in northern Canada, and ice production and export from the western Arctic.

We compare a simple stochastic model, as in Hasselmann (*Tellus*, 28:473-485, 1976), with the form where V' is the ice volume anomaly, S' is the ice source anomaly (taken to be Gaussian white noise representing variations in atmospheric forcing), and k is the fraction of ice volume exported through Fram Strait. The constant k and the variance of the white noise forcing were obtained from analysis of a 7 yr simulation using a primitive equation sea ice model, similar to that of Hibler (*Mon. Wea. Rev.*, 108:1943-1973, 1980), which used observed daily atmospheric forcing from 1979-85. Realizations of the stochastic model produce outflow anomalies, kV', with decadal scale variability commensurate with the ice anomalies discussed in Mysak et al. (1990). Qualitative agreement between this simple stochastic model and observations points to the need for caution when inferring causal mechanisms for the observed Greenland Sea ice variability.

THE PARAMETERIZATION OF THE CONDUCTIVE HEAT FLOW THROUGH A SEASONAL SNOW AND SEA ICE VOLUME

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Over much of the year the conductive heat flow from the freezing ice/ocean interface to the snow surface of a seasonal sea ice volume limits surface cooling by partially offsetting the large radiative heat losses incurred by the surface. Totals of the conductive heat flux, which represent the largest of the energy sources to the surface, display marked seasonality.

Relationships between this surface heat source and both the snow/ice geophysical properties and aspects of the ambient climate are analyzed from observations obtained during the 1991 and 1992 Seasonal Ice Monitoring and Modeling Site (SIMMS) field experiments. This paper introduces a framework for a parameterization strategy of the conductive heat flux, and discusses the extent to which remote sensing information can be accommodated within the parameterization scheme.

Poster No. 6

EDDIES SOUTHWEST OF THE DENMARK STRAIT

J.G. Bruce
Naval Oceanographic Office, Stennis Space Center, MS 39522, U.S.A.

Numerous cold cyclonic eddies (20-40 km diameter) have been observed in satellite IR imagery (NOAA-11, Ch 3 and 4) along the edge of the East Greenland Shelf to the southwest of the Denmark Strait and appear to be advected along in the East Greenland Current. The path of the

eddies is coincident with the location of numerous current meter observations from previous surveys during which the strong pulses of overflow water (recorded speeds of over 150 cm sec^{-1}) had spectra peaked at periods of 1.5-2.5 days. It is suggested that the pulses are the signal observed from energetic, advected cyclonic vortices formed by vortex stretching associated with the sinking of dense overflow water downstream from the sill of the Denmark Strait. The signature of the vortices at the sea surface appears in the IR imagery as a cold cyclonic eddy.

Poster No. 7

THE SEASONAL SEA ICE MONITORING AND MODELING SITE (SIMMS)

D. Barber[2], E. LeDrew[2], A. Silis[1], T. Agnew[1], T. Papakyriakou[2], R. De Abreu[2]
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[2]Earth Observations Laboratory, University of Waterloo, Waterloo, Ontario N2L 3G1

The Earth Observations Laboratory at the University of Waterloo developed SIMMS in 1990 to better understand the physical and biological processes occurring through the atmosphere-cryosphere-ocean interface and to provide surface validation data for SAR (Synthetic Aperture Radar) and other satellite and airborne sensors. To date 3 spring field programs have been successfully completed and this presentation will concentrate on the field measurements program during 1992. The field activity was based out of Polar Continental Shelf (PCSP) in Resolute Bay, NWT with a field camp on Griffith Island approximately 20 kilometres southwest of PCSP. There were four primary measurement sites: first-year ice site; a home site; a multiyear ice site and ice edge site. Snow pits were used to record snow depth, salinity, density, wetness, dielectrics, and crystal size and shape. Ice cores were taken to study the physical, dielectric and microstructural properties of sea ice. The measurement of these parmeters are important to understanding microwave scattering which occurs in the snow and ice volume and surface energy balance processes.

The presentation will concentrate on the energy and radiation balance at the sites over the the period of the field experiment from early April, 1992 to the onset of snow melt in June. Surface microclimate data were collected to evaluate the turbulent (sensible and latent heat fluxes), conductive, and radiative energy exchanges over different snow ice surfaces.

Wednesday/Mercredi a.m. Room/Salle 303

ATMOSPHERIC DYNAMICS
DYNAMIQUE DE L'ATMOSPHÈRE

Chair/Président: H.-R. Cho, University of Toronto

THERMAL FORCING OF SLOW TRANSIENTS BY THE SYNOPTIC SCALE EDDIES IN THE ATMOSPHERE

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Using 700mb ECMWF analyzed data for 5 winters(1981/82-85/86), the thermal characteristics of the low-frequency variability are examined. The thermal forcing is defined as the convergence of heat flux

by the synoptic scale eddies. It is found that there exists an out of phase relationship between the low-frequency temperature field and the thermal forcing, most notably in the climatological storm track regions. The synoptic scale eddies act to dissipate the low-frequency temperature variability on a time scale of several days.

The dominant thermal forcing patterns are determined by EOF analysis. The leading EOF mode in both ocean sectors depicts the fluctuations of the thermal forcing along the storm track axes. The pattern of the temperature field associated with the leading EOF mode of the thermal forcing is also identified. The temperature pattern associated with the first Atlantic thermal forcing mode shows a wave-train structure like EU pattern, whereas the one associated with the first Pacific mode has more localized feature.

The relative importance of the thermal forcing comparing with other processes in maintaining the low-frequency temperature variability is discussed through a thermal variance budget analysis. The source of the thermal variance is the temperature advection over the east portions of Asian and North American continents, and the adjacent oceanic areas. Both the thermal forcing by the synoptic scale eddies and the effect of the vertical motion dissipate the thermal variance, where the effect of the former is about 2/3 that of the latter.

ON THE INTERACTIONS BETWEEN SYNOPTIC SCALE EDDIES AND THE PNA TELECONNECTION PATTERN

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The interactions between the monthly mean Pacific/North American (PNA) anomaly patterns and the synoptic scale eddies are investigated. The study is based on 23 winters of NMC data at the 250, 500 and 850 hPa levels and focuses on the barotropic interaction between the eddies and the PNA anomalies. The eddy vorticity forcing of the PNA fluctuations is represented in terms of monthly mean geopotential tendencies. These geopotential tendencies are found to be spatially in phase with the PNA anomalies throughout the troposphere. The strongest vorticity forcing is in the upper troposphere where the characteristic time scale of the forcing is about 6 to 10 days, indicating that the interaction is significant for the dynamics of the PNA pattern. It is also found that the strongest anomaly in eddy forcing is collocated with the largest amplitude PNA centre over the northern Pacific. The study shows that the eddy vorticity forcing is spatially in phase with the PNA pattern for both the positive and negative phases of the PNA anomalies.

POTENTIAL VORTICITY DYNAMICS IN AN ATMOSPHERIC GCM

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The global distribution of Ertel potential vorticity (PV), simulated by the Canadian Climate Centre general circulation model is examined for January conditions. An expression for PV in terms of an arbitrary vertical coordinate is formulated. Using this expression, temporally averaged PV is calculated from the model in both a coarse-grain and fine-grain sense. The difference between these respective averages, representing a transient contribution to the evolution of the mean PV field, is quantified. Differences are most pronounced in the jet stream regions of both hemispheres, that is at midlatitude heights of about 200 mb.

Effects of PV altering processes arising from parameterized thermal and momentum sources and sinks are considered. A PV flux vector, describing the dynamics of global PV transport in the model is calculated and its horizontal component examined at different levels. Zonally averaged vertical cross-sections are also displayed. The relative magnitude of advective and non-advective components of the flux is quantified in order to assert the utility of PV as a large scale atmospheric tracer. In the horizontal component of the flux, non-advective contributions prove significant in distinct regions of the model atmosphere, most notably gravity wave drag regions of the lower stratosphere and regions of fairly intense heating associated with heavy precipitation over the Indian Ocean. PV is transported approximately southward in the former case and northward in the latter suggesting that non-advective effects are more prevalent in the meridional than in the zonal direction. The vertical component of the PV flux is characterized by nearly equal contributions from advection and thermal forcing over the entire model domain; the contribution associated with momentum sources and sinks is comparable in magnitude only in the planetary boundary layer.

LEAKY MODONS

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Modons correspond to isolated dipole vortex solutions of the quasi-geostrophic equations. They have been proposed as prototype models for some ocean vortices and atmospheric blocks. The classical solution obtained by Larichev and Reznik did not permit a Rossby wave contribution in the exterior region of the modon. However, it is now known (e.g., Butchart et al., J. Atmos. Sci., 1987; Haines and Marshall, Quart. J. Roy. Meteorol. Soc., 1987) that the gravest mode associated with a normal mode decomposition for a modon in a continuously-stratified fluid of finite depth necessarily radiates energy away in the form of a Rossby wave tail in the downstream region. The same effect can be formally re-created in an equivalent-barotropic model of a stationary modon in a constant eastward flow, where the flow speed is an allowed Rossby wave group speed. We present a solution for such a modon in which the exterior Rossby wave field satisfies the appropriate radiation condition in the upstream region.

GENERAL CIRCULATION MODELING OF STRATOSPHERIC INTERANNUAL VARIABILITY

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The GFDL "SKYHI" general circulation model is designed to perform comprehensive simulations of the dynamics of the global troposphere, stratosphere and mesosphere. In the version considered here the primitive equations are discretized on a grid with 3° horizontal resolution and 40 levels between the ground and the mesopause. A 30 year control simulation was performed using a climatological annual cycle of sea surface temperatures. The interannual variability of the stratospheric circulation in this model has some impressively realistic features. In particular the simulated variance of monthly-mean, zonal-mean temperature and wind in the extratropical Northern Hemisphere agrees fairly well with observations. The major deficiency is the absence of a realistic quasi-biennial oscillation (QBO) in the simulated winds in the tropical lower stratosphere.

The model has also been run through a large number of boreal winter simulations with perturbations imposed on the control experiment. In one set of experiments the Pacific sea surface temperatures have been changed to those appropriate for strong El Nino or La Nina conditions. Another set of integrations involved arbitrarily altering the mean flow in the tropical lower stratosphere to be

appropriate for different extremes of the QBO. The effects of these modifications on the simulated circulation in both the tropical and extratropical middle atmosphere will be examined in this paper.

DAILY RADIATIVE ENTROPY VARIATIONS FROM THE EARTH RADIATION BUDGET EXPERIMENT

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The outgoing longwave radiation (OLR) carries both energy and entropy. Although energy conservation forces a link between incoming and outgoing fluxes, entropy is free to be created within the earth system. Since most of the outgoing longwave entropy flux is created within the earth's atmosphere, we might expect a connection between the radiative entropy and the state of the earth's atmosphere. In particular if the entropy is properly nondimensionalized, we can show that it provides a measure of the degree of disequilibrium in the OLR radiation field. Ultimately, a correlation between the radiative entropy and some measure of the internal atmospheric mass distribution, such as the available potential energy (APE) or the mass entropy, can be expected and hence be used in climate diagnostics and prediction.

In this work the global radiative entropy is calculated twice daily (ascending and descending nodes) for January 1985 using the NOAA9 and ERBS satellites that are part of the Earth Radiation Budget Experiment (ERBE). The average horizontal resolution is 50 km allowing mesoscale variance to contribute to the entropy signal. The significance of the daily variations will be discussed and correlated with calculations of the APE and mass entropy from NMC daily analysis. The signal consists of both a seasonal trend and daily variations. The role of clouds and regional budgets will be discussed.

FORECASTING POLAR LOWS IN THE LABRADOR SEA

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Polar lows are systems that form poleward of major jet streams or frontal zones and are mainly convective in nature. Their small spatial scale (< 500km) and time scale (< 24 hours) are beyond the capabilities of present forecast models. Recent climatological studies have shown that polar lows are a quite common feature of the Labrador Sea. It is for this reason that it is important to improve the ability of numerical forecast models to forecast these systems.

The operational (100km) version of the Canadian Regional Finite Element Model was used to simulate a polar low that occurred in the Labrador Sea on Jan. 11, 1989. The sensitivity of the model development to resolution was tested using 50km and 25km versions of this model as well as using an enhanced sea-surface temperature analyses to test the sensitivity to surface fluxes of heat and moisture.

As expected, increasing the model resolution resulted in a more intense polar low development. It was also found that the storm development depended strongly upon the accuracy of the sea-surface temperature analysis. This indicates the importance of fluxes of heat and moisture from the sea surface in the development of polar lows in this area.

An additional experiment was performed using the newest version of the RFE (1992) run at 25km resolution. This model incorporates four additional sigma layers and a much larger central high

resolution domain. A conceptual model of the Labrador Sea polar low was created based on the output from this experiment. Comparisons are made to existing conceptual models of polar lows in other areas.

MOMENTUM BUDGET FOR ATMOSPHERIC OROGRAPHIC FLOWS USING OBSERVATIONS OF THE PYREX FIELD EXPERIMENT

R. Benoit

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The PYREX experiment was run during October and November 1990 over the Pyrenees mountain range to collect a comprehensive database that would allow the validation of future meso-beta-scale meteorological models on orographic flows. Over the last 20 years, the study of orographic effects has emerged as one of rich and still largely unexplored phenomenology and as the key to drastic improvements of numerical forecasts both at meso and larger scales. The keystone for understanding the dynamics of most of the phenomena in mountain meteorology is a quantitative appraisal of the momentum budget over a pertinent volume. PYREX, ever since its planning, with a high level of cooperation between numerical models, used as laboratories, and experimental platforms, attempts to obtain all the terms of the budget.

The platforms were numerous: surface stations, staffed or automated, mesonet across the Pyrenees with microbarographs and real-time orographic drag calculation; 12 upper air sites organized in two concentric arrays; five acoustic sounders; four wind profilers; constant level balloons from three sites; four aircrafts with various flight plans, instrument packages and altitude ranges. The observations have been quality-checked and put into standard formats. A relational database management system has been used to put all the data into a single integrated and documented PYREX DATABASE. The PYREX scientific team plans to release the database for public use early in 1993.

The author is completing momentum budget calculations based solely on high-resolution radiosonde data. Data is projected on a fine 3D grid (10 km by 50 levels) by interpolation and variational splines schemes and numerical quadrature is used to obtain the budget integrals from mountain surface upward. Early results have been presented last year at the CMOS '92 Congress; subsequent work has indicated good agreement of the observations-based budgets with synthetic budgets derived purely from high-resolution numerical modelling, at least in the lower half of the troposphere. Current results on the major PYREX IOPs having orographic wave activity will be presented.

Wednesday/Mercredi p.m. Room/Salle 102

WORLD OCEAN CIRCULATION EXPERIMENT
ÉXPERIENCE CONCERNANT LA CIRCULATION OCÉANIQUE MONDIALE

Chair/Président: B.R. Ruddick, Dalhousie University

DEEP AND INTERMEDIATE CIRCULATION IN THE TROPICAL PACIFIC - WOCE OBSERVATIONS

L.D. Talley (Invited)
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Large-scale westward flows asymmetrically centered about the equator, at 10-12°S and 7-10°N and 2000-3000 meters depth, are evident from two meridional WOCE sections in the central Pacific. Delineated for the first time by these data are the westward flow north of the equator and a narrow band of possibly eastward flow at 2°S separating the westward flows in the northern and southern hemispheres. The southern westward flow is the well-known plume which attains its warm, hydrothermal characteristics in the eastern Pacific. However, the rough symmetry of the two westward currents and evidence for similarly equatorially-symmetric currents at 2000-3000 meters in the Atlantic suggests that the primary forcing is not hydrothermal as has been suggested for the South Pacific plume.

At the equator, stacked eastward and westward flows are suggested by the water properties and the large-scale alternation of pycnostads and pycnolines throughout the water column centered at the equator. The westward bottom flow appears to be a continuation of southward flow along the East Pacific Rise in the North Pacific (Johnson and Toole, 1992).

THE EFFECT OF THERMODYNAMIC SEA ICE ON THE STABILITY AND VARIABILITY OF THE THERMOHALINE CIRCULATION

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A 3-dimensional spherical planetary geostrophic ocean general circulation model is coupled to a thermodynamic sea ice model to examine the effect of sea ice on the stability variability of the thermohaline circulation. The model has an idealized box geometry of 60^0 latitude and 60^0 longitude, with a horizontal resolution of 2^0, and 15 vertical levels. Annual mean surface forcing of wind stress, and surface temperature and salinity is used. The coupled system is first forced using restoring conditions on both temperature and salinity to reach a steady state which includes ice in the high latitudes.

Upon a switch of the surface forcing to mixed conditions (restoring on temperature and flux on salinity), an interdecadal oscillation of period 17 years is observed in the magnitude of the thermohaline circulation and the ice extent. The oscillation is due to a feedback between ice cover and ocean temperature: as ice forms only where the surface heat flux is negative, the thermal insulation

of an increased ice cover would make the ocean warmer, which in turn would melt the ice. Salinity rejection associated with ice formation is shown to be unimportant. With an ocean-only model, earlier results show that sub-freezing temperatures develop together with a total collapse of the thermohaline circulation. Our results thus show the importance of the temperature feedback due to ice extent in ocean-climate modelling studies.

DEVELOPMENT OF A GLOBAL STEADY-STATE FINITE-ELEMENT BAROTROPIC MODEL

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The most commonly used numerical technique in ocean modelling is that of finite differences. However, another technique which offers a number of advantages over the basic finite difference method is that of finite elements. These advantages include accuracy of the solution, good conservation properties and the ability to simply discretize irregular domains. Different parts of the domain can also be discretized with different resolutions in a simple manner without loss of accuracy.

Over the last two decades, finite elements have gained in popularity in tidal and coastal modelling. However, they have rarely been used in larger scale ocean modelling, despite their many advantages. To this end, a global scale steady-state finite-element barotropic model is being developed. The model has been compared against several analytic and exiting finite-difference numerical solutions in simple box domains.

THE STERIC COMPONENT OF SEA LEVEL RISE ASSOCIATED WITH ENHANCED GREENHOUSE WARMING: A MODEL STUDY

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Future sea level rise from the ocean's thermal expansion under global warming was studied using a sophisticated coupled GCM and a simple reduced gravity model. Atmospheric carbon dioxide was increased by 1 % per year in the coupled model, which showed that the northern North Atlantic and the Southern Ocean to be regions of largest heat flux from the atmosphere to the ocean. To explain some features of the observed rising sea level distribution from the coupled model, a simple reduced gravity model was used to represent the first baroclinic mode response to the source regions in the northern North Atlantic and the Southern Ocean. This modified Rossby adjustment problem with the simple model shed light on the role of coastal and equatorial Kelvin waves and Rossby waves in distributing the excess sea level from the source regions.

THE MEAN CIRCULATION IN THE WESTERN NORTH ATLANTIC DIAGNOSED BY THE MELLOR ET AL METHOD

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The temperature and salinity fields obtained from archived data are used to determine the mean circulation in the western North Atlantic for summer, and for the cold (December-May) and warm (June-November) seasons. The data set is the Marine Environment Data Service (MEDS) archived data and is supplemented by a subset of the National Oceanographic Data Centre (NODC) data from Joe Reid and by the 1980s additional data of Fukumori and Wunsch (1991). These archived data are objectively analyzed onto a grid with a horizontal resolution of 1/3° by 1/3° together with 33 vertical levels. The objective analysis scheme used is a modification of the one used by Levitus (1982). In order to diagnose the circulation, the Mellor et al. (1982) method was applied to the density fields.

The Mellor et al (1982) method gave a total summer transport of 39 Sv in both the Labrador Sea and in the Irminger Sea. In fact, most of the transport through the region is driven by the transport through 30 W to the East and it is also found that the local wind stress forcing does not play an important role in describing the dynamics of the western North Atlantic. The best current structure is obtained by combining the results from the Mellor et al. method together with a level of no motion (at the bottom) calculation. Using these two methods bottom currents can be evaluated and hence the current structure for the whole domain can be determined. It is found that bottom currents follow the planetary potential vorticity (f/H) lines closely. The strongest currents are observed within the coastal regions: along both the East and West Greenland coast and along the Labrador Coast.

The data are then averaged over the two intervals 1950-1964 and 1970-1984 representing the warm and cold periods of Kushnir (1993). Two additional inverse calculations are done for these periods and the interdecadal variability of the circulation is discussed.

INTENSE CURRENTS IN THE DEEP NORTH-EAST PACIFIC OCEAN

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Observations of deep currents in the N.E. Pacific Ocean are reported which indicate that although the eddy kinetic energy level is, as expected, generally low, the deep N.E. Pacific is subject to occasional intensely energetic events. These events are energetic enough to dominate the distribution of kinetic energy in the water column and the depth averaged kinetic energy. We can no longer make the assumption that deep flows are weak when estimating near surface flows.

SEMI-LAGRANGIAN SOLUTIONS TO THE THREE-DIMENSIONAL ADVECTIVE-DIFFUSION EQUATION

S. K. Das
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We have developed an algorithm based on semi-Lagrangian method for the three dimensional advection-diffusion equation appropriate for the marine environment. The scheme is tested in both its

interpolating and non-interpolating mode. The advantages and disadvantages are discussed by applying the algorithm to a number of test problems whose exact solutions are known.

THE EQUATORIAL KELVIN WAVE IN FINITE-DIFFERENCE MODELS

M.K.F. Ng and W.W. Hsieh
Dept. of Oceanography, University of British Columbia, Vancouver, B.C., V6T 1Z4

Global climate GCMs generally have grid resolution of several degrees of latitude, which fails to resolve even the equatorial Rossby radius. Whether such models can adequately model the narrow, equatorially confined Kelvin wave and currents, key to the important El Nino Southern Oscillation phenomenon, is questionable. Further to our last year's CMOS presentation, we have now greatly expanded our study of the equatorial Kelvin wave in finite-difference models using the Arakawa A, B, C and E grids. Exact analytic solutions of the equatorial Kelvin wave with meridional velocity v=0 have been found for the A, C and E grids, in models with no damping and in models with Rayleigh friction and Newtonian cooling. The dispersion relation is unaffected by the meridional grid resolution in these grids. Solutions for the equatorial Kelvin wave in B-grid models, due to increased complexity from the non-vanishing v, are obtained numerically. The Kelvin wave phase speed now decreases with worsening resolution. The mean zonal heat transport by the Kelvin wave in an El Nino is compared on the various grids, with the B grid showing the highest accuracy.

Wednesday/Mercredi p.m. Room/Salle 125

ATMOSPHERIC MODELLING
MODÉLISATION DE L'ATMOSPHÈRE

Chair/Président: R. Benoit, Atmospheric Environment Service, Dorval (1340-1450)
Chair/Président: H. Ritchie, Atmospheric Environment Service, Dorval (1600-1740)

REDUCING THE GAUSSIAN GRID IN SPECTRAL FORECAST MODELS: ADVANTAGES AND IMPACT ON WEATHER FORECASTING

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It is well known that the density of Gaussian grid points increases significantly as we approach the polar region in spectral numerical weather prediction models. In the near future, it is expected that the limit of the spectral truncation will be pushed to a much higher level, and the question naturally arises as to the necessity of this high density of grid points at high latitudes, considering the fact that a triangular truncation provides a uniform spatial resolution of the fields over the globe.

Recently there have been attempts to reduce the number of Gaussian grid points in the polar region in spectral forecast models and the technique has been implemented in the ECMWF model and at other national weather centers. The reduced Gaussian grid at high latitudes is already in use in the Canadian operational analysis program since 1987. Our intention is to introduce this technique in our

operational spectral forecast model. The main advantage of this technique is a significant gain in efficiency without noticeable loss in the forecast precision.

We shall examine different criteria that may lead to a reduction of the Gaussian grid points at high latitudes in spectral models and we shall find the best strategy in terms of efficiency and precision. A series of 5-day forecasts will be presented and our method will be compared to others.

METEOROLOGICAL PERFORMANCE OF HIGHER RESOLUTION VERSIONS OF THE CANADIAN GLOBAL SPECTRAL FORECAST MODEL

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The global spectral model used as the data assimilation model and medium range forecast model at the Canadian Meteorological Centre has a triangular 79-wave (T79) truncation in the horizontal, 21 levels (L21) with variable spacing in the vertical, and uses a semi-implicit semi-Lagrangian time integration scheme with a 30-minute time step. Due to operational constraints, this configuration is the highest resolution that could be implemented on the CRAY X-MP computer. However, with the implementation of the NEC SX3 computer, we are now developing higher resolution versions for medium range forecasts.

The resolution is being increased in both the horizontal and vertical directions and the sensitivity to the time step at various resolutions is being examined. Based on the experience at other leading forecast centres, when increasing the resolution it is important to maintain a balance between the horizontal and vertical resolutions. In view of the large time steps permitted by the semi-Lagrangian scheme, it is also important to adjust the time step to keep a balance between the time truncation and space truncation errors. Preliminary tests with a T119L21 configuration have indicated improved meteorological performance with this increase in horizontal resolution, and tests with optimized codes indicate that a configuration of T133L24 or even T159L24 should be technically feasible for implementation within several months. Further expected optimizations and formulation changes should make it possible to implement a configuration of about T200L30 in the not-too-distant future. A more extensive series of experiments is going to be performed in order to study the meteorological performance of these higher resolution versions and latest results will be presented at the congress.

GLOBAL BALANCE OF THE HEAT AND MOISTURE BUDGETS IN THE CANADIAN SPECTRAL MODEL

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The replacement of a moist convective adjustment scheme by a Kuo deep cumulus convection scheme, the development of a shallow cumulus convection scheme, and the development of a cloud parameterization – for the first time made fully interactive with improved solar and infrared radiation schemes – consistent with both convection schemes are evaluated in terms of the ability of the model to maintain an acceptable global thermal and hydrological balance.

Poster No. 9

THE DEVELOPMENT OF A SHALLOW CUMULUS CONVECTION SCHEME FOR THE CANADIAN GLOBAL SPECTRAL MODEL

C. Girard

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The turbulence parameterization used in the model and strictly only valid when the atmosphere is unsaturated has been generalized to include the saturated case. The exchange-coefficient closure assumptions are henceforth applied on the conservative (in absence of precipitation) variables: total water content and liquid water potential temperature. Within acceptable thermodynamic approximations, heat and buoyancy fluxes are then found to depend exclusively on the temperature profiles and therefore not to require the explicit treatment of liquid water. Shallow convection is then parameterized as the special condition whereby a fraction of a model grid area may be considered saturated even though the relative humidity may be far less than unity. Results will show in particular that, when combined to a Kuo scheme to parameterize deep cumulus convection, such a shallow cumulus convection scheme is able to correct major systematic errors which otherwise develop in the forecast mean structure of the moisture field in the tropics.

Poster No. 10

THE IMPLEMENTATION OF A KUO SCHEME IN THE CANADIAN GLOBAL SPECTRAL MODEL

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Implementation of a Kuo scheme to parameterize cumulus heating, in replacement of a moist convective adjustment scheme, has been a major objective of RPN and CMC for the past few years. We have recently achieved this goal, but not without major changes to our turbulence parameterization to include shallow convection and to our cloud parameterization. We will describe and justify these changes. We will compare the two schemes and show in particular that the Kuo scheme leads to three major improvements: reduced spin-up in precipitation forecasts, improved tropical moisture field and reduced global systematic cooling.

A COMPRESSIBLE MULTI-SCALE MODELLING TOOL FOR THE CANADIAN ATMOSPHERIC RESEARCH COMMUNITY: THE MC2 MODEL

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At Recherche en Prévision Numérique (RPN) and at Université du Québec à Montréal (UQAM), a group is working actively to soon provide a versatile modelling tool, applicable to a variety of needs of the Canadian research community. The Montreal-based CCRM (Cooperative Centre for Research in Mesometeorology) had previously used the Canadian Regional Finite-Element Model for its studies. In a search for a more general successor that would even allow applications at the meso-gamma scale, a joint project began in May 1992, taking as a starting point the fully-elastic, nonhydrostatic model developed recently by Drs. André Robert, Monique Tanguay and René Laprise.

Due to its numerical algorithms of semi-Lagrangian advection and semi-implicit time differencing, this model is accurate and efficient. The equations are solved on a limited-area domain with time-dependent nesting of the lateral boundary conditions supplied by a larger-scale model/analysis. Additional features included recently are orography, Gal-Chen vertical coordinate, variable resolution. From various results obtained sofar, it appears that the mc2 model can give excellent simulations over a wide spectrum of scales, from a full scale synoptic storm down to a few centimeters (e.g. convection tank).

The group has been working since last summer and has already produced two versions of mc2, under limited use by CCRM members; the second one is available for examination since January 1993. The team's commitment is 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...) 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 late Spring 1993, a complete version of mc2 should be available for use by the Canadian research community. Sample results are presented and project status is described.

AN INTERCOMPARISON OF CMC, ECMWF, AND NMC OPERATIONAL ANALYSES

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The majority of previous comparisons of operational analyses have examined differences between only two datasets. Although such comparisons identify areas of lack of agreement between the datasets, they offer little information on which of the two analyses might be preferable in a given application. If a third dataset is used in the intercomparison, then more information is available to choose the most appropriate analyses.

The results of a global three-dataset comparison using the analyses of the Canadian Meteorological Centre (CMC), the European Centre for Medium-Range Weather Forecasts (ECMWF) and the National Meteorological Center (NMC) will be presented for January and July.

THE REGIONAL FORECAST SYSTEM AT CMC: IMPLEMENTATION OF A HIGHER RESOLUTION VERSION

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The Canadian Meteorological Centre has implemented an integrated regional analysis and forecast system last December. The limited area grid of the system is focused on North America where the resolution is 100 km. In the new version, scheduled for this summer, the resolution of the analysis and the regional finite element model (RFE) will increase to 50 km. A new source of data, satellite derived humidity profiles (HUMSAT), will be added to the data assimilation cycle. It has been shown to produce improved moisture analyses, especially on data sparse areas such as over the oceans. The RFE model will use climatological fields directly on its working grid, avoiding unnecessary interpolations. That, with the increased resolution, will provide a better topography and good coherence among various surface fields. Tests are underway on a new parametrization scheme for convection and a radiation module that is fully interactive with the clouds in the model. The new system should be in operation at the time of the conference. The presentation will focus on differences between the current operational system and the new version. The effects of the modifications on regional forecasts will be illustrated with recent cases.

A NUMERICAL STUDY OF WINTER FRONTAL PRECIPITATION SYSTEMS

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Much of the weather in the mid-latitude wintertime is associated with baroclinic synoptic scale disturbances. The classical model of stable upgliding above sloping frontal surface is still widely accepted as the generating mechanism of frontal cloud and precipitation. In this study, a 2-D cloud-resolving numerical model is used to simulate the cloud and precipitation in warm frontal systems. Initial conditions are characterized by a non-divergent shear flow blowing from the warm side of a baroclinic environment. Realistic sloping warm frontal zones characterized by enhanced horizontal temperature gradients, temperature inversions and strong vertical wind shear were simulated. In accord with the classical model, weak ascent was generated above the frontal surface, producing wide-spread stratiform cloud and precipitation. Banded mesoscale precipitation features near the surface front were also simulated in some cases. Frontogenetic mechanisms, the dynamics of the precipitation system as well as their sensitivities to the ambient conditions and model physics will be discussed.

LARGE SCALE TRANSPORT STUDIES: A RADON AND LEAD EXPERIMENT

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The Canadian Climate Centre (CCC) GCM is being used to study tropospheric atmospheric chemistry. Radon (Rn-222) and lead (Pb-210) tracers have been used in an experiment to study the processes of transport, dispersion and subgrid mixing. The radon decay to lead allows an analysis of the impact of the global model, on the transport of species having short and long lifetimes respectively. This provides a simple analogy of a chemical system with a primary precursor pollutant and a dependent secondary

pollutant. Parameterization of the convective mixing has been done using two different approaches to compare a diffusive scheme with another which mixes unstable columns on a much shorter time scale. Both schemes provide advantages and limitations based on physical and numerical aspects.

Species distibution over specific regions are characteristic of the large scale circulation and sink/sources distribution. Sub-grid mixing also has a significant impact on the species profiles during summer by increasing the transport of species into the free troposphere. Subsequently, the strength of the tracers' mass flux through the tropopause is also being affected. Comparison with measurements in the northern hemisphere shows some agreement with model results over continental regions throughout the year.

Initial assessment and sensitivity studies of a first 16 month seasonal run, have been aimed in particular at a number of areas of uncertainty in the model, including: tropical and mid-latitude convective mixing, cross-tropopause transport and interhemispheric and seasonal transport signatures of the models' tracer transport climate. This experiment also presents an opportunity to test a spectral advective scheme in a case where species sink/sources distribution are spatially discrete.

Wednesday/Mercredi p.m. Room/Salle 205

FOREST AND AGRICULTURAL METEOROLOGY
MÉTÉOROLOGIE À FORESTIÈRE ET AGRICOLE

Chair/Président: R.B.B. Dickison, Atlantic Weather & Environmental Consultants Ltd.

A CANDIDATE JOINT VELOCITY PROBABILITY DISTRIBUTION FUNCTION FOR CANOPY TURBULENCE

S. Du and J. Wilson
Department of Geography, University of Alberta, Edmonton, Alberta T6G 2H4

Random Flight (RF) simulation is the most realistic way to calculate the spread of pesticides (etc.) in plant canopies. Since Thomson (1987) gave rigorous selection criteria for RF models, the accepted starting point for building a good model has been to specify the joint probability density function (g_a) for the Eulerian velocity.

Within a canopy g_a is observed to be strongly non-Gaussian. In this talk we will report on the suitability, as a joint velocity pdf for canopy flow, of the form:

$$g_a(u,w) = p_u(u)p_w(w) \ (1 + C \ uw) \qquad (1)$$

Since the marginal pdfs p_u and p_w are here arbitrary, eqn (1) permits correct single velocity moments to any order, as well as correct covariance $\langle uw \rangle$. We will compare the values for cross statistics such as $\langle u^2w \rangle$ and $\langle uw^2 \rangle$ that follow from eqn (1) with observations in a wind tunnel canopy flow.

ANALYSIS OF TURBULENT STRUCTURES ABOVE A FOREST CANOPY USING THE WAVELET TRANSFORM

B.J. Turner and M.Y. Leclerc
Dept. of Physics, Univ. du Québec à Montréal, Montreal, Quebec, Canada. H3C 3P8

Above and within forest canopies, a large proportion of the turbulent fluxes (e.g. heat, momentum) is contributed by a few localized, intense events. However, traditional mathematical descriptions of turbulence, such as the Fourier transform, anticipate a time-independent behaviour. For intermittent records, the Fourier spectrum cannot distinguish between the scales of intense structures and the distance between them.

When aperiodic events appear in time series, a local transform such as the wavelet transform is able to identify the main scales of the events more clearly than the Fourier transform. Comparisons of wavelet and Fourier spectra will be shown of turbulence observations from an instrumented tower above a forest. A space-scale view of the contributions of different eddies to turbulent fluxes is also provided by the wavelet transform. The relative importance of locally down-gradient and counter-gradient flux events at each scale can be evaluated and discussed.

PRESSURE FLUCTUATIONS AND COHERENT MOTIONS INSIDE A FOREST

Y. Zhuang
AECL Research, Whiteshell Laboratories, Pinawa, Manitoba R0E 1L0

Two-dimensional (x-z) pressure fluctuations associated with coherent motions within a forest flow are calculated using the highly truncated Navier-Stokes equations. The phase relationships between the pressure and velocities are demonstrated. The dynamic significance of the pressure fluctuations in understanding of transport processes in forest flow is discussed.

AN ALGORITHM FOR PREDICTING FOG WATER INPUT IN THE MARITIME PROVINCES

X. Yin and P.A. Arp
Faculty of Forestry, University of New Brunswick, Fredericton, N.B. E3B 6C2

Fog may contribute considerably to total precipitation in the Maritime Provinces, and is ecologically important because of high chemical concentrations. An empirical equation was developed to predict year-round fog frequency from air temperature, season, and distance from the southern coast, for any location in the region. Predicted fog frequency was converted to fog droplet deposition on forests using a model described by Unsworth and Crossley (In "Effects of Atmospheric Pollutants on Forests, Wetlands and Agricultural Ecosystems," Edited by T.C. Hutchinson and K.M. Meema, NATO ASI Series, Vol. G16, 1987). Predicted fog water input effectively resolved inconsistencies between simulated and observed monthly streamflow volumes for forested watersheds in Nova Scotia and New Brunswick.

Wednesday/Mercredi p.m. Room/Salle 205

JOINT SESSION:
HYDROLOGY-FOREST AND AGRICULTURAL METEOROLOGY
SESSION CONJOINT:
HYDROLOGIE ET MÉTÉOROLOGIE FORESTIÈRE ET AGRICOLE

Chair/Président: R. Soulis, University of Waterloo

THE RESPONSE OF THE LAND SURFACE HEAT AND MOSITURE BALANCE TO SMALL-SCALE TEMPERATURE AND WETNESS INHOMOGENEITY

Y. Guo and P.H. Schuepp
Dept. of Renewable Resources, Macdonald Campus, McGill Univ., Ste-Anne-De-Bellevue, Quebec H9X 3V9

Based on detailed modeling of the surface energy balance, small-scale patchy surface temperature and wetness heterogeneity is found to have a significant effect on the surface heat and moisture flux distributions. This results not only in a change in available energy partition between sensible and latent heat fluxes, caused by spatial differences in patchy surface characteristics, but also in a re-allocation of a portion of available energy between the patches by local advection. The two effects may frequently and simultaneously be present in landscapes like wetlands, or surfaces exhibiting broken ice or snow patterns, heterogeneous vegetation cover, precipitation, irrigation and land use, etc. The first effect depends mainly on the relative area proportions of the different kinds of patches involved, whereas the second effect depends on the absolute sizes and combinations of these patches. When patches are small, the second effect can produce a big influence on the surface heat and moisture balance, in addition to that by the first effect. Therefore, neglecting this effect could introduce significant errors into calculations of both local and cumulatively regional surface heat and moisture fluxes. The modeled results show that such errors may vary during clear summer days up to about 200% for evaporation and 67% for Bowen ratio when dry/wet patch sizes are unequal, or up to about 35% for evaporation and 47% for Bowen ratio when dry/wet patch sizes are equal. This suggests (a) that the currently-used surface schemes (e.g. as used in mesoscale and global circulation models or hydrological models) should incorporate the second effect for complete consideration of the subgrid-scale surface heterogeneity, in order to improve their applicability to heterogeneous surface; (b) that the improvement of remote sensing image resolution for the identification of subgrid small-scale surface patches is necessary for accurate determination of surface heat and moisture flux distributions.

A COMPARISON BETWEEN SUMMERTIME AND WINTERTIME EDDY FLUXES AND PROFILES OVER AND WITHIN A DECIDUOUS FOREST IN SOUTHERN ONTARIO

H.H. Neumann and G. den Hartog
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

As part of the Canada-U.S.A. EMEFS experiments in July-August 1988 and March-April 1990, extensive micrometeorological measurements were made from two towers (heights, 43 m and 20 m) in the forest (canopy height 18 m) at C.F.B. Borden. These included eddy correlation flux measurements of momentum (4 levels), heat (4 levels), water vapour (2 levels), and ozone (2 levels). Vertical profiles of wind (4 levels), temperature (12 levels), and ozone (4 levels) were also obtained. The

relative magnitudes of the fluxes and the shapes of the profiles changed considerably between the summer experiment (leafed canopy) and the late winter experiment (leafless canopy).

In summer, the upper third of the canopy was the major sink for momentum and ozone and the major source for sensible heat and water vapour. This was reflected in the shapes of the measured profiles within the canopy, where the most rapid changes also occurred in the upper third of the canopy. Typically, in the daytime, fluxes measured at midcanopy were 10% or less of the above- canopy values. At night the lower canopy became decoupled from the above-canopy flow and this situation persisted throughout much of the forenoon period.

In winter the lower portions of the canopy and the forest floor became important contributors to the fluxes and this was reflected by more gradual changes in profile shapes through the canopy. During the day at the lowest flux measurement height of 3 m, fluxes relative to above-canopy values averaged 7% for momentum, 25% for heat, 45% for water vapour, and 75% for ozone. At night, the lower canopy tended to become decoupled from the above-canopy flow but, in contrast to the summertime, the situation did not usually persist for an hour or two after sunrise. The varying contribution from below 3 m for the different fluxes implied differences in the vertical source-sink distributions. These differences would have implications in the application of K-theory for this canopy and the often assumed equality of K's for heat, water vapour, and trace gases transport.

ON THE NEED TO DETERMINE LOCAL SCALE VARIATIONS IN EVAPORATION RATES

W.J. Stolte
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Evaporation is the single greatest consumer of water in the prairies and as such has the most impact on the hydrologic cycle there. Ironically, it appears to also be one of the least understood phenomena. This is illustrated by the fact that present day methods of calculating evaporation do not do justice to the variations in evaporation that can occur on a local scale.

The author's research into soil salinity has highlighted the lack of knowledge about local-scale variations in evaporation rates. It is becoming apparent from the research that localized build-ups in salinity can result from the concentration of water in sloughs and the movement of this water upslope in the surface soil layer caused by high evapotranspiration rates in the upslope regions adjacent to the sloughs. These high evapotranspiration rates decrease with distance upslope, particularly where the slope is steep enough to cause increased soil suctions and reduced hydraulic conductivity. These differences in evapotranspiration rates have given rise to the common concepts of potential and actual evapotranspiration. Of course, the variations in the evapotranspiration rates along the hillslope also give rise to different usages of energy along the hillslope. Since there is less evaporation near the top of the slope, and hence less energy use, than at the bottom, there must be importation of energy from upslope positions to the downslope locations.

This paper concerns itself with the salinity development around several prairie sloughs and how this development implies the scenarios outlined above. The paper will focus on the shortage of data and models to account for the phenomenon. The paper will end by detailing the type of research that should be done to elucidate it.

MODELLING STUDIES OF GAS FLUXES FROM LAKES AND PONDS

J. Kwan and P.A. Taylor
Dept. of Earth and Atmospheric Science, York University, North York, Ontario, M3J 1P3

A semi-empirical model is presented for low solubility gas flux estimates from lakes and ponds. Recent studies suggest that in addition to the wind speed as a factor determining gas transfer velocity, k(U), over water fetch and upwind conditions can also affect the total gas fluxes from a small lake or pond. A case study was for the emission of gases of low solubility such as CH_4 and CO_2 from ponds in the regions of Hudson Bay Lowlands of Canada. Our model is based on an assumption that when wind is blowing from land out over water surfaces, the wind speeds measured over land will be modified by the step change of surface roughness to the water surface. We use an existing "guidelines" model, proposed by Walmsley et al., to account for this change and to estimate "correction factors" (relative to calculations assuming horizontal homogeneity) for total gas fluxes from a lake. For circular lakes of area $\approx 200m^2$ the correction factor can be of order -30% but it switches to +30% or more for lakes with area $\approx 20000m^2$.

Some initial results for finite lake size effects on the fluxes of high solubility gases will also be presented.

Wednesday/Mercredi p.m. **Room/Salle 303**

HAZARDS
LES PHÉNOMÈNES DANGEREUX AU CANADA

Chair/Président: T.S. Murty, Institute of Ocean Sciences

CANADIAN HAZARDS FROM WIND: ASSESSING AND REDUCING THE RISKS

A.G. Davenport
Boundary Layer Wind Tunnel Laboratory, University of Western Ontario, London, ON N6A 5B9

Canada's vast geographical extent and climatic ranges makes the task of predicting the hazards due to wind unusually challenging.

The paper reviews these hazards in Canada, including the extreme events such as severe windstorms and blizzards, tornados, rapidly deepening depressions, thunderstorms and occasionally hurricanes.

The translation of these hazards into catastrophic events involves human intervention and the steps that are - or are not - taken to prevent them. A major source of disaster is structural failure. The paper describes how severe wind is translated into damaging pressures on buildings and the influence of the aerodynamics and structural responses both steady and fluctuating. The influence of exposure (terrain roughness and topography) is highlighted. The paper discusses the methods to assess the risk of severe wind speed and ways it can be used to improve the design of structures. Improvements are suggested which would reduce the uncertainty and reduce the risks.

The paper concludes with reference to other wind hazards such as dust storms, wildfire, and ice and blizzards.

THE INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION - A PROGRESS REPORT

J.P. Bruce
U.N. Scientific and Technical Committee, IDNDR 1875 Juno Ave., Ottawa, Ontario K1H 6S6

The United Nations General Assembly declared the 1990's as the Decade for special efforts to reduce losses in natural disasters. In doing so, Member countries were influenced by three main factors:

(a) the enormous increases in human and economic losses that have been accompanying demographic and environmental change,

(b) the fact that, proportionately, damages and suffering are greatest in least developed countries, and

(c) that application of available techniques and further improvements in them, can substantially reduce losses.

On the recommendation of the Scientific and Technical Committee, the U.N. General Assembly approved in 1991, goals and a technical framework for Decade programs. More than 100 National Committees or Focal Points for the Decade have been designated and are undertaking a wide range of valuable disaster mitigation activities according to national and local needs. The global scientific community has been mobilized around some 25 international demonstration projects designed to improve prediction of hazards and mitigation of losses, as well as training and public information activities. Promotion of the goals and activities of the IDNDR has been undertaken by the Special High Level Council and by a number of inter-governmental agencies and NGO's.
The outcome of UNCED'92 (The Rio Earth Summit), especially Agenda'21 and the Framework Convention on Climate, has placed further emphasis on disaster loss reduction as a key element in achieving sustainable development.

ENVIRONMENT CANADA'S APPROACH TO TO THE IDNDR

A. Szlazak
Special Projects, Atmospheric Environment Service, Hull, Québec K1A 0H3

The presentation will describe how, in 1992-93, Environment Canada (EC) defined its opportunities for participation in the Canadian program for the IDNDR and how the framework for the EC segment of the Canadian program was developed. it also will provide some preliminary information concerning the implementation of EC's IDNDR program and departmental preparations for the mid-term review of the Decade which the United Nations General Assembly has scheduled for 1994. The UN's mid-term review will include the May 1994 World Conference on Natural Disaster Reduction, to be held in Yokohama, Japan.

RECENT PROGRESS IN THE IDENTIFICATION, CLASSIFICATION AND FORECASTING OF SUMMER SEVERE WEATHER

P. Joe[1], M. Leduc[2], B. Murphy[2], S. Knott[2], S. Siok[2], L. Legal[2], G. Strong[2], P. Chadwick[2], G. Vickers[2], J. Archibald[2], T. Nichols[2], J. Abraham[2], G. Fournier[3], A. Holt[4] and E. Torlaschi[5]

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Summer severe weather (SSW) can strike suddenly and unexpectedly with disastrous consequences for human activity. Considerable progress has been made in the past few years in the identification, classification and forecasting of SSW. Traditionally, SSW was defined to consist of tornadoes, strong winds, hail, lightning and heavy rain. Hazardous effects of strong winds have recently been expanded to include microbursts, macrobursts, derechos and surfacing of the rear inflow jet behind mesoscale convective systems. Doppler radar was first used to diagnostically and then later to prognostically relate surface damage to the appropriate atmospheric phenomena. This correct classification has fedback to and improved the forecast process. Concurrent progress has been made in the use of the synoptic observations. The concept of helical wind profiles and analysis of dry mid-level air has improved the forecasting of tornadoes and strong gusty winds. Moisture flux convergence, derived from surface measurements, shows great promise in identifying areas of storm initiation. Satellite imagery has been used to identify deformation boundaries and mid-level water vapour plumes which provide the moisture to initiate upper level weather systems. Studies of temporal lightning strike patterns have hinted at their possible use for the forecasting of the evolution of severe mesoscale convective systems. Polarization radar results have shown progress in the correct classification of hail from rain, the improved measurement of heavy rains and the possible application for the identification of storm structure and hence forecasting. One of the new exciting areas is the nontraditional radar observation of clear air boundaries, their interaction and the potential for the forecasting of thunderstorm initiation. Progress has also been made in the forecasting of hurricanes. Though, not traditionally considered part of SSW, hurricanes share many of the same hazardous features. Hurricane Hugo passed through the King radar coverage and provided excellent observations of the hurricane interacting with a cold front.

OIL SPILL: A MAJOR THREAT TO THE MARINE ENVIRONMENT

M. El-Sabh

Département d'océanographie, Université du Québec à Rimouski, Rimouski, Québec, G5L 3A1

A wide variety of material is dumped into the oceans and coastal waters of the world both by plan and by accident. The introduction of petroleum products and crude oil following the two Gulf wars, from ship accidents and damaged platforms into the ocean is, of course, the best publicized example. This is clearly on the rise as oil exploration on continental shelves intensifies and supertanker traffic increases each year. Some 2.5 million tons of oil were spilled from the 11 major oil accidents that occurred between 1976 and 1993.

Oil spilled on water undergoes physical, chemical and biological alteration. Wind effects are well recognized as a major factor in oil slick motion. Other rapid physical processes include water currents, evaporation of volatile components, emulsification, dispersion as small droplets into the water, spray injection into the air, dissolution and sedimentation. Surveying the effect of physical oceanographic

processes on oil spills over the last twenty years shows the great variability of controlling processes from one spill to the next. An offshore spill driven by oceanic circulation and large-scale field is followed by a coastal spill in which littoral currents, shoaling waves, and coastal morphology play dominant roles. In other cases, estuarine dynamics and density frontal dynamics are of paramount importance. In this presentation, reference will be made to the actual situation in the St. Lawrence system and the many efforts deployed by different organizations to compact any future accident that may occur.

OIL SPILL MODELLING - A REVIEW OF MAJOR OIL SPILLS IN CANADIAN COASTAL WATERS

S. Venkatesh
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

Over the last 25 years a number of major oil spills have occurred in Canadian coastal waters. Some of these have resulted in extensive damage to the coastal environments. Most of these major spills have been the result of accidents during transportation of the oil, with human error being one of the most common causes for the accidents. Such spills include 'The Arrow' and 'The Kurdistan' in the 1970's and more recently 'The Nestucca' and 'The Tenyo Maru'. There have been practically no major accidental spills during hydrocarbon exploration in Canadian waters.

The Kurdistan spill was different from the others in that it occurred in ice-infested waters while the others were in open water. Understanding the behaviour of these spills and being able to predict their movement can be a significant factor in minimizing the damage from these spills.

This paper will review the modelling of the drift and spread of some of these spills. Some of the more recent developments in spill modelling, particularly in ice-infested waters, will be discussed.

THE TSUNAMI FROM THE 1917 EXPLOSION IN HALIFAX HARBOUR

D.A. Greenberg[1] and T.S. Murty[2] and A. Ruffman[3]
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The explosion of the ammunition ship Mont Blanc in Halifax Harbour produced a strong tsunami (tidal wave) locally. There was not an operational tide gauge at the time to document the changes in sealevel, but there are several narrative reports of extreme high and low water. In this study we examine the tsunami looking at and integrating three different aspects. We have collected narrative reports to see what quantitative information might be obtained from them. We have estimated the height of the initial wave that would be produced from an explosion of 2.9 kilotons in the harbour narrows where the Mont Blanc grounded. Finally, we have formulated a numerical model to follow the progress of the wave through the harbour, into Bedford Basin and out towards the Atlantic Ocean. Various analytical, empirical and numerical models on explosion generated waves provide an estimate for the tsunami amplitude as a function of the explosive charge and limited by the water depth. For the Halifax explosion, the tsunami elevation would have been limited to a maximum amplitude of approximately 16 metres. The results of our model computations indicate that there was a significant wave in the narrows, but in the outer harbour and Bedford Basin the wave was less than three metres high. The remnants of the wave exiting the harbour to the North Atlantic were so small that they would only be detectable with careful observations.

A SEVERE THUNDERSTORM CLIMATOLOGY FOR ALBERTA

B.J. Paruk and S.R. Blackwell
Alberta Weather Centre, Atmospheric Environment Service, Edmonton, Alberta T6B 2X3

A continuing demand exists for severe thunderstorm and severe event climatologies. As with common meteorological parameters such as temperature and wind, a requirement exists for information on hail, strong wind gusts, heavy rain, and tornadoes. Severe thunderstorms and severe event climatologies have a much lower reliability than the more common parameters because of a number of factors, nearly all related to the relatively small size and localized nature of these events. Nonetheless, over the last ten years, an ever increasing effort and a continually expanding resource allocation have been brought to bear on the prediction and detection of severe thunderstorms in Alberta. The data base of severe weather events is now large enough to allow an analysis and interpretation.

The frequency distribution of the over 800 severe events recorded in Alberta over the years 1982 to 1991 has been developed in the traditional fashion. As well, the distribution has been corrected to take into account the population distribution of the province, as public education and awareness seem to be one of the factors affecting the reporting of severe thunderstorm events. When corrected, the climatology shows substantial differences between the raw and the final distributions, and suggests that some 300 events (34%) go unnoticed or unreported in the province each year.

Using the corrected climatology, users can assess risk in various sections of the province, and more importantly, gain an appreciation for the problems involved with determining a true frequency and distribution of severe events. Caution must be exercised in drawing conclusions from the correction because of the large uncertainties involved, but some encouragement can be gained from the knowledge that the patterns obtained seem similar to the subjective impressions of Alberta thunderstorm behaviour.

Thursday/Jeudi a.m. Room/Salle 102

PHYSICAL-BIOLOGICAL INTERACTIONS IN THE OCEAN
INTERACTIONS PHYSIQUES-BIOLOGIQUES DANS L'OCÉAN

Chair/Président: F.H. Page, St. Andrews Biological Station

PHYSICS-BIOLOGY INTERACTIONS: ROLES OF MESOSCALE AND SMALL SCALE MOTIONS IN PLANKTON ECOLOGY

D.L. Mackas (Invited)
Dept. of Fisheries and Oceans, Institute of Ocean Sciences, Sidney B.C. V8L 4B2

Compared to terrestrial systems at similar latitudes, the upper ocean environment is rather homogeneous. For example, diel and seasonal temperature fluctuations are small, and there is relatively little biological structuring of physical habitat. Yet populations of plankton and fish are strongly patterned in space, and total biomass, species mix and spatial distribution shift dramatically over time. Major goals of biological and fisheries oceanography are to quantify, to explain, and perhaps eventually to forecast this variability.

A fashionable (and often effective) working hypothesis is that physical environmental conditions are responsible for the observed biological variability - hence the "theme session" status at this Congress. What physical variables and processes are most informative? Historically, emphasis was placed on growth, behavioral, and distributional response to "concentrations" of scalar environmental variables such as temperature, light intensity, and nutrients. Processes such as upwelling and mixing were recognized as important, but mostly as modifiers of these scalar fields. More recently, there has been increased attention to direct effects of water motions. This is not a new approach at very large space and time scales: zoogeographers and evolutionary biologists have known for decades that maps of species ranges and major ocean current systems correspond very closely. But new tools (satellites, instrumented drifters, acoustics, molecular genetics) and better integration of existing biological and physical sampling methods now allow effective synoptic resolution of patterns and linkages at smaller scales ranging from 100s of km and 10s of days down to microscale turbulence. I will step through this scale range and give some examples of recent results and interpretation.

Large flow-regime "features" such as filaments, meanders and rings include community composition "patches" that are stretched and deformed parallel to dynamic topography contours. Depending on the class of feature, either displacement or retention can be greatly enhanced compared to surrounding waters. A major question is whether patch residents in some way select their "favourite" cross-feature location or are simply tracers of upstream source water.

At smaller scales, strong aggregations of one or more species often occur along frontal and bathymetric boundaries. Individual aggregations form, disperse, and form again over time scales of about 1 day (at roughly the same location). Recurrent sites are important feeding grounds for mobile predators. High resolution surveys with Acoustic Doppler Current Profilers suggest causal links to convergence and divergence of tidal and secondary flow fields.

Finally, there is increasing evidence that plankton are affected by the local intensity of small scale turbulent shear. Direct field observation of both biology and physics is extremely difficult at this scale, so most interpretation has been based on models, laboratory experiments, and inference from larger scale distribution patterns.

Thursday/Jeudi a.m. Room/Salle 102

HYDROLOGIC CYCLE I: LAND PROCESSES AND HYDROLOGIC MODELLING
CYCLE HYDROLOGIQUE I: PROCESSUS TERRIENS ET MODÉLISATION HYDROLOGIQUE

Chair/Président: R.G. Lawford, National Hydrology Research Centre (0900-1020)
Chair/Président: D. Verseghy, Canadian Climate Centre (1050-1210)

LARGE-SCALE HYDROLOGIC MODELING

E.F. Wood (Invited)
Water Resources Program, Princeton University, Princeton, NJ 08544

The development of land surface parameterizations for AGCMs or the analyses of water and energy fluxes at regional to global scales requires the understanding of the scaling behaviour of water and

energy fluxes from small catchment scales to scales compatible with satellite sensors (such as SSM/I) or AGCMs. A small scale, detailed input data set consisting of land surface characteristics (soils, topography, vegetation), precipitation and net radiation was compiled for a 1.5x1.5 degree grid in the Red River basin in the southern Great Plains region of the United States. Net radiation, and therefore the atmospheric evaporative demands, were estimated using a radiation model, surface airways data and operational radiosonde data. This detailed data set serves as a workbench to study the scaling behaviour of land surface parameterizations at various scales. The land surface water and energy fluxes are calculated at scales ranging from O(100m) to O(1000m). The large scale models can then be applied to the Red River, a basin of over 80,000 sq km, to determine regional scale water and energy fluxes. Future challenges of integrating the results from terrestrial water-energy models with atmospheric observations of water fluxes, and carrying out coupled, interactive land-atmospheric modeling studies at regional scales will be discussed.

USING THE CANADIAN LAND SURFACE SCHEME (CLASS) IN THE CMC GLOBAL FORECAST MODEL

Y. Delage
Recherche en prevision numerique, AES, Montreal, Que H3A 2K6

The surface scheme developed by Diana Verseghy at the Canadian Climate Centre for use in the general circulation model has been introduced into the global forecast model of the Canadian Meteorological Centre for experimentation. A novel requirement for this new environment is the correct specification of soil condition at initial time, in particular moisture and temperature. The forecast model is sensitive to soil moisture input, especially to dry anomalies. At the time of writing this abstract only preliminary results have been obtained, but the presentation will report on present ongoing work.

STAND-ALONE COMPARISONS OF LAND SURFACE SCHEMES

D. Verseghy
Canadian Climate Centre, Atmospheric Environment Service, Downsview, ON, M3H 5T4

Stand-alone testing provides a convenient method of evaluating the performance of various subsections of a GCM code. Although such testing necessarily neglects feedback effects, it often yields useful and inexpensive indications of systematic errors or shortcomings in the subsection in question.

Two land surface schemes of widely varying complexity were tested in stand-alone mode, using atmospheric forcing fields derived from a GCM run. The two schemes were run to equilibrium for three selected grid cells: one tropical, one temperate and one arctic. Large differences in the models' surface climates are evident, particularly in the water balance variables, such as the evaporation and runoff rates and the snow cover. The differences are explained in terms of the structure of the two schemes. First-order comparisons of the modelled energy budgets with field observations are also undertaken.

HYDROLOGICAL CYCLE IN SIMPLE ATMOSPHERE-OCEAN MODELS

D. Mercer
Atmospheric Science Program, Dalhousie University, Halifax, N.S. B3H 4J1

The thermohaline circulation in the North Atlantic (NA) transports heat north, which is released into the atmosphere, causing cooling and subsidence of the high salinity water, and driving the so-called conveyer belt. If the salinity is reduced enough, subsidence is stopped, and there is a reduced air-sea heat flux, cooling the northern climate. One proposed mechanism is an increase in the northward transport of water vapour and precipitation in the subsidence regions. There is evidence for a weak or nonexistent conveyer during the Younger Dryas, as well as a cooler climate and lower salinity surface waters in the NA. Also, different types of coupled atmosphere-ocean models predict multiple circulation modes which are sensitive to the atmospheric water vapour flux.

We are implementing a one-dimensional atmospheric energy balance model (EBM) which will be coupled with the Stocker-Wright two-dimensional ocean climate model. This model contains an explicit hydrological cycle, and has atmosphere and ocean coupled by radiation, and convective fluxes of sensible and latent heat. Horizontal fluxes of heat and water are advective-diffusive, and the dynamical structure is parameterized by temperature gradients. There is a Hadley cell region and a baroclinic region. Radiation is separated into a short-wave and long-wave regime, there are parameterized clouds, and carbon dioxide and water vapour are included as greenhouse gases. There is also a crude parameterization for sea ice. We first examine this model with a purely diffusive mixed layer ocean to confirm that it models the current climate adequately. Then we investigate the parameterization of northward vapour flux.

AN EXAMINATION OF THE SURFACE ENERGY AND WATER BUDGETS OF THE CCC CLIMATE MODEL

G.A. McBean and R.A.S. Hourston
Department of Oceanography, University of British Columbia, Vancouver, B.C., V6T 1Z4

The surface energy and water budgets for 3 grid points in British Columbia are examined. Generally, the features of the simulation were physically consistent and are useful for investigating the budgets. With the doubling of CO_2, the precipitation generally increased in fall and winter while the evaporation increased in the spring. An interesting feature was the episodicity of the surface fluxes, particularly of sensible heat flux. It showed very large deviations occurring with outflows of cold air from the interior to the coastal locations. These caused abrupt decreases in ground temperature and increases of the frozen soil moisture content. With only a single soil layer in the model, the transition of the ground temperature from above to below freezing has to be delayed until all moisture is frozen. This unrealistic feature is being eliminated in newer versions of the soil parameterization.

APPLICATION OF THE U.B.C. WATERSHED MODEL TO TWO CLIMATICALLY DIFFERENT WATERSHEDS

M.C. Quick, A. Loukas, R. Millar, D. Nixon and E. Wu
Dept. of Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4

The response of two watersheds in different climatic regions of British Columbia has been analyzed. The first watershed, Campbell, is located on the eastern, leeward side of the Vancouver Island mountains. The main climatic features of coastal British Columbia are warm but not hot summers,

mild winters, a small range of temperature, and highly variable weather. Precipitation is mainly in the form of rain except at higher elevations. The second watershed, Illecillewaet, is located on the Columbia mountains. The climate of the area is continental, with cold winters and warm summers with frequent hot days. Precipitation falls mainly as snowfall during the winter months. Showers and thunderstorms produce the majority of summer precipitation.

The U.B.C. watershed model has been used in this study. The model is a combined rainfall-snowmelt runoff model, which separates the runoff into various components, namely the fast, medium, and slow or groundwater components. Parameter values which are used to assign the rainfall or snowmelt to the various components as well as those associated with flow routing, are obtained during calibration of the model using observed air temperature, precipitation and streamflow data. The model has been calibrated for the two study watersheds using an optimization procedure. Four years of data were used for the calibration period and two years of data were used to verify the simulation results. The model performance is strongly affected by the quality of the data available for the calibration. For the Campbell watershed, there are meteorological records from only two stations. The statistical parameters of the simulation for the four years were acceptable with the Nash-Sutcliffe model efficiency and the coefficient of determination being about 0.75. For the Illecillewaet watershed there are reliable data from three stations which cover the whole elevation range. Furthermore, the precipitation in this interior watershed is mainly snowfall which follows a more predictable pattern increasing with elevation. The calibration results were better for this watershed than the Campbell watershed. The Nash-Sutcliffe model efficiency and the coefficient of determination were about 0.90.

Examination of the calibrated model parameters showed that the different climatic conditions and hydrological processes in the watersheds are reflected in the parameter values. The calibration procedure has shown that the various runoff components of the model have a much faster response for the Campbell than the Illecillewaet watershed. The Campbell watershed is a typical coastal watershed characterized by shallow soil, relatively shallow and variable snowpacks, the presence of preferential runoff pathways in the soil and high soil moisture throughout the year. These factors result in faster response of the Campbell watershed. On the other hand, deep snowpacks, high soil moisture deficit before the snowmelt period and the snowmelt dominated runoff of the watershed explain the slower response of the Illecillewaet watershed. The values of the statistical parameters for the two year verification period are similar to those of the calibration period indicating consistent model performance. The above results indicate that when the precipitation records are reliable and representative, the U.B.C. watershed is capable of accurately predicting the runoff from either rainfed or snowfed watersheds.

GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX)

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The Global Energy and Water Cycle Experiment (GEWEX) is one of the major activities of the World Climate Research Program (WCRP) which is sponsored by the World Meteorological Organization, the International Council for Scientific Unions, and the Intergovernmental Oceanographic Commission. GEWEX incorporates in a single, coordinated program relevant aspects of climate science from model development and data assimilation to the deployment and operation of pertinent observing systems. A central goal of GEWEX is to improve our ability to model global precipitation and evaporation and to assess the sensitivity of the hydrological cycle and water resources to climatic change. The GEWEX Continental-scale International Project (GCIP), as the first major new project under GEWEX, will study the water and energy budgets of the Mississippi River basin. One of the principal scientific

objectives for GCIP is to develop and validate macroscale hydrological models, related high resolution atmospheric models, and coupled hydrological/atmospheric models.

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. In keeping with this objective, a central goal of the Canadian implementation strategy should be: 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. As a complement to GCIP, 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). An update of activities related to the Canadian GEWEX programme will be given at the conference.

Thursday/Jeudi a.m. Room/Salle 125

PHYSICAL-BIOLOGICAL INTERACTIONS IN THE OCEAN
INTERACTIONS PHYSIQUES-BIOLOGIQUES DANS L'OCÉAN

Chair/Président: F.H. Page, St. Andrews Biological Station

JUVENILE ATLANTIC COD IN THE NORTHERN GULF OF ST.LAWRENCE, CANADA

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Changes in the dynamics of 0- and 1-group cod are thought to play a role in the current decline of both numbers and size at age of Atlantic cod (*Gadus morhua*) in the northern Gulf of St. Lawrence. We examined the broad habitat requirements and preferences of demersal juveniles, the size and age frequency distributions of 0-group cod prior to winter, and the post-winter distribution, size at age, and physiological condition of the survivors. Our results indicate that few 0-group cod colonize nearshore regions, show no evidence of size-dependent winter mortality, and that post-winter 1-group cod are in good condition with high levels of storage lipids. From the time of settlement until well into the next growth season, 0-group cod largely distribute themselves within regions where a permanent cold water layer (< 0 °C) impinges on the bottom.

THE ONTOGENY OF SCALLOP LIFE HISTORY STAGES IN RELATION TO THE PHYSICAL ENVIRONMENT IN THE QUODDY REGION

S.M.C. Robinson and F.H. Page
Department of Fisheries and Oceans, Biological Station, St. Andrews, N.B., E0G 2X0

The annual settlement patterns of the sea scallop *Placopecten magellanicus*, were studied in Passamaquoddy Bay and the Fundy Isles of the Quoddy region from 1989 to 1992 in relation to the local hydrographic conditions. Spat were collected using onion bag collectors at 25 stations in a uniform grid pattern. Hydrographic measurements were taken monthly at each station using an internally recording CTD. The results indicated very consistent inter-annual patterns of scallop spat settlement with the northern part of Passamaquoddy Bay having the highest settlement rates and mean shell

heights. The spatial pattern of spat settlement closely reflected the known oceanographic properties of the area and were consistent with observations on scallop larval densities and observed chlorophyll *a* levels. However, the areas of highest larval abundance were not spatially coincident with the adult scallop beds. It is postulated that the northern part of Passamaquoddy Bay may be acting as a larval nursery area for the scallop populations in the area. We will discuss some of the possible physical mechanisms that may be occurring in the recruitment process of this population.

MODELLING THE DISPERSAL OF SEA SCALLOP LARVAE ON GEORGES BANK IN AUTUMN: THE EFFECTS OF MEAN ADVECTION, BEHAVIOUR AND LARVAL ORIGIN

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There have long been suggestions that the residual circulation gyre on Georges Bank allows a prolonged residence time of fish eggs and larvae over the Bank. The sea scallop Placopecten magellanicus is of particular interest because it comprises a substantial portion of the bivalve biomass and is a dominant commercial species. The primary objective of this paper is to evaluate the relative importance of mean circulation and biological behaviour to the movement of scallop larvae on GB, and to potential exchange among the three main adult aggregations in particular. Our approach is to build on the spatio-temporal persistence of the physical regime provided by the tidal forcing, and track passive and active (biologically) particles in a three-dimensional (3-d) circulation model. A necessary companion objective is to evaluate the consistency of the model flow field with available current observations from the primary scallop spawning period of September-October.

A model solution forced by nonlinear semidiurnal tidal interactions, seasonal density gradients and seasonal mean wind stress is in approximate agreement with the observed residual gyre, although the recirculation rate is slightly underestimated. Cross-isobath currents are weak but otherwise in poor agreement with those observed, although the observational pattern is not well-defined. Particle trajectories in this flow field, and sensitivity runs involving behaviour and additional flow field components, suggest that there is significant exchange of larvae among the primary scallop aggregations, but limited self-sustenance of the areas. The exchange is particularly sensitive to the uncertain weak cross-isobath flow, and biological behaviour influencing the depth of larvae and the duration of their planktonic drift stage.

COMPUTER SIMULATIONS OF THE INFLUENCE OF OCEAN CURRENTS ON THE RETURN MIGRATIONS OF FRASER RIVER SOCKEYE SALMON: 1950-1990

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We have hypothesized that Northeast Pacific Ocean surface currents affect coastal migration routes and return times of Fraser River sockeye salmon (Oncorhynchus nerka). Using the Ocean Surface

Current Simulations model, sockeye return migrations were simulated for the period from 1950 to 1990. The simulated latitude of landfall and return time anomalies have ranges of up to 550 km and two weeks, dependent upon the modelled swim speed and compass orientation, and most particularly, the geographic region from which sockeye initiate their homeward migration. One hundred and sixty-eight indices of surface current speed were calculated in an attempt to find an index for the correlation models used by fisheries managers to predict Northern Diversion Rate (percentage of sockeye returning to the Fraser River around the north end of Vancouver Island) and return times. The correlations show that a strong Alaska Gyre circulation tends to yield higher diversion rates, earlier return times for the Early Stewart and Chilko stocks, and later return times for the Dominant Adams stock. The largest correlation coefficient was obtained with Early Stewart return time ($r = -0.532$, $p < 0.01$); the correlations with diversion rate were not significant (stock-specific diversion rates may yield better results).

Our simulations show that ocean currents affect sockeye return migration paths and migration rates; however, other oceanic and coastal variables account for greater portions of the observed variance in diversion rate and return times. Further work may yield current speed indices to enhance existing correlation models, or may reveal critical current speed values indicative of years when the Alaska Gyre circulation dominates. Individual-based biophysical models, which simulate sockeye behaviour within the complex space-time variability of the oceanic and coastal environments, have the potential to increase our knowledge of the kinematics of sockeye return migrations. Ultimately, they may provide fisheries managers with more effective predictions than correlation models.

SEASONAL AND INTERANNUAL VARIABILITY OF PHYTOPLANKTON PIGMENT CONCENTRATIONS IN FOUR EASTERN BOUNDARY CURRENT REGIONS

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Monthly composite images from the global Coastal Zone Color Scanner data set are used to illustrate and compare seasonal and interannual variability of phytoplankton pigment concentrations in four major eastern boundary current (EBC) regions of the global ocean. The study areas extend along the western coasts of South and North America and southern and northern Africa in the Peru, California, Benguela and Canary Current Systems respectively. The analysis utilizes the entire time series of available data (92 months, from November 1978 to June 1986) to calculate mean annual cycles and indices of interannual variability for a series of both latitudinal and cross-shelf regions within each current system. Seasonal and interannual patterns in phytoplankton pigment patterns are then compared to large-scale atmospheric forcing using concurrent ECMWF wind fields. Pigment patterns within each boundary current show persistent high concentrations (> 2.0 mg m^{-3}) within 40 km of the coast. However, there is strong variability, both on a seasonal basis and interannually, of the offshore extent of high concentrations beyond 40 km. Additionally, there are considerable latitudinal differences within each EBC of this variability. Comparisons with the wind fields indicate that a direct relationship of the observed pigment variability to wind forcing in these upwelling regions is not always present.

SOURCES OF VARIABILITY IN PHYTOPLANKTON CROP COMPOSITION IN SPRING

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Dinoflagellates are not very abundant in temperate waters during spring diatom increases. The cause(s) of this is (are) not well known. Diatom blooms typically begin when water is turbulent and this energy dissipation could shear flagella off dinoflagellate cells. Also, photosynthetic rates of diatoms are large and can cause the pH of seawater to reach 8.6 in afternoons of sunny days. Thus, the capacity of cells to take up dissolved inorganic carbon (DIC) could also influence the taxonomic structure of phytoplankton crops in spring. We investigated the carbon-concentrating mechanisms of a dinoflagellate, *Amphidinium carterae* Hulbert, a chrysophyte flagellate, *Isochrysis galbana* Parke and a diatom, *Thalassiosira weissflogii* Grunow, and found the latter two to have similar systems, which were different from that of the dinoflagellate. The pyrrophyte concentrated 10X more intracellular DIC than did the chrysophytes, while these species had 25X more extracellular carbonic anhydrase than did the former. The three species exhibited similar kinetics for rates of carbon uptake into acid-stable compounds when exposed to varying amounts of HC_3^{-1}. The maximum rate for the dinoflagellate was enhanced and that of the diatom depressed when CO_2 was substituted for HC_3^{-1}. The influence of these differences on crop composition will be discussed.

OVERVIEW OF SCIENTIFIC PROGRESS OF THE OCEAN PRODUCTION ENHANCEMENT NETWORK

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Recent achievements of the Ocean Production Enhancement Network will be reviewed, with particular emphasis on work in physical oceanography and its relevance to problems in biological oceanography and fisheries pertinent to cod, salmon and scallops.

Poster No. 11

IMPORTANCE OF OXIDATIVE PROCESSES IN THE PHYSIOLOGICAL CONDITION OF MYTILUS EDULIS L. SUBMITTED TO NATURAL ENVIRONMENTAL FACTORS IN THE LOWER ST. LAWRENCE ESTUARY

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Free radicals are often associated with aging and toxicity mechanisms in mammals. However, information is sparse about the importance of oxidative processes in the physiological condition of invertebrates subjected to various environmental factors in the intertidal zone. The purpose of this study was to evaluate the importance of the oxyradical generation in relation with physico-chemical factors and to characterize antioxidant defence systems in *Mytilus edulis L.*

A comparative study was achieved between bivalves present at two sites on the north coast of the lower St. Lawrence estuary: (1) Franquelin (FR), a tidal flat geographically oriented East; (2) Baie des Anglais, (BC), a steep rocky shore, oriented NE. Bivalves were transferred from Franquelin to Baie

des Anglais. Indigenous and transferred animals were followed regularly. Measures of hydroxyl radical scavenging molecules (carbohydrates, GSH), enzymes, (SOD, catalases and peroxydases), malonyldialdehyde (MDA: end product of lipid peroxidation), and metabolic substrates were done in the digestive gland. Sampling of Mytilus edulis L. was done at days 0, 1, 3, 7, 15, 31 and 63. Mussels were immediately frozen on dry ice in the field and kept at -70 ^{0}C.

We observed high levels of MDA and high catalase activity in the digestive gland at day 15 in all the sites. The tide was low that day, in broad daylight at noon, thus exposing the bivalves to high temperatures. Moreover, the difference between the maximum and the minimum temperature was the highest that day. At day 31, MDA returned to basal levels in Franquelin. In Baie des Anglais, bivalves exposed to strong waves showed high levels of MDA. Catalase activities returned to normal levels in all the sites in days 31 and 63. GSH levels increased in the control site at day 31 while an evident seasonal variation was observed between day 0 and day 63 in all the sites.

These results show that mussels can suffer an oxidative stress due to natural environmental factors. Strong influences from natural factors could decrease the resistance of organisms to stress and lead to a poor physiological condition explaining in part the variability in growth of bivalves in an estuarine ecosystem.

Poster No. 12

INFLUENCES OF MEAN ADVECTION AND SIMPLE BEHAVIOUR ON THE DISTRIBUTION OF COD AND HADDOCK EARLY LIFE STAGES ON GEORGES BANK

F.E. Werner[1], F.H. Page[2], D.R. Lynch[3], J.W. Loder[4], R.G. Lough[5], R.I. Perry[6], D.A. Greenberg[4] and M.M. Sinclair[4]

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Results of a modeling study designed to explore the influences of physical advection and certain biological mechanisms on the distribution of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) early life stages on Georges Bank are described. Using a late-winter/early-spring 3-D circulation field driven by the M2 tidal current, mean wind stress and Scotian Shelf inflow, we examine the distribution of cod and haddock larvae spawned on the Northeast Peak of the Bank. The sensitivity to a March-April baroclinic field is also explored. Results indicate that larvae remaining in the surface Ekman layer are generally advected off-bank. However, downwelling associated with Ekman layer convergence near the shelf break provides a mechanism for larvae to exit from the off-bank surface drift. Larvae below the surface layer are transported southwestward along the southern flank of Georges Bank and are retained on the Bank if their position immediately upstream of the Great South Channel is shoalward of (roughly) the 70 m isobath. Within the Great South Channel region and between the 50 m and 70 m isobaths, retention can depend on the phase of the tide. Spawning shoalward of the 50 m isobath on the Northeast Peak greatly increases the chances of retention. These results apply to passive larvae and to those with specified vertical distributions and migration based on observations. Directional on-bank swimming at rates of 0.5 to 1 body-length per second would substantially enhance shoalward displacement resulting in larval distributions during the first two months that are consistent with field observations.

Thursday/Jeudi a.m. Room/Salle 205

WORLD OCEAN CIRCULATION EXPERIMENT
EXPÉRIENCE CONCERNANT LA CIRCULATION OCÉANIQUE MONDIALE

Chair/Président: W.W. Hsieh, University of British Columbia

COMPARISON OF OSCURS MODEL OUTPUT TO WOCE SURFACE DRIFTER TRACKS IN THE NORTHEAST PACIFIC

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The OSCURS model predicts surface water motion in the North Pacific using daily wind fields and a climatic version of geostrophic currents. The model has been used in studies of fish migrations and of the drift of spilled footwear. The availability of WOCE Surface Velocity Program drifters (drogued at 15 m) provides the opportunity for further verification of OSCURS. Results of the comparison process will be presented.

CONVECTION FROM AN ISOLATED SOURCE IN A ROTATING STRATIFIED FLUID

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Laboratory experiments are performed to investigate the behavior of a rotating stratified fluid in response to heating from a source much smaller than the dimension of the basin. The work of Brickman and Kelley 1993 (for the non-stratified case) found 3 phases to the response, including a middle phase of cyclonically rotating convecting vortices at lower levels, plus a final phase where large vortices develop at the front between heated and unheated water. To investigate the effects of stratification we look here at how these phases are influenced by the addition of a second layer of different density, as well as the conditions under which buoyant plumes can penetrate the interface separating the two layers.

THE NORTH ATLANTIC TRACER RELEASE EXPERIMENT: A SUMMARY OF THE FIELD PROGRAM

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The North Atlantic Tracer Release Experiment (NATRE) was designed to study vertical mixing processes. It began in May 1992 with the injection of a tracer in the eastern North Atlantic at (25° 40'N, 28° 20'W) by Jim Ledwell and Andy Watson. The tracer has been successfully surveyed in three cruises at an interval of one month, six months and one year. Microstructure measurements have been made by Schmitt and Toole at WHOI just prior to the injection and by Oakey and Ruddick in two cruises at six months and one year. Data from moorings, several Lagrangian bobber floats, and a

drifting float to measure Richardson Number all contribute to an extensive data set in this very successful field program.

We will present an overview of the experiment and explore some of the implications of the study on our understanding of mixing processes and its parameterization.

A FIRST LOOK AT MICROSTRUCTURE MEASUREMENTS FROM THE NORTH ATLANTIC TRACER RELEASE EXPERIMENT

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The North Atlantic Tracer Release Experiment (NATRE) was designed to measure vertical diffusivity in the Canary Basin from the vertical rate of spread of an injected tracer, sulfur hexafluoride. In addition to having this estimate of mixing, microstructure measurements obtained during this experiment using the EPSONDE microstructure profiler enable us to identify the processes causing this mixing and also to test various models used in the study of mixing.

Microstructure measurements allow us to estimate the dissipation of mechanical energy and temperature variance. This can then be used to calculate the rate of vertical mixing using various models. It is also important that we use the microstructure and finestructure measurements to identify the physical processes occurring during this experiment.

Two microstructure field studies have been completed, one in November, 1992 and a second in May, 1993. We will present some preliminary results from the analysis of the microstructure data obtained on these cruises, including early estimates of dissipation and identification of physical processes, as well as outlining future work.

Thursday/Jeudi a.m. **Room/Salle 205**

TRACERS IN THE OCEAN
LES TRACEURS DANS L'OCÉAN

Chair/Président: E.P. Jones, Bedford Institute of Oceanography

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A SUITE OF ANTHROPOGENIC HALOCARBON TRACER MEASUREMENTS IN THE GREENLAND AND NORWEGIAN SEAS

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During November/December of 1991 and 1992, we made measurements of CFC-12 ($CC1_2F_2$), CFC-11 ($CC1_3F$), CFC-113 ($CC1_2FCC1F_2$), methyl chloroform (CH_3CC1_3) and $CC1_4$, in the Greenland and Norwegian Seas during cruises of the RV Johan Hjort. Earlier transient tracer studies had suggested

that deep convection in this region, particularly the renewal of Greenland Sea Deep Water (GSDW), was strongly reduced apparently during the 1980's. The Johan Hjort cruises provided a means to establish an annual time-series of tracer measurements which would provide an unequivocal signal of deep convection. Results from the 1991 cruise confirmed that the CFC levels in GSDW have remained essentially unchanged from the concentrations measured in 1982, indicating that renewal was still restricted. Water mass ages calculated using the observed ratio of CCl_4/CFC-11, suggest that the GSDW and the Norwegian Sea Deep Water (NSDW) share an apparent age of ~22 years, although transient tracer concentrations in the NSDW are significantly lower than those in GSDW. The water mass ages suggest that there was major renewal and `resetting' of the tracer inventories of this region's densest water masses around 1970, possibly associated with a series of anomalously cold years immediately prior to that time. CFC-11 concentrations in NSDW have doubled between 1982 and 1991. A signature of slightly `younger' water was found in deep waters overlying the Mohn Ridge, perhaps an indication of some ventilation of the deep waters at the basin boundaries. Results from the 1992 cruise will be presented for comparison with the 1991 data. A comparison of the water mass ages derived from the halocarbon data together with ages derived from tritium and helium^{-3} measurements made on the same samples will also be presented.

Poster No. 13

ASSESSING RECENT VENTILATION OF THE LABRADOR SEA: MEASUREMENT OF HALOCARBON AND TOTAL DISSOLVED INORGANIC CARBON

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Concern about anthropogenic greenhouse gases and global warming has focused attention on the oceans' role as an important sink for excess atmospheric carbon dioxide. Various attempts have been made to determine the rate of CO_2 uptake by the oceans, but the estimates disagree by as much as 250 to 300%.

To estimate the uptake rate of anthropogenic CO_2 in areas of down-welling, we have made high-precision measurements of total dissolved inorganic carbon (C_T) in the Labrador Sea where deep convection occurs during the winter months. We have also measured a suite of conservative water mass tracers (including the chlorofluorocarbons CFC-11, CFC-12, CFC-113 and carbon tetrachloride CCl_4) to help in modelling the rate of transport of surface water to the intermediate and deep water masses in the North Atlantic.

Tracer distributions in the Labrador Sea provide evidence that ventilation of the upper 2000 to 2400 meters of the Labrador Sea has occurred during the last several years. Time series measurements of C_T with a precision of greater than 1 part per thousand will allow us to follow the anthropogenic signal in these recently formed water masses.

Poster No. 14

THE DEEP WATER OF THE CANADIAN BASIN

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The Oden 91 Expedition has provided a data set from which it is possible to deduce new and much more detailed ideas regarding the origin and circulation of waters in the Arctic Ocean. We propose three sources for the deep water of the Arctic Ocean: (1) density flows down the continental slope that are induced by the formation of dense water by freezing on the continental shelves, (2) inflow of Atlantic Water that is transformed on the Barents Sea shelf and subsequently sinks down the St. Anna Trough into deeper regions of the Arctic Ocean, and (3) the inflow of Norwegian Sea Deep Water through Fram Strait. Of these three sources, the Norwegian Sea Deep Water is probably the least important.

The Eurasian Basin communicates with the Canadian Basin partly through the boundary current along the Eurasian continental slope, and partly through a spillover across the Lomonosov Ridge through the deeper rifts found more towards the centre of the Arctic Ocean. The return flow from the Canadian Basin to the Eurasian Basin takes place as a boundary current along the continental slope north of Greenland. A temperature decrease is observed in the deepest levels of the Canadian Basin, while the temperature of the bottom water in the Eurasian Basin increases towards the bottom. This shows that, in spite of the presence of the Lomonosov Ridge, the deeper waters of the Canadian Basin are primarily ventilated advectively by water spilling over the Lomonosov Ridge, not by convection from the shelves.

A model, which incorporates density flows triggered by high salinity shelf water and water overflowing the Lomonosov Ridge from the Eurasian Basin, is used to reproduce the observed profiles in the Makarov Basin and to estimate the relative amounts of each of these sources in the deeper layers of the Canadian Basin. Incorporating carbon-14 profiles into the model allows the estimate the strength of the deep circulation in the Canadian Basin.

MODIFICATION OF HALOCLINE SOURCE WATERS DURING FREEZING ON THE BEAUFORT SEA SHELF: EVIDENCE FROM OXYGEN ISOTOPES AND DISSOLVED NUTRIENTS

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During some, but not all winters, waters on the Mackenzie shelf of the Beaufort Sea become sufficiently saline to ventilate the halocline of the adjacent Canada Basin. This occurred in March 1988, at which time a survey of the temperature, salinity, dissolved nutrient and 18O properties of the ventilating waters was completed. The 18O-salinity properties of the cold, saline shelf waters revealed that in the winter of 1987-88, ice was grown from water initially more saline by about 1.5 than is typical for the area. The higher initial salinity appears to have been a consequence of a two-stage conditioning of shelf waters by storms in the autumn of 1987. Since the amount of ice growth, and consequent salt rejection, over the winter of 1987-88 was abnormally low, this conditioning played a

crucial role in the formation of the ventilating water mass. Nutrient concentrations in ventilating waters were the same as those of waters unaffected by freezing. Thus significant regeneration of nutrients within the cold saline shelf waters did not occur during their six-month period of formation. In consequence, the nutrient signatures carried into the arctic halocline by winter shelf waters from this area tended to erode, rather than to reinforce the nutrient maxima. Waters in the Chukchi and northern Bering Seas during the same period had 18O values intermediate between those on the Mackenzie shelf and those in the arctic halocline. Thus winter shelf waters are supplied to the arctic halocline with a range of nutrient, temperature, salinity and 18O properties. On average, the southern Canada Basin is an impressive net producer of sea ice. Total net production from the upper 150 m is about 10-15 m, far exceeding the 4 m net production of the central arctic.

ATLANTIC WATER IN THE ARCTIC OCEAN

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The intermediate depth waters of the Arctic Ocean formed from inflowing Atlantic water and water produced on the continental shelves are confined to, but can move freely between, the different deep basins of the Arctic Ocean. These layers are supplied from the North Atlantic by inflows through Fram Strait and over the Barents Sea. The re-merging of the two branches north of the Kara Sea creates interleaving and inversions that help to identify the flow paths of the intermediate water. The intermediate depth waters from these two sources are transformed by interaction with sinking water made dense by freezing and ice growth on the shallow shelves. The warm Atlantic Layer is cooled and heat is redistributed downwards by the descending density flows. A model calculation for the Canadian Basin shows how the introduction of dense shelf water can explain the observed property changes. Based on chlorofluorocarbon concentrations, the residence times of the intermediate waters are about one decade in the Eurasian Basin and somewhat longer in the Canadian Basin, with the deeper layers being the oldest. Several loops are identified in the Eurasian Basin. A similar flow pattern in the Canadian Basin is suggested based on properties of outflowing Canadian Basin Water near the Morris Jesup Plateau.

Thursday/Jeudi a.m. Room/Salle 303

MODERNIZING CANADA'S WEATHER SERVICES
LA MODERNISATION DES SERVICES MÉTÉOROLOGIQUES CANADIENS

Chair/Président: F. MacNeil and K. MacDonald, Atmospheric Environment Service, Bedford

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A FOUNDATION FOR THE FUTURE

J. Mills (Invited)
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

The weather services have contributed to Canadians' safety, health and prosperity for well over a century and have continually adapted to change. The last decade in particular has seen the emergence

of environmental issues as a major source of interest and concern to scientists and the public. The weather services present a strong foundation on which to base Canadian response to these issues. John Mills, Director General of the Weather Services Programme of the Atmospheric Environment Service, will discuss the current weather services, environmental issues and other factors of change, and what is required to ensure that Canada's weather services meet these challenges.

MODERNIZATION OF WEATHER SERVICES IN NEW BRUNSWICK

R. Lefebvre
New Brunswick Weather Services Office, Fredericton, N.B. E3B 6Z3

The opening of Weather Services Office (WSO) across Canada is a key element of the AES modernization plan. A revitalized weather service program will be achieved through the relocation and retraining of professional and technical staff, the introduction of new technologies, and most important, an increased emphasis on service delivery.

These changes are being driven by the desire of Canadians to have access to the information required to make wise environmental decisions. To meet this need, the emphasis within the WSO will be on service delivery through improved science and technology. The New Brunswick WSO will provide more timely, detailed and diversified information on the environment in general, including weather.

The WSO will be an integral part of the New Brunswick science community. Its broad objective is to share knowledge concerning environmental issues, the state of the environment and responsible environmental decisions and actions. Its goal, is a healthy environment and a sound economy based on sustainable development.

AVIATION TERMINAL FORECASTS BASED ON AUTOMATED OBSERVATIONS (FTAUTO)

J. Anderson and B. Shannon
Prairie Weather Centre, Atmospheric Environment Service (AES), Winnipeg, Manitoba

For the first time in Canada, on October 9, 1992, aviation terminal forecasts were issued operationally based on unmanned weather observations. The observations are obtained from a system developed by the Atmospheric Environment Service known as the Remote Environmental Automatic Data Acquisition Concept (READAC). This represents a major change in the observational information used both directly by the aviation community and by those preparing aviation forecasts. The site chosen for the implementation of this initial forecast program is Big Trout Lake, Ontario (YTL) which is located in a remote area in Northwestern Ontario. The FTAUTO forecasts are being issued by the Prairie Weather Centre in Winnipeg, Manitoba.

This paper discusses briefly the planning, training and implementation process involved in the FTAUTO forecasting program. It then presents a review of aviation user and forecaster assessments of the observing and FTAUTO programs since October 1992. An important aspect of the forecasting process is the need to treat the automated observation as a new type of data and to accept the fact that it must be interpreted differently from the manned observation with which we are so familiar.

FTGEN - AN AUTOMATED FT PRODUCTION SYSTEM

B. Whiffen
Newfoundland Weather Centre, Atmospheric Environment Service, Gander, Nfld. A1V 1W7

A software procedure, called FTGEN, has been developed at the Newfoundland Weather Centre (NWC) to produce aviation terminal forecasts (FT's). The process incorporates user-manipulation of numerical model output, a climatological database, and assimilation of present conditions.

FTGEN presently resides on a developmental software package called the Forecast Production Assistant (FPA), a nationally co-ordinated program designed as part of the future weather centre workstation. Amongst other capabilities, FPA provides a platform upon which the forecaster can download and display output from the Canadian Regional Finite Element (RFE) Model. The interface permits manipulation of the isobaric and temperature fields and allows for input of a variety of weather patterns, including precipitation and cloud cover. FPA resides on an HP9000 workstation. FTGEN is written primarily in PROLOG.

Generation of terminal forecasts by FTGEN comprises three main steps. First, the wind direction, speed and precipitation fields for a particular aerodrome are sampled at one-hour intervals from FPA and merged into reasonable part periods. These values are a composite of RFE output and forecaster intervention. Secondly, the climatological database is accessed to determine most probable ceiling and visibility categories for each period. Probability values are used to determine the main, variable (VRBL) and occasional (OCNL) components of each part period. Most recent ceilings and visibilities are then accessed and incorporated into the forecast in a manner consistent with probability of occurrence. All parameters are then quality controlled and processed to generate the terminal forecast.

Feasibility testing for a number of stations within NWC's area of responsibility has recently begun. Preliminary results have been encouraging. Development will be ongoing through 1993. The presentation will include a comparison of FTGEN output with operational FT's.

TRANSPORT CANADA PROPOSED R&D ACTIVITIES ON ATMOSPHERIC SENSORS AND THEIR INTEGRATION FOR AVIATION METEOROLOGY

G. Fournier
Transport Canada Aviation, Ottawa, Ontario K1A 0N8

After talking about meteorological factors impacting safety and efficiency of air operations, the sensors constituting the current Canadian Weather Observing Network will be listed. Then aviation requirements for final weather products will be described in a general sense, and the most important reasons for which the current Observing System does not fully meet aviation requirements will be given.

Transport Canada Aviation R&D approach to the Observing System deficiencies will be demonstrated using the results of in-house Preliminary Studies on potential sensor technologies for Next Generation Automated Weather Observing System (AWOS). R&D efforts on a multi-parameter dual X-Ka Band Doppler radar is a consequence of a Preliminary Study, and potential benefits of such a system as the core of an Intelligent Integrated Airport Atmospheric System will be described.

Then a new study aiming at improvements in all final Aviation Weather products (detection, characterization, forecast) will be described taking the multi-parameter dual X-Ka Band Doppler radar technology as an example. The new study will help in the identification of areas where future R&D

will be the most fruitful. We will be able to identify long and short term solutions to the requirements, as well as analyze them in terms of effectiveness, and time and effort required for the implementation.

Finally the status of the Transport Canada Low Level Wind Shear Data Collection Program will be presented.

A KNOWLEDGE BASE SYSTEM TO ANALYZE AND SYNTHESIZE LARGE AMOUNT OF METEOROLOGICAL DATA

R. Verret, G. Babin, D. Vigneux, R. Parent
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The Canadian Meteorological Centre (CMC) has developed SCRIBE, an interactive system for composition of meteorological forecasts. The heart of SCRIBE is the knowledge base system (SCRIBE/KBS) which is used to synthesize large amounts of meteorological data when processing the weather element matrices that include statistical weather element guidances and direct model output parameters. The processing of the matrices is done to generate the concepts which represent the ideas hidden behind the digital weather element forecasts available at specific projection times. The knowledge base system has to scan the data and do cross-validation to come up with a synthesis of the content of the matrices. The knowledge base system is also used to generate plain language text forecasts from the concept file. The only component of the system that is needed to be changed to generate the text is the rule file that comprises the knowledge proper to the text generation.

The three major functional constituents of the SCRIBE/KBS are the compiler to compile the rules, the inference engine to query the rules and the fact database management system. They work together to extract and manipulate the concepts imbedded in the raw data, based on the knowledge represented by an ensemble of rules and to solve the truth system particular to each meteorological situation.

The main advantage of the SCRIBE/KBS is that it uses a predicate language. It is thus possible to generate and modify rules easily and rapidly. It is also possible to develop a knowledge base editor that will allow the users of SCRIBE to tailor the knowledge base system to their local needs.

The knowledge base system will be described and examples of its capabilities will be presented.

THE SIGNIFICANT EVENT DESK

P. Chadwick
Ontario Weather Centre, Atmospheric Environment Service, Toronto, ON, L5P 1B1

The Significant Event Desk is like the Science Console on board the Starship Enterprise! With scanners on maximum sensitivity and range, the Significant Event Meteorologist probes for the potential development of environmental events. The "Science Officer" of the enterprising Weather Centre is familiar with the latest meteorological models and concepts and not afraid of applying them to the real environment. The Significant Event Meteorologist keeps everyone informed as the science leader on the crew and prevents the Enterprise from self-destructing.

Ongoing evaluation, diagnosis and prognosis of incoming data allows the Significant Event Meteorologist to anticipate event development and evolution. Scientific services and products are adjusted to best describe the particular event and to meet the needs of the clients. There is no limit

on scanning range for events. The needs of the clients and the ability of the sciences are the most important considerations.

The Significant Event Desk has been operational at the Ontario Weather Centre since December 1991. The Desk continues to evolve but the successes over the past year and a half have been notable.

A WORKSTATION FOR THE AES WEATHER SERVICES OFFICE ENVIRONMENT

K. Macdonald[1], D. Dueck[2], N. McLennan[3], M. Schaffer[4] and A. MacAfee[1]
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[4]Atmospheric Environment Service, Gander, Newfoundland

The WSO Workstation is being developed as a project of the Atmospheric Environment Service (AES). The Project objectives are to develop, prototype and implement an interactive, computer-graphics workstation for the forecast production and dissemination role of new Weather Services Offices (WSOs) which the AES is in the process of implementing. This is largely an in-house project with most of the software development effort being carried out by AES meteorologists at Weather Centres across the country.

The development strategy for the Project has been based on an evolutionary development and prototyping approach. This has been achieved by having development work carried out in the Weather Centres under the direction of Regional project leaders. Each Weather Centre was provided with development hardware and was assigned a set of development activities based on a set of Project functional specifications. These functional specifications, which themselves are allowed to evolve as the Project advances, include such capabilities as: the display and manipulation of conventional observation data including surface and upper-air plots, cross sections, objective analyses and time series; the display and manipulation of geostationary and polar orbiting satellite imagery with automatic mapping to polar stereographic projection, enhancement curve control and the ability to perform multi-spectral analysis; the display and manipulation of volume-scan radar data; the overlay and animation of various independent data types, e.g., conventional, satellite, radar and spherics information; the display, manipulation and editing of NWP data (including statistically-derived products) in various forms including contoured charts, cross-sections and time-series; the automatic generation of a broad range of forecast products from inputs such as graphical weather depictions and tabulated data; the automatic dissemination of forecast products in a wide range of formats, e.g., text, graphics, voice.

An operational version of the Workstation has been implemented at the first WSO which opened in Kelowna, B.C. in the spring of 1993. A second version of the Workstation, with broader capabilities, will be completed early in 1994. This version will be installed as the operational system in all AES WSOs and Weather Centres.

Poster No. 15
AN APT SATELLITE STATION USED IN AN OPERATIONAL METEOROLOGY ENVIRONMENT

D. Ball
Prairie Weather Centre, Atmospheric Environment Service (AES), Winnipeg, Manitoba

GOES-7 is currently the only geostationary platform providing satellite coverage of western North America, and it is coming to the end of its operational lifetime. Its replacement, GOES-1, has yet to be launched, due to continued development problems, and may not be capable of providing satellite imagery over western North America until late 1994, and possibly later. The use of half hourly satellite imagery from this type of platform is critical to the production of weather forecasts in western Canada. To maintain the availability of satellite imagery in the event of a GOES-7 failure, several tasks have been undertaken.

One solution involves the purchase of inexpensive satellite ground stations for several regions that utilize APT imagery from NOAA polar orbiting satellites. This imagery is readily available from two NOAA platforms as well as Russian METEOR and COSMOS satellites and a number of others. Numerous companies make APT satellite ground stations, and it took nearly a year of testing to select a system that would meet the needs of the Prairie Weather Centre. The intention of this discussion is to demonstrate the Dartcom APT satellite system and to show how the imagery that is received is being used within an operational meteorology environment.

Poster No. 16
CLIMATE INFORMATION SYSTEMS - A PERSPECTIVE

K.C. Heidorn
Axys Environmental Consulting Ltd., Sidney, B.C V8L 3S8

Climate Information Systems are database management and archive systems containing either raw observations or information statistically derived from observations designed to make weather and climate data accessible to a wide range of users. Climate Information Systems may be designed as catalogues of databases, almanacs of statistical summaries and/or specific data collections.

Data archives of national and global holdings have been in existence for years but the need for large datasets for use in global environmental change studies has placed a strain on the ability of these archives to respond to user needs. In addition, the amount of climate data collected around the world is vast and growing rapidly. For example, the NOAA data holdings collected over the past century stand at over 100 terabytes with a current daily addition of 55 gigabytes of information with this plethora of data, storage and ease of access become the major concern to the data management community.

However, rapid advances in computer and communications technology has opened the door to increased accessibility, improved data display and rapid interactive analysis. Many climatic and environmental information systems have been developed in recent years or are currently in the process of being developed. This paper provides a synopsis of several Climate Information Systems.

Thursday/Jeudi p.m. Room/Salle 102

OZONE AND THE ULTRAVIOLET
L'OZONE ET LES RAYONS UV

Chair/Président: W.F.J. Evans, Trent University

TOTAL OZONE CHANGES SINCE THE ERUPTION OF MT. PINATUBO

A.J. Krueger (Invited)
Laboratory for Atmospheres, Goddard Space Flight Center, Greenbelt, MD 20771 U.S.A.

Significant decreases have been observed in total ozone since the June 1991 eruption of Mount Pinatubo. Record low values were reported in ground-based data from Canada and Europe. Data from Total Ozone Mapping Spectrometer (TOMS) instruments on the Nimbus-7 and Meteor-3/5 satellites confirm these observations and extend them globally. In 1991, small (2 - 4 %) losses in equatorial ozone are attributable to Pinatubo aerosols but the Antarctic ozone hole was not appreciably different from prior years. This was expected because the aerosols did not reach south polar latitudes until the depletion was nearly complete. In 1992, after the aerosol had mixed in both hemispheres, decreases were found in subtropical ozone from April to November, and the area of the Antarctic ozone hole increased by 15 % over recent years. In addition, the normal winter increase at northern hemisphere mid-latitudes was very weak. As a result the global average ozone during much of 1992 and early 1993 was the lowest observed in the TOMS data set. These low ozone values are believed to be due to the concurrence of negative ozone perturbations from a combination of QBO, solar cycle, secular trend, and volcanic aerosol effects.

OZONE WATCH AND UV INDEX ENVIRONMENTAL INFORMATION TO THE PUBLIC

A.M. O'Toole (Invited)
Environmental Service Initiatives Branch, Atmospheric Environment Service, Downsview, Ontario M3H 5T4

Over the past year Canadians have seen the introduction of two new products that provide information on the environment around them. This information is on the current status of the stratospheric ozone layer and daily forecasts of UV intensity at the surface.

The Ozone Watch and UV Index services were initiated to address public concerns over the depletion of the ozone layer. One of the major objectives of the program was to increase public awareness of the issues. People are then able to make decisions on actions that can protect the environment and that can protect their health.

UV rays occur naturally and exposure to UV has always been a health concern. Excessive exposure to the sun's ultraviolet rays leads to sunburn and, in some cases, can lead to skin cancer and eye cataracts. Health authorities recommend sun-smart action: limit time spent in the midday sun when UV is strongest, wear a hat and other protective clothing and sun-glasses which are UV-rated, and use a sunscreen.

The presentation will describe the production and delivery of Ozone Watch and the UV Index. Indications of how Canadians are responding and making decisions based on this new type of environmental information has been obtained from follow-up surveys and anecdotal information. The assessment results to date will be included along with plans for the coming years.

MEASUREMENT AND FORECASTING OF ULTRAVIOLET RADIATION AND SUNBURN TIME OVER SOUTHERN ONTARIO

W.F.J. Evans
Environmental Resource Studies, Trent University, Peterborough, Ontario K9J 7B8

Studies of the depletion of ozone which have been conducted from ground networks and the TOMS instrument on the NIMBUS 7 satellite indicate that total ozone has declined by 6 % over the last 12 years at most mid-latitudes in the northern hemisphere typical of southern Ontario. The measurement of the actual resultant increases in UVB in now important. A monitoring program of UVB (biologically active solar ultraviolet radiation) has been conducted for the last 36 months at a site near Bolton, Ontario and at Peterborough. The sunburn time varies from less than 17 minutes in late July, to over 4 hours in December on clear days. The levels depend on solar insolation and total ozone column. The ultraviolet levels are strongly affected by cloud and sky conditions. A method for deriving UV levels from cloud conditions is presented. The problem of predicting the effects of future ozone depletion on the sunburn time is discussed.

STATISTICAL TOTAL OZONE ANALYSES AND FORECASTS FOR CANADA

L.J. Wilson and M. Vallée
Meteorological Services Research, Atmospheric Environment Service,
Downsview, ON M3H 5T4

During the summer of 1992, an objective total ozone forecasting procedure was run operationally at CMC to provide input to the new daily ozone-UV-B forecast service. The procedure was based only on potential temperature and 500 mb heights, and was validated and tuned on a rather small sample of data from April, 1992. Eighteen hour, thirty hour, and forty-two hour forecasts were prepared daily using output of the global spectral model, then were corrected by a manual procedure using the previous day's observations.

Since the fall of 1992, we have been working on various ways of improving the forecasts. For 1993, we have developed a statistical (perfect prog) forecast procedure based on up to 30 years of observations from 4 Canadian stations. This has been tested on a dataset of observations and model output from the summer of 1992. We have also developed an objective analysis method for total ozone which takes into account the climatology of ozone, and which uses real time observations from ten Canadian stations that are equipped with Brewer spectrophotometers. Since observation data are not available in cloudy conditions, the analysis also includes a procedure for adding bogussed observations computed from previous observations at the site and from other observations taken at the same time. The weights in the bogussing procedure take into account the temporal and spatial correlations of total ozone.

The form of the analysis and forecast technique that is operational will be described, along with the results of tests of the new technique. Sample forecast products will be shown. The presentation will also include a brief discussion of the meteorology of ozone as it relates to the predictors used in technique development.

AN EVALUATION UV INDEX FORECAST

P. Dionne
Météomédia/The Weather Network, Montréal, Qué H2K 4P6

Since June 1992 Meteomedia/The Weather Network have been broadcasting AES forecasts of uvb radiation for clear skies. These forecasts are verified with observations from UV sensors installed at 24 Canadian stations. We first show the verifications when surface observations report clear skies. Then, we compare the ratio of forecasted uvb over observed uvb as a function of the observed cloud opacity. From there, we find statistical relations on the effect of clouds on uvb radiation.

THE POTENTIAL IMPACT OF A MAJOR VOLCANIC ERUPTION ON GLOBAL CLIMATE, STRATOSPHERIC OZONE AND SURFACE UV-B RADIATION

R.K.R. Vupputuri[1] and K. Higuchi[2]
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A coupled 1-D radiative-convective-phototchemical diffusion model, which takes into account the influence of ocean inertia on global radiative perturbations, is used to investigate the impact of a major volcanic eruption (similar in magnitude to that of Mt. Tambora in 1815 and Mt. Pinatubo in 1991) on global climate, stratospheric ozone and surface UV-B radiation. A volcanic cloud was introduced into the model stratosphere between 20-25 km, and the global average peak aerosol optical thickness was assumed to be 0.25. Both the aerosol optical thickness and aerosol composition which determine the optical properties, were allowed to vary in the model atmosphere during the life cycle of the volcanic cloud. The results of the model experiment indicate that the globally averaged surface temperature decreases steadily from the date of the eruption, with maximum cooling of 1°K occuring in about one year following the eruption. The calculations also show significant warming of the stratosphere, with temperature increase of up to 15°K at 25 km in less than 6 months after the date of eruption. The important effects on the stratospheric ozone and surface UV-B radiation will be discussed.

STRATOSPHERIC OZONE VARIATIONS, ARE THEY IMPORTANT TO STUDIES OF MARINE CLIMATOLOGY?

B.J. Topliss
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High frequency variations in the total column ozone field have already been used as a proxy for upper-level potential vorticity distributions of baroclinic disturbances, allowing researchers to use satellite data of total column ozone to study variations in the height of the tropopause. This study has taken historic records of monthly averages and found that, at least for the one region studied, the lower frequencies inherent in the monthly ozone data still retain a small but significant link to variations in the height of the tropopause. The sign of the relationship was negative, consistent with the hypothesis that troughs of baroclinic disturbances would be associated with elevated total ozone levels as ozone rich stratospheric air replaced ozone poor tropospheric air. It is suggested that the frequency of disturbances on a monthly timescale has retained the ozone-tropopause link thereby showing up in seasonal interannual variability. A larger data set of atmospheric and marine parameters and climatic indices were searched for evidence of similar interannual variability. None of the analyses on climatic indices yielded significantly similar interannual variations but isolated parameters from both the atmospheric and marine data did yield similar interannual variability at a very high statistical

significance level. These individual cases will be discussed as will the possible mechanisms by which such interannual variations might enter the marine environment.

CASE STUDY OF MAKING THE GREEN CHOICE BETWEEN OZONE DEPLETING AND GLOBAL WARMING TECHNOLOGIES

J.D. Reid
Atmospheric Environment Service, Ottawa, Ontario K1A 0H3

The threats of ozone depletion and global warming, and international actions to limit global atmospheric changes, have motivated attempts to make environmentally favourable choices; but it is often not obvious what the green choice is. The selection of a chiller for a building air-conditioning system, with the choice being between systems containing HCFC-123 or HFC-134a, is examined. A methodology which weights the environmental impacts, based on tax rates on ozone-depleting and greenhouse-enhancing substances in various jurisdictions, is developed and applied.

The analysis shows that the environmental impacts are dominated by the way the electricity used by the system is generated — whether greenhouse-gases are emitted — and not the choice of refrigerant which has only a minor impact on electricity usage. Second in importance is ensuring that refrigerant losses are limited and that refrigerant is not allowed to escape at the end of the equipment life. If emissions occur, HCFCs may be slightly more desirable than HFCs. Where system capacities, losses, and other environmental impacts, vary between the options, a specific calculation for each option is needed.

Thursday/Jeudi p.m. Room/Salle 125

MESOSCALE AND TROPICAL METEOROLOGY
MÉTÉOROLOGIE À LA MÉSOÉCHELLE ET TROPICALE

Chair/Président: G.B. Lesins, Dalhousie University

KELVIN WAVE-CISK AND THE MADDEN-JULIAN OSCILLATIONS OF THE EQUATORIAL TROPOSPHERE

H.F. Cho
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Kelvin wave-CISK has been proposed as a possible mechanism to explain the Madden-Julian oscillations observed in the equatorial troposphere. But it has been observed that cumulus clouds in the Western Pacific form mesoscale clusters which propagate westward at a speed of about 10 ms^{-1}. The westward propagation of these clusters introduces a phase lag between the maximum cumulus heating and the maximum low-level convergence caused by the background Kelvin wave, and this phase lag will depend on the propagation speed of the Kelvin wave as well as that of the clusters. When this phase lag is parameterized, the resultant Kelvin wave becomes dispersive, and the Kelvin wave-CISK analysis shows a maximum growth rate at the long-wave end of the spectrum, i.e., wave number 1 and 2, instead of the short wave end as traditional linear Kelvin wave-CISK theory would

predict. The results of this study seems to suggest that (1) cumulus clouds does not lead to the presence of the Madden-Julian oscillations directly; instead they are organized into cloud clusters which are meso-α scale phenomena; (2) the Madden-Julian oscillations are caused by distribution of latent heat release in cloud clusters. Therefore the presence of the cloud clusters must be parameterized directly in models that cannot resolve their dynamics adequately; (3) The observed hierarchical organization of clouds is therefore an integral part of the dynamical processes which leads to the 30-60 day oscillations of the tropical troposphere.

PRINCIPAL OSCILLATION PATTERN ANALYSIS OF OBSERVED AND SIMULATED TROPICAL SUMMERTIME SYNOPTIC SCALE DISTURBANCES

J. Fyfe
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Principal oscillation pattern (POP) analysis is a diagnostic technique for determining the spatial and temporal variability in a multi-component data set. In this paper we exploit the POP technique to obtain the three-dimensional structure and propagation characteristics of tropical synoptic scale disturbances (with periodicities between 2 to 10 days) as seen in (1) an 8-year series of U.S. National Meteorological Center (NMC) analyses and 2) an 8- year numerical simulation with the T32 General Circulation Model (GCM) of the Cana- dian Climate Centre. Some connections seen between the characteristics of synoptic scale variability and the 30-60 day intraseasonal oscillations in both the observational analyses and model simulation will be described and compared.

A NUMERICAL STUDY OF THE MESOSCALE ORGANIZATION OF TROPICAL CONVECTION: SQUALL LINE INITIATION IN GATE PHASE III

V. Balaji[1], G.P. Klaassen[1] and J.-L. Redelsperger[2]
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Mesoscale cloud clusters are a frequently observed feature of the tropical atmosphere, and are responsible in large part for the observed large-scale vertical mass flux. During the 3-week period of GATE Phase III, for example, over 500 such events were observed, most often showing line organization. Given that the forcing for such convection comes from widely separated scales (boundary layer motions on the scale of 1 km, and large-scale ascent due to the easterly wave trough on the scale of over 1000 km) the organization of low-level ascent into the 10--50 km scale associated with deep convection and cloud clusters remains an important problem. In the first part of this study (Balaji et al. 1993) we proposed a mechanism for the formation of shallow mesoscale cloud lines, showing that their scale selection is modified by the presence of deep gravity wave modes above the cloud layer. In the present study, we demonstrate that certain classes of squall lines observed in GATE Phase III occur in environments dynamically similar to those of Part I, but with a layer of much greater conditional instability extending to the tropopause. The dominant deep modes are principally due to the shear structure and thus reproduced in the present set of numerical simulations. We show that the random forcing of the planetary boundary layer by inhomogeneous surface fluxes coupled with a large-scale forcing term corresponding to the easterly wave trough gives rise to deep gravity waves which organize low-level ascent on the mesoscale and eventually lead to deep precipitating cumulonimbus. This also produces sustained boundary layer moisture convergence coupled to the propagating cumulonimbi, giving rise to a tropical squall line system.

THE TRANSATLANTIC FATE OF HURRICANES AND TROPICAL STORMS

J.L. Walmsley
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The histories of two hurricanes, one in the Pacific, the other in the Atlantic, were followed as they were downgraded to tropical storms, merged with extratropical low pressure systems, crossed the eastern coast of North America and made their transatlantic voyages to Britain and Europe. The first of these systems, originating as Hurricane Lester, made a landfall in Ireland about 0000 GMT, 30 August 1992. A trough of warm air associated with this first storm was then aloft over southwestern Wales, where fifteen minutes earlier a strong tornado was reported. Three and a half days later, the second system, formerly Hurricane Andrew, crossed southern Scotland en route to Norway. Rain and cumulonimbus were reported as the system passed.

There are other examples of former tropical systems that caused damage in Britain. Tropical Storm Flossie and the Ark Royal storm of 16-17 September 1978 is one case. An argument can also be made that tropical air flowing out from Hurricane Floyd caused the high tropopause height in the warm sector of the Great Storm of 15-16 October 1987.

It is recommended that labels on "post-tropical" storms be retained for many days after they lose their identity and become connected to extratropical depressions. Tropical systems often contain more moisture and energy than are normally present in mid-latitude storms. Labelling post-tropical systems would alert forecasters to the potential for above-average precipitation, strong winds and severe weather such as thunderstorms and tornadoes.

BREAKING INTERNAL GRAVITY WAVES

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We employ numerical techniques to examine the breaking 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. We demonstrate that, for certain amplitudes and frequencies, the breaking of internal gravity waves is dominated by a transition to three-dimensional motion, which leads to an injection of energy into the dissipation range. 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 observed spectrum of internal gravity waves will be discussed.

A THERMODYNAMIC APPROACH TO ATMOSPHERIC ENERGETICS

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Energetics of atmospheric circulations can be investigated thermodynamically by considering the atmosphere to be the working fluid of a heat engine. Heat enters the system as sensible and latent

energy and is rejected to space via radiation. By applying the ideas of finite time thermodynamics to this atmospheric heat engine, work, power, efficiency and entropy production are calculated for the circulation. Representing deep tropical convection with a steady-state closed loop, a value for power generation is calculated to be 7 Watts/m^2 which is of the order of estimated dissipation rates. Sensitivity of the power generated to sea surface temperature and to the height of the tropopause are also investigated.

A MESO-SCALE PRECIPITATION INDEX BASED ON MOIST SYMMETRIC INSTABILITY: RESULTS FOR CENTRAL ALBERTA

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The Meso-scale Precipitation Index (MPI) is defined as follows: A parcel from 85 kPa is lifted along a surface of constant angular momentum dry adiabatically until saturation occurs, and then pseudo-adiabatically to 50 kPa. The slantwise lifted 50 kPa temperature is then subtracted from the observed 50 kPa temperature. A negative value for MPI indicates the potential for moist symmetric instability. Since moist symmetric instability usually produces steady precipitation, we explored the usefulness of MPI to predict the likelihood of precipitation within the next 12 hours.
A complete year of twice-daily soundings from Stony Plain, Alberta, provided the experimental data set. During the winter, MPI values were positive indicating stable conditions, with very few exceptions. During the summer, however, about 5-8% of the soundings indicated unstable conditions (i.e. negative MPI values). Negative MPI values, combined with relative humidity values ≥60% at low levels, proved to be a skilful predictor of summer-time precipitation. The data also indicated that larger rainfall amounts were correlated with larger negative MPI values.

MESOSCALE POTENTIAL VORTICITY ANALYSIS OF A COLD FRONT

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Extratropical cyclones and their associated fronts have been a matter for vigorous scientific debate for many years. Because of the explosive deepening of these cyclones on temporal and spatial scales of a few hours and a few hundred kilometers, with deepening rates of ten millibars or more per six hours, such development requires a unique interaction of synoptic, mesoscale, and boundary-layer processes. Current observations and technologies make it feasible to observe cyclones and the associated fronts over the ocean and critically evaluate the conceptual and theoretical models.

The mesoscale properties of a surface cold front within a moderate marine cyclone over the ocean is studied. The potential vorticity structure within the cold front is analyzed. It is found that the air in the warm sector of the front and above the front is subject to conditional symmetric instability (CSI). The precipitation in the warm sector could be the result of the release of the instability. This cold front is characterized by the high potential vorticity in the frontal zone. This result shows that potential vorticity can be viewed as a valuable indicator of the surface frontal position.

The effects of diabatic processes, such as air-sea interaction, turbulent mixing and latent heating as well as friction, on the potential vorticity structure are estimated. These results indicate that turbulent mixing processes play a dominant role in the formation of the high potential vorticity area. A simple mixing model is constructed to illustrate the turbulent mixing effects. These results confirm the results

obtained from numerical modelling studies by other scientists (Keyser and Anthes, 1982 and Baldwin et al, 1984, Knight, 1987).

Thursday/Jeudi p.m. Room/Salle 205

CLIMATOLOGY AND IMPACTS
CLIMATOLOGIE ET INCIDENCES

Chair/Président: R. Lefebvre, Atmospheric Environment Service, Fredericton

ON THE APPLICATION OF AIRPORT VISIBILITIES TO DISTANCES OVER 25 KM

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Visibility observations have been made at Canadian airports for several decades and constitute the only long-period record for this weather element. However, since they were beyond 15 miles (24 km), and generally only recorded "15+" when such conditions occurred. It has generally been thought that this practice has rendered the airport visibility archive of little use in air quality applications where these larger visibility ranges are of great importance.

In this presentation, we will describe a successful attempt to extend airport visibility observations beyond their 15 mile limit through a curve fitting technique. It was found that a particular theoretical distribution function fitted actual visibility frequency distribution functions so well that the curve could be extrapolated with confidence to the median value of the distribution and beyond. The technique was tested for a wide variety of geographical areas, times of the year and weather conditions and in each case was successful in obtaining confidence intervals about the expected median value that were small enough for the median value to have considerable value. Median visibility values obtained in this way were consistent with expectations about the geographic and seasonal variation of visibility in Canada.

DEFINING THE SYNOPTIC SEASONS IN SOUTHWESTERN ONTARIO

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The lower Great Lakes region is an area frequently crossed by migratory cyclones and anticyclones. These weather systems often bring distinct changes in characteristic atmospheric patterns such as temperature, humidity, cloud cover and pollution levels. The march of surface weather systems across southwestern Ontario may be characterized by a set of regularly recurring pressure and frontal patterns. The synoptic climatology of these surface weather patterns has been studied over a 25-year period (1963-1987). In addition, a 10-year period (1978-1987) was examined for patterns in the 50 kPa surface. From these data, Seasonal Synoptic Indices have been defined which have been used to define the synoptic seasons.

The Seasonal Synoptic Indices show an annual cycle similar to the annual temperature and solar radiation cycles. The singularity features "Indian Summer" is evident as a distinct break in the synoptic patterns whereas "January Thaw" is not. The combined surface and upper air Seasonal Synoptic Index showed seasons of approximately 90-day length.

Poster No. 17

SURFACE AND 50 kPa SYNOPTIC CLIMATOLOGIES FOR SOUTHWESTERN ONTARIO

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Synoptic climatologies for southwestern Ontario were determined by defining recurring weather patterns for both surface and 50 kPa surfaces. An eight-pattern classification system was developed for surface synoptic weather systems which cross southwestern Ontario while seven classes were chosen to characterize the 50 kPa synoptic patterns. The application of these classifications to daily surface (1963-1987) and 50 kPa (1978-1987) showed regular monthly and seasonal variations in the frequencies and joint-frequencies of many classes. For some classes, the distribution showed distinct high frequencies in winter and low frequencies in summer while others showed low frequencies in winter and high frequencies in summer. Seasonal patterns of joint frequencies indicate that the lower Great Lakes basin is a prime area for cyclogenesis in fall and winter and anticyclogenesis in the summer and spring.

WEATHER AND HEALTH: CAN IT EVER BE IN CANADA?

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Although research spread out around the world has identified links between weather and health, recognition and application of this knowledge in Canada is not evident. This paper presents some of these relationships (neurological, cardiovascular, musculoskeletal, ...) to inform the audience. The paper also suggests the pressing need for the medical and meteorological communities in Canada to merge their efforts in order to achieve significant results in aid to health care in Canada. This implies economic studies and extensive cross-education of meteorological and medical professionnals. Examples are presented to demonstrate the difficulty of such an initiative.

Thursday/Jeudi p.m. Room/Salle 205

COASTAL OCEAN
OCÉAN CÔTIER

Chair/Président: D.A. Greenberg, Bedford Institute of Oceanography

WAVE- AND WIND-DRIVEN FLOW ON THE CONTINENTAL SHELF

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In the past, wave-driven and wind-driven flows have been regarded as somewhat separate processes. The stress due to waves has been associated primarily with wave breaking and, consequently, with surf zone processes. This paper draws attention to the fact that, when the earth's rotation is taken into account, the wave stress associated with non-breaking waves may be significant. It may be necessary to consider both wave- and wind-driven flows even when considering shelf scale processes.

We first briefly review the theories of Coriolis-induced wave stress in a rotating deep water by Ursell and Hasselmann and viscosity-induced wave stress in a non-rotating shallow water by Longuet-Higgins. Next we combine the two theories for a shelf region which is both rotating and shallow. Longuet-Higgins' virtual tangential wave stress is re-derived succinctly and rigorously. It is shown that the virtual stress is a projection on the surface slope of two viscous normal stresses acting on the vertical and horizontal planes. Then we present a simple Eulerian model for the steady flow driven by waves, and by waves and winds. This simple Eulerian model demonstrates that the wave forcing can be easily included with other conventional forcing, rather than resorting to complicated and lengthy perturbation analysis of the Lagrangian equations of motion. The wave-driven steady flow given by the model yields an unified formula between Ursell and Hasselmann's inviscid but rotational theory and Longuet-Higgins' viscid but non-rotational theory, and it becomes an Eulerian counterpart of Madsen's deep water solution when the deep water limit is taken. The model is further expanded for the case of unsteady wave forcing, yielding a general formula for any type of time variation in the wave field. Finally, using the scale argument, we discuss the significance of the inclusion of wave stress into shelf dynamics in interpreting observed current data.

CIRCULATION ON THE SCOTIAN SHELF FORCED BY MESOSCALE VARIABILITY IN THE WIND FIELD

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A computationally-efficient, three dimensional spectral model (Sheng and Thompson, J. Geophys. Res. 1993) is used to examine the wind-forced response of the Scotian Shelf during the Canadian Atlantic Storms Program, November 1985 - April 1986. The wind stress field over the Scotian Shelf was mapped in three ways: (i) by setting the wind at every grid point equal to the observed wind at Sable Island; (ii) by interpolation of the winds measured at Sable Island and five coastal stations, after correction for land effects; (iii) by analysis of the mesoscale pressure fields produced by Strapp et al.

(Environment Canada, 1988) for certain Intense Observation Periods during CASP I. We quantify the errors in the wind-driven circulation due to an inaccurate specification of the wind field. In particular, we assess the feasibility of using Sable wind alone to drive a real-time, wind-forced surge model for the Scotian Shelf. Finally, we use the model to examine the response of the shelf to propagating coastal trapped waves and forcing from the deep ocean.

SHELF CIRCULATION AND FOUR DIMENSIONAL DATA ASSIMILATION

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An assimilative shelf circulation model has been developed and used operationally for flow field mapping on the Scotian Shelf. Circulation over the outer Scotian shelf is highly complex and not well described by simple transfer functions applied to easily measured quantities like the local wind or coastal sea level. So we have used a method of data assimilation which infers the forcing at the open boundaries of a limited area model from scattered current observations made within. Unlike simple optimal interpolation schemes, the resulting current field obeys realistic dynamical equations. Information contained in the entire timeseries of the observations is used to adjust the boundary flows at any instant. This is accomplished by running the adjoint of the dynamical model backwards in time to compute `sensible' adjustments of the control variables required to iterate quickly toward the minimum of the `cost function', one term of which includes the misfit of the model to the observations. The usefulness of the model depends critically on the choice of control variables and form of the cost function, since together these overcome the ill-posedness of the problem. Hindcasts will be presented for three cruises during which ADCP, telemetering current meter and drifter observations were used to drive a linear model featuring a time-dependent barotropic component and a steady, but slowly evolving, geostrophic baroclinic component. Perhaps the most remarkable result of the second cruise is that the salient features of the circulation history are reproduced in the model even when it is driven with only the ADCP data. The third cruise was in November and December 1992 and was the final Ocean Production Enhancement Network (OPEN) Larval Tracking cruise. It was on this cruise that the model was tested operationally. All indications are that we were successful in staying with the same cohort of larvae for 19d.

PREDICTION OF STORM SURGES IN NEWFOUNDLAND

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In parts of Newfoundland there have been many coastal floodings caused by the combination of large meteorologically-induced surges and high tides. Of particular note is the Placentia/Argentia area of Placentia Bay which is very prone to large storm surges when intense lows pass just west of the area.

It is the responsibility of the Atmospheric Environment Service of Environment Canada to alert the public when a storm surge in excess of 60 cm. is expected. To carry out this forecast task it is desirable to have a storm surge climatology of the area and a prediction model or equations.

There is long-term data available from six tide gauge sites in Newfoundland and Labrador, namely, Port aux Basques, St. John's, Argentia, Lark Harbour, West Ste. Modeste and Nain. A climatology of storm surges for these locations bas been assembled.

To develop prediction equations attention was focussed on St. John's, Argentia and Port aux Basques as this data exhibited the most quality control. Linear regression equations were developed for each site using gridded pressure data and considering only cases where surges were 50 cm. or greater. Two equations were derived for St. John's, each for different storm tracks. Single equations covered Port aux Basques and Argentia. Typically all equations require pressure data at T=0, T-6hr. and T-12hr. So far the equations are based on a small data set but will be modified as more historic data is added. Applied in a hindcast mode the equations have given good results.

OPTIMAL ESTIMATION OF EDDY-VISCOSITY FOR A QUASI-THREE-DIMENSIONAL NUMERICAL TIDAL AND STORM SURGE MODEL.

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It is shown that the eddy-viscosity profile in a quasi-three-dimensional numerical tidal and storm surge model can be estimated by assimilation of velocity data from one or more current meters located on the same vertical line. The computational model used is a simplified version of the so-called vertical/horizontal splitting algorithm proposed by Lardner and Cekirge (1988). We have estimated eddy-viscosity both as a constant and a variable parameter.

The numerical scheme consists of using a two-level leapfrog method to solve the depth-averaged equations and a generalised Crank-Nicolson scheme to compute the vertical profile of the velocity field. The cost-functional in the adjoint scheme consists of two terms. The first term is a certain norm of the difference between computed and observed velocity data and the second term measures the total variation of the eddy-viscosity function. The latter term is not needed when the data are exact for the model but is necessary to smooth out the instabilities associated with "noisy" data. It is shown that a satisfactory minimization can be accomplished using either the Broyden-Fletcher-Goldfarb-Shanno (BFGS) quasi-Newton algorithm or Nash's truncated Newton algorithm. Very effective estimation of eddy-viscosity profiles is shown to be achieved even when the amount of data is quite small.

Thursday/Jeudi p.m. Room/Salle 303

HYDROLOGIC CYCLE II - HYDROLOGIC APPLICATIONS OF REMOTE SENSING
CYCLE HYDROLOGIQUE II - APPLICATIONS HYDROLOGIQUES DE LA TÉLÉDÉTECTION

Chair/Président: R.F. Hopkinson, Atmospheric Environment Service, Regina

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CANADA AND THE GPCP ALGORITHM INTERCOMPARISON PROGRAMME

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The WMO/ICSU World Climate Research Programme established the Global Precipitation Climatology Project (GPCP) to provide climate researchers with global precipitation statistics for the period

1986-1995. The GPCP utilizes raingauge measurements in continental areas and satellite data in oceanic areas. An Algorithm Intercomparison Programme (AIP) was established to evaluate alternative satellite estimation techniques. To date, one intercomparison experiment has been completed (Japan), one is in its final stages (Europe), and a third is in the planning stage (South Pacific). Three of the 27 techniques submitted to AIP/1 were Canadian. Garand (AES Dorval) contributed one technique (Garand, 1989, J. Appl. Meteor., 29, 913-924). Hogg and King submitted a simple threshold technique and results from the RAINSAT algorithm, which was originally developed at McGill (Lovejoy and Austin, 1979, Atmos.-Ocean, 77-92). During the AIP/1 workshop in Washington in May, 1991, the RAINSAT algorithm was identified as unique. Correlation coefficients between RAINSAT estimates of rainfall and the Japanese "ground truth" dataset were consistently among the highest of all the techniques using geostationary satellite data only. Furthermore, RAINSAT results seemed to be quite different from or out of phase with all the other VIS/IR techniques and these differences were often improvements. The workshop participants concluded that further investigation was warranted. RAINSAT was the only technique in AIP/1 to make use of satellite data in the visible wavelengths (VIS). It seemed probable that this use of VIS data would explain the differences in rainfall estimates. Results of an experiment investigating this will be presented.

ESTIMATING AREAL SNOW WATER EQUIVALENT OF NORTHWEST TERRITORIES USING PASSIVE MICROWAVE DATA

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Snow is the major source of water in the North. In view of the size and remoteness of Northwest Territories, the only feasible way to estimate accurately the amount of water available from snow (snow water equivalent) is via remote sensing (RS), for RS provides us with data distributed in time and in space. Therefore, the Water Resources Division of Indian and Northern Affairs Canada (DIAND) in Yellowknife has acquired more than ten years of sateliite snow maps. These maps give us an overall picture of the areal distribution of snow in NWT. However, these maps, prepared by PhD Associates in Calgary, are based on an algorithm developed for Saskatchewan. Discrepancies are therefore expected even though the algorithm is somewhat adjusted with respect to NWT's vegetation.

The development of an algorithm by a stepwise multiple regression technique for converting passive microwave data of DMSP SSM/I and SMMR satellites to snow water equivalent for Northwest Territories is described. Data used were brightness temperature of SSM/I and SMMR, land use data, mean weekly maximum temperature data and snow course data collected by the Indian and Northern Affairs Canada (DIAND) and Atmospheric Environment Service (AES). The satellite data were pre-processed by Canadian Climate Centre of AES in Downsview while the landcover data, originally prepared from NOAA images by the Manitoba Remote Sensing Centre, were aggregated by the use of SPANS (a Canadian GIS) in the GNWT Remote Sensing Centre to a resolution compatible with that of SSM/I data, which is about 30 km. The temperature data were generated from using about 40 years of temperature data of 30 climatic stations of AES and a stochastic model adapted from the seasonal, lag-1 autoregressive model of Thomas-Fiering. Preliminary results show that the snow course data alone may be too noisy and airborne gamma data might be needed to enhance the development of the algorithm.

OPERATIONAL WATER SURFACE TEMPERATURE MAPPING USING AVHRR DATA.

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An integrated system that allows fast and accurate processing of NOAA AVHRR images has been developed. Raw data stored on the Exabyte tapes can be obtained from the AES satellite data lab in Downsview in near real time or from the AES Edmonton receiving station with some minor delays. The reception range of the antennas located in these two places covers most of North America and the Arctic. The whole procedure is performed on a microcomputer and consists of two main steps. First, by using a very precise automatic navigation algorithm, a raw image is extracted and remapped to user requested projections. Secondly, calibration equations are computed for the particular pass and calibrated temperatures are corrected for nonlinearity of the sensors and atmospheric attenuation. This latter part requires an upper air sounding, which is modified with the use of the Atlantic Region Upper Air Display Program, and then input to Version 5 of the Lowtran algorithm to obtain the atmospheric correction tables. Calculated temperatures are close to temperatures reported by the Great Lakes buoys and on average are 0.4 degrees Celsius cooler (the difference can range from 0 to 1° Celsius). Full statistical verification can be done after a greater number of analyses is available.

Currently the entire process takes about two hours using a 386/20 MHz IBM PC and requires very little or almost no human intervention. It is anticipated that this time can be shortened to about half an hour with the use of a 486DX2/66 MHz IBM PC.

So far the system has been applied to compute the Great Lakes and St. Lawrence River water surface temperatures, to study ice breakup on Great Slave Lake, to examine positions of polynyas in the Arctic and to follow water circulation patterns in James and Hudson Bays. The potential applications of this very simple-to-operate system are virtually endless.

Thursday/Jeudi p.m. Room/Salle 303

HYDROLOGIC CYCLE III - HYDROMETEOROLOGICAL PROCESSES
CYCLE HYDROLOGIQUE III - PROCESSUS HYDROMÉTÉOROLOGIQUES

Chair/Président: R.F. Hopkinson, Atmospheric Environment Service, Regina

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MOISTURE BUDGET COMPUTATIONS OF EVAPOTRANSPIRATION FROM SEQUENTIAL RADIOSONDES

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Diurnal changes in the atmospheric moisture budget over a 100-km square area of central Saskatchewan were computed using sequential radiosonde soundings from the 1991 *Regional Evaporation Study* (RES). Synoptic data are now used to calculate the advective component of changes in this moisture budget for select days, leaving regional evapotranspiration as the residual. Non-precipitating, weakly baroclinic days are considered in this analysis; that is, days which are

initially warm and relatively cloud-free, and which tend to have the highest rates of evaporation. Comparisons with results from other methods of computing evapotranspiration are presented.

Two other problems related to forecasting operations are considered. First, the suitability of using synoptic soundings at 12-hour intervals to make routine moisture budget computations of evapotranspiration on the Prairies is evaluated. Second, the role of local evaporation in the production of convective clouds and precipitation on the Prairies is discussed. Some preliminary results using simple cloud models are presented. These questions have impact on the parameterization of evapotranspiration in both NWP models and GCMs.

RELATIONSHIPS BETWEEN PRECIPITATION AND ATMOSPHERIC CIRCULATION FOR BRITISH COLUMBIA

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Although the precipitation for British Columbia shows considerable small scale variation, it is possible to prepare regional indices, using 42 years of data from across the Province. These indices are examined for their variation with time and for their interrelationships. Of particular interest is the relationship between these regional precipitation indices and the 50-kPa height field, as representing the large-scale atmospheric circulation. It is found that the wintertime coastal precipitation is most dependent on the strength of the atmospheric flow off the Pacific and perpendicular to the Coastal Mountains, as expected. Precipitation in other seasons is more dependent on ridging or troughing over the Province. The results of this analysis will be presented.

Friday/Vendredi a.m. Room/Salle 102

REMOTE SENSING
TÉLÉDÉCTION

Chair/Président: F.W. Dobson, Bedford Institute of Oceanography

THE FIRST EUROPEAN REMOTE SENSING SATELLITE ERS-1: DEVELOPMENT, DATA PRODUCTS AND APPLICATIONS

E.P.W. Attema (Invited)
European Space Research and Technology Centre, Noordwijk, The Netherlands

Europe's first remote sensing satellite ERS-1 is now almost two years in orbit. It was launched by an ARIANE-4 launcher from the Kourou launch site in French Guiana on 16 July 1991 after a long period of technical development and scientific algorithm development: the decision to develop ERS-1 was made by the participating states of ESA during the late 1970's. The ERS-1 payload includes the active microwave instrument, a combination of a C-band (5.3 Ghz), VV polarization synthetic aperture radar and a wind scatterometer, a radar altimeter, an along-track scanning infrared radiometer, a microwave sounder, a precision range and range rate measuring equipment and a laser retro-reflector.

The main mission objectives for ERS-1 were to make a contribution to the scientific study of the earth's environment and on a pre-operational basis provide data for operational meteorology, sea-state forecasting and offshore activities. The primary ERS-1 data products are the surface wind speed and direction over the ocean, the directional spectrum of the ocean waves, the sea surface temperature, the water vapour content of the atmosphere and high-resolution radar mapping of land, ocean, ice and coastal zones. During the last two years in orbit the ERS-1 instruments have given an uninterrupted stream of well-calibrated data, the retrieval algorithms have been validated and the geophysical data products are currently being used operationally. It is the objective of the talk to give an overview of the ERS-1 system, the calibration and validation process and the operational experience with the data products during the first two years in orbit.

AVHRR SATELLITE OBSERVATIONS OF THE INTENSIFICATION OF THE SHELF BREAK CURRENT DURING AN UPWELLING EVENT OFF VANCOUVER ISLAND

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AVHRR satellite imagery of the west coast of Vancouver Island during July 1984 was used to investigate the spatial and temporal variability of the intensification of the shelf break current during an upwelling event. Thermal imagery shows that the initial indication of the upwelling event appears as a plume of cold water that originates at the tip of Brooks Peninsula. As the winds increase in strength, the plume of cold water migrates equatorward from Brooks Peninsula and takes on a jet-like structure; the central cross-shore axis of the jet is centered slightly seaward along the shelf break. Cross-shore scales of the thermal fronts just south of Brooks Peninsula are comparable to the internal Rossby radius, but further south, the cross-shore scales appear to be modified by topography. The equatorward migration of the cold water is presumably due to the combined processes of advection and shelf break upwelling. As the winds dramatically weaken following the five-day upwelling event, there is intense warming of the surface waters along the shelf, but a band of cold water persists along the shelf break.

Near the end of the upwelling event, an oceanographic cruise took place and *in situ* sea surface temperature measurements were in agreement with those obtained from AVHRR measurements. Coastal lightstations also provided temperature measurements, and the temperature decrease in the coastal records was related to the increased strength of the wind measured at climatological stations along Vancouver Island. In addition, a subsurface mooring provided current measurements that were on order with velocity estimates obtained from the AVHRR data.

RADAR AND INFRARED MEASUREMENTS OF A THERMAL FEATURE MADE UNDER VARYING ATMOSPHERIC CONDITIONS

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Simultaneous measurements of radar backscatter by a radar sensor operating at the ERS-1 frequency and sea surface temperature (SST) by an aircraft infrared (IR) radiometer, were made over a cold eddy in the Tyrrhenian Sea. The purpose of the study was to investigate whether the radar backscatter data showed any dependence on SST. During the experiment the atmospheric conditions changed. The infrared view of the eddy remained consistent throughout the experiment whereas the radar

backscatter data gave a more intermittent view of the eddy and that view appeared to change from day to day. For a two day period of very light winds and calm sea conditions the radar signature mapped the main thermal gradient features of the eddy. For a further three days with moderate winds from the north to east quarter, the radar data did not identify the major thermal gradients of the eddy. Changes in the radar view of the eddy might occur due to changing wind fields or atmospheric stability patterns over the thermal front and these hypotheses were discussed with regard the differing atmospheric conditions occurring during the experiment.

ANNUAL VARIATION OF SEA SURFACE SLOPES OVER THE SCOTIAN SHELF AND GRAND BANKS FROM GEOSAT ALTIMETRY

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The Geosat radar altimeter data from ~60 repeat cycles of the Exact Repeat Mission (ERM) over the period November 1986 to September 1989 have been analyzed to show the annual variations of the sea-surface slopes corrected for ocean tides over the Scotian Shelf and the Grand Banks. A coastal tidal model developed at the Bedford Institute of Oceanography, combined with the global tidal model of Schwiderski, is employed to remove the tidal signals from the sea-surface heights over those regions. Linear regression technique is used to estimate the sea-surface slopes over the inner shelf region and the outer shelf region (or) over the shelf and shelf-break along the Geosat ground tracks. The harmonic analysis method is applied to the time series of the sea-surface slopes to derive the annual signals, showing the amplitudes of the order of 5 cm/100 km with slopes up in winter and down in summer toward the coast.

The larger annual cycles occur over the outer portion of the Laurentian Channel and southwest Grand Banks, uniformly up in winter and spring and down in summer and fall. The annual cycles of the sea-surface slopes over the Scotian Shelf vary between the eastern and western portions: the eastern portion synchronizing with the Laurentian Channel, and the western portion up in fall and winter and down in spring and summer. The signals over the eastern Scotian Shelf vary between the eastern and western portions: the eastern portion synchronizing with the Laurentian Channel, and the western portion up in fall and winter and down in spring and summer. The signals over the eastern Scotian Shelf are comparable with the geostrophic surface currents estimated from hydrographic data along the Halifax section. The signals over the western Scotian Shelf are consistent with the adjusted sea level at Halifax. The annual variabilities of the sea-surface slopes over the Scotian Shelf and the Grand Banks are thought to be induced by the seasonal outflow through the Cabot Strait from the Gulf of St. Lawrence, and possibly by an annual cycle in the Slope Water current.

A STUDY ON ALTIMETER DATA ASSIMILATION TO A TWO-LAYER ROSSBY WAVE MODEL BY ADJOINT METHOD

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The adjoint equation method to assimilate Geosat altimeter data has been examined in terms of reconstruction of mesoscale features. A one-dimensional two-layer Rossby wave model has been chosen as a test bed. The simulated data with realistic low resolution are extracted from theoretical solution at specific tracks and repeat periods in a similar way to those of the Geosat data. The space of control

variables is composed of initial and boundary conditions. The cost function includes the difference between the data and assimilation solution, as well as regularization terms which are the second-order spatial and time derivatives of the solution. A focus of this paper is put on two potential problems existing in the altimeter data assimilation: one is low cross-track resolution, and the other is vertical projection of the data measured at the sea surface.

It is noted here that the theoretical solution is well reconstructed in all numerical experiments, even for a short wave with only two data points in one wavelength. Vertical projection of sea-surface information has been effectively assimilated by an optimal procedure in two sub-spaces: a parameter expressing a ratio of pressure amplitudes in the two layers, and the subset of initial and boundary control variables. Combination of this procedure with the assimilation by the adjoint method ensures quick convergence starting with an arbitrary first guess of the control variables. Reduction of the space of control variables is also useful to speed up the convergence. An analysis of the Hessian matrix can improve performance of this technique. Influence of measurement errors in the data is studied by adding a set of random noise. It is found that random noise induces only local error around data points, which means that this linear system is quite robust to the random noise.

RAINFALL RETRIEVAL DURING GPCP/AIP-1: A PATTERN RECOGNITION APPROACH USING SATELLITE DATA AND CMC FORECAST MODEL FIELDS

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Using a multifeature classification approach, we examine methods which retrieve rainfall by combining information from geostationary satellite imagery and short-term weather prediction model fields. In particular, the model forecast of rain rate is used as an additional classification parameter. For the data and time period examined here (Global Precipitation Climatology Project data at 1.25 degree resolution from June and July/August 1989 over Japan) it is shown that a combined satellite-model method can yield improved retrievals of rainfall relative to those obtained by using either satellite data or model forecasts alone. Satellite estimates are superior to model forecasts in detecting heavy rain events associated with extremely cold cloud tops, and in identifying cloud-free regions. Model estimates are superior to satellite retrievals in terms of dynamic range and regional bias. During June both model and satellite estimates were of comparable accuracy. However, in July/August satellite retrievals largely underestimated monthly rainfall, while the model produced poor hourly forecasts. If results obtained during June are found to be valid for other regions of the globe, the method could be used in a real time operational NWP environment since it is computationally rapid, with only satellite observations and model predicted fields needed to derive the estimates.

AN EVALUATION OF SEA SURFACE WIND MEASURMENT FROM TWO DIFFERENT SATELLITES: SSM/I & ERS-1

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A systematic comparison of satellite sea-surface wind measurments with the forecast wind of the Canadian global model is presented. Results indicate the limits of validity of this data, and are used for an evaluation of the quality of SSM/I wind speeds and ERS-1 wind speeds and directions.

Results of similar comparisons between winds measured by moored buoys and the forecast of the CMC global model let us appraise the quality of ERS-1 winds.

WIND STRESS MEASUREMENTS DURING THE ERS1 CAL-VAL EXPERIMENT

R.J. Anderson, S.D. Smith and F.W. Dobson
Dept. of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth N.S. B2Y 4A2

A "dissipation" system for measuring sea-surface wind stress and heat flux using a bow-mounted propellor-vane anemometer and fast response temperature sensors was operated from the C.S.S. Hudson on the Grand Banks during the ERS1 Cal-Val Experiment in November, 1991. Measurements were made before, during and immediately following the ERS1 satellite overpasses at its crossover point and at other times of interest. Some data were taken near a WAVEC wave buoy and a MINIMET meteorological buoy. Data were logged and analysed by an automated PC-based system. Spectra of wind speed and temperature were obtained for a wind speed range of 6-19 m/s and sea-air temperature differences of -2 to +5°C.

The wind stress on the sea surface, a key parameter in oceanic and atmospheric dynamics studies, is calculated using the inertial dissipation technique. The inertial subrange portion of the downwind spectrum, where the spectrum is proportional to $f^{-5/3}$, usually occurs above 0.35 Hz and thus is not affected by ship's vertical motion. Data have been compensated for ship's velocity. Drag coefficients are higher than other published values for similar wind speeds at offshore sites.

RECENT RESULTS FROM THE GRAND BANKS ERS-1 SAR WAVE EXPERIMENT

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Dept. of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S., B2Y 4A2

The aerodynamic roughness of the sea surface, or equivalently the wind stress, can be related to the state of development of the sea surface wave field only if the wind-driven component of the wave field can be separated from the swell. Measurements of the wind stress (see Anderson, Smith & Dobson, this meeting) and directional spectra of the waves made in the open ocean in November 1991 during the Grand Banks ERS-1 SAR Cal-Val Experiment are used to investigate the wind stress-sea state relationship. A physical interpretation is made in terms of the surface meteorology and the degree of saturation of the waves in the high-frequency part of the wave spectrum.

THE McGILL DOPPLER RADAR FACILITY

A. Singh, A. Kilambi, E. Ballantyne, A. Bellon, B. Katz, and I. Zawadzki
McGill Radar Weather Observatory, Ste. Anne de Bellevue, Québec H9X 3V9

The current version of the Radar Data Processing System (RDPS) has been in use at the Meteorological Centre of Quebec (CMQ) since 1988. This system allows the real-time reception and processing every five minutes of 3-D reflectivity data from the Marshall Radar Observatory (MRO) operating at 10 cm wavelength. Data resolution of the 24 elevation angles is 1 to 2 km in range by 1° in azimuth. A larger number of standard radar products are generated based on user-selected schedules and interactive requests. Recently, other products have been added such as VIZ (Vertically Integrated Reflectivity) and a severe weather indicator.

The CAPPI and echo top products are combined with the corresponding maps from two other radars near Ottawa and Quebec City. This composite image is in turn joined with a map of rainfall estimate from GOES satellite data which is part of the RAINSAT system also operational at CMQ since 1990.

We are in the process of Dopplerizing our S-band radar and record both velocity and reflectivity data over the 24 elevation angles while still maintaining our current data acquisition cycle of five minutes at 6 rpm. Unambiguous velocity of ± 31 m/sec is collected up to a range of 125 km using a pulse pair algorithm while, simultaneously, unambiguous reflectivity data is recorded up to a 500 km range. The software of the existing RDPS system has been upgraded to incorporate the display of Doppler PPIs and of the VAD and mesocyclone analyses.

The MRO facility also includes an X-band vertically pointing radar with a temporal and spatial resolution of two sec and 15 m respectively. Fine resolution 3-D data (250 m and 0.12^{o}res) from the S-band radar within a 48 km range can also be archived and displayed on a PC workstation. This fine resolution data, combined with data from the McGill wind profiler, has proven to be essential in understanding small scale phenomena and an ideal tool for examining the vertical profile of reflectivity.

INFERENCE OF ENERGY AND RADIATIVE FLUXES WITHIN A SNOW COVERED SEA ICE VOLUME FROM MICROWAVE SCATTERING

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Microwave energy interacts with a seasonally varying snow cover on sea ice as a direct consequence of the snow dielectric properties. These in turn are determined by the phase proportions of water and the fractional volumes of ice and brine within the snow cover. The energy fluxes of the volume cause changes in the phase proportions which are reflected in the radiative interaction at the surface of the snow. Knowledge of these geophysical and electrical properties of the snow cover can be exploited to allow inference of energy fluxes from the microwave scattering at 5.3 GHz to a Synthetic Aperture Radar (SAR). Modelling results show that the integrated climatological shortwave albedo and the seasonal evolution of the scattering cross section (σ) are highly correlated. Observational results show that SAR data from the European Earth Resources Satellite-1 (ERS-1) can be used to infer both the conductive sensible heat flux and radiative flux of the snow cover during seasonal metamorphosis from winter to late spring. An assessment of the operational utility of this measurement with mesoscale climate models concludes this paper.

Poster No. 18

CANADIAN SEA ICE ATLAS FROM MICROWAVE REMOTELY SENSED IMAGERY

E. LeDrew[2], D. Barber[2], and T. Agnew[1]
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Sea Ice is an integral part of the global climate system especially in its capacity to act as a major planetary heat sink at the poles and as a thermal and moisture barrier between the polar oceans and the atmosphere. This atlas estimates sea ice concentration and extent from the Special Sensor Microwave Imager (SSM/I) using the Canadian sea ice algorithm developed by AES/York University

(Dr. R. Ramseier). The Atlas documents the variability in sea ice cover over the northern hemisphere for the period July, 1987 to June, 1990. Considerable regional differences occur from year to year reflecting variability in regional climate and these will be illustrated in the presentation and interpreted in terms of changes in atmospheric circulation and regional climate.

The presentation will also discuss microwave properties of sea ice, sea ice algorithms, and the use of satellite microwave remote sensing as an important tool in monitoring variability and trends in regional arctic climate.

Friday/Vendredi a.m. Room/Salle 125

OZONE AND THE ULTRAVIOLET
L'OZONE ET LES RAYONS UV

Chair/Président: J. McConnell, York University

METOZ: THE GENERATION OF OZONE AND ULTRAVIOLET RADIATION MAPS FROM METEOROLOGICAL DATA

L.R. Poulin[1] and W.F.J. Evans[2]
[1]St. Raphael Street, Sudbury, Ontario
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A procedure for the generation of maps of ozone and ultraviolet radiation from upper air maps has been successfully developed. This program is called the METOZ algorithm. Comparisons of the ozone fields have been conducted against ground network measurements and ozone maps from the TOMS instrument on the NIMBUS 7 satellite. These indicate that total ozone agrees better than 6% at mid-latitudes in the northern hemisphere. Comparisons of the UV levels with the measurement of the actual UVB levels show good agreement on clear days. The UV levels depend on solar insolation and total ozone column, but are strongly affected by cloud and sky conditions. The problem of predicting the effects of future ozone depletion on the sunburn time is discussed. Studies of the Arctic ozone crater over the last two winters are shown. The difference between the METOZ and the TOMS ozone imagery has been used to study the pattern of chemical depletion within the Antarctic ozone hole in fall, 1992.

THE SYNOPTIC CLIMATOLOGY OF SURFACE OZONE IN RURAL SOUTHERN ONTARIO

K.C. Heidorn
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The partitioning of surface ozone concentrations by surface and 50 kPa weather patterns has provided a means whereby large-scale meteorological influences may be studied. The classic "back of the high" pattern for high concentrations of ozone and "front of the high" pattern for low ozone concentrations are evident from the synoptic climatology of warm-season weather patterns. However, in the cold season, the patterns are reversed - highest concentrations occurring in front of the high and lower on the back of the high.

Combining surface and upper air patterns in determining mean ozone concentrations showed highest summer ozone concentrations occurred when the "back of the high" surface pattern combined with weak 50 kPa gradients. Some evidence for stratospheric intrusion in the late winter and spring is seen although it is not conclusive.

SURFACE OZONE LEVELS AND TRENDS IN CENTRAL AND EASTERN CANADA DURING 1980-1991

J.D. Fuentes, T. Dann and S. Beauchamp
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

Ground-level ozone (O_3) data for the period 1980-1991 have been analyzed to provide an update and a summary of levels and trends of O_3 experienced in central and eastern Canada. This regional data analysis is essential to ascertain whether O_3 is increasing in mid-latitude regions. Exceedances of the Canadian 1-hour average acceptable air quality objective of 82 parts per billion (ppb) are presented to assess the improvement or deterioration in air quality during the last decade, and to delineate the areas subject to high O_3 concentrations.

Southern Ontario and Quebec frequently endure high O_3 concentrations when episodes lasting up to 8 days are experienced. Peak O_3 concentrations during typical episodes in this region of Canada are often more than twice 82 ppb, with maximum recorded values of approximately 200 ppb. Ozone exceedances in souther Ontario and Quebec are almost exclusively confined to May through September. Ozone exceedances in New Brunswick and Nova Scotia are largely attributed to imported pollutants. This is supported by the fact that O_3 maxima frequently occur during the night, while peaks associated with locally generated O_3 would be expected to occur during mid- and late afternoon. Peak O_3 concentrations in the 90-150 ppb range occur during pollution episodes in the region. Ozone exceedances in New Brunswick and Nova Scotia are substantially less frequent than those in Ontario or in Quebec.

THE ANTARCTIC OZONE HOLE IN 1970 FROM IRIS

E. Paat and W.F.J Evans
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The infrared spectral emission data from the IRIS instrument on NIMBUS 4 has been analyzed for ozone and other constituents. The total ozone field has been processed for several days in spring, 1970 over the Antarctic. The images were displayed using the GADS GIS program. These images show the state of the Antarctic ozone hole in early October, 1970. There is no definite evidence of any observable ozone depletion in spring, 1970. This pattern is contrasted with TOMS images in early October from recent years which demonstrate the development of the Antarctic ozone hole each spring and the growth throughout the 80's.

OZONE DEPLETION AND DEVELOPMENT OF ENHANCED C^{10} DURING THE 1991-92 ARCTIC WINTER USING A 3-D CTM.

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With the dramatic development of the austral ozone hole over the last 13 years the question has arisen as to whether there are similar but reduced effects in ozone in the boreal polar region. Aircraft expeditions in 1990 had measured dramatic evidence of chemical processing of chlorine in clouds, but during the boreal winter of 1991-1992 the Microwave Limb Sounder (MLS) instrument on board the Upper Atmospheric Research Satellite (UARS) measured enhanced layers of ClO over Europe. We have applied the 3-D spectral Chemical Transport Model of Kaminski run at R15 from mid-December to mid-January using objectively analyzed wind data from the Canadian Meteorological Centre output at R15. The meteorological data indicate that in mid-January that the vortex was off-set from the pole and that a cold pool of air developed over Greenland between 20-60 mb. The results for a period for the second week in January, 1992, show that there was significant processing of odd chlorine and that the model did indeed develop a ClO cloud over Europe which converted to a ClNO3 cloud at night. We will present some results of the simulation and compare with the MLS observations. In addition, we will address the question of the amount of extra ozone depletion that occurred as a result of the processing. We will also present some results on the importance of transport versus chemistry in the polar budget (for latitudes > 55° N) during this period.

Friday/Vendredi a.m. Room/Salle 125

CLOUD PHYSICS AND CHEMISTRY
PHYSIQUE ET CHIMIE DES NUAGES

Chair/Président: H.G. Leighton, McGill University

THE HYDROMETEOROLOGY OF CANSAP AND CAPMoN PRECIPITATION CHEMISTRY SAMPLERS

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In the 1970's as concern mounted over acidic deposition, Environment Canada established the Canadian Network for Sampling Precipitation (CANSAP) to monitor the chemistry of precipitation across the country. The original sampler was a Sangamo Precipitation Collector-Type A which had many operational difficulties especially in parts of the country with little precipitation and/or high evaporation. These difficulties were recognized and the sampling protocol was modified in 1980 in an effort to reduce evaporation losses. Although the change resulted in some improvement, the data quality was still questionable.

In 1983, a newer sampler was introduced to correct previous design faults and a new network, Canadian Air and Precipitation Monitoring Network (CAPMoN) began. Within a couple of years, CAPMoN replaced CANSAP and remains the backbone of the Canadian precipitation chemistry network today.

Both the CANSAP and CAPMoN precipitation chemistry samplers were tested at the Regina Airport from September 1984 to November 1987. The study demonstrated that the change from the CANSAP to CAPMoN sampler greatly reduced evaporation losses. Both samplers are relatively good rain gauges but, lacking any shielding from the effects of the wind, they are abysmal snow gauges. A discussion of the impact of the evaporation on the calculated concentrations of major ions for both samplers will be presented.

SEASONAL FOG AND PRECIPITATION CHEMISTRY AT FORESTED MOUNTAIN SITES IN SOUTHERN QUEBEC

R.S. Schemenauer, C.M. Banic and Natty Urquizo
Atmospheric Environment Service, Downsview, Ontario M3H 5T4

The Chemistry of High Elevation Fog (CHEF) program has been making measurements, since late 1985, of fog and precipitation chemistry, ozone concentrations, meteorological data, and fog frequency, at canopy top at two (three in 1986) mountain sites in southern Quebec. The fog, precipitation and mixed fog-precipitation chemistry data for the period 1985 to 1988 are presented here along with data from one co-located valley site. The canopy top fog pH values are consistently (19 of 25 seasons) below 4.00 and about one-half a pH unit lower than in precipitation. The ion concentrations ($SO_4^=$, NO_3^-, Cl^-, Na^+, NH_4^+, K^+, Ca^{++} and Mg^{++}) and ion ratios show differences between the Roundtop Mountain (Sutton) site (southeast of Montreal) and the Mont Tremblant site (northwest of Montreal) but both exhibit the expected dominance of sulphur chemistry in the warm season ($NO_3^-/SO_4^=$ 0.29 to 0.48) and enhanced nitrate chemistry ($NO_3^-/SO_4^=$ 0.71 to 0.91) in the cold season. Calculations of wet deposition to these mountain forests show that the input from the frequent fog cover significantly exceeds the input from precipitation. The seasonal chemistry data will enable realistic deposition estimates, of annual inputs to these high elevation forests, to be made for the first time.

COLLISION RATES OF SMALL DROPLETS IN WEAKLY TURBULENT CLOUDS

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In the process of laminar sedimentation, collision rates of small water droplets (radii less than 10 μm) are relatively small. We have examined whether weak turbulent fields can enhance these collisions. Our estimates of the probability of collisions between pairs of drops are based on calculations of drop trajectories.

Turbulence was represented in the form of random Fourier modes and scaled in a manner to reproduce appropriate energy spectra in the inertial and dissipation sub-ranges. Turbulence on small length scales is sufficiently well represented by the two first term of a Taylor expansion, i.e. the superposition of uniform and linear shear flows. Consequently, hydrodynamic forces and torques experienced by drops were obtained as linear combinations of effects of uniform translation, rotation and shear.

Our calculations show that weak turbulence characterized by energy dissipation rates in the range of 1-10 $cm^2\ s^{-3}$ has a significant effect on droplet collisions.

SOLAR RADIATIVE TRANSFER FOR WIND SHEARED CUMULUS CLOUDS

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Canadian Climate Centre, Downsview, Ontario M3H 5T4

All solar radiative transfer models used by global climate models and satellite retrieval algorithms assume that clouds are plane-parallel and homogenous. Real clouds, however, are far from possessing these ideal attributes. In fact, substantial portions of real clouds are highly variable over a wide range of scales. Over the past two decades, much work has been done towards comprehending how inhomogeneous cloud transports solar radiation. One of the most intensely researched brands of inhomogeneity has been simply arrays of finite cloud cells such as fair weather cumulus or broken stratocumulus. In general, such arrays reflect more (less) radiation than their plane-parallel counterparts for low (high) sun. In all such studies, the cloud cells were assumed implicitly to exist in the absence of wind shear. Usually, however, fields of broken cumuli (fair weather and trade cumuli especially) exist in substantial wind shear. Unmistakably, the dominant effect of wind shear on cloud geometry is the apparent effect of clouds being pulled along by their tops. This effect was imparted on normal cuboidal clouds and Monte Carlo photon transport simulations were done.

If clouds are sheared away from the sun, the overall reflectance of the cloud field at visible wavelengths can be up to 25% or 45% larger than if the clouds are sheared towards the sun. This is a significant variation whose magnitude exceeds reflectance differences between plane-parallel clouds and most other forms of inhomogeneity studies thus far. On account of reduced side illumination for clouds sheared towards the sun, the reflectance of such individual clouds is up to 15% larger than their counterparts sheared away from the sun. Not only are these radiative transfer dependencies on relative solar azimuth potentially important for climate simulations, they can also substantially govern cloud optical properties inferred from satellites (particularly when second-order shearing effects on cloud droplet size distributions can effect upwelling radiances).

AIR QUALITY SIMULATIONS - HOW MUCH BIAS AND ERROR CAN CLIMATE INTRODUCE?

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This paper examines how biases in a meteorological data set can effect air quality modelling results. Regulatory agencies often require the use of *"real"* meteorology for air quality assessment, and this data usually is not available at the location where the assessment is to be done. Are the errors introduced significant in an assessment?

SENES Consultants Limited was contracted to do an assessment of the impact of changes to a landfill in Maple, Ontario. This study involved the calculation of short-term extreme values, as well as 24-hour averages and long-term predictions of dust (SPM). The modelling involved the use of the Industrial Source Complex (ISC) Model and the Fugitive Dust Model (FDM) which requires detailed meteorological data as input.

The potential bias was investigated by:

(a) Comparing Toronto Pearson Airport and North Maple Reservoir data
  (1) using different methods for stability class calculations;
  (2) for different wind speeds;
  (3) for different wind directions; and
  (4) showing meteorological biases;

(b) Using ISC (for point sources) and FDM (for area source) to show model sensitivity to the different parameters; and
(c) Comparing model sensitivities for both short-term and long-term runs to examine whether or not any bias persists over the longer term.

The paper explores the relationship between long-term climate normals at Toronto (Pearson) International Airport and the North Maple Reservoir site meteorological measurements (20 km from the Airport) and the implications of the differences on analyses done for regulatory purposes.

The paper examines whether the biases in meteorology will be reproduced as biases in air quality predictions; makes some conclusions as to which method of two standard stability class determinations is best; and reflects on the question *"Should we be using "real" meteorology for assessments for regulatory purposes"*?

Friday/Vendredi a.m. Room/Salle 205

COASTAL OCEAN
OCÉAN CÔTIER

Chair/Président: C.L. Tang, Bedford Institute of Oceanography

RESIDUAL CURRENTS IN A THREE-DIMENSIONAL BAROCLINIC MODEL AT THE CENTRAL STRAIT OF GEORGIA, B.C.

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A one-year numerical simulation using a three-dimensional baroclinic model of the Straits of Georgia and Juan de Fuca system is performed to study the residual currents of the central Strait of Georgia. A previous study [Marinone and Fyfe, AO 30(1), 1992] for the same area with a depth-averaged model showed that a fully three-dimensional model was necessary to simulate the observed currents in the Strait (especially its magnitude). The modelled currents from the three-dimensional model are closer to the observations, particularly the low frequency component, in both spatial and temporal variability. Budgets of momentum, vorticity and energy will be presented for the modelled area as well as results of experiments designed to simulate deep water renewal.

A NUMERICAL MODEL OF THE CIRCULATION IN KNIGHT INLET, BRITISH COLUMBIA

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Knight Inlet is a fjord in which the circulation is noticeably influenced by freshwater runoff, the winds and the tides. During 1988 and 1989, month long observations of velocity, temperature and salinity were made throughout the water column both up-inlet and down-inlet of the sill. The observations from 1988 were made during a period of low freshwater runoff and those from 1989 were made during

a period of high freshwater runoff. Measurements were made at 2, 4, 6, 9 and 12 m depth using S4 current meters, at depths down to about 200 m using profiling current meters, and at depths deeper than 200 m using Aanderaa current meters. Anemometers were deployed at two locations along the inlet.

A laterally-integrated, two-dimensional, numerical model of Knight Inlet that uses the Mellor and Yamada level 2.5 turbulence closure scheme and that accounts for the combined influence of the winds, the tides and freshwater runoff has been used to produce thirty day simulations of the velocity and density field in the inlet. The fortnightly, diurnal, semi-diurnal and shallow-water tidal constituents are relatively well simulated. When the simulated and observed velocity and density fields are averaged over the thirty days they exhibit the classical estuarine circulation with outflow of low salinity water near the surface. Simulated time series of density and velocity near the surface of the inlet, where the wind plays an important role in the circulation, exhibit fluctuations that compare favourably with the observations.

NUMERICAL STUDY OF HUDSON BAY SUMMER OCEAN CIRCULATION: GYRES, MEANDERS, SEPARATIONS AND COASTAL JETS

J. Wang, L. Mysak and R. G. Ingram
Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, H3A 2K6

A numerical study of the summer ocean circulation in Hudson Bay with a 27.5 X 27.5 km grid (comparable to the internal Rossby radius of deformation) and realistic bottom topography is carried out under monthly climatological forcing of wind stress, oceanic inflow/outflow, freshwater and heat fluxes (control run, or CR). Aside from the CR, we carry out the following runs: 1) same as CR, except for constant depth (120 m everywhere); 2) same as the CR, except for no wind forcing; 3) same as the CR, except without oceanic inflow/outflow; 4) same as the CR, except for no heat and salt fluxes; and 5) same as the CR, except for barotropic run (i.e., temperature and salinity are homogeneous in the simulation).

The strong steering of the current by the topographic configuration is examined. The meso-scale topographic gyres and meanders of the circulation triggered by topography are simulated. The separation of the coastal current induced by bumps is a striking feature of the flow. In the CR, well-developed vortices of 120-150 km in diameter, triggered by topography, can be seen, whereas they disappear in the case of constant depth. Positive and negative vortices occur alternatively, which represent a pattern of standing waves. In run 2, we see that oceanic inflow/outflow induced cyclonic circulation in the Bay is a basic pattern of the ocean circulation yearlong, supporting the earlier hypothesis proposed by Prinsenberg [1986]. Run 3 shows the important effect on the surface current of wind forcing and that cyclonic circulation exists all the time no matter from what direction the surface winds are blowing, due to water mass balance in the Bay. The other two runs also show that the density-driven effect, which enhances coastal currents, is an important mechanism in Hudson Bay. From the stream function fields, it is estimated that the wind-driven transport in the Bay is about 0.5-0.6 Sv (1 Sv=10^6 m^3/s), which is about three times the density-driven transport (0.2 Sv) and twice the inflow/outflow induced transport (0.3 Sv). An important result is that the wind-driven circulation in the Bay shows a re-circulation, whereas the density-driven and inflow/outflow induced transports do not have such a pattern. The coastal jets are well simulated along the west, south and east coasts, rather than along the north coast.

UPPER OCEAN CIRCULATION MODEL

J. Gan[1], R.G. Ingram[1], R.J. Greatbatch[2] and P. Chen[1]
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The two and a half layer upper ocean model, which resolves the oceanic mixed layer and the thermocline, was developed and applied to Baie des Chaleurs during the upwelling season. Forcing with observed wind, buoyancy and remote forces, thermodynamic and hydrodynamic response of the mixed layer and thermocline will be discussed.

A NUMERICAL STUDY ON CIRCULATION IN THE BAIE DES CHALEURS

P. Chen and R.G. Ingram
Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, H3A 2K6

The Baie des Charleurs, at the western Gulf of St. Lawrence, is subject to the influence of dominantly westerly wind and St. Lawrence River plume and the cyclonic circulation and upwelling are prominent phenomena. A numerical modelling study with a time dependent, three dimensional primitive equation model is underway to better understand the nature of circulation and associated upwelling/ downwelling events, coastal waves, temperature and salinity characteristics etc.

The model uses realistic coastal geometry and bottom topography. Idealized forcing has been tested to study the respective roles of different forcing components. It is found that the less dense coastal current from the north (the extension of St. Lawrence river plume) is largely responsible for the cyclonic circulation in the bay. An eastward wind intends to generate an anticyclone so as to weaken the existing cyclonic flow due to plume. On the contrary, westward wind enhances the cyclone. The upwelling/downwelling events are produced in the model and may be explained by wind generated pressure gradient along the bay in addition to classical Ekman transport. Northern inflow does not enter the bay following the coast, which is also suggested by current measurement at the entrance of the bay. Experiments also show that reducing the northern boundary inflow weakens the cyclonic current in the bay, and that the addition of weak meridional wind does not change the major features. The river discharges changes the general circulation little but their affect on salinity distribution is important.

Friday/Vendredi a.m. Room/Salle 205

OCEAN MIXING
MÉLANGE OCÉANIQUE

Chair/Président: K.G. Lamb, Memorial University of Newfoundland

BASIN MIXING IN A TIDALLY ENERGETIC FJORD

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Vertical diffusion in fjord basins is driven predominantly by tidal energy fluxes, with wind mixing playing a role near the surface. In shallow silled fjords, deep water penetrations are rare, and low oxygen conditions can persist for long periods. For aquaculturists who use coastal inlets for operation, the infrequent deep water replacement can cause upwelling of oxygen depleted water and pose a threat to fish stocks.

Sechelt Inlet, B.C., is home to over 25 aquaculture sites and was recently the subject of an extensive dynamics experiment. Sechelt is a tidally energetic, shallow silled fjord with two side branching inlets. The experiment was designed to observe high and low frequency variations over the entire water column for a period of 5 months; complementary CTD casts were made nearly monthly for 3 years.

Salinity in the deep basin is seen to decrease by 0.12 per year due to the vertical diffusion of salt to the surface. Tidal oscillations are strong throughout the water column, and the influence of wind stress can be seen clearly in the upper 20 m. The goal of this project is to quantify the forces responsible for driving vertical diffusion and to understand the effects of geometry and variations in forcing on the general inlet circulation.

TURBULENT MIXING IN SOLITONS

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A field study of the evolution and decay of solitons at the edge of the Scotian Shelf was conducted in the fall of 1987. In several instances during the passage of a packet of soliton waves, intensive measurements of turbulence were made using EPSONDE coincident with the measurement of acoustic backscatter using a four frequency acoustic array (12kHZ, 50kHZ, 120kHZ and 200kHZ). From microstructure measurements we calculated the expected backscatter intensities using the Thorpe - Brubaker model and compared these estimates to the results from the acoustic array.

There is a strong correlation between the acoustic results and the model results using microstructure. A discussion of the experiment and these results will be presented.

TURBULENCE AND MIXING IN THE STRAIT OF GIBRALTAR

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Two cruises in the Strait of Gibraltar were undertaken as part of the Gibraltar Experiment, to study the influence of turbulence and mixing on the two layer exchange flow in the Strait, and to examine the characteristics of turbulence in the energetic Strait regime. The surveys (with over 1100 microstructure profiles) were carried out in the Strait October 12-20, 1985 and May 4-16, 1986. Results from the cruises (sampling of temperature, conductivity and small scale velocity, as well as ship mounted velocity and echosounder profiling in the upper 275m) are analyzed and discussed.

Mixing accounts for the changes in the inflowing layer along the Strait. In the west end the inflow layer is virtually pure Atlantic water. In the total inflow of 1.2Sv observed at the east end, 0.4Sv is unchanged Atlantic water and 0.8Sv is half Atlantic and half entrained Mediterranean water. The CTD and velocity data are used to predict turbulent and mean transport across isopycnals, due to entrainment between the inflow and outflow layers. We use this estimate to predict buoyancy fluxes. This data set shows the importance of a thick interfacial layer (60-120m) and the non-coincidence of the velocity and density interfaces. The high dissipation and mixing at the Camarinal Sill is nearly large enough to account for predicted buoyancy fluxes. Due to tidal flows, velocity and density structure are highly variable, complicating analysis of water mass change within any short sequence of profiles.

The key high dissipation region is the internal hydraulic jump at Camarinal Sill which was sampled repeatedly. Peak dissipation rates observed at the jump were $> 10^{-2}$ W kg^{-1} in a 10m thick layer. Overturns downstream of the jump were often larger than 50m thick. A second important source of mixing is internal bores propagating eastward, which were also sampled repeatedly. The dissipation signal in the bores decays fairly rapidly; samples 15km and 25km east of the Sill are markedly different.

Turbulence in the Strait was extremely high, typically 2 to 4 orders of magnitude higher than in open ocean thermocline samples. Dissipation rates were highly variable and could not be parameterized in terms of the shear observed in ADCP profiles. Thorpe and Ozmidov scales are nearly equal.

Velocity and density data from the east end of the Strait show that the exchange was different between October and May; it was submaximal in October and maximal in May.

MODELLING OF DOUBLE DIFFUSIVE INTRUSIONS

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The intrusion model of Toole and Georgi (1981) provides the standard picture of the mechanism by which a statically stable, motionless fluid with lateral salinity and temperature gradients can be unstable to quasi-lateral intrusions. The growth of such intrusions leads to cross-front fluxes of heat and salt at oceanic fronts. Recent data show that intrusions have vertical wavelengths significantly larger than theory predicts. In an attempt to explain this discrepancy between theory and observation, we have considered a generalized version of the model of Toole and Georgi, in which the salt diffusivity Ks is not constant (as T-G assumed), but is instead a function of the stability ratio R. Our results show that allowing a non-constant diffusivity Ks(R) leads to some interesting differences between our results

and those of Toole and Georgi. In particular, we find solutions with somewhat larger vertical scales, in better agreement with observations. Our solutions for the intrusion growthrate, vertical wavenumber, and cross-front slope reduce approximately to those of Toole and Georgi if the salt diffusivity Ks used in their calculation is replaced by the larger "effective diffusivity" Ks+(rf-R)*dKs/dR, where rf is the salt finger flux ratio.

Friday/Vendredi a.m. Room/Salle 303

HYDROLOGIC CYCLE IV - VARIABILITY IN HYDROMETEOROLOGICAL PATTERNS
CYCLE HYDROLOGIQUE IV - VARIABILITÉ DES CONFIGURATIONS HYDROMÉTÉOROLOGIQUES

Chair/Président: D.A. Daugharty, University of New Brunswick

INTER-HEMISPHERE COMPARISONS OF HYDROCLIMATIC PATTERNS ALONG THE WESTERN COASTS OF THE AMERICAS

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Many similarities exist in the hydroclimatologies of the west coasts of North and South America. These similarities arise from geographic features such as a north-south coastal mountain chain and coastal currents. However, as this comparative analysis shows, there are also a number of distinctive features in the hydroclimatologies of the two continental coasts. An understanding of the causes of these differences is important for predicting their responses to global change.

In this paper hydroclimatic patterns along a 100 km wide zone extending from 70°N to 55°S are described. The differences and similarities for similar latitudes in each continent are compared for a number of parameters including precipitation, temperature and components of the energy budget. It will be shown that latitudinal variations in these parameters strongly influence the hydrology and vegetative cover along the coasts. The paper concludes with a brief review of the importance of hydrometeorological processes in linking large-scale atmospheric controls to landscape scale and site-specific effects associated with local manifestations of global change. The interdisciplinary program, AMIGO (America's Interhemisphere Geo-Biosphere organization), which provided the context for this analysis, will also be briefly described.

RECENT OBSERVED TRENDS AND MODELLED HISTORICAL INTERANNUAL VARIABILITY IN CANADIAN SNOW COVER

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This paper investigates recent (1955-89) variations in observed snow cover duration at Canadian stations, and goes on to place these within the context of the longer-term (~1880-1990) natural variability in snow cover duration estimated from an empirical degree-day snow-melt model. Temporal

variability in snow cover duration is evaluated for several regions of Canada, and comparisons are carried out with temperature and precipitation data to gain further insight into longer-term climate/snow cover relationships.

Recent variations in snow cover duration at Canadian stations were derived from daily measurements of mean snow depth covering the period 1955-89. Linear regression analysis revealed a consistent reduction in snow cover duration across all regions of Canada over the 35 year period: of the approximately 150 stations analyzed, only 5 stations exhibited a positive slope and none of these were statistically significant. A comparison of fall and spring half-year periods indicated that most of the observed decrease had occurred in the spring. These results are consistent with other snow cover studies (e.g. Foster, 1989; Stuart et al., 1991; Robinson et al., 1992), and with recent trends toward earlier spring ice break-up observed at many Canadian lakes (Skinner, 1992) and the Great Lakes (Hanson et al., 1992). The snow cover duration trends are broadly consistent with recent air temperature trends.

Longer-term variability in snow cover duration was investigated by reconstructing daily snow depths from observed daily snowfall and estimated daily snow-melt. The latter was derived from a simple melting degree-day model which was seasonally calibrated against observed snow cover duration data covering the period 1955-89. The technique was found to work well over most of the interior of Canada south of the tree-line, and was typically able to explain 70-80% of the variance in observed annual snow cover duration (snow depth >3 cm).

To analyze the results, snow cover duration anomalies were computed with respect to a 1961-80 reference period at each station. These were spatially averaged and low-pass filtered to investigate long-term variability in snow cover duration for several regions (the Western Prairies, Southern Ontario, and the Maritimes). Snow cover duration was observed to have experienced significant fluctuations at decadal and longer time scales, and while all three regions exhibited quite different scales of variability, a common feature was a trend toward increasing snow cover duration from the 1930s to the late 1960s, followed by a rapid decrease in snow cover duration during the 1970s and 80s. The latter trend was most evident in the Western Prairies.

POINT PMP ESTIMATION OVER NORTHERN SASKATCHEWAN

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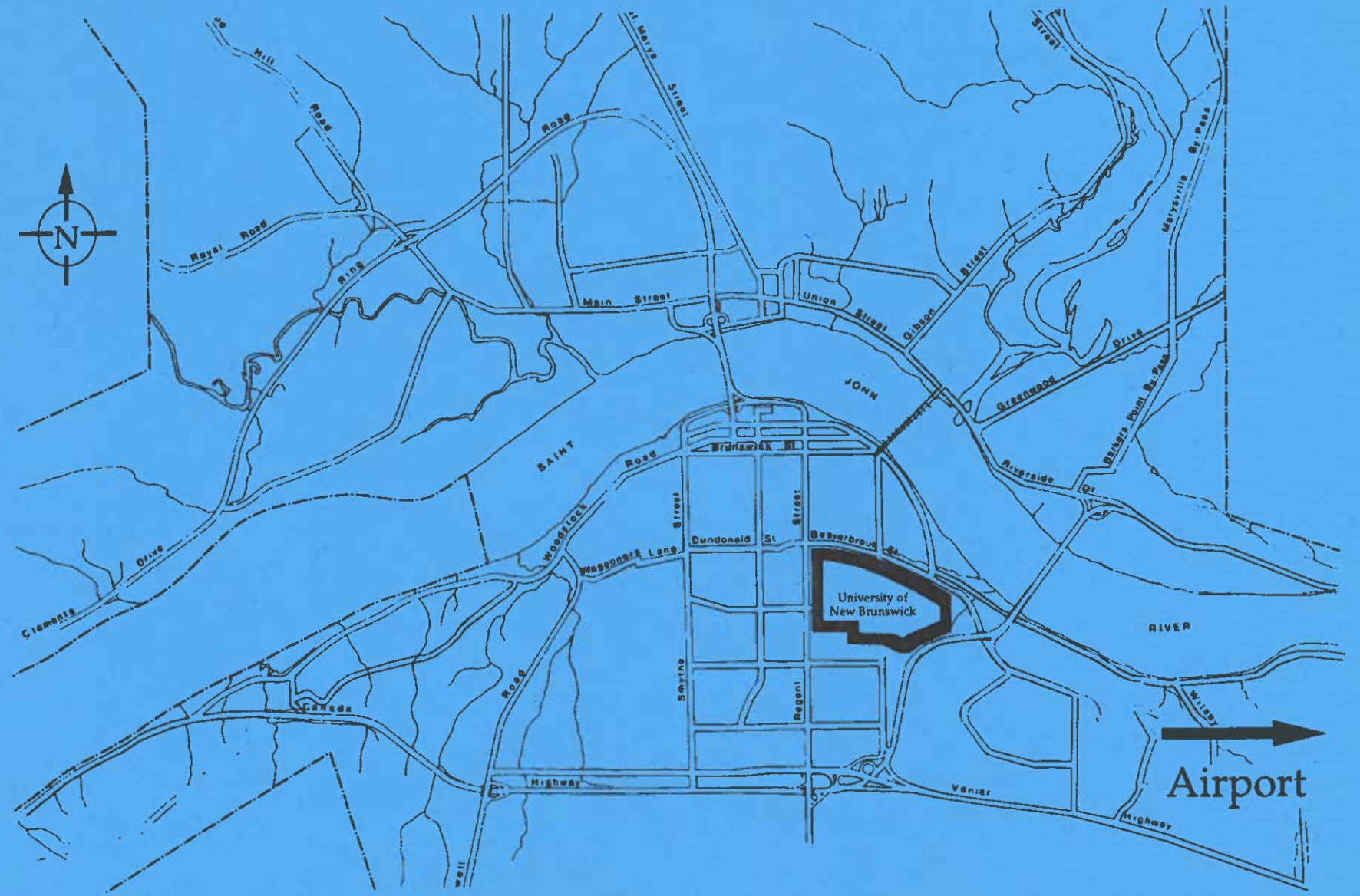
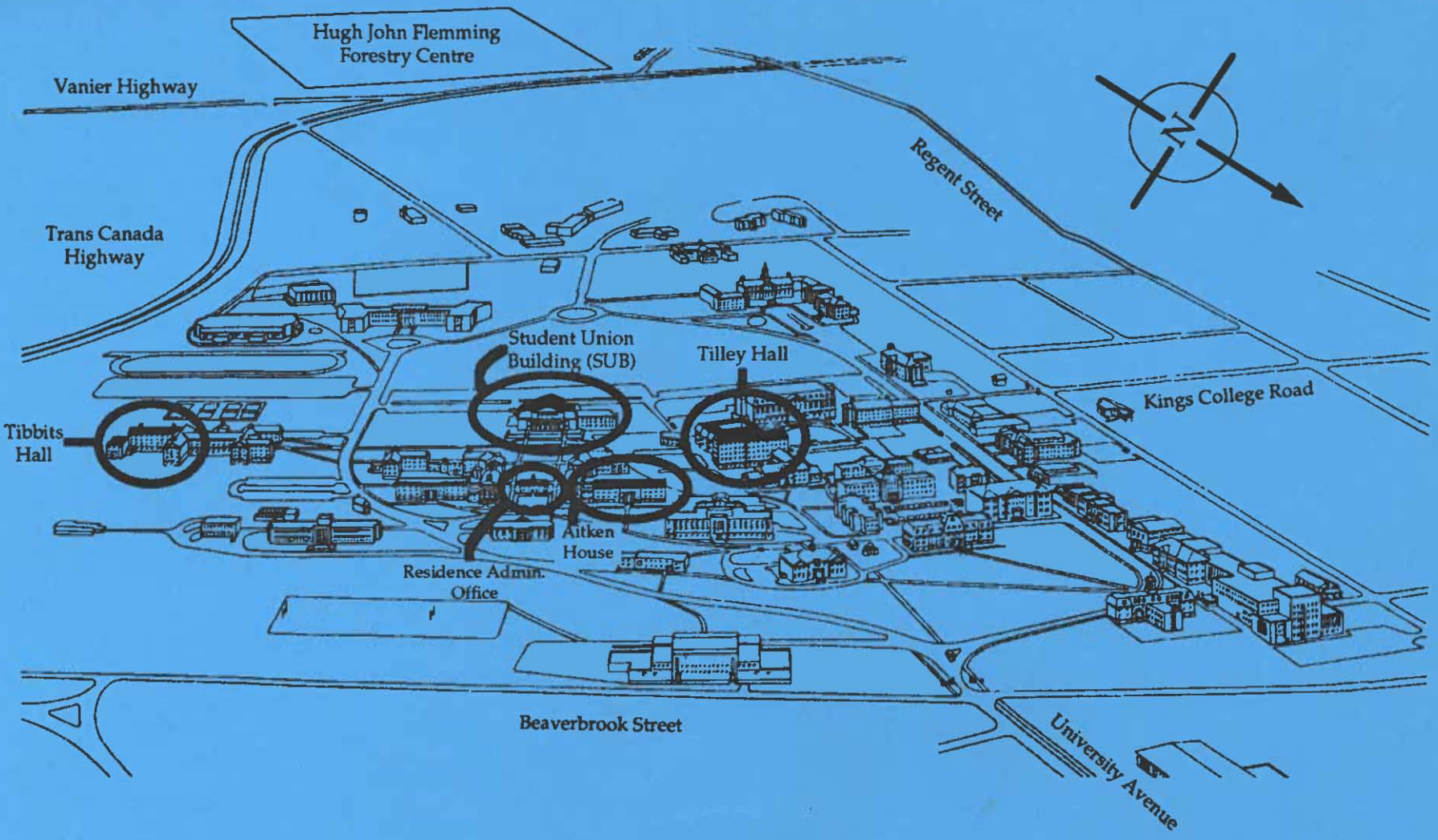
Probably Maximum Precipitation (PMP) is an important design concept for structures that, should they fail, would cause loss of life or significant environmental damage. In recent years, several uranium mines have been developed in northern Saskatchewan and several more are in various stages of environmental hearings. The tailings ponds associated with these developments contain or will contain considerable quantities of radionuclides and toxics that would cause unacceptable environmental damage should a pond be overtopped in a heavy rainfall event.

In the past, a design storm or rule of thumb approach has been used as estimates of the small area (i.e. point or 1.0 km^2) PMP. This report provides a more rigorous approach of storm maximization and transposition, as recommended by WMO, to a specific site (Collins Bay, Saskatchewan) and provides a methodology for estimating the point PMP at other locations in the northern half of Saskatchewan.

City of Fredericton





University of New Brunswick, Fredericton