
32 Congress/Congrès
Canadian Meteorological and Oceanographic Society
La Société canadienne de météorologie et d'océanographie
Theme / Thème
"Atmosphere-Ocean Climate Variability"
"Variabilité climatique dans l'atmosphère et l'océan"
CMOS
SCMO
Holiday Inn, Dartmouth, NS
1-4 June/Juin 1998
Webpage: http://dfomr.dfo.ca/science/ocean/cmos/congrs98.html
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CMOS
SCMO

32nd CMOS Congress
32e Congrès de la SCMO

Program & Abstracts
Programme et Résumés

Halifax, Nova Scotia
1-4 June • juin, 1998

32nd CMOS Congress
32e Congrès de la SCMO

Program and Abstracts

Atmosphere-Ocean Climate Variability

Variabilité climatique dans l'atmosphère et l'océan

Canadian Meteorological and Oceanographic Society
Société canadienne de météorologie et d'océanographie
Holiday Inn, Dartmouth, NS Canada
1-4 June/juin 1998

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Susan Woodbury

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Sandy Burtch

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Welcome to the 32nd CMOS Congress

The organizing committees of the 32nd Annual Congress of the Canadian Meteorological and Oceanographic Society are pleased to present to you this program and abstracts book.

Registrants to the Congress are invited to attend any sessions or committee meetings and may feel free to move between sessions to hear specific papers in coincident sessions; please move during the break between presentations if possible.

We wish to give a special welcome to Nova Scotia teachers attending the Education Day sessions on June 3. We hope there will be a fruitful interaction between you and the CMOS delegates and that all will benefit from this endeavour to enhance communications.

Authors are reminded that the time allotted for most presentations is 15 minutes + 5 minutes for discussion, 20 minutes in total, except for plenary and invited presentations. Chairs have been instructed to adhere closely to this schedule which benefits us all.

We hope you enjoy the Congress in all its aspects - scientific sessions, Education Day, Industry Day, exhibits, social events and for most a free Wednesday afternoon - followed by our banquet, awards, and entertainment.

The Halifax area is a great place and you are in the middle of it. The ferry ride across the harbour is delightful - find time to enjoy Historic Properties, the Maritime Museum of the Atlantic, Halifax Citadel and the great bars and restaurants. (You may need to stay on to enjoy it all!)

Peter Smith and Dan Wright
Chairs, Scientific Program Committee

Clive Mason
Chair, Local Arrangements Committee

32nd CMOS Congress
Holiday Inn
Dartmouth, Nova Scotia
1-4 June, 1998

Bienvenue au 32e congrès de la SCMO

Les comités organisateurs du 32e congrès annuel de la Société canadienne de météorologie et d'océanographie ont le plaisir de vous présenter le présent programme et le recueil de résumés.

Les personnes inscrites au Congres sont invitées à assister à toute séance ou à toute réunion du comité. Elles peuvent à leur gré aller d'une séance à une autre pour écouter des exposés dans des séances simultanées. Veuillez si possible profiter de la pause pour aller d'un exposé à un autre.

Nous désirons souhaiter la bienvenue, en particulier, aux enseignants de Nouvelle-Écosse assistant le 3 juin aux séances de la Journée de l'éducation. Nous espérons qu'il y aura une fructueuse interaction entre vous-même et les délégués de la SCMO et que tout le monde profitera de cette initiative de rehaussement des communications.

Nous rappelons aux AUTEURS que le temps alloué à la plupart des exposés est de 15 minutes, plus 5 minutes de discussion, soit 20 minutes au TOTAL, sauf pour les exposés de la séance plénière et les exposés sollicités. On a demandé aux présidents de faire observer de près ces règles et ce, dans l'intérêt de toutes et de tous.

Nous espérons que le Congrès vous plaira sous tous ses aspects : séances scientifiques, Journée de l'éducation, Journée de l'industrie, expositions, évènements sociaux et, pour la plupart, après-midi libre du mercredi, suivi de notre banquet, de nos prix et de divertissement.

La région de Halifax est captivante et vous vous trouvez au beau milieu de celle-ci. La traversée en bac du port est une expérience exquise. Consacrez un moment à la visite des Propriétés historiques, du Musée maritime de l'Atlantique, de la citadelle de Halifax , sans oublier les excellents cafés et restaurants. (Vous devrez peut-être prolonger votre visite pour ne rien manquer!)

Peter Smith et Dan Wright
Présidents du Comité des programmes scientifiques

Clive Mason
Président du Comité des arrangements

32e congrès de la SCMO
Holiday Inn, Dartmouth, N.-É.,
du 1er au 4 juin 1998

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About the Society

The Canadian Meteorological Society was formed in 1967 from a branch of the Royal Meteorological Society. In 1977 when the oceanographic community joined, the name of the Society was changed to the Canadian Meteorological and Oceanographic Society (CMOS).

The Society was subsequently incorporated with this name in 1984. CMOS is a national society of individuals, centres and chapters dedicated to advancing all aspects of atmospheric sciences, oceanography, and related disciplines in Canada. The Society also offers accreditation of meteorological consultants and endorsement of media weathercasters.

Fourteen Society centres and chapters across Canada serve as focal points for local and regional activities. Scientific interests of the Society include: operational meteorology, climatology, hydrology, air pollution, agriculture/forestry meteorology, mesoscale meteorology, floating ice, physical, chemical and fisheries oceanography.

The Society offers travel bursaries for students to attend Annual Congresses, a secondary school teacher travel bursary for the AMS/NOAA Workshop "Project Atmosphere", and the "Weather Research House/CMOS/NSERC" graduate student supplementary scholarship.

The main publications of CMOS are the bimonthly "CMOS Bulletin SCMO" and Atmosphere-Ocean (A-O), a quarterly refereed journal for the publication of results of original research. The Society also maintains an electronic Web Site, with information on the Society and its activities, and on meteorological and oceanographic science and education across Canada.

Detailed information on CMOS can be found on this web site at http://www.meds.dfo.ca/cmos/

la Société...

La Société canadienne de météorologie fut formée en 1967, d'un chapitre de la Royal Meteorological Society. Lorsque les océanographes s'y joignèrent, en 1977, le nom de la Société fut changé à Société canadienne de météorologie et d'océanographie. La Société fut subséquemment incorporée sous ce nom en 1984. La SCMO est une organisation nationale regroupant des individus, centres et chapitres voués à la promotion de la météorologie et d'océanographie au Canada, ainsi que des disciplines environnementales connexes, sous tous leurs aspects. La Société offre aussi la certification des experts-conseil météorologiques et l'agrémentation des présentateurs météo.

Quatorze centres locaux ou sections servent de foyers pour les activités locales et régionales. Les interêts scientifiques de la Société incluent :

l'hydrologie, la météorologie d'exploitation, la climatologie, la pollution de l'air, la météorologie agricole et forestière, les glaces flottantes, la mesométéorologie, et l'océanographie chimique, physique et halieutiques.

La Société offre des bourses de voyages aux étudiants pour participer au congrès, une bourse de voyage à un enseignant pour l'atelier "Project Atmosphere" de l'AMS/NOAA, et la bourse du troisième cycle "Weather Research House/SCMO/CSNRG".

Les principales publications de la Société sont le CMOS Bulletin SCMO bi-mensuel et Atmosphere-Ocean une revue scientifique trimestrielle presente des articles, préalablement soumis à la critique, sur les résultats des recherches originales ou des revues. La SCMO publie aussi une page d'accueil - on y trouve de l'information générale sur la SCMO et ses activités, ainsi que sur les sciences et l'enseignement météorologiques et océanographiques au Canada. On trouvera plus d'information sur la page d'accueil de SCMO à http://www.meds.dfo.ca/cmos/.

A Word from Our President

On behalf of the CMOS Council, I welcome you to the 32nd Annual Congress of the Canadian Meteorological and Oceanographic Society. It's a pleasure to be in Nova Scotia again, and to return to Halifax-Dartmouth where oceanography and meteorology have deep roots. Today we think of the Bedford Institute of Oceanography for research, Dalhousie University for education, The Maritimes Weather Center - Bedford for public service, and Seimac Limited for industry as continuing the heritage in their respective domains.

The 32nd Congress is significant for me, not just because it marks the completion of my year as President, but also because it is in Nova Scotia where I gained my first weather forecasting experience trying to forecast the vagaries of Atlantic fog. I recall Rube Hornstein telling me at the time they had solved that problem years before-but it was a technique that better forecasters than I were never able to master!

Once again the Society has been fortunate to find willing and capable volunteers to organize the Congress, with leadership from Clive Mason and Don Lawrence for Local Arrangements, and Dan Wright and Peter Smith for the Scientific Program. As you can tell from the program, the Congress theme of "Atmosphere-Ocean Climate Variability" has attracted some promising papers. In addition to attending these presentations, be sure to come to the Annual General Meeting, and enjoy the Banquet. You will have the opportunity to participate in Education and Industry Days.

Please take that opportunity to encourage the future and diversification of our sciences.

Again, welcome to the Congress.

John D. Reid
PRESIDENT

Un mot de notre Président

Au nom du Conseil de la SCMO, je vous souhaite la bienvenue au trente-deuxième Congrès annuel de la Société canadienne de météorologie et d'océanographie. C'est un plaisir d'être de nouveau en Nouvelle-Écosse, et de se retrouver à Halifax-Dartmouth ou l'océanographie et la météorologie sont profondement racinées.

Aujourd'hui nous associons l'Institut océanographique de Bedford à la recherche, l'Université Dalhousie à l'éducation, le Centre Météorologique Maritime - Bedford au service au public, et Seimac Limited à l'industrie pour la poursuite de l'héritage dans leurs domaines respectifs.

Le trente-deuxième Congrès est significatif pour moi, non seulement parce qu'il marque la fin de mon année comme président, mais aussi parce qu'il est en Nouvelle-Écosse ou j'ai fait mes premières armes comme prévisionniste essayant de prévoir les caprices du brouillard atlantique. Je me rappelle de Rube Hornstein qui me disait que le problème était resolu depuis des années -- mais c'était une technique que de meilleurs prévisionnistes que moi n'arrivaient jamais a maîtriser!

La société a été de nouveau chanceuse de trouver les volontaires disposés et capables d'organiser le congrès, sous les directions de Clive Mason et Don Lawrence pour les agencements locaux et de Dan Wright et Peter Smith pour le programme scientifique. Comme vous pouvez le constater dans le programme, le thème du congrès "Variabilité climatique dans l'atmosphère et l'océan" a attiré quelques présentations prometteuses. En plus d'assister à ces présentations, assurez vous de participer à l'assemblée générale annuelle, et d'apprécier le banquet.

Vous aurez l'occasion de participer aux journées dédiées à l'éducation et à l'industrie. Je vous prie de saisir cette occasion pour encourager le futur et la diversification de nos sciences.

Encore une fois, bienvenue au Congrès.

John D. Reid
PRÉSIDENT

Welcome to Halifax

The CMOS Halifax Centre is delighted to be hosting the 32nd Annual Congress of the Canadian Meteorological and Oceanographic Society. Just in case you were wondering why we said "Welcome to Halifax" when you are attending meetings in Dartmouth, here is the reason. The Halifax Regional Municipality came into existence on April 1, 1996 as a result of the amalgamation of the cities of Halifax and Dartmouth, the Town of Bedford and Halifax County Municipality.

Congress Location The Congress is being held in the Conference Centre at the Holiday Inn Harbourview in Dartmouth. Both Conference Centre and Hotel are wheelchair accessible. The hotel is conveniently located at the head of the MacDonald Bridge leading to Halifax, adjacent to the bus terminal and the sports centre, and a 10 to 15 minute walk from the ferry terminal (about a kilometre). Ferry and bus routes are transfer connected.

Parking There is free parking for those staying at the Holiday Inn and for those registered at the congress.

Bridge construction The Angus L. MacDonald Bridge, which is located beside the Holiday Inn Harbourview, is being widened. Nighttime closures are generally scheduled Sunday to Thursday from 19:00 to 05:30. During these periods, the walkway is also closed to pedestrian traffic. Please bear this in mind when making plans for your stay in the Halifax area. For up-to-date bridge closure information, contact 463-8655. The A. Murray MacKay bridge is open for business as usual.

Buses The ferries which ply Halifax Harbour are an entertaining way to travel between the two cities. Ferry and bus schedules are available at the registration desk. If you want to know how to get from A to B, you can call the information line at 490-6600.

Registration Desk The registration desk is located near the Lake City Ballroom. Tickets for Wednesday's Patterson lunch and additional tickets for the CMOS Awards Banquet on Wednesday evening are for sale here. In addition, CMOS application forms and visitor information are available.

Hours of operation

Sunday:	13:00 - 18:00
Monday:	07:00 - 17:30
Tuesday:	08:00 - 17:30
Wednesday:	08:15 - 12:45
Thursday:	08:30 - 17:30

Lunches Buffet lunches on Monday, Tuesday and Thursday are included in the full registration price. They are held in the Terrace area, surrounded by the exhibitors and the posters, with a great view of Halifax Harbour.

Patterson Lunch A special lunch is scheduled for Wednesday, June 3rd, 12:45 -14:45 in the Hawthorne-Sullivan rooms. The Atmospheric Environment Service's Patterson Medal for outstanding contribution to meteorology will be awarded. Tickets are $20.00 and are available at the registration desk. If you have any special dietary restrictions, please inform the person at the registration desk.

CMOS Awards Banquet The banquet will be preceded by a cocktail hour beginning at 18:00. Music will be provided by a Jazz trio under the direction of Paul Simons. After dinner entertainment will be provided by Jeff Irwin, a Maritime comedian. Jeff has appeared on national CBC Radio shows such as "Madly Off in All Directions" and "Richardson's Roundup". There is one ticket included in each full registration package. Additional tickets are $41.00 and are available at the registration desk. If you have any special dietary restrictions such as allergies to seafood, please inform the person at the registration desk. An alternate entree will be provided.

The Accompanying persons program Meeting with Halifax Tourism Representative - Monday at 10:15; Guided Tours: The Titanic Exhibit at the Maritime Museum of the Atlantic - Tuesday; Glass Blowing at Nova Scotian Crystal - Wednesday at 9:00; Free afternoon for Sightseeing or Shopping - Wednesday afternoon; Reception & Banquet - Wednesday 18:00 to 22:00 Day passes for the Dartmouth Sportsplex are available at the Inn's front desk. Pool, hot tub & sauna, aerobics, weight room, and squash courts are available.

Questions If you have any questions, or require some assistance, please ask at the registration desk. We will be happy to help you.

Congress Web Site http://dfomr.dfo.ca/science/ocean/cmos/congrs98.html

Bienvenue à Halifax

Le centre de Halifax de la SCMO est fier de recevoir le 32e congrès annuel de la Société canadienne de météorologie et d'océanographie. Si vous vous demandez pourquoi nous vous souhaitons la bienvenue à Halifax alors que les réunions ont lieu à Dartmouth, et bien en voici la raison : La municipalité régionale de Halifax a été créée le 1er avril 1996 à la suite de l'amalgamation des villes de Halifax, de Dartmouth et de Bedford, ainsi que de la municipalité du Comté de Halifax.

Lieu du Congrès Le Congrès aura lieu au centre de conférences du Holiday Inn Harbourview, à Dartmouth. Le centre de conférence de même que l'hôtel sont accessibles en fauteuil roulant. L'hotel est situé aux abords du pont MacDonald qui mène à Halifax, tout près du terminus d'autobus et du centre sportif et à dix ou quinze minutes de marche du traversier (environ 1 kilomètre). Les correspondances d'autobus sont valides sur les traversiers.

Stationnement Le stationnement est gratuit pour les personnes qui séjournent au Holiday Inn et pour celles qui sont inscrites au Congrès.

Travaux de construction sur le pont Le pont Angus L. MacDonald, situé près du Holiday Inn Harbourview, fait l'objet de travaux d'élargissement. Le pont est généralement fermé les nuits du dimanche au jeudi de 19 h à 5 h 30. Durant ces périodes, le trottoir est également fermé aux piétons. Veuillez prendre note de ces restrictions lorsque vous planifierez votre séjour dans la région de Halifax. Pour des détails plus à jour concernant la fermeture du pont, composez le 463-8655. Le pont A. Murray MacKay demeure ouvert.

Autobus/traversiers Les traversiers qui sillonnent le port de Halifax offrent un moyen très agréable de se déplacer entre les deux villes. L'horaire des traversiers et des autobus est disponible au bureau d'inscription. Si vous voulez savoir comment voyager de A à B, vous pouvez joindre la ligne d'information, au 490-6600.

Bureau d'inscription Le bureau d'inscription est situé près du salon Lake City Ballroom. On peut y acheter les billets pour le déjeuner Patterson, tenu le mercredi à midi, de même que pour le banquet de la SCMO, qui aura lieu mercredi soir.

Heures d'ouverture

Dimanche :	13 à 18 heures
Lundi :	7 h à 17 h 30
Mardi :	8 h à 17 h 30
Mercredi :	8 h 15 à 12 h 45
Jeudi :	8 h 30 à 17 h 30

Déjeuners Les buffets servis lundi, mardi et jeudi sont inclus dans le prix de l'inscription complète. Ils seront servis sur la terrasse parmi les exposants et les affiches et en présence d'une vue formidable du port de Halifax.

Le déjeuner Patterson Un déjeuner spécial est prévu le mercredi 3 juin de 12 h 45 à 14 h 45 aux salons Hawthorne-Sullivan. On décernera le prix Patterson de Service de l'environnement atmosphérique pour contribution exceptionnelle à la météorologie. Les billets sont en vente au bureau d'inscription pour 20 $. A l'inscription, veuillez signaler au personnel si vous avez des besoins spéciaux en matière de nourriture.

Banquet de remise de prix SCMO Le banquet sera précédé par un apéritif à 18 h. La musique proviendra d'un trio de Jazz sous la direction de Paul Simons. Après le diner, Jeff Irwin, comédien des Maritimes, vous divertira. Jeff s'est produit à des émissions de radio de la société Radio-Canada telles que "Madly Off in All Directions" et "Richardson's Roundup".

Un billet est inclus avec votre inscription complète. On peut obtenir des billets supplémentaires, au coût de 41 $ chacun, au bureau d'inscription. Si vous avez des besoins alimentaires spéciaux, telles que des allergies aux fruits de mer, veuillez en aviser le personnel au bureau d'inscription; un autre choix de plat sera servi.

Programme pour personnes qui accompagnent Rencontre avec un représentant du bureau de tourisme de Halifax : lundi à 10 h 15; Visites guidées : L'exposition du Titanic au Musée maritime de l'Atlantique : mardi; Le verre soufflé à Nova Scotian Crystal : mercredi 9h Après-midi libre pour la promenade et le magasinage : mercredi après-midi Réception et banquet : mercredi 18 h à 22 h. Des laissez-passer pour le centre sportif Sportsplex sont disponibles à la réception du Holiday Inn. Une piscine, un sauna, un centre aérobique et des courts de squash comptent parmi les installations offertes.

Questions Si vous avez des questions ou si vous avez besoin d'aide, veuillez demander l'assistance du personnel au bureau d'inscription. Nous nous ferons un plaisir de vous servir.

Page d'accueil du Congrès http://dfomr.dfo.ca/science/ocean/cmos/congrs98.html

Congress 1998 Organizing Committees

Les comités organisateurs du Congrès de 1998

Scientific Program Committee

Peter C. Smith (Co-Chair)
DFO, Bedford Institute of Oceanography, Dartmouth, NS

Dan Wright (Co-Chair)
DFO, Bedford Institute of Oceanography, Dartmouth, NS

Hal Ritchie
Recherche en Prevision Numerique/AEB, Dorval,QC

Jim Abraham
AEB, Bedford, NS

Keith Thompson
Department of Oceanography, Dalhousie University, Halifax, NS

Glen Harrison
DFO, Bedford Institute of Oceanography, Dartmouth, NS

John N. Smith
DFO, Bedford Institute of Oceanography, Dartmouth, NS

Norm MacFarlane - Canadian Centre for Climate Modelling and Analysis, University of Victoria, Victoria, BC

Local Arrangements Committee

Clive Mason (Chair)
DFO, BIO, Dartmouth, NS

Don Lawrence (Vice Chair & Scientific Liaison)
DFO, BIO, Dartmouth, NS

Billie Beattie (Registration)
AEB, Bedford, NS

Peter Bowyer (Education Day)
AEB, Bedford, NS

Paul Chapman (Web Page)
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Keith Thompson (Education Day)
Dalhousie University, Halifax, NS

Susan Woodbury (Publications)
Seimac Limited., Dartmouth, NS

Acknowledgements

Remerciements

The organizing committee would like to thank the following people who graciously offered their time and expertise to ensure the success of this Congress:

Neil Campbell
(Executive Director, Canadian Meteorological and Oceanographic Society, Ottawa, ON)

Daniel Pokorn and Mike Mitchell for assisting in French translation,

Paul Chapman for providing technical support for the Congress web site,

Art Cosgrove and Bob Lively for assisting in the design of the Congress poster,

Sean Malone for assisting in the installation of our computer systems,

Keith Thompson and the Department of Oceanography, Dalhousie University for hosting our web site,

John Gray for advice on communications and public relations.

CMOS also acknowledges the Atmospheric Environment Service, the Department of Fisheries and Oceans and Seimac Limited for enabling several staff members to participate in the Scientific Program and Local Arrangements Committees for the 32nd Congress, and for providing the use of their facilities.

Our corporate sponsors are also graciously acknowledged for their financial assistance.

Commercial Exhibits

Expositions commerciales

Commercial exhibits are located in the Exhibit Hall of the Holiday Inn. Exhibitors are featuring the latest hardware, software, systems and services. Exhibitor's introductions are scheduled for Monday, June 1 at 9:05 a.m. with the displays opening at noon that day. Coffee breaks, receptions, lunches and poster sessions are being held in the Exhibit Hall through Thursday, June 4. All attendees/guests must be wearing a badge to enter the exhibit hall. Guest passes issued by exhibitors can be exchanged for an "Exhibits Only" badge at the registration desk.

Commercial exhibits hours:

Monday, June 1	**12:00 - 16:00 Exhibit Hall, Second Floor**
Tuesday, June 2	**09:30 - 16:00 Exhibit Hall, Second Floor**
Wednesday, June 3	**09:00 - 13:00 Exhibit Hall, Second Floor**
Thursday, June 4	**09:00 - 13:00 Exhibit Hall, Second Floor**

Commercial exhibits provide a vital link between science and technology. The Canadian Meteorological and Oceanographic Society would like to extend its sincere thanks to all the exhibitors for their support at the 32nd Annual Congress of the Canadian Meteorological and Oceanographic Society.

Coffee Sponsors

Fournisseurs du café

The Canadian Meteorological and Oceanographic Society wishes to extend its thanks and appreciation to the following Coffee Sponsors for their support:

Campbell Scientific (Canada) Corp.
192 St Clair Street, Chatham, Ontario N7L 3J6, Contact: Carl de Leeuw
Tel: (519) 354-7356, Fax: (519) 354-1558, E-mail: campsci@kent.net

Canadian Institute for Climate Studies
University of Victoria, Victoria B.C., Contact: Guy Flavelle
Tel: (604) 864-0343, E-mail: guy@flavelle.com

TeraMach Technologies Inc.
18 Auriga Drive, Napean, Ontario, Contact: Christian Nguyen
Tel: (613) 226-7775, Fax: (613) 226-8434, E-mail: christian@teramach.ca

World Weatherwatch
401 Bentley Street, Unit #4, Markham, Ontario L3R 9T2, Contact: Mory Hirt
Tel: (905) 477-4120, Fax: (905) 477-0824, E-mail: info@worldwx.com

The American Meteorological Society (AMS) publishes eight prestigious scientific journals, a number of which are on display. The Society also organizes national and international meetings, specialized conferences, symposia and workshops. The AMS also provides many opportunities for professional development by offering short courses and workshops each year. The AMS provides a number of exhibition opportunities for manufacturers of hardware and systems, service providers and publishers of text books, reference books, and electronic media. A calendar of upcoming meetings and exhibitions in 1998 and 1999 is available at the AMS booth. The Certified Consulting Meteorologist (CCM) Program is a service for the general public. The CCM Program was established to certify that certain individuals have been tested and found to meet or exceed standards of technical competence, character and experience for those who seek advice and consultation in meteorology to the public. Project ATMOSPHERE is one of several educational initiatives of the AMS to foster teaching of atmospheric topics across the curriculum in grades K-12. The Society administers an array of undergraduate scholarship and graduate fellowships with the support of its membership, corporations and government agencies.

The National Weather Services organization is responsible for the coordination, national implementation, and ongoing development and support of monitoring and service delivery components of the Atmospheric Environment Program of Environment Canada. These include the program components of data acquisition, communications, forecast production and delivery, commercial services, information services and the provision of atmospheric, climate, hydrological and ice services. The major thrusts of National Weather Services include Aviation Weather Observing System (AWOS) performance evaluation and retrofit of existing equipment to automate the weather monitoring network, the establishment of the Canadian Lightning Data Network, the modernization and expansion of the Canadian Radar Network, and the provision of services to major clients such as NavCanada, the Department of National Defence and the Canadian Coast Guard. For more information about the activities of the National Weather Services Directorate contact Leslie Malone at (416) 739-4941 or by e-mail at Leslie.Malone@ec.gc.ca.

Your window on the weather

Votre fenêtre sur la météo

This year marks our 20th anniversary of serving our Canadian clients in their monitoring and data acquisition needs. At this year's CMOS conference we will be displaying a number of our portable, battery operated, dataloggers including the CR23X, CR10X and CR500; the CR23X being our newest datalogger. The rugged CR23X is a self-contained, low-power datalogger that includes a battery-backed real-time clock and 1 Mbyte of non-volatile data storage (500,000 data points). It features a 24-character-by-2-line alphanumeric display for reviewing programs and data. Final Storage labels, instruction parameters, and help menus can now be viewed directly on the datalogger. The CR23X offers 12 differential (24 single-ended) analog input channels with five input ranges from +/- 10mV to +/- 5000mV. Measurement resolution is 15 bits. Along with our new PC208W, version 2.3, datalogger support software we will also be demonstrating our new PC200W. PC200W is a simple, Windows-based tool for direct communication with our dataloggers and features a new graphical user interface. PC200W was designed to help new and veteran users get up and running as quickly as possible. For further information on Campbell Scientific products, call 519-354-7356 (in Eastern Canada) or 403-454-2505 (in Western Canada).

HOSKIN SCIENTIFIC

Hoskin Scientific is an environmental supplier in the areas of water quality, fisheries, water level, ground water and weather monitoring. We provide all components of a complete weather station including sensors, dataloggers, towers, and training sessions if requested.

We provide a wide range of sensors including wind speed, wind direction, rainfall, solar radiation, temperature, relative humidity and barometric pressure. We can provide customized equipment on an application basis, or we have complete systems available at reasonable prices.

We can also combine both meteorological and water quality systems into the same system for both easy access or remote locations. We can set up long-term field stations or portable systems depending on your needs.

Call us with your equipment needs and product applications. Whatever your budget, we can put together the right system for you.

World Leader in Ice Information Service

Over four decades of knowledge-based expertise and technological advances help the Canadian Ice Service deliver world class ice information service to the Canadian Coast Guard and the marine user community in Canadian Waters. Our combined expertise in areas such as remote sensing, ice modeling, and ice climatology has allowed us to assist the research community, the weather services, the Department of Fisheries and Ocean, universities and many other organisations. Drop by our display to discuss how the Canadian Ice Service can benefit to your organisation.

Chef de file mondial du service de l'information sur les glaces, plus de quarante ans d'expertise jumelée aux percées technologiques ont aidé le Service canadien des glaces à fournir un service d'information des glaces hors du commun à la Garde cotière canadienne et aux usagers de la communauté maritime transigeant dans les voies navigables canadiennes. Nos connaissances combinées dans des domaines tels que la télédédection, la modélisation, et la climatologie des glaces nous permettent d'appuyer la communauté scientifique, les services météorologiques, le département des pêches et océans, les universités ainsi que d'autres organisations. Venez visiter notre kiosque afin de discuter ce que le Service canadien des glaces peut contribuer à votre organisation.

Client Service - Service à la clientèle
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Environment Canada - Your window on the weather

Environment Canada's Remote Video Access System **(RVAS)** provides real-time video images from remote locations. Meteorologists use these images to produce more accurate weather forecasts and warnings. Numerous businesses such as Road Maintainers or Ski Hill Operators can also benefit from Environment Canada's RVAS.

RVAS images can detect: • thunderstorms • ice accretion • fog formation • precipitation type • cloud type • low ceilings • snow depth

The **RVAS**: • Is totally Year 2000 compliant • allows automatic retrieval of pictures • has archiving capability • is available at a relatively low cost • has automatic system and communications monitoring and reboot capability • displays high Resolution Images.

RVAS - A valuable tool for any forecast office!

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Your window on the weather

Votre fenêtre sur la météo

The United Nations has declared 1998 as the International Year of the Ocean (IYO) to focus attention of the need to protect the marine environment and to ensure a healthy ocean. Countries around the world will be celebrating International Year of the Ocean with planned activities and events.

The objectives of the International Year of the Ocean, as stated by the United Nations, are to:

- increase public awareness of the importance of the ocean and its relation to the everyday life of all people, whether they live on, near or far from the coast;
- bring ocean-related issues to the attention of policy and decision-makers and decide on courses of action; and
- engender continuing support for the ocean and initiate the ocean-related programs needed to resolve issues.

The resolution to create International Year of the Ocean was endorsed by Canada at the United Nations. Canada has one of the longest coastlines in the world: 250,000 kms touching on three oceans. Yet the Canadian public is largely unaware of the critical role oceans play in our daily lives. International Year of the Ocean offers a unique opportunity to engage Canadians in understanding the role of the oceans in our economy, our society and our cultural life.

DFO as the lead federal department on oceans issues, is taking this unique opportunity to promote International Year of the Ocean, and the messages it carries. Across the country hundreds of activities such as school presentations, curriculum development, community festivals, scientific lectures, Ocean Charter signings and international workshops are taking place to mark this significant initiative. For more information on International Year of the Ocean in Canada, you can visit our website at www.oceanscanada.com/iyo.

TECHNOLOGY MAKING WAVES AROUND THE WORLD

Don't miss the following events sponsored by Seimac at this congress:

- view our products at our exhibit booth
- leave your business card for a chance to win an exciting prize
- register for a tour of Seimac on Wednesday afternoon, June 3rd

Seimac provides a broad range of products and services to the oceanographic and meteorological communities. These include satellite telemetry equipment, oceanographic buoy products, mooring monitoring devices, integrated weather stations, site-specific weather forecasting services and both hardware and software design services.

BOOTH HIGHLIGHTS:

- Mooring Marker Locator - (MML) makes use of GPS and the ARGOS satellite system to continuously monitor the position and status of high value surface and subsurface buoys and moorings.
- RadarLink - offers clients the ability to access RADARSAT satellite imagery in near real time. It is ideal for use in marine monitoring applications.

You can identify Seimac employee at this congress by the blue tag attached to their name tag. Please come and visit us.

Incorporated in 1996, NSOI is a business network developed from the third largest "brain-trust" in the world in ocean related sciences. The group's objective is to provide solutions to the challenges in exploration and sustainable development of ocean resources. The delivery mechanism is innovative collaboration within an integrated, multi-sectoral, technology network.

Built on leading edge ocean sector organizations, the NSOI network combines the resources of universities, government labs, private sector specialists, plus NGO agencies and other industry associations in collaborative efforts for global ocean projects. NSOI also collaborates and partners with other ocean sector organizations, to increase our solutions capabilities, and ultimately, to increase the Oceans Industry contribution to Canada's GDP.

NSOI's role is to enhance communications and cooperation. The mechanism is the use of various business models (consortia, alliances, partnerships, business networks, etc.) in collaborative efforts to provide solutions to targeted global markets.

Plenary Speakers

Conférenciers des plénières

WOCE/CLIVAR **Session 1-A**
Lake City Ballroom Monday, June 1 - 09:25
Dr. N.C. Lau (GFDL/NOAA, Princeton U., Princeton, NJ)
Interactions between Global SST Anomalies and the Midlatitude Atmospheric Circulation

Biological Cycles & Ocean Biogeochemistry at High Latitudes 2-A
Lake City Ballroom Tuesday, June 2 - 09:05
Dr. L. Legendre (Dept. of Biology, Laval U., Quebec, QC)
Food Web Structure and Fluxes of Biogenic Carbon in Polar Marine Waters

Arctic Marine and Atmospheric Chemistry **Session 3-A**
Lake City Ballroom Wednesday, June 3 - 09:05
Dr. R. MacDonald (Institute of Ocean Sciences, Sidney, BC)
Contaminants in the Arctic Ocean - the importance of pathway

Forecasting the Coupled Atmosphere-Ocean System **Session 4-A**
Lake City Ballroom Thursday, June 4 - 09:05
Dr. Tim Stockdale (Euro. Cen. Med-Range Weather Forecasts)
Seasonal Prediction Studies with a Coupled Atmosphere-Ocean System at ECMWF

Invited Speakers

Conférenciers invités

WOCE/CLIVAR 1 **Session 1-B1**
Hawthorne Room Monday, June 1 - 10:30-10:11
Dr. Michael S. McCartney (WHOI, Woods Hole, MA)
The ocean in climate: the dilemma of midlatitude variability

Industry Day **Session 2-A**
Lake City Ballroom Tuesday, June 2 - 08:35-09:05
Mr. Cal Ross (Senior Environmental Advisor, SOE Inc.)
What the offshore industry requires from meteorologists and oceanographers

GLOBEC **Session 2-B3**
Alderney Room Tuesday, June 2 - 10:10-10:50
Dr. David G. Mountain (Nat. Mar. Fish. Serv., Woods Hole, MA)
U.S. GLOBEC - Climate Variability and Fisheries

Education Day **Session 3-B2**
Sullivan Room Wednesday, June 3 - 10:10-10:30
Dr. Nathalie Gauthier (Société Cyberscol Inc.)
The InterMET Project: Using the Internet to Improve the Teaching of Meteorology in Quebec High Schools

Education Day **Session 3-B2**
Sullivan Room Wednesday, June 3 - 11:10-11:50
Mr. David Phillips (Atmos. Env. Serv., Downsview, ON)
What's up with the weather?

Committee Meetings and Social Events

Réunions du comité et événements sociaux

Time	*Meeting/Event*	*Chair/Contact*	*Room*
SUNDAY MAY 31			
09:00-1700	Canadian National Comm. for SCOR	Brian Nicholls	MacNab A
09:00-1700	National Climate Network	Jacques Derome	MacNab B
09:00-12:00	Prizes & Awards	Dr. Moore	633
09:30-12:30	Publications	Richard Asselin	619
11:00-13:00	High School Met Issues	Gerhard Reuter	607
13:00-16:00	Science Committee	Charles Lin	633
13:00-16:00	CMOS Centre Chairs	Bill Pugsley	621
13:00-15:00	Education	Gerhard Reuter	719
15:00-17:00	Private Sector	Ambury Stuart	619
16:00-18:00	CMOS Council	Rob Cross	Windmill Rm.
MONDAY, JUNE 1			
17:30-19:00	Ice Breaker		Terrace
19:00-20:00	Future of AO	Richard Asselin	Hawthorne
20:00-22:00	Annual General Meeting		Sullivan-Alderney
TUESDAY, JUNE 2			
17:30-19:30	Industry Reception		
19:30-20:30	GLOBEC	John Loder	Hawthorne
WEDNESDAY, JUNE 3			
12:00-13:00	Teacher's Lunch		MacNab A&B
12:45-14:45	Patterson Lunch		Hawthorne-Sullivan
18:00-22:00	CMOS Reception & CMOS Awards Banquet		Lake City Ballroom

Week at A Glance

Un aperçu de la semaine

Monday June 1	Tuesday June 2	Wednesday June 3	Thursday June 4
Session 1-A 08:30-10:10 Lake City Ballroom 08:30 Env. Minister Christine Stewart 08:50 Open (G.Holland) 09:05 Exhibit Intros. O. Koren 09:25 WOCE Plenary Dr. N.C. Lau Chair: J. Derome	**Session 2-A** 08:30-09:50 Lake City Ballroom 08:30 Announcements 08:35 Industry Day C. Ross 09:05 Biolog. Cycles Dr. L. Legendre Chair: G. Harrison	**Session 3-A** 08:40-09:50 Lake City Ballroom 08:40 Announcements 08:45 Education Day S. Miller 09:05 Arctic Chemistry Dr. R. MacDonald Chair: L. Barrie	**Session 4-A** 09:00-09:50 Lake City Ballroom 09:00 Announcements 09:05 Forecasting Dr. T. Stockdale Chair: H. Ritchie
10:10-10:30 Health Break	09:50-10:10 Health Break	09:50-10:10 Health Break	09:50-10:10 Health Break
Session 1-B 10:30-12:30 B1- WOCE/CLIVAR I B2- Climate Modelling B3- Extreme Events	**Session 2-B** 10:10-12:10 B1- Biogeoch. Cycles B2- Long-range Forecst B3- GLOBEC I B4- Middle Atmosphere	**Session 3-B** 10:10-12:10 B1- Arctic Chemistry B2- Education B3- GEWEX/MAGS B4- Weather Forecast.	**Session 4-B** 10:10-12:10 B1- Forecasting B2- Boundary Layer B3- Air-sea Interac. I
12:30-13:40 Lunch	12:10-13:40 Lunch	12:00-13:00 Teacher's Lunch 12:45-14:45 Patterson Lunch	12:10-13:40 Lunch
Session 1-C 13:40-15:00 C1- WOCE/CLIVAR II C2- Air Quality C3- Coastal Oceanog. C4- Alt. Serv. Delivery	**Session 2-C** 13:40-15:00 C1- GLOBEC II C2- Ice Storm '98 I C3- Data Assimilation I	**Session 3-C** 13:00-15:00 C1-Teaching Discussion	**Session 4-C** 13:40-15:00 C1- Atmos. Mod. I C2- Cloud & Precip. C3- High-lat Proc.
15:00-15:20 Health Break POSTER SESSION	15:00-15:20 Health Break POSTER SESSION		15:00-15:20 Health Break
Session 1-D 15:20-17:00 D1- WOCE/CLIVAR III D2- Trends and Variab. D3- Coast. Oc. Model. D4- Radiation	**Session 2-D** 15:20-17:00 D1- GLOBEC III D2- Ice Storm '98 II D3- Data Assimil. II		**Session 4-D** 15:20-17:00 D1- Atmos. Mod. II D2- Grav. Waves&Mix D3- Air-sea Interac. II
17:30-19:00 Icebreaker Reception	17:30-19:30 Industry Reception	18:00-22:00 Reception CMOS Awards Banquet	
19:00-20:00 A-O Future	19:30-20:30 Can. GLOBEC Meeting		
20:00-22:00 CMOS Annual General Meeting			

am • Monday, June 1 Schedule • Horaire du lundi 1er juin • am

PLENARY SESSION 1-A: WOCE (JOHN REID) LAKE CITY BALLROOM

8:25 Welcoming remarks and introduction (**John Reid**)
8:30 Minister, Environment Canada (**Christine Stewart**)
8:50 Opening Address (**G.Holland**)
9:05 Exhibtors' Prestations (**Oscar Koren**)
9:25 1A1.1 **Dr. Ngar-Cheung Lau,** Interactions between Global SST Anomalies and the Midlatitude Atmospheric Circulation (Chair: Allyn Clarke)

10:10 - 10:30 Health Break

10:30-12:30 start times only	**Session 1-B1** **WOCE/CLIVAR I** **Chair: Ross Hendry** **Hawthorne Room**	**Session 1-B2** **Climate Modelling** **Chair: I. Rutherford** **Sullivan Room**	**Session 1-B3** **Extreme Events** **Chair: H. Hengeveld** **Alderney Room**
10:30	1B1.1 - The ocean in climate: the dilemma of mid-latitude climate variability **Mike McCartney**	1B2.1 -The Impact of Aerosols and Surface Forcings on Low-Frequency Atmospheric Circulations **Lionel Pandolfo** and Xuhua Li	1B3.1 - Climate Extremes Indices in Northern Climates **W.D. Hogg** and V.R. Swail
10:50	1B1.2 - The ocean in climate: the dilemma of mid-latitude climate variability **Mike McCartney**	1B2.2 - Radiative Characteristics of the Canadian Climate Center Third Generation General Circulation Model **Li Jiangnan**	1B3.2 - Spatial and temporal characteristics of heavy precipitation events in Canada **Xuebin Zhang**, W. D. Hogg, and Eva Mekis
11:10	1B1.3 - The Arctic Ocean and Global Thermohaline Circulation **E. P. Jones**, L. G. Anderson and B. Rudels	1B2.3 - The NARCM-LITE intercomparison study **L. Spacek**, J.-P. Blanchet, R. Hoff, L. Barrie, S. Gong, H. Leighton and Q. Song	1B3.3 - Changes in Cyclone Frequencies and Strengths in a Transient Enhanced Greenhouse Warming Simulation **Steven J. Lambert**
11:30	1B1.4 - Circulation and overflow in the Denmark Strait in fall 1997 **Bert Rudels**, Grsnvall Hannu, Riikka Hietala and Jouko Launiainen	1B2.4 - Impact of different model physics on the distribution of sulphate aerosols **Ulrike Lohmann**, N. A. McFarlane and Johann Feichter	1B3.4 - The Saxby Gale Part 1 **Jim Abraham** and George Parkes
11:50	1B1.5 - Measurements of North Atlantic Current Volume and Heat Transport **R.M. Hendry**, I.M. Yashayaev and R.A. Clarke	1B2.5 - Sensitivity experiments of a 1.5 dimensional climate model **Zhaomin Wang** and Lawrence A. Mysak	1B3.5 - The Sable Gale Part II, The Saxby Tide and Other Storm Surge Events in the Bay of Fundy **G.S. Parkes**, L.A. Ketch and C.T.O'Reilly
12:10	1B1.6 - Deep Circulation in the Equatorial Atlantic Ocean in January-February 1993 **M. Lux**, H. Mercier and M. Arhan		1B3.6 - The Saxby Gale Part III, Forensic Study of the Impacts **Alan Ruffman**

12:30-13:40 LUNCH

pm

13:40-15:00 start times only	**Session 1-C1** **WOCE/CLIVAR II** **Chair: R. Greatbatch** **Hawthorne Room**	**Session 1-C2** **Air Quality** **Chair: L. Barrie** **Sullivan Room**	**Session 1-C3** **Coastal Oceanography** **Chair: P. Cummins** **Alderney Room**	Session 1-C4 **Alt. Service Delivery** Chair: D. O'Neill *McNabs Room*

	Atlantic and North Pacific Oceans *Igor Yashayaev and Igor Zveryaev*	Brunswick **Claude Cote**, Mike Howe and David Waugh	with application to Georges Bank **C. G. Hannah**, John W. Loder, Shen Yingshuo and Zhigang Xu	Atmospheric Environment Program, **David Grimes**
14:00	1C1.2 - Water Masses and Circulation in the North-West Atlantic at the End of the Twentieth century **Igor Yashayaev** and Allyn Clarke	1C2.2 - An Evaluation of the CANFIS - Statistical Model prediction of ground level ozone concentrations for the Saint John area in 1997 **David Waugh**, Dr. Bill Burrows and Jacques Montpetit	1C3.2 - A Method for Estimating the Flocculation Time of Monodispersed Sediment Suspensions **Elizabeth A. Gonzalez** and Paul S. Hill	1C4.2 - Alternate Service Delivery Study of the Atmospheric Environment Program, **David Grimes**
14:20	1C1.3 - Modeling upper ocean winter processes in the Labrador Sea **C.L. Tang**, Q.Gui and B.M. DeTracey	1C2.3 - On Transport Affecting the Canadian Southern Atlantic Region Oxidants-Observation and Modelling During the Atlantic 96 Intensive Period **Wanmin Gong**, Frank Froude, Steven Beauchamp, Sylvain Menard	1C3.3 - Thermocline and Circulation Modelling of Conception Bay Newfoundland **Fraser J.M. Davidson**, R.J.Greatbatch and B. de Young	Discussion
14:40	1C1.4 - Modelling the North Atlantic General Circulation **D.G. Wright**, D. Brickman and J. Bobanovic	1C2.4 - Regional to Urban Scale Modelling of Air Quality With an On-line Photochemical Model **D. A. Plummer**, L. Neary, J. W. Kaminski and J. C. McConnell	1C3.4 - The Effect of an Undercurrent on Upwelling Through a Canyon **S E Allen**, X Chen, C Vindeirinho and R E Thomson	Discussion
15:00-15:20	**Health Break, Poster Session and Exhibits**			
15:20-17:00 start times only	**Session 1-D1** **WOCE/CLIVAR III** **Chair: D. Wright** **Hawthorne Room**	**Session 1-D2** **Trends & Variability** **Chair: W. Hogg** **Sullivan Room**	**Session 1-D3** **Coastal Oc. Modelling** **Chair: C. Hannah** **Alderney Room**	**Session 1-D4** **Radiation** **Chair: W. Evans** **McNabs Room**
15:20	1D1.1 - Vertical mixing in the upper pycnocline **Dan Kelley**	1D2.1 - Regional Patterns of Temperature and Precipitation for Newfoundland and Labrador during the Past Century **Colin E.Banfield**, J. D. Jacobs	1D3.1 - Tides of the Northwest Atlantic Calculated Using the CANDIE Circulation Model with a Free Surface **Youyu Lu**, Keith R. Thompson and Jinyu Sheng	1D4.1 - A Review of Measurements of Surface Radiative Forcing by Greenhouse Gases **Wayne F. J. Evans** and Eldon Puckrin
15:40	1D1.2 - Parameterizing mesoscale eddy transport in ocean circulation models **Richard J. Greatbatch**	1D2.2 - Synoptic-scale flow patterns associated with storm track variability over Atlantic Canada **Shawn S. Allan** and John Gyakum	1D3.2 - Modelling Diurnal Tides and Coastal-Trapped Waves off Vancouver Island **Patrick F. Cummins** and Micheal G.G. Foreman	1D4.2 - Consequences of high Resolution Topography on Radiation Balance and Aerosol Circulation in NARCM **Fabien Zuretti**, Jean-Pierre Blanchet and R. Laprise
16:00	1D1.3 - Model Simulations Using Mesoscale Eddy Parameterisations Implemented In The Momentum Equations Of An Ocean General Circulation Model **Guoqing Li** and R. Greatbatch	1D2.3 - Persisting Dewpoint and Point PMP for the Prairie Provinces **R.F. Hopkinson**	1D3.3 - Numerical Modelling of the Gaspe Current **Mateusz K. Reszka** and Gordon E. Swaters	1D4.3 - Application of NARCM to the Earth Radiation Mission Measurement Synergetics **J.-P. Blanchet**, M. Larocque, P. Park, S.R. Pal, L. Spacek, R. Girard, M.W.P. Cann, D. Donovan
16:20	1D1.4 - The Parametrization of Eddies using Frontal-Geostrophic Models **Richard Karsten** and Gordon Swaters	1D2.4 - A Temperature-Precipitation Departure Index as an Indicator of Climate Variability - A Case Study of the Maritime Provinces of Canada **Peter J. Lewis** and I.E. MacSwain	1D3.4 - Seasonal-mean and tidal circulation on the eastern Scotian Shelf **Guoqi Han** and John W. Loder	1D4.4 - On the Coupling Aerosol Radiative Properties to Prognostic Aerosols in NARCM **J.S. Fontecilla**, J.-P. Blanchet and L. Spacek
16:40	1D1.5 - Vorticity fluxes in a shallow water ocean model **K. Andrew Peterson**, R.J. Greatbatch and Dwayne Hart	1D2.5 - Evidence of Natural Variability in Climate Change during the Past Millenium and Its Possible Role in Current and Future Trends **M.R. Morgan** and R. Pocklington	1D3.5 - What is the influence of indented walls on the oceanic circulation? **Frederic Dupont**, David Straub and Charles A. Lin	

am • Tuesday, June 2 Schedule • Horaire du mardi 2 juin • am

PLENARY SESSION 2-A: INDUSTRY DAY AND BIOLOGICAL CYCLES - LAKE CITY BALLROOM

8:30 Announcements
8:35 2A1.1 **Cal Ross**, What the Offshore Industry Requires from Meteorologists and Oceanographers.
9:05 2A1.2 **Dr. L. Legendre**, Food-web structure and fluxes of biogenic carbon in polar marine waters (Chair: G. Harrison)

09:50-10:10 Health Break and Exhibits

10:10-12:10 start times only	**Session 2-B1** **Biogeochemical Cycles** **Chair: Glen Harrison** **Hawthorne Room**	**Session 2-B2** **Long-range Forecasting** **Chair: J. Derome** **Sullivan Room**	**Session 2-B3** **GLOBEC I** **Chair: P. Smith** **Alderney Room**	Session 2-B4 Middle Atmosphere **Chair: J. McConnell** McNabs Room
10:10	2B1.1 - Abundance of bacteria in the Labrador Sea **W.K.W. Li**	2B2.1 - Surface temperature anomaly forecasts over periods ranging from five to ninety days **R. Verret**, A. Bergeron, L. Lefaivre and A. Plante	2B3.1 - U.S. GLOBEC - Climate Variability and Fisheries **David G. Mountain**	2B4.1 - The Canadian Middle Atmosphere Model **S.R. Beagley**, J. de Grandpré, J.N. Koshyk, N.A. McFarlane and T.G. Shepherd
10:30	2B1.2 - On The Ecology Of Calanus Spp. In The Labrador Sea. **Erica Head**, Leslie Harris and Robert Campbell	2B2.2 - Numerical Simulation of the Atmospheric Response to Middle Latitude SST Anomalies in the Northeast Pacific **Hua Sheng** and Harold Ritchie	2B3.2 - U.S. GLOBEC - Climate Variability and Fisheries **David G. Mountain**	2B4.2 - On the climatology of atmospheric constituents in the Middle Atmosphere **J. de Grandpré**, S.R. Beagley, J.C. McConnell and J.W. Sandilands
10:50	2B1.3 - Dissolved Organic Carbon (DOC) in the Labrador Sea **P.E.Kepkay** and J.B.C.Bugden	2B2.3 - A new predictor for winter conditions over the North Pacific and North America **Hai Lin** and Jacques Derome	2B3.3 - Interannual Variability Of Boundary Fluxes And Water Mass Properties In The Gulf Of Maine And On Georges Bank **Peter C. Smith**, Robert W. Houghton, R.G. Fairbanks and D.G. Mountain	2B4.3 - Aircraft emission and its potential impact on the middle atmosphere ozone photochemistry **J. de Grandpré**, J.C. McConnell, S.R. Beagley and D.J. Chartrand
11:10	2B1.4 - Modeling DOC export in the Labrador Sea **Rucheng Tian** and Alain F. Vezina	2B2.4 - Long-Range Prediction of the Yield and Protein Content of Western Canadian Durum Wheat **J.C. Babb** and E.R. Garnett	2B3.4 - Water And Current Properties On Western Bank **Gleb Panteleev**, Brad deYoung, A. Bowen, C. Reiss and C. Taggart	2B4.4 - Heterogeneous chemistry modeling in the Chemistry Transport Model (CTM) **J.C. McConnell**, D.J. Chartrand and Edna Templeton
11:30	2B1.5 - Dynamics of Bacterial Dimethylsulfide (DMS) Production from Dissolved Dimethyl-sufoniopropionate (DMSPd) in the Labrador Sea. **S. Schultes** M. Levasseur, S. Michaud, G. Cantin, M. Gosselin and S.J. de Moral	2B2.5 - Climate Variability In A Simple Atmospheric Gcm With Constant Forcing **Nick Hall**	2B3.5 - Prediction of surface currents on the northern British Columbia Shelf **W.R. Crawford**, J.Y. Cherniawsky and Patrick F. Cummins	2B4.5 - The role of an anisotropic gravity wave spectrum in maintaining the circulation of the middle atmosphere **A.S. Medvedev**, G.P. Klaassen
11:50	2B1.6 - A tracer of anthropogenic CO2 in the Labrador Sea region **V. K. Tait**, R. M. Gershey, E. P. Jones, I. Yashayaev and J. R. N. Lazier	2B2.6 - On the relationship between the PNA pattern and the atmospheric predictability **Jian Sheng**	2B3.6 - UW-NMS performance in the coastal waters and interior of British Columbia **Henryk Modzelewski** and R. Stull	

12:10-13:40 LUNCH and EXHIBITS

pm

13:40-15:00 start times only	**Session 2-C1** **GLOBEC II** **Chair: W. Crawford** **Hawthorne Room**	**Session 2-C2** **Ice Storm '98 I** **Chair: J. Abraham** **Sullivan Room**	**Session 2-C3** **Data Assimilation I** **Chair: M. Tanguay** **Alderney Room**	

	J. W. Loder, Shen Yingshuo and C.E. Naimie		Judy St-James and Pierre Gauthier
14:00	2C1.2 - Hindcasting Circulation over Eastern Canadian Shelves: Progress and Prospects **Jinyu Sheng** and K.R. Thompson	2C2.2 - The Ice Storm of 1998 **John R. Gyakum**	2C3.2 - Background error statistics modelling in a 3D variational data assimilation scheme: estimation and impact on the resulting weather forecasts **Mark Buehner** and Pierre Gauthier
14:20	2C1.3 - Influence of submarine canyons on zooplankton aggregation **Carine Vindeirinho**, S.E. Allen and Richard E. Thomson	2C2.3 - The Operational Forecasters' Challenge **Gilles Babin** and Jennifer Milton	2C3.3 - Some Statistical Considerations Associated with the Data Assimilation of Precipitation Observations **Luc Fillion**, Ronald Errico, Douglas Nychka and Zhan-Qian Lu
14:40	2C1.4 - Comparison of Two Instruments and Methods for Estimating Turbulent Dissipation Rate **Barry Ruddick** and Dave Walsh	2C2.4 - Canadian Freezing Drizzle Project III: More drizzle than we ever thought. **G.A. Isaac**, S.G. Cober, A.V. Korolev, J.W. Strapp, A. Tremblay and D.R. Marcotte	2C3.4 - Occurence And Impacts Of Discontinuities Of The Ras Moist-Convective Parameterization Scheme For Variational Data Assimilation With Physics **Jean-Marc Belanger** and L. Fillion
15:00-15:20	**"Health Break, Poster Session and Exhibits"**		
15:20-17:00 start times only	**Session 2-D1** **GLOBEC III** **Chair: P. Smith** **Hawthorne Room**	**Session 2-D2** **Ice Storm '98 II** **Chair: J. Abraham** **Sullivan Room**	**Session 2-D3** **Data Assimilation II** **Chair: M. Tanguay** **Alderney Room**
15:20	2D1.1 - Recent Observations Of The Distribution Of Calanus Finmarchicus On And Around The Scotian Shelf In Spring **E. Head**, L. Harris and B. Petrie	2D2.1 - Storm Details **Stan Siok**	2D3.1 - Statiform versus Convective Precipitation in the Context of Variational Data Assimilation **Philippe Segers** and Luc Fillion
15:40	2D1.2 - Long Term Changes in Zooplankton and Phytoplankton on the Scotian Shelf **Doug Sameoto**	2D2.2 - Client Needs: Insurance Industry **Heather Auld**	2D3.2 - Sensitivity analysis with the global variable resolution GEM model **Monique Tanguay** and Saroja Polavarapu
16:00	2D1.3 - Coupling of the life-cycle of Calanus finmarchicus with the hydrodynamics of the Gulf of St. Lawrence-Scotian Shelf System **B. Zakardjian**, Y. Gratton, S. Plourde, J. A. Runge, K. Thompson	2D2.3 - Direct Ice Measurements in Quebec **Jean Laflamme**	
16:20	2D1.4 - Larval Fish Assemblages on the Scotian Shelf: is spatial distribution a function of water mass characteristics or surface circulation patterns. **C. Reiss**, G.Panteleev, C.T. Taggart, and B. deYoung"	2D2.4 - Return Period Analysis of the January, 1998 Ice Storm in Eastern Canada **Arnold Ashton**	
16:40	2D1.5 - Climate Variability and Ecosystem Response in a Box Model of the Strait of Georgia and Juan de Fuca Strait **Ming Li**, K. Denman, A. Gargett, Dave Mackas and Dick Beamish	2D2.5 - El Nino and Climate Change as Possible Factors in the 1998 Ice Storm **Henry Hengeveld** and Amir Shabbar	
17:00		2D2.6 - AEP Program Assessment: How well did we do? **Joe Shaykewich** and Pierre Tourigny	

am • Wednesday, June 3 Schedule • Horaire du mercredi 3 juin • am

Plenary Session 3-A: Education Day and Arctic Chemistry - Lake City Ballroom

8:40 Announcements
8:45 Steve Miller, Education Day
9:05 **Dr. Robbie MacDonald**, Contaminants in the Arctic Ocean - the importance of pathway (Chair: L. Barrie)

09:50-10:10 Health Break and Exhibits

10:10-12:10 start times only	Session 3-B1 Arctic Chemistry Chair: John Smith Hawthorne Room	Session 3-B2 Education Chair: Steve Miller Sullivan Room	Session 3-B3 GEWEX/MAGS Chair: J. Gyakum Alderney Room	Session 3-B4 Weather Forecasting Chair: W. Appleby McNabs Room
10:10	3B1.1 - An Arctic Haze Simulation with NARCM **J.-P. Blanchet**, L. Barrie, H. Leighton, S. Gong, Q. Song and L. Spacek	3B2.1 - The InterMET Project: Using the Internet to Improve the Teaching of Meteorology in Quebec high schools **N. Gauthier**	3B3.1 - The Canadian Climate Research Network Land Surface Node -- The First Three Years **Diana Verseghy**	3B4.1 - Efficiency through automation **R. Verret**, D. Vigneux, F. Petrucci , L. Pelletier, J. Marcoux, C. Landry, G. Hardy
10:30	3B1.2 - The anthropogenic aerosols in Arctic **Eric Girard**, Jean-Pierre Blanchet	3B2.2 - Environment Canada's, Prairie and Northern Region, Warning Preparedness Meteorologist... A New Link to the Education Community. **John Parker**	3B3.2 - Predicting Monthly Energy and Water Budgets over the Mackenzie River Basin using the Canadian Land Surface Scheme **Ekaterina Radeva** and H. Ritchie	3B4.2 - Aviation Weather Analysis and Forecasting for Airports Using a One-Dimensional Numerical Model **Robert Tardif**, Peter Zwack, Anne Frigon and Andre April
10:50	3B1.3 - Circulation Features in the Western Arctic Ocean Revealed by Tracers from European Nuclear Fuel Reprocessing Plants **John N. Smith**, Katherine M. Ellis and Timothy Boyd	3B2.3 - ""The Weather Forecaster at Discovery Centre **Blair J.W. Greenan**, F.W. Dobson, Jim Abraham and Steve Miller	3B3.3 - Atmospheric moisture budget over Mackenzie basin **Muyin Wang**, Geoff Strong, Alan Barr and Brian Proctor	3B4.3 Normalization Techniques for the Verification of Aviation Forecasts **Kent A. Johnson**
11:10	3B1.4 - Are polynyas a problem for high resolution sea ice models? **Halldor Bjornsson** and L.A. Mysak	3B2.4 - What's up with the weather **Dave Phillips**	3B3.4 - Diurnal Variations in Atmospheric Moisture during GEWEX/MAGS **G.S. Strong**	3B4.4 - Verification **Phil Chadwick**
11:30	3B1.5 - Modelling the Interannual Variability of the Arctic sea ice cover **Gilles Arfeuille** and L. A. Mysak	3B2.5 - What's up with the weather **Dave Phillips**	3B3.5 - Solar Radiation Budgets for MAGS **J. Feng** and H.G. Leighton	
11:50	3B1.6 - Singular Value Decomposition of Arctic Sea Ice Cover and Overlying **Dingrong Yi**, L. A. Mysak and S. A. Venegas		3B3.6 - An Enhanced Data Collection Period for the Mackenzie GEWEX Study **B. Kochtubajda** and G.S. Strong	
12:00-13:00	**Teacher's Lunch**			**pm**
12:45-14:00	**Patterson Award Luncheon**			

POSTER SESSIONS: MONDAY (JUNE 1) AND TUESDAY (JUNE 2)

Exhibit Area: Harbour and City Terraces

P1 - Variability in Phytoplankton Biomass
Glen Harrison, Trevor Platt, John Loder and Brian Petrie

P2 - Remote Sensing of Ocean Color and Sea Surface Temperature in the Labrador Sea
Glenn F. Cota, Trevor Platt, Shubha Sathyendranath and Glen Harrison

P3 - Near-Surface Measurements of Ocean Turbulence with a Tethered Free-Fall Glider
Blair J. W. Greenan, Neil S. Oakey and Fred W. Dobson

P4 - Computer Atlas of the North-West Atlantic **Igor Yashayaev** and Allyn Clarke

P5 - Remote Video Acquisition System-A Canadian Approach
David Wartman and Ben Hunter

P6 - Filling the Pacific Data Void with Tethered Guided Balloons (TGBs)
Roland B. Stull and Ron McTaggart-Cowan

P7 - Weather Prophecies of E. Stone Wiggins
John D. Reid

P8 - Climate-Driven Variability of Primary Productivity in the Northwest Passage on Interannual and Seasonal Scales
Glenn F. Cota and W. Glen Harrison

P9 - The North Atlantic Ocean
Robert J. Anderson, F.W. Dobson and Albert J. Hartling

P10 - Global Ocean Ecosystem Dynamics (GLOBEC) Canada: Northewest Altantic and Northeast Pacific Studies.

P11 - Modelling the vertical transport of trace gases in reservoir
Nathalie Barrette, René Laprise" and Marc Lucotte

P12 - Characteristics of Winter Leads and Polynyas over the Arctic Basin from 85.5 GHz DMSP SSM/I and NOAA/AVHRR Imagery
T.A Agnew, L. Le and M. Shokr

P13 - An Interactive Aviation Weather Database
R. Verret, M.-F. Turcotte, V. Souvanlasy and M. Baltazar

P14 - BiNet Xplorer: A software to Explore Radar Bistatic Data
Christian Page, Isztar Zawadzki and Alain Protat

am • Thursday, June 4 Schedule • Horaire du jeudi 4 juin • am

PLENARY SESSION 4-A: FORECASTING - LAKE CITY BALLROOM

9:00 Announcements
9:05 **Dr. Tim Stockdale**, Seasonal Prediction Studies with a Coupled Atmosphere-Ocean System at ECMWF (Chair: H. Ritchie)

09:50-10:10 Health Break and Exhibits

10:10-12:10 start times only	**Session 4-B1** **Forecasting** **Chair: K. Thompson** **Hawthorne Room**	**Session 4-B2** **Boundary Layer Meteorol.** **Chair: P. Taylor** **Sullivan Room**	**Session 4-B3** **Air-sea Interaction I** **Chair: F. Dobson** **Alderney Room**
10:10	4B1.1 - The Atlantic Environmental Prediction Research Initiative **Harold Ritchie**	4B2.1 - Modelling longitudinal vortices in boundary-layer airflow over 2D wavy surfaces Wensong Weng, Stefano Gallino and **Peter Taylor**	4B3.1 - On The Climatology Of Surface Marine Winds Near The Western Coast Of Canada **Manon Faucher**, Lionel Pandolfo and William R. Burrows
10:30	4B1.2 - Development of a 15 km Model at the Canadian Meteorological Center **Gérard Pellerin**, André Methot, Richard Moffet and Alain Patoine	4B2.2 - Stably-Stratified Flow Over Hills, and Wave Drag Jingnan Zhou, Yoseph Mengesha, **Peter A Taylor** and Ying Qi	4B3.2 - The Impact of Air-Sea Coupled Dynamics on Ocean Waves **William Perrie**, Liangming Wang and Bash Toulany
10:50	4B1.3 - The Use of Coupled Meteorological and Hydrological Models at Regional Scale **Pierre Pellerin**, H. Ritchie, R. Benoit, N. Kouwen and R. Soulis	4B2.3 - Guidelines Model Developments Joyce Kwan, James Salmon, Peter Taylor, John Walmsley and **Wensong Weng**	4B3.3 - Impact of a Coupled Atmospheric and Ocean Wave System on the atmospheric and ocean wave forecasts **Serge Desjardins**, Jocelyn Mailhot, Roop. Lalbeharry and Laurie Wilson
11:10	4B1.4 - Water Level Forecast of the St. Lawrence River **D. Lefaivre**, M. Gaulin, B. Tessier, B. Morse, G. Ouellette, N. Roy " and S. Dumont	4B2.4 - A One-and-Half Order Closure Model of the Translient Turbulence Matrix **H. Modzelewski** and Roland Stull	4B3.4 - The influence of the mesoscale feature of the SST distribution on the marine boundary layer winds during the Storm of the Century **Serge Desjardins**
11:30	4B1.5 - Application of A Direct Inverse Method to Tidal Modelling on the Newfoundland and Labrador Shelves **Zhigang Xu**, R. Hendry and J. Loder	4B2.5 - Boundary Layer Wind and Temperature Profiles in the Radix Layer **Edi Santoso** and Roland Stull	4B3.5 - On the Dynamics of Surface Marine Winds near the Western Coast of Canada **Manon Faucher**, Lionel Pandolfo
11:50	4B1.6 - An integrated forecast system for short-term ice-ocean forecasts **C.L. Tang** and B.M. DeTracy		4B3.6 - Wave Hindcasts Forced by Remotely-Sensed Wind Fields **William Perrie**, Bash Toulany and Michael Dowd

12:10-13:40 LUNCH and EXHIBITS

pm

13:40-15:00 start times only	**Session 4-C1** **Atmospheric Modelling I** **Chair: H. Ritchie** **Hawthorne Room**	**Session 4-C2** **Cloud & Precip. Physics** **Chair: G. Isaac** **Sullivan Room**	**Session 4-C3** **High Latitude Processes** **Chair: D. Kelley** **Alderney Room**
13:40	4C1.1 - Implementation Of A New Forecast And Assimilation System Based On The Unified GEM Model At CMC Michel Roch, Stephane Laroche	4C2.1 - Blowing Snow Modelling with Pietuk-Comparisons with Schmidt's Field Data **Jingbing Xiao**, Stephen Dery " and Peter Taylor	4C3.1 - Sea-ice anomalies and atmospheric circulation in the Arctic Ocean **S. A. Venegas** and L. A. Mysak

14:00	4C1.2 - Applications of Ensemble Forecasts at the Canadian Meteorological Centre **Louis Lefaivre**, Peter L. Houtekamer, Alain Bergeron and Richard Verret	4C2.2 - Joint Distributions of Temperature and Moisture in the Convective Planetary Boundary Layer, A Cumulus Population Factor" **Larry Berg** and Roland Stull	4C3.2 - Modelling Flow Through the Arctic Archipelago **David A. Greenberg**
14:20	4C1.3 - Ensemble Forecast Generation by Selective Introduction of Hazardous Modes **Joshua Hacker** and Roland Stull	4C2.3 - Measurement of Water Vapour Mixing Ratios Using the Purple Crow Raman Scattering Lidar **C. Bryant**, S. Argall, R. J. Sica and R. M. Hoff	4C3.3 - Thermohaline Intrusions in the Arctic Ocean **Brian D. May** and Dan E. Kelley
14:40	4C1.4 - SocioEconomic Benefit of Ensemble Weather Forecasts in SW British Columbia **Sarah Lowes** and Roland Stull	4C2.4 - Cloud droplet spectra formation by ripening process **Fikrettin Celik** 4C2.5 - Ripening Process in Polluted and Ocean Stratoform Clouds F. Celik	4C3.4 - A dynamical model for ice drift based on the air-ice-ocean momentum exchange **Will Perrie** and Yongcun Hu
15:00-15:20	**Health Break**		
15:20-17:00 start times only	**Session 4-D1** **Atmospheric Modelling II** **Chair: Pierre Dubreuil** **Hawthorne Room**	**Session 4-D2** **Gravity Waves & Mixing** **Chair: N. Oakey** **Sullivan Room**	**Session 4-D3** **Air-sea Interaction II** **Chair: W. Perrie** **Alderney Room**
15:20	4D1.1 - On the Baroclinic Response of Spatially-Averaged Eulerian and Semi-Lagrangian Treatments of Mountains **Harold Ritchie**, Monique Tanguay, Real Sarrazin and Jocelyn Mailhot	4D2.1 - Linear Stability of Inertio-gravity Waves **Ka-Hing Yau**, Gary Klaassen and Len Sonmor	4D3.1 - Estimation of Ocean Waves using SAR Image Cross-Spectra **Michael Dowd**, Paris W. Vachon, Fred W. Dobson and Richard B. Olsen
15:40	4D1.2 - Lake Breeze Modelling with MC2 Ying Qi, **Xin Qiu**, D. Sills and P. Taylor	4D2.2 - Broad-spectrum effects on gravity-wave interactions **Len Sonmor** and Gary Klaassen	4D3.2 - Validation of ERS-2 scatterometer winds in Storm Wind Study II **Yuri S. Geshelin** and F.W. Dobson
16:00	4D1.3 - Comparison and Validation of the RPN-MC2 and UW-NMS Mesoscale Weather Forecast Models for Spring 1997 **H. Modzelewski**, J. Hacker and R. Stull	4D2.3 - Shear Excitation of Large Amplitude Internal Waves Observed in the Laboratory **B.R. Sutherland** and P.F. Linden	4D3.3 - On the Relationship Between Ship and Buoy Wind Speeds **Bridget Thomas**
16:20	4D1.4 - Improvements to the Canadian Global Spectral Forecast Model in Support of the Middle Atmosphere Initiative **Harold Ritchie**, Nils Ek and Christiane Beaudoin	4D2.4 - An airborne case study of evolving Kelvin-Helmholtz waves **Fikrettin Celik**	4D3.4 - Shipboard measurements of air-sea fluxes in the Labrador Sea **R.J. Anderson** and F.W. Dobson
16:40		4D2.5 - Mixing in a Coastal Environment **Neil S. Oakey** and B.J.W. Greenan	4D3.5 - Wind stress and wave measurements in storm force winds **Fred W. Dobson**, R.J. Anderson, Peter K. Taylor and Robin Pascal

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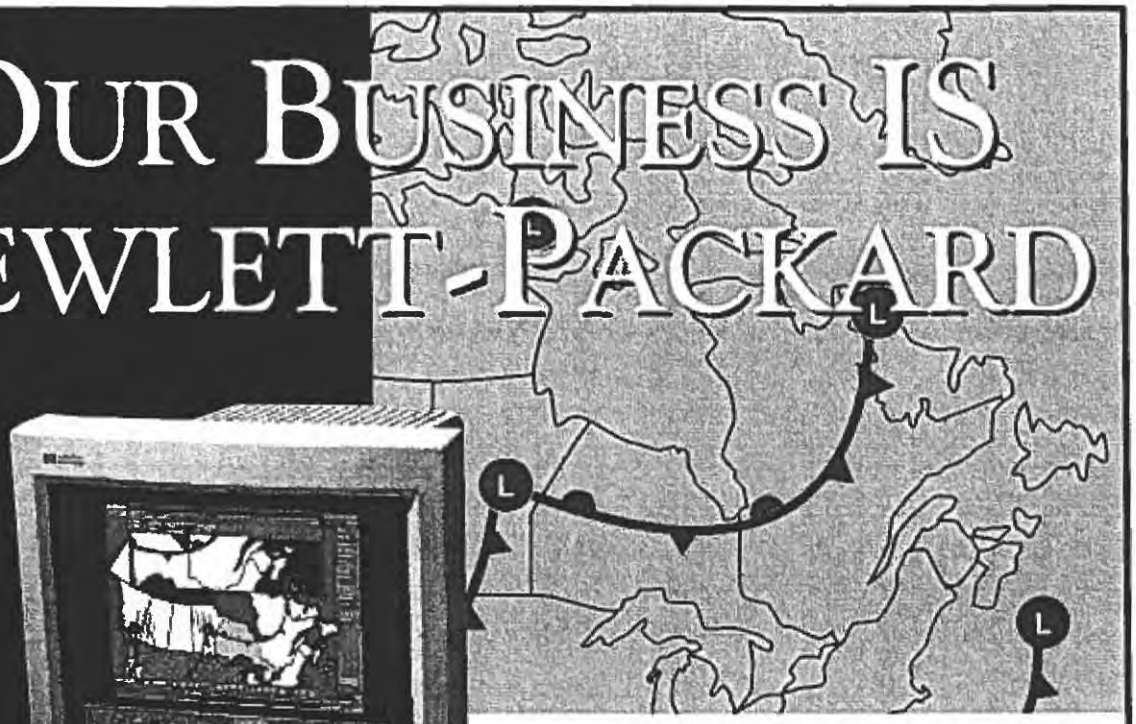

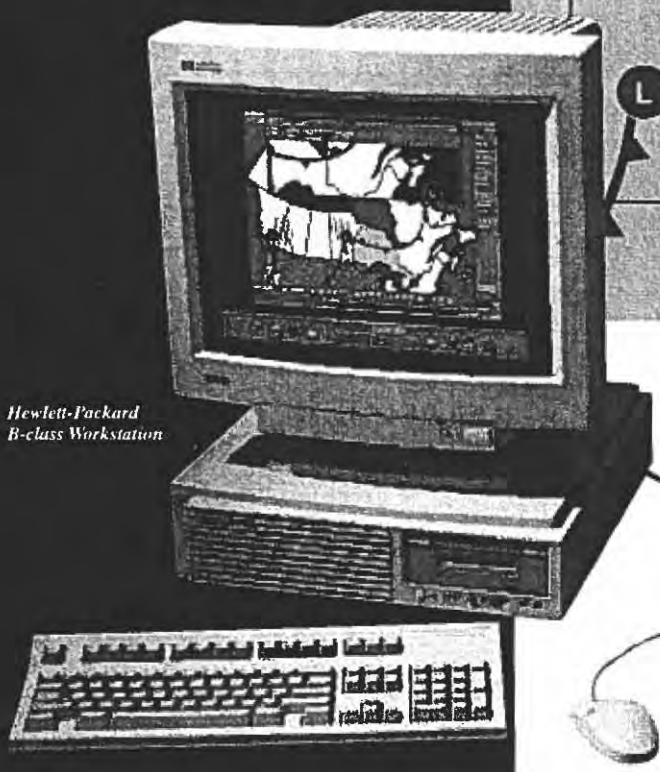

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Coding Explanation

Explication des codes de résumés

Each paper has been given a unique 4-part code that serves to locate it in time and space.

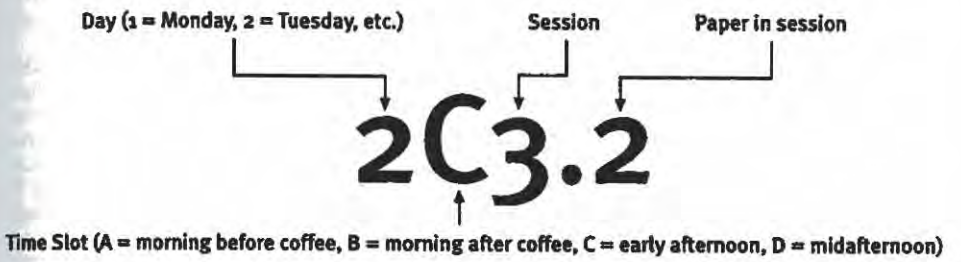
digit (1-4) denoting the day (Mon-Thurs)

letter (A-C) denoting the part of the day (plenary, morning, afternoon)

digit (1-4) denoting which of the up to 4 parallel sessions it is in

digit (1-n) denoting the consecutive number of the paper's time slot within a session

EXAMPLE:
2C3.5 denotes the paper in the 5th time slot of session 3 on the afternoon of Tuesday



Session 1-A
WOCE

Monday, June 1
08:30 - 10:10
Lake City Ballroom

1A.1
Interactions between Global SST Anomalies and the Midlatitude Atmospheric Circulation Ngar-Cheung Lau (1) ((1) Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University)

A review is given of the processes contributing to variability of the atmosphere-ocean system on interannual time scales. Particular emphasis is placed on the relationships between midlatitude atmospheric fluctuations and sea surface temperature (SST) anomalies in various geographical sites. Various hypotheses are tested using output from a coordinated set of general circulation model (GCM) experiments, which are subjected to time-varying SST forcing observed during the past few decades in different parts of the world's oceans. It is demonstrated that tropical Pacific SST fluctuations associated with El Nio-Southern Oscillation (ENSO) episodes produce a strong extratropical response in the model atmosphere, whereas the atmospheric signal associated with midlatitude SST anomalies is less robust. Analysis of a 100-year control experiment, which is conducted in the absence of any interannual SST forcing, indicates that a substantial fraction of the simulated atmospheric variability may be attributed to internal dynamical processes alone.

The observed coexistence of tropical ENSO events with SST anomalies in the extratropical North Pacific is successfully reproduced by forcing the model atmosphere with tropical Pacific SST variations, and allowing the atmospheric perturbations thus generated to drive a simple ocean mixed layer model inserted at ocean grid points outside the tropical Pacific. This simulation affirms the role of the atmospheric circulation as a "bridge" linking SST changes in different parts of the world's oceans.

Session 1-B1
WOCE/CLIVAR 1

Monday, June 1
10:10 - 12:10
Hawthorne Room

1B1.1 & 1B1.2
The ocean in climate: the dilemma of mid-latitude climate variability
Mike McCartney (1) ((1) Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA)
(unavailable)

1B1.3
The Arctic Ocean and Global Thermohaline Circulation
E. P. Jones (1), L. G. Anderson (2) and B. Rudels (3) ((1) Bedford Insititute of Oceanography, (2) Department of Analytical and Marine Chemistry, Goteborg University, Sweden, (3) Finnish Institute for Marine Research, Helsinki, Finland)

The global conveyor belt symbolizes global ocean circulation and the ocean's role in climate and climate change by portraying pathways for oceanic heat transport. Convection in the Greenland and Iceland Seas has been described as a main driving force of the global conveyor belt, feeding dense water over the Greenland-Scotland Ridge into the deep North Atlantic and subsequently throughout most of the ocean. The question we address is not what waters may be present in the outflow over the Greenland-Scotland Ridge, but where the water that drives the outflow is formed. We present a plume entrainment box model based on shelf-slope processes that occur within the boundaries of the Arctic Ocean and constrained by tracer distributions within the deep basin. These tracers, whose source is the atmosphere, can enter the deeper water, below 500 m, only through convection processes, i.e., plumes within the Arctic Ocean. The model shows that the volume of water formed in the Arctic Ocean below 500 m is about five times greater than the volume formed in the Greenland Sea below the same depth. We conclude that the Arctic Ocean is the main driver of the Greenland-Scotland outflow contributing to the global conveyor belt.

1B1.4
Circulation and overflow in the Denmark Strait in fall 1997
Bert Rudels (1), Grsnvall Hannu (1), Riikka Hietala (1) and Jouko Launiainen (1) ((1) Finnish Institute of Marine Research)

The Arctic Mediterranean Sea is the main source for North Atlantic Deep Water. Atlantic Water is transformed, north of the Greenland-Scotland Ridge,into a low salinlity and low density surface mode and into a high density mode, comprising the various intermediate and deep water masses, which originate in the different seas. The formed water masses eventually join the East Greenland Current and flow southward. Most waters pass through Denmark Strait into the Norh Atlantic , the denser waters to supply the North Atlantic Deep Water. In Fall 1997 RV Aranda of the Finnish Institute of Marine Research conducted, as a part of the EC supported VEINS programme, a CTD survey in the Denmark Strait. The observations show that the densest water rises high on the Iceland continental slope, suggesting a circulation eastward north of the strait. The intermediate waters, comprising the temperature maximum, do not join this flow and pass through the strait. Downstream of the strait the overflow plume is stratified and frequently capped with a low salinity layer, probably originating in the Arctic Ocean. This low salinity layer is upstream located high in the water column and does not have to flow through the deeper part of the strait. It may pass over the shallower shelf area to the west and then sink down the slope. The survival of such a low salinity lid down to 2000m implies a small entrainment rate of ambient water into the plume.

1B1.5
Measurements of North Atlantic Current Volume and Heat Transport
R.M. Hendry (1), I.M. Yashayaev (1) and R.A. Clarke (1) ((1) Fisheries and Oceans Canada, Bedford Institute of Oceanography)

Atlantic Current Meter Mooring Array 6 [ACM6] realized a WOCE Science Plan concept that spatially coherent moored current measurements at critical points of the ocean circulation could constrain estimates of large-scale meridional heat flux. This 8-mooring array, a cooperative effort with the University of Rhode Island, spanned a 400 km line across the North Atlantic Current (NAC) near latitude 43 N during the period August 1993 to June 1995. The array monitored parts of the southward-flowing limb of the subpolar gyre and the combined northward-flowing limbs of the subpolar and subtropical gyres comprising the NAC. Mean and time-varying volume and heat transports for the section were derived by combining the direct measurements with a seasonal climatology of upper layer temperature and salinity. Mean volume transports for the southward- and northward-directed flows were approximately -20 Sv (million cubic meters per second) and 140 Sv, respectively. The flow-weighted temperatures of these two flow regimes were 2.9 C and 8.5 C, giving northward heat fluxes of approximately -0.2 PW and 4.9 PW and a net heat flux of 4.7 PW, referenced to 0 C. The basin-wide heat flux at 43 N depends on the flow-weighted temperature of the -121 Sv southward flow outside the ACM6 section (allowing for -1 Sv from Bering Strait inflow). A flow-averaged temperature of 8.1 C for this return flow gives 0.7 PW net meridional heat flux, the order of published estimates at these latitudes. These direct measurements can constrain future North Atlantic analyses aimed at realistic estimates of meridional heat transport.

1B1.6
Deep Circulation in the Equatorial Atlantic Ocean in January-February 1993
M. Lux (1), H. Mercier (1) and M. Arhan (1) ((1) Laboratoire de Physique des Oceans, CNRS/IFREMER/UBO, IFREMER Centre deBrest, B.P. 70, 29280 Plouzan?, France)

Hydrographic and geochemical data and shipborne ADCP along two zonal and two meridional sections at 7.5°N, 4.5°S, 35°W and 4°W, occupied in January-March 1993, are combined in an inverse model to estimate interhemispheric exchanges of mass and properties. Before inversion, an a priori velocity field is built using thermal wind balance and a deep reference level , dependent on location and consistent with the tracers fields. Tracer advection-diffusion balances are written for layers in boxes defined by the sections. The geostrophic inverse model looks for a circulation as close as possible, in a least square sense, to the a priori velocities, while satisfying conservation constraints an realistic diffusivities.

This study focussed on the North Atlantic Deep Water (NADW) shows a large conversion of its lower into its upper components in the equatorial region. The upper NADW flow is also reinforced by an important diapycnal flux from Intermediate Water (IW), mainly located in the very eastern and western part of the covered equatorial band and implying a stronger overturning cell South of the equator than North. The obtained eastward flows of NADW and IW near the equator and the southward transports of

NADW east of the M.A.R. at 4.5°S as well as the conversions locations show the importance of the eastern equatorial basin for the thermohaline circulation even though the western boundary remains the main interhemispheric exchanges zone. Surface flows confirm a important connection between zonal and meridional currents in the western equatorial basin in good agreement with other studies. This kind of inversion is now being applied, in collaboration with A. Clarke and R. Hendry (Bedford Institute of Oceanography), to three repetitive cruises realized in the Newfoundland basin region.

Session 1-B2
Climate Modelling

Monday, June 1
10:10 - 12:10
Sullivan Room

1B2.1
The Impact of Aerosols and Surface Forcings on Low-Frequency Atmospheric Circulations
Lionel Pandolfo (1) and Xuhua Li (1) ((1) Department of Earth and Ocean Sciences, University of British Columbia)

Atmospheric General Circulation Models (AGCMs) are often used to study how the climate system would respond to perturbations of its present state. In this particular investigation an AGCM has been used to conduct a set of numerical experiments to understand objectively the low-frequency responses of atmospheric circulations to various climatic perturbations. The numerical experiments were designed to isolate and study the effects of volcanic-type aerosols and variability of sea-surface temperatures and sea-ice extent on the earth's atmospheric circulations. Results from our analyses indicate that certain atmospheric circulation patterns are more sensitive than others to imposed climatic perturbations.

1B2.2
Radiative Characteristics of the Canadian Climate Center Third Generation General Circulation Model
Li Jiangnan (1) ((1) University of Victoria)

In the Canadian climate center third generation GCM model, a number of observational datasets (e.g. ERBE, ISCCP ect.) are used to access the quality of the radiative characteristics of the model. In solar radiation, the two band radiative transfer scheme has been replaced by a four band scheme in order to correctly handle the vertical variation of the solar spectrum. The longwave continuum and the transmission of N2O have been improved, which results obviously better clear sky outgoing longwave radiation (OLR) in comparison with ERBE. The cloud radiative treatment has also been improved for both solar and longwave radiation. Updated parameterisations and data are used. Cloud

radiative forcing (CRF) from the GCM are compared to CRF from ERBE data. The zonal averaged CRF is in excellent accord with observations.

1B2.3
The NARCM-LITE intercomparison study
L. Spacek (1), J.-P. Blanchet (2), R. Hoff (3), L. Barrie (4), S. Gong (4), H. Leighton (5) and Q. Song (5) ((1) C2GCR and Department of Earth Sciences, University of Quebec at Montreal, (2) Earth Sciences Department, University of Quebec at Montreal, (3) Atmospheric Environment Service, Centre for Atmospheric Research Experiments, (4) Air Quality Research Branch, Atmospheric Environment Service, (5) Dept. of Atmospheric and Oceanic Sciences / C2GCR, McGill University)

The space borne Lidar experiment carried on board the US space shuttle during September 1994 provide a good case study for comparison and possible validation of the NARCM model. The comparison of the model output for the period from 7 to 20 September 1994 and the LITE observations has been done at the level of optical property : lidar backscattering profile and aerosol optical depth. Sulphate particles from the continental American plume are represented by size segregated aerosol having eight size bins ranging from .01 to 2 micron. Aerosols are assumed to change with humidity according to their water uptake in equilibrium with moist air. Backscattering ratio calculated in the model is resulting from interaction of cloudiness and sulfate aerosol particles radiation. Lidar data are compared to model simulation along the track of the spacecraft orbit.

1B2.4
Impact of different model physics on the distribution of sulphate aerosols
Ulrike Lohmann (1), Norman A. McFarlane (2) and Johann Feichter (3) ((1) Atmospheric Science Program, Department of Physics/Oceanography, Dalhousie University, (2) Canadian Centre for Climate Modelling and Analysis, (3) Max Planck Institute for Meteorology)

Aerosol-cloud interactions are twofold. First aerosols can act as cloud condensation nuclei (CCN). The number of available CCN is one of the parameters that determines the cloud droplet number concentration, cloud albedo and precipitation formation in warm clouds. Second, most sulphate aerosols are formed by heterogeneous processes, i.e. by in-cloud oxidation of sulphur dioxide. Also as sulphate aerosols are washed and rained out, their lifetime strongly depends on the presence of clouds. Lohmann and Feichter (JGR 102, 12685-13700, 1997) showed that a coupled cloud microphysics-sulphur cycle model inside a general circulation model (GCM) is very sensitive to changes in the autoconversion rate and cloud cover parameterization by going from pre-industrial to present-day sulphur emissions. Therefore we will study the results of sulphur cycle simulations with two GCMs which employ the same chemistry code. As will be discussed, the distribution of sulphur species will be different in both GCMs, because of differences in the advection scheme, parameterization of convection and vertical diffusion. Thus, the travelling time before a sulphur dioxide particle reaches a cloud, the lifetime of clouds and with that the residence time of aerosols, the liquid water content,

and the precipitation frequency will differ in both GCMs. Factors affecting these differences between model simulations will be discussed.

1B2.5
Sensitivity experiments of a 1.5 dimensional climate model
Zhaomin Wang (1) and Lawrence A. Mysak (1) ((1) Department of Atmospheric and Oceanic Sciences and Center for Climate and Global Change Research, McGill University, Montreal, Quebec, Canada)

A sectorially averaged (over different continents and ocean basins) energy-moisture balance model (EMBM), a land surface model, a sea ice model and the zonally averaged ocean model of Wright and Stocker are coupled together for long-term climate change studies. In this climate model, an almost realistic present day land-ocean configuration is employed, which includes the major continents, three ocean basins and ACC region; a seasonal cycle is incorporated.

The surface air temperature, specific humidity and precipitation are predicted in the EMBM. Due to the large temperature contrast between the atmosphere over land and that over the ocean, the zonal heat and moisture transports are considered. The zonal heat transports are parameterized as a diffusion process; the zonal moisture transports are from cold regions (with low moisture content) to warm regions (with high moisture content), which are not in the form of a diffusion process. The land surface temperature, snow depth and river runoff are calculated in the land surface model. In the sea ice model, ice thickness and concentration are calculated based on Semtner and Hibler's work. The sensitivity experiments show that this multi-component model has the capacity to simulate the present day climate.

Session 1-B3
Extreme Events

Monday, June 1
10:10 - 12:10
Alderney Room

1B3.1
Climate Extremes Indices in Northern Climates
W.D. Hogg (1) and V.R. Swail (1) ((1) Climate Research Branch, AES, Environment Canada)

The purpose of this paper is to both describe Canadian climate data available to researchers for use in generating indices of climate extremes and to provide some discussion points on the nature of the indices themselves in high latitude climates. Because of Canada's high latitude location, the type of climate extreme that is significant may differ from much of the rest of the world. Because of its large area, low population

density and sparse climate networks, availability of Canadian data is important for both national and global analyses.

The prime data concern for climate change analysis projects is the homogeneity of the time series. Environment Canada's Climate Research Branch has relied upon two techniques to assure homogeneity of climate data time series. Where station density is high compared to spatial variability of the parameter in question, difference series with surrounding stations are used to identify and adjust inhomogeneities. Vincent (1997) describes a technique that has been applied to generate homogeneous temperature time series covering 1895-1995 for 210 Canadian Stations. For more variable fields, such as precipitation, Canadian networks are not sufficient to apply this neighbouring station technique. For such parameters, the philosophy has been to remove all known measurement program induced inhomogeneities for a selection of high quality, long record stations.

Mekis and Hogg (1998) describe a 500 station homogeneous dataset of precipitation for 1895-1996 developed in this way. These data have been used in the production of a gridded time series for Canada of monthly temperature and precipitation for this century, using an approach described by Hogg et al. (1996).

For marine data, we are generating a 40-year gridded time series of surface (10 m) winds and ocean waves for the North Atlantic Ocean based on the NCAR/NCEP global reanalysis (Kalnay et al., 1996) wind fields, augmented by interactive subjective assimilation of wind observations such as ships, platforms and hourly Canadian moored buoy data. Considerable care is being taken to adjust wind speeds for differences due to observational method, anemometer height, etc., to account for biases identified by Cardone et al. (1990).

These datasets are being used to develop and track indices which characterize changes in climate extremes and are associated with significant economic or social impact. The suitability of various indices is examined and their regional variability over the 20th century is discussed.

Cardone, V.J., J.G. Greenwood and M.A. Cane, 1990: On trends in historical marine data. J. Climate, 3, 113-127.

Hogg, W.D., P.Y.T. Louie, A. Niitsoo and E. Milewska, 1996. Time series of water balance parameters for the Canadian Mackenzie Basin GEWEX Study Area. Preprints, 2nd Int'l Scientific Conf. on GEWEX, Wash. pp. 188, WCRP.

Kalnay, E.,et al., 1996: The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc., 77, 437-471.

Mekis, E. and W.D. Hogg, 1998. Rehabilitation and analysis of Canadian daily precipitation time series. Preprints, 10th Conference on Applied Climatology, Reno, AMS, Boston.

Vincent, L.A., 1998: Technique for the Identification of Inhomogeneities in Canadian Temperature Series. Journal of Climate, In Press.

1B3.2
Spatial and temporal characteristics of heavy precipitation events in Canada
Xuebin Zhang (1), W. D. Hogg (1) and Eva Mekis (1) ((1) Climate Research Branch, Atmospheric Environment Service, Environment Canada)

Daily precipitation data for the period 1900-1995 were used to identify heavy precipitation events by season. Heavy events were defined for each season and station separately by identifying a threshold which was exceeded by an average of 3 events per year, corresponding approximately to the 90th percentile. Time series of number of exceedances per year were then generated for each station and season. Heavy events for rainfall and snowfall were identified and analysed separately. In an innovative effort to aggregate station data into regional time series, stations of coherent variability of number of events were grouped, using cluster analysis.

It was found that stations belonging to the same group are generally located in a continuous region, indicating that the time series of number of events are quite coherent spatially. It was also those for heavy rain fall events.

Regional heavy precipitation indices were constructed by averaging the number of events at stations within the same group. Strong interdecadal variability exists in these indices but evidence of trends is limited and varies markedly between clusters or regions. In southern Canada, especially in the Canadian prairies, the number of heavy snowfall events has an upward trend from the beginning of this century until the later 1950s, and a downward trend afterwards. In northern and Atlantic Canada, the number of heavy snowfall events has been increasing since the 1950s. In Atlantic Canada and Quebec, the number of heavy spring rainfall events was high during the 1950s and again in the late 1970s and 1980s. The number of spring heavy rainfall events has been consistently increasing in the northern Prairies since the beginning of this century and in British Columbia since the late 1950s.

Significant positive correlation exists between total amount of snowfall contributed by heavy events and that by non-heavy events at most stations, especially these located in the west. This suggests that the occurrence of heavy snowfall events is linked to positive snowfall anomalies. Significant correlation between total amount of rainfall in heavy events and non-heavy events was found only at a few stations (less than 20% of stations), implying that the occurrence of heavy rainfall events are not always linked to positive rainfall anomalies.

The trend in the number of heavy events in the last 45 years is also consistent with the trend in the magnitude of daily rainfall and snowfall at 90 percentile. During the last 45 years, the 90 percentile of daily precipitation has been increasing over much of the country except over the south and the Yukon region. However, this upward trend is

mainly caused by upward trend in heavy snowfall, while the 90 percentile daily rainfall shows a negative trend over almost the entire country. It appears that p recipitation events have been getting more extreme over the last 45 years due to more extreme snowfall.

1B3.3
Changes in Cyclone Frequencies and Strengths
in a Transient Enhanced Greenhouse Warming Simulation
Steven J. Lambert (1) ((1) Canadian Centre for Climate Modelling and Analysis)

A previous equilibrium enhanced greenhouse warming simulation by the Canadian Centre for Climate Modelling and Analysis (CCCma) General Circulation Model (GCM) exhibited an overall decrease in cyclone event frequencies but an increase in intense events. This behaviour in the equilibrium simulation is compared and contrasted to the behaviour of cyclone events in transient enhanced greenhouse warming simulations also carried out using the CCCma GCM.

1B3.4
The Saxby Gale Part 1
Jim Abraham (1) and George Parkes (2) ((1) Environment Canada, (2) Environment Canada Maritime Weather Centre)

Hurricanes are considered by many as beasts unique to southern latitudes; yet on average, two or three tropical cyclones do affect Canada and the adjacent offshore waters each year. These systems, which are leaving the warm tropical waters and are normally in the decay stage of their life-cycle, still possess an extraordinary amount of energy and pose a unique and difficult prediction problem. In fact, perhaps the worst natural disaster in Canadian history occurred as a result of a hurricane that killed as many as 4000 mariners off the coast of Newfoundland in 1775. While the most famous hurricane in modern days is “Hazel”, that killed 83 in Southern Ontario in October 1954, the “Saxby Gale” likely resulted an as much or more death and damage when it struck New England and the Maritime Provinces in 1869. This storm was made famous by the almost one year prediction of Lt. S.M. Saxby of the Royal Navy that a storm of unusual violence with an extraordinary rise in tide would strike the Earth on the morning of 05 October 1869.

Tropical cyclones moving over colder waters into middle and northern latitudes are usually accelerating under the influence of the mid-latitude westerly circulation. This acceleration is accompanied by a shift in the low-level wind pattern, with the strongest winds observed along and to the right of the storm track. The precipitation pattern also shifts to an asymmetrical distribution similar to that of an extra-tropical storm, with the bulk of precipitation along and to the left of the storm track. The strong winds, heavy rains, storm surge and high surf are seldom as intense as when the tropical cyclone was further south. Nevertheless, there remains a risk unique to the middle latitudes that of a rapid re-intensification as a result of the interaction with a baroclinic system. Indeed, “Hazel” was such a hybrid storm, with extremely heavy rainfalls of over 200mm in less than one day that caused severe flooding. As it turns out, our examination of the meteorological situation from a forensic study of the “Saxby Gale” suggests that it too

was a hybrid re-intensification like “Hazel”. We will use this comparison to develop a conceptual model that describes the meteorological set-up associated with this rare and extreme event.

1B3.5
The Sable Gale Part II, The Saxby Tide and Other Storm Surge Events in the Bay of Fundy
G.S. Parkes (1), L.A. Ketch (1) and C.T.O’Reilly (2) ((1) Environment Canada Maritime Weather Centre, (2) Canadian Hydrographic Service, Bedford Institute of Oceanography, Dartmouth, Nova Scotia)

Maximum water levels in the Bay of Fundy are achieved when large storm surges are coincident with perigean spring tides. The Saxby Tide was such an event, and this is perhaps the most noteworthy aspect of the Saxby Gale and the main reason why this historic storm is of relevence to us today.

The Saxby Tide drove northeastward up the Bay of Fundy flooding many shoreline communities and overflowing the Acadian dykes in Chignecto Bay and Minas Basin. In this presentation the recent climatology of Bay of Fundy storm surges is discussed with special reference to recent high water level and minor flooding events. A description of the Saxby Gale and accompanying Saxby Tide, partly based on a recent forensic study (A. Ruffman - this congress), is presented together with some estimates of its elevation.

1B3.6
The Saxby Gale Part III, Forensic Study of the Impacts
Alan Ruffman (1) ((1) Geomarine Associates Ltd.)

A massive event-specific search supported by the Atmospheric environment Branch of the Canada Department of Environment has been completed for the October 1869 Saxby Gale. Most of the primary sources from Atlantic Canadian and Maine newspapers have been captured, along with material gathered by the New Brunswick Musuem in the early part of the 20th century, later articles and some personal accounts. The original December 1868 and September 1869 letters to The Standard, of London, England, by Stephen Martin Saxby (1804 - 1883) have been recovered, wherein he predicted not only a very high ‘spring’ astronomic tide, but that it would be accompanied by equinoctial gales at 0500 local time on October 5, 1869. He was proven right in the Bay of Fundy and Maine though the cause was a tropical cyclone that had been travelling up the eastern seaboard of the U.S. for at least two days before. Saxby’s predictions got considerable play in Nova Scotia and may have led to a great degree of preparation and less lives lost.

The newspaper accounts present an often graphic view of the eye of the hurricane making landfall in the area of the Maine/New Brunswick border. Winds were strong enough to cause forest blowdown and an increased forest fire hazard in the years following. Significant building damage was reported in the area immediately adjacent to the border, with roads and railways blocked by debris. Many vessels blew ashore in the Passamaquoddy Bay area. The counterclockwise flows drove the storm surge up the Bay

of Fundy to overtop most dykes and lowlands. On the ‘left’ side of the track huge amounts of rain were unloaded in the northern New England states through to eastern New York State.

The newspapers in Atlantic Canada are fairly well catalogued and the locations of collections are known. All but one have been microfilmed. The Maine Newspaper Project is in its early stages so that the locations of collections of Maine newspapers are not well known and some newspapers have not yet been microfilmed. This project stumbled on some collections not known to the Maine State Archives. None of the newspapers for the Fall of 1869 are indexed so one can only find the hurricane data by scanning each paper for four to six weeks (for a weekly) after the event, or for about a month for a daily. In the order of 600 articles were collected. In Maine many articles compared the Saxby Gale to the September 8, 1869 hurricane that had a greater impact than the Saxby Gale in the southern part of Maine and southwards into Massachusetts and Rhode Island.

Session 1-C1
WOCE/CLIVAR 2

Monday June 1
13:40 - 15:00
Hawthorne Room

1C1.1
Seasonal Cycle in the Boundary Layer of the North Atlantic and North Pacific Oceans
Igor Yashayaev (1) and Igor Zveryaev (2) ((1) Bedford Institute of Oceanography, (2) P. P. Shirshov Institute of Oceanology, Moscow, Russia)

In our study of seasonal variability in the North Atlantic and North Pacific we analyzed distributions of amplitudes and phases of seasonal harmonics and contribution of seasonal and interannual components to total variability.

To construct sea surface temperature (SST), air temperature (AT), sea level pressure (SLP) and humidity time series we used COADS; time series of atmospheric parameters up to 500 hPa - NCEP/NCAR reanalysis; and time series of temperature and salinity below the sea surface - hydrographic data from various sources. We used a harmonic model of the seasonal cycle. Though, 12, 12/2, 12/3, 12/4 months harmonics were used in its approximation, we considered only annual and semiannual ones, contributing together more than 95% of the seasonal variability. The seasonal cycle was subtracted from the time series, and for further consideration the residuals were subdivided into non-regular intraseasonal and interannual components.

Amplitudes of annual harmonics of SST, AT and humidity are the highest near the western boundaries of the oceans. The contribution of the seasonal cycle to total variability of these parameters exceeds 80% in mid and, partially, high latitudes, and reaches its maximum (95%) in the centers of Subtropical Gyres. We define a phase as a

delay of cycle's minimum from January 1. Generally, SST, AT and humidity annual phases tend to increase in the direction of the eastern tropical parts of the oceans. SST-AT annual phase differences vary from 1 to 3 weeks (AT leads). High values of this difference spread along the western coast and the western boundary currents, which is in agreement with the spatial distribution of integral air-sea heat flux estimates.

A common feature in distributions of SLP annual amplitudes for the North Atlantic and North Pacific is a zonal belt of low values along the Equator (0-10N). There are three large areas of high SLP annual amplitudes in the North Pacific: south-east Asian, Aleutian and Californian, but only one in the North Atlantic, stretching from Greenland to Iceland and to the Newfoundland Basin. Analysis of phases of SLP seasonal harmonics revealed trajectories of propagation of annual and semiannual cycles.

Analysis of the global NCEP/NCAR data sets has demonstrated the differences in seasonal cycles over the continents and oceans. The maximum contribution (90%) of the seasonal cycle contribution to the total variability was observed over the eastern part of Eurasia. The seasonal cycle pressure dominates total variability of 500 hPa heights both over the continents and over the oceans. As seen from analysis of phases, annual and semiannual oscillations in the 500 hPa height fields propagate generally in the meridional direction - from high and mid latitudes to the tropics. A remarkable feature in the North Pacific climate is a maximum of semiannual SLP amplitudes, centered around 40N;170W. In both COADS and NCEP/NCAR fields it also represents an absolute maximum in the entire Northern Hemisphere. It is not so well pronounced at 500 hPa.

Annual amplitudes of upper ocean temperature and salinity are the highest near the western coast. The contribution of the seasonal cycle to total variability in the ocean is the lowest near the fronts and areas of high eddy activity. Phases of the temperature and salinity seasonal cycle increase with depth. The rate of this increase is higher in the regions with higher vertical stratification. The seasonal cycle extends deeper in the waters of Subtropical origin.

1C1.2
Water Masses and Circulation in the North-West Atlantic at the End of the Twentieth century Igor Yashayaev (1) and Allyn Clarke (1) ((1) Bedford Institute of Oceanography)

An examination of the recent data for the North-West Atlantic collected in support of WOCE (1988-1997) reveals large changes in water mass properties and the strength of the circulation from what had been observed in the 50's through the 70's. Over the whole region, all of the intermediate and deep waters formed through convective processes in the northern North Atlantic have become colder and fresher. This cooling and freshening is not just seen in the source regions for these waters or in the deep western boundary currents, but has extended throughout these water masses within the sub-polar gyre of the North Atlantic.

The changes in the properties of Labrador Sea Water (LSW) over the past decades is well described from data collected within the Labrador Sea. Our analysis shows that its

distribution has also exhibited considerable changes with time. Largely absent in sections crossing the western boundary currents in Newfoundland Basin and Subtropical Gyre during the 60's and 70's, it now appears as a strong salinity minimum both in the southward flowing deep western boundary currents and also within the northward flowing North Atlantic Current. By the early 90's, LSW was 0.8°Δ11
C colder, 0.06 psu fresher, denser and deeper than it was during the 60's state. This salinity change is equivalent to an accumulation of 1.6 metres of fresh water over the entire sub-polar gyre of the North Atlantic over two decades.

The deep and bottom waters of the North-West Atlantic also became colder and fresher during the same period. Denmark Strait Overflow Water (DSOW) in the Labrador Sea cooled and freshened by 0.4°C and 0.05 psu. The changes in the North-East Atlantic Deep Water (NEADW) are less than those of either LSW or DSOW, it cooled and freshened by 0.2°C and 0.04 psu.

In contrast with the cooling and freshening of the sub-polar gyre, the upper waters of the sub tropical gyre are becoming warmer and saltier. This has been well documented at Bermuda and also at the location of OWS D in the Newfoundland Basin.

The strength of the circulation has also changed. The dynamical topography of the Newfoundland Basin shows that the strength of the North-Atlantic Current, Gulf Stream and the Mann Eddy have all increased in the 90's. The strength of the southward transport of waters from the Labrador Sea along the upper continental slope has also increased at the same time. The inc reased transport of the NA Current as well as the presence of warmer and saltier waters in the sub-tropical gyre should be transporting greater heat and salt into the sub-polar gyre.

1C1.3
Modeling upper ocean winter processes in the Labrador Sea
C.L. Tang (1), Q.Gui (2) and B.M. DeTracey (1) ((1) Bedford Institute of Oceanography, Dartmouth, NS, (2) Guideng Research, Vancouver, British Columbia)

A coupled ice-mixed layer model has been developed to study winter convection, heat flux, ice formation, mixed-layer properties, and effects of salinity and meteological conditions on winter processes in the Labrador Sea. Objectively analyzed temperature and salinity fields for November are used as initial state of the model ocean. Monthly climatology from the NCEP reanalysis project is used to drive the model. The results show that heat loss of the ocean reaches a maximum at the end of January. High heat loss, 250 to 420 W/m**2, occurs in northern Labrador Sea between 57N and 61N off the ice edge. Sea-ice significantly reduces the heat loss with a typical value of 40 W/m**2 in ice covered water. Surface cooling caused the mixed layer to deepen continuously through winter and reaches a maximum in late March (500-900m) when the net surface heat changes sign. A reduction of surface salinty by 1% decreases the mixed layer depth by 25-40%. The high stratification associated with the low surface salinity has little effect on ice coverage, because the reduced level of mixing cannot lower the surface temperature sufficiently to increase the ice area. This suggests that freshening of the

Labrador Sea during the Great Salinity Anomaly in the late 1960's did not promote ice production. An increase in wind speed by 40% and decrease in air temperature up to 4?, representing conditions of cold winters, double the mixed-layer depth, and extend the maximum southern ice limit by 200 km on northern Grand Banks. This suggests that interannual variation of convection and ice extent are mainly controlled by meteorological conditions.

1C1.4
Modelling the North Atlantic General Circulation
D.G. Wright (1), D. Brickman (2) and J. Bobanovic (2) ((1) Bedford Institute of Oceanography, Dartmouth, NS, (2) Dalhousie University, Halifax, NS)

Work on the development of an eddy-permitting, primitive equation General Circulation Model of the North Atlantic will be reviewed. The discussion will focus on the DieCAST family of models, formulated by Dr. David Dietrich. These models include fourth order numerics, have relatively low dissipation, and are computationally efficient. Two versions of the model will be briefly described, a standard C-grid formulation and a novel formulation which combines features from the standard A and C-grid formulations. Results for two idealized test problems will then be presented and discussed. The first test problem shows that the two formulations give very similar results for the rectification of a barotropic, oscillatory, wind-driven flow over a coastal canyon. On the other hand, the second test case shows that the hybrid formulation gives clearly superior results for the propagation of a bottom-trapped topographic Rossby wave in a stratified ocean. Given the importance of deep western boundary currents and deep water mass properties to the Gulf Stream separation problem, this property lends support to the contention that the hybrid formulation yields superior results for this aspect of the general circulation. Preliminary results by ourselves and by Dr. Dietrich suggest that this is the case, but this has not yet been uneqivocally demonstrated. Runs of the two formulations with identical North Atlantic geometries, initial conditions, forcing and model parameters are now in progress and results will be discussed at the conference. If the hybrid model does indeed result in improved performance, a detailed analysis will be undertaken to determine the underlying reasons for the improvements.

Session 1-C2
Air Quality

Monday June 1
13:40 - 15:00
Sullivan Room

1C2.1
National Pilot Project on Smog Forecasting in Southern New Brunswick
Claude Cote (1), Mike Howe (1) and David Waugh (2) ((1) New Brunswick Weather Centre (Fredericton, NB), Atmospheric Environment Branch, Environment Canada, (2) Atmospheric Environment Branch, Environment Canada)

The New Brunswick Weather Centre (NBWC) in Fredericton was selected to conduct a National Pilot Project on Smog Forecasting in southern New Brunswick during the summer of 1997. This Environment Canada initiative is seen as a natural evolution from weather forecasting to environmental prediction. The necessity of a smog forecast is also supported by the latest medical studies indicating a positive correlation between hospital admissions due to cardiorespiratory complications and deteriorating air quality.

During the summer of 1997, the NBWC produced and disseminated a smog forecast bulletin twice a day providing forecast information of the expected smog concentrations for day one and day two. The bulletin also included a health and education section which served to improve public understanding of the air quality issue. The provision of a daily smog forecast is viewed as an opportunity to assist users with the planning of their daily activities so that one can make an informed decision. This is particularly useful for people suffering from respiratory problems.

During the summers of 1995 and 96, the NBWC produced a daily internal smog forecast. This provided the opportunity to develop the scientific skill and expertise necessary for the launch of a full public smog forecast program.

Increased scientific understanding of air quality dynamics and chemical reactions enhanced by improved numerical modeling and new technology provide the meteorologist at the NBWC the components necessary to adequately forecast expected smog concentrations. The intent of this paper is to present the methodology used in smog forecast production as well as the verification of forecast skills.

1C2.2
An Evaluation of the CANFIS - Statistical Model prediction of ground level ozone concentrations for the Saint John area in 1997
David Waugh (1), Dr. Bill Burrows (2) and Jacques Montpetit (2) ((1) Environment Canada, Atmospheric Environment Branch, (2) Environment Canada, Numerical Prediction Research Division)

The CANFIS statistical model was developed in support of Environment Canada's Air Quality Prediction Program. Output in forecast mode, was produced during the Smog Prediction Pilot project for the Saint John, New Brunswick area in the summer of 1997. Verification statistics from the CANFIS forecast output for the Saint John area revealed that it has significant skill in forecasting ground level ozone concentrations. Forecasters will benefit from having the CANFIS output as a tool in predicting ground level ozone concentrations. CANFIS has demonstrated sufficient skill and will continue to improve as its learning database expands. The advantages and disadvantages of the model will be discussed.

1C2.3
On Transport Affecting the Canadian Southern Atlantic Region Oxidants-Observation and Modelling During the Atlantic 96 Intensive Period

Wanmin Gong (1), Frank Froude (2), Steven Beauchamp (3) and Sylvain Menard (4) ((1) Atmospheric Environment Service, Downsview, ON, (2) AES, Centre for Atmospheric Research Experiments, Egbert, ON, (3) Atmospheric Environment Service, Bedford, NS)

Past studies, including field and modelling, have shown that the transport from the US east coast over the Gulf of Maine plays an important role in the occurence of elevated ground-level ozone in Nova Scotia and southern New Brunswick. It has also revealed (from the NARE93 field study) that the lower atmosphere over the Gulf especially towards the Nova Scotia coast often has complicated layering structures. Then the questions are 1) how will the structure of the lower atmosphere over the Gulf of Maine influence the transport, and 2) are we seeing pollutants transported within the marine boundary layer or being brought down from upper levels due to enhanced vertical mixing (e.g. coastal fumigation or weakened thermal stability)? During the ATLANTIC96 (part of the NARSTO-CE activity) intensive period, tethersonde measurement of vertical profiles of ozone and meteorological parameters were made at Chebogue Point, on the southwestern coast of Nova Scotia. This measurement, covering the lowest 400 meters of the atmosphere, was to characterize the vertical structure of marine/coastal boundary layer and as part of the effort in addressing the above mentioned transport issues. Regional oxidant model simulation of the field study period was also carried out. In this paper we will present some of the results from both the measurement and the model simulation. We will focus on two cases when higher ozone levels were observed during the intensive field campaign. It is indicated that both episodes are cases of fairly fast transport from the southwest at low levels.

1C2.4

Regional to Urban Scale Modelling of Air Quality With an On-line Photochemical Model

D. A. Plummer (1), L. Neary (2), J. W. Kaminski (2) and J. C. McConnell (2) ((1) Centre for Earth and Space Science, (2) Earth and Atmospheric Science Department, York University)

Trace gas observations made at a rural site in south-eastern Ontario during the summers of 1992 and 1993 point to the possibility that lake breeze circulations may play an important role in the dispersion of pollutants emitted from Toronto. To study this effect we have developed an on-line photochemical model based on the Mesoscale Compressible Community (MC2) model. The model is referred to as ‘on-line’ since the advection and ch emical reactions of the trace species are calculated during the integration of the meteorological model. This differs from the traditional approach where the necessary meteorological fields are computed and stored for later use by a separate chemical transport model.

The advection of trace species is calculated using the semi-lagrangian semi-implicit advection scheme native to MC2. The gas-phase chemistry mechanism is identical to the one currently used within the Acid Deposition and Oxidant Model (ADOM), while clear-sky photolysis rates and the chemical solver have been modified from that used in ADOM. Biogenic emissions are calculated on-line using a modified version of the Biogenic Emissions Inventory System, version 2.

The ability of MC2 to perform one-way nesting has been extended to the chemical fields. This allows a high-resolution modelling study of the lake breeze over Lake Ontario using meteorological and chemical boundary conditions derived from a regional scale run.

Model results have been compared against observations of ground-level ozone made during the first week of August, 1988 as part of the Eulerian Model Evaluation Field Study. This comparison indicates that the model performs no worst than other existing photochemical models. The fine-scale lake breeze simulations show the formation of a vertically thin layer of ozone over Lake Ontario during the afternoon as a result of precursor emissions from Toronto. As the lake breeze penetrates inland along the north shore of Lake Ontario high concentrations of ozone are advected inland. The MC2 model does have difficulty generating the observed inland penetration of the lake breeze front and this is reflected in the spatial distribution of pollutants.

Session 1-C3
Coastal Oceanography

Monday June 1
13:40 - 15:00
Alderney Room

1C3.1
Models for suspended sediment drift and dispersion, with application to Georges Bank
Charles G. Hannah (1), John W. Loder (1), Shen Yingshuo (1) and Zhigang Xu (1) ((1) Fisheries and Oceans Canada, Bedford Institute of Oceanography)

Models for the drift and dispersion of suspended material in the benthic boundary layer are being developed, for use in evaluating the fate of drilling wastes released in the vicinity of valuable benthic organisms such as the sea scallop on Georges Bank. A ‘local’ version, which assumes a horizontally-uniform physical environment and can be forced by either observed or 3-d model current profiles, has been extended to include continuous sediment input, and improved representations of the near-bottom region and vertical mixing. A proof-of-concept ‘spatially-variable’ version, which allows 3-d spatial variability in the physical environment using current fields from a 3-d circulation model, has been developed. Applications of these models to explore the spatial patterns of drift and dispersion on the Northeast Peak of Georges Bank will be described, using current profiles from both moored measurements and a 3-d circulation model as forcings. Sensitivities to vertical distribution of the sediment, season, and temporal and spatial variability will be discussed.

1C3.2
A Method for Estimating the Flocculation Time of Monodispersed Sediment Suspensions
Elizabeth A. Gonzalez (1) and Paul S. Hill (2) ((1) Bedford Institute of Oceanography, (2) Department of Oceanography, Dalhousie University)

By causing particles to clump together into larger aggregates, flocculation increases the settling velocity, and hence the dispersion patterns, of marine particles. The critical time at which abrupt changes in the particle size spectrum occur is called the flocculation time. A new method is presented for determining the flocculation time of monodispersed sediment suspensions. This method predicts flocculation times to within 6% of values predicted by a geometric sectional aggregation model (Batterham R.J, J.S. Hall and G. Barton (1981) In: Proceedings, 3rd International Symposium on Agglomeration, Nurnberg, Federal Republic of Germany, pp. A136-A150), but uses only a fraction of the computational effort. Flocculation times estimated in this way are superior to estimates of flocculation time scale made using half-life because particle geometry and differential settling encounter are taken into account.

The proposed model is based on typical size distributions calculated using Batterham et al.'s model. These size distributions have approximately equal mass in geometrically increasing size classes, i.e. they are Junge-dispersed. By assuming that the suspension remains Junge-dispersed throughout its evolution, the system of differential equations required to describe the suspension reduces to a single differential equation. For a given set of inputs, flocculation times calculated in this way are linearly related to those calculated using the Batterham et al. model, but the slope of the relationship varies with fractal dimension. Multiple linear regression equations are developed to directly relate the two.

1C3.3
Thermocline and Circulation Modelling of Conception Bay Newfoundland
Fraser J.M. Davidson (1), Dr. R.J.Greatbatch (1) and Dr. B de Young (1) ((1) Memorial University)

We apply an eddy resolving numerical C-grid circulation model CANDIE (based on the DieCAST model) to the eastern Newfoundland Shelf. The model domain size is 200km by 200km in the horizontal and 400m deep and includes two bays (Trinity and Conception Bays). Model forcing includes topography, time-dependent wind, surface heating and salinity inflow by the Labrador Current. We will discuss the forcing terms in the model as well as the open boundary conditions. The nearshore thermocline displacement will be explored using linear and non-linear versions of the model. Comparisons are made with a simple 1.5 layer shallow water model using an idealized bay topography. Results will be discussed regarding the effect of the non-linear terms, topography, initial stratification and the vertical resolution of the model.

1C3.4
The Effect of an Undercurrent on Upwelling Through a Canyon
S E Allen (1), X Chen (1), C Vindeirinho (1) and R E Thomson (2) ((1) Earth and Ocean Sciences, University of British Columbia, (2) Institute of Ocean Sciences)

Canyons have been shown to be regions of enhanced upwelling. Here we will con
sider the changes in response due to the presence of an undercurrent.

Theoretical arguments and numerical simulations show that an undercurrent on the slope should have no effect on the amount of water upwelled through a canyon and only a slight effect on the flow patterns. The flow up a canyon is driven by the pressure gradient at its rim which is in balance with the flow over the shelf. As verification, current meters were moored in Juan de Fuca Canyon from May 9 to October 21, 1993. A mooring maintained further North over the slope shows the undercurrent forming about July 7. Within the canyon, up-canyon flow at 200m is coherent with cross-canyon flow at 75m. Monthly average currents at 200m are up-canyon for all 5 months (May - Sept.) and are as strong in August as in May. Numerical simulations for short canyons will also be presented.

Session 1-C4
Alt. Service Delivery

Monday June 1
13:40 - 15:00
McNabs Room

C4.1 & 1C4.2
Alternate Service Delivery Study of the Atmospheric Environment Program
David Grimes (1) ((1) AES)

The Atmospheric Environment Program (AEP) of Environment Canada provides weather, climate, sea ice and air quality services to Canadians, operates national hydrometric networks and undertakes atmospheric research. Its products and services are important to a broad range of clients including the general public, transportation, the oceans community, natural resources sectors, environmental policy makers and others. Severe resource reductions during the past several years have seriously affected the AEP's ability to respond to the demands placed upon it.

An Alternative Service Delivery (ASD) Study of the Atmospheric Environment Program has been underway for several months. Phase I of the Study involved detailed identification and examination of the critical issues facing the program. A survey of interested organizations provided important initial feedback, based on the first discussion paper "Towards a Renewed Atmospheric Environment Program". The focus of Phase II, currently underway, is on identifying opportunities for the renewal of the AEP. The AEP is currently undertaking cross country consultations during this phase.

This presentation will include an overview and status report on the ASD study and provide an opportunity for participants to raise questions or comment on various aspects of the study.

Session 1-D1
WOCE/CLIVAR 3

Monday June 1
15:20 - 17:00
Hawthorne Room

1D1.1
Vertical mixing in the upper pycnocline
Dan Kelley (1) ((1) Dalhousie University)

The vertical diffusivity, Kv, in the upper half-kilometer of the North Pacific subtropical pycnocline is estimated from observations of the spreading rate of anthropogenic tritium. The calculation is based on approximately 300 profiles made since tritium was introduced to the atmosphere via bomb testing in the 1960s. The data coverage does not permit detailed mapping of tritium penetration, especially in the sparsely-sampled western Pacific. For this reason, and to minimize advective effects, the spreading rate is averaged within the closed streamlines of the subtropical gyre spanning ~ 5° N to ~ 40° N. The result, Kv = (1.5 +/- 0.7) x 10^-5 m^2/s, is consistent with inferences from microstructure and tracer-injection measurements in the North Atlantic, confirming that the rate of mixing in the upper pycnocline is substantially lower than the canonical Munk estimate for the lower pycnocline.

1D1.2
Parameterizing mesoscale eddy transport in ocean circulation models
Richard J. Greatbatch (1) ((1) Department of Oceanography, Dalhousie University)

A new approach to parameterizing mesoscale eddy transport is described. Forcing terms proportional to the isopycnal flux of potential vorticity are added to the momentum equations for the time-averaged flow. The new parameterization is a simple extension of the well-known Gent and McWilliams parameterization and has the property, unlike Gent and McWilliams, that there is always consistency with the averaged potential vorticity equation. The new parameterization drives barotropic mean flows similar to the Neptune Effect of Holloway and predicts an upslope, bolus flux of tracer consistent with the observation of a cold dome over seamounts in tidally oscillating flow. The new parameterization has been implemented in a 3-D ocean circulation model for climate studies, and results will be described in the companion presentation by Li and Greatbatch.

1D1.3
Model simulation susing mesoscale eddy parametirisations implanted in the momentum equations of an ocean general circulation model
Guoqing Li (1) and Richard Greatbatch (2) ((1) Memorial University of Newfoundland, (2) Department of Oceanography, Dalhousie University)

We implement three kinds of parameterisation schemes for mesoscale eddies into a global ocean general circulation model which is similar to the well-known Bryan-Cox-

Semtner model. The three parameterisations are i) Greatbatch (1998); ii) Gent and McWilliams (1990); and iii) Greatbatch and Lamb (1990). Hereafter they are referred to as G98, GM90 and GL90, respectively. The parameterisations introduce an eddy transport velocity (also called bolus velocity), and consequently, the tracer fields will be affected by both the Eulerian-mean velocity and the bolus velocity. In the original GM90 (Danabasoglu et al. 1995), the bolus velocity was introduced in the tracer equations. In this study, it is implemented in the momentum equations. Greatbatch (1998) has shown the two approaches are almost equivalent. GL90 and G98 have not been implemented in a general circulation model before. G98 is derived from the conservation of potential vorticity and has an effect of driving barotropic mean flow similar to the neptune effect. This study shows all parameterisations leads to significant improvements to model solutions compared with the model with conventional horizontal mixing. Among the parameterisation schemes, the barotropic streamfunction with G98 shows a stronger northern gyre in the northern North Atlantic. The tracer fields with G98 also give the minimum root mean square of model solution minus observation, but improvements displayed in G98 is only marginal. Further investigation with a finer resolution will probably help to illustrate the real advantage of G98.

1D1.4
The Parametrization of Eddies using Frontal-Geostrophic Models
Richard Karsten (1) and Gordon Swaters (2) ((1) University of Alberta)

The ocean circulation is strongly dependent on the transient fluxes of energy/potential vorticity and the induced mixing that occur as a result of small-scale baroclinic instability in frontal regions. Accurate modeling of fronts and an understanding of these processes is necessary if they are to be parametrized and included in coarse scale OGCMs which are limited in their ability to resolve small scale features. Fronts are regions of relatively large isopycnal variations, and the approximations made in developing classical mid-ocean models break down. As such, frontal-geostrophic (FG) models have been developed to recognize the large amplitude variations of the fronts and yet retain the desirable large-scale approximation of geostrophy. In addition, FG models cover a range of length scales, from the Rossby deformation radius to planetary scales, making them ideal to explore the interaction of small-scale eddies with larger scales associated with general ocean circulation. In this talk, the properties of the FG models will be examined in the light of parametrizing the transport properties associated with the observed instabilities. The question of stability of fronts lies in the balance of the destabilizing kinetic and potential energy stored in the front versus the stabilizing background vorticity gradient supplied by the beta plane and/or local bottom topography. This balance is illustrated through the examination of several models with varying horizontal and vertical length scales. These models, though simple two-layer, shallow-water approximations, capture the essential nonlinear nature of frontal dynamics. Within these models, nonlinear effects can lead to stable structures or explosive instabilities depending on a relationships between zonal and meridional scales. In general, nonlinear interactions lead to a cascade of energy to scales 3-4 times the Rossby deformation radius, concentrated near frontal outcroppings where eddy growth occurs. A general FG model is used to provide estimates of the length and time scales involved in eddy growth.

The effects of local topography, deep ocean flow, and local forcing are examined. As well, the extension to continuously stratified models is explored and compa

1D1.5
Vorticity fluxes in a shallow water ocean model
K. Andrew Peterson (1), R.J. Greatbatch (1) and Dwayne Hart (2) ((1) Department of Oceanography, Dalhousie University, (2) Dept. of Physics and Physical Oceanography, Memorial University)

We investigate vorticity fluxes in a shallow water ocean model in order to gain insight into eddy parametrizations. We find that the model verifies that the eddy flux of potential vorticity can be parametrized as being down the potential vorticity gradient. However, in the case of the single layered model, the eddy thickness flux appears not to be related to either the mean thickness or the mean potential vorticity gradients. In addition, we also demonstrate the importance of properly factoring out the neccessary gauge fields.

Session 1-D2
Trends & Variability

Monday June 1
15:20 - 17:00
Sullivan Room

1D2.1
Regional Patterns of Temperature and Precipitation for Newfoundland and Labrador during the Past Century
Colin E.Banfield (1) and John D. Jacobs (1) ((1) Memorial University of Newfoundland)

We have analysed the mid-to-late 20th century instrumental record of winter and summer temperatures and precipitation for 6 stations representative of Newfoundland subregions and of central and coastal Labrador. These modern records have been extended into the 1800's by using portions of records from Belle Isle and the city of St.John's. The modern (post-1940) temperature records show a significant trend toward cooler winters over the entire region. Summer temperatures in Labrador and north-central Newfoundland also show significant cooling in that period; however, this trend is not present in the southwestern or southeastern parts of the island, suggesting subregional or mesoscale influences which work to counter the regional trend. The longer records for Belle Isle and St.John's show winter temperatures for the period 1870 to 1930 to have been similar to the post-1970 averages, with the 1940 to 1970 period significantly warmer by 1-2 degC. While summer temperatures at Belle Isle declined by 0.5 degC since 1880, at St.John's summer temperatures rose by almost the same amount. Comparative examination of the precipitation record for these stations also reveals subregional contrasts in the degree of variability and trend for annual and seasonal totals. For St.John's a representative continuous series is constructed to show variability in the annual total from the late 1800's, from analysis of records at three local stations; this exhibits no significant overall

trend. However, there is evidence of upward trends in the recorded amounts of annual total precipitation, winter snowfall and summer rainfall for parts of central and western Newfoundland. Spatial and temporal variability in the hydrologically important ratio of snowfall to rainfall during winter is also examined. These results are examined in relation to other studies of recent climatic trends in northeastern Canada and the northwest Atlantic and their association with decadal shifts in atmospheric circulation patterns across the North Atlantic.

1D2.2
Synoptic-scale flow patterns associated with storm track variability over Atlantic Canada
Shawn S. Allan (1) and John Gyakum (1) ((1) McGill University)

We examine high wind storms affecting Sable Island for the period 1979 through 1995. Tracks and composites of the 30 highest wind storms in each meteorological wind quadrant (east-northeasterly, south-southeasterly, west-southwesterly, north-northwesterly) are gnerated using the National Centers for Environmental Prediction (NCEP) gridded reanalysis data set. A cluster correlation analysis of sea-level pressure anomalies is performed on each group of storms.

1D2.3
Persisting Dewpoint and Point PMP for the Prairie Provinces
R.F. Hopkinson (1) ((1) Atmospheric and Environment Branch, Environment Canada, Regina,
Saskatchewan)

Hourly dewpoint data for meteorological stations in the three prairie provinces and adjacent areas were processed for the 40-year period 1953 to 1992 to determine the maximum 12-hour persisting dewpoint for the months April to October. This updated a similar analysis performed by McKay (1963) based on much more limited data. The changes from Mckay's study of the maximum 12- hour persisting dewpoint values over the southern prairies were relatively minor, but significant differences were evident in data sparse regions in the north. This information is required for the rational method of storm maximization to calculate the Probable Maximum Precipitation (PMP) in compliance with WMO practices. In addition, the paper includes a method to determine the point (1.0 km2) PMP which is applicable to small projects such as tailings ponds. Finally, the dewpoint data were reviewed for trends and an assessment was made of the potential for altered PMP as a result of climate change.

1D2.4
A Temperature-Precipitation Departure Index as an Indicator of Climate Variability - A Case Study of the Maritime Provinces of Canada
Peter J. Lewis (1) and I.E. MacSwain (1) ((1) Atmospheric Environment Branch, Environment Canada, Atlantic Region)

Temperature and precipitation are two of the most important variables describing climate and form the basis of most climate classification schemes. While extremes of these

elements can have severe social or economic impacts, these impacts can either be exacerbated or ameliorated when accompanied by extremes in the other. An index which combines the fluctuactions in both temperature and precipitation - the Temperature-Precipitation Departure Index (TPDI) - is suggested for use as an indicator of climate variability. Periods of high and low fluctuation can be identified from the time series of the index. Time series for two long-term records in Maritime Canada for the period 1911-1990 show similarities in fluctuation and both show a marked increase in the magnitude of fluctuations since 1950. In a regional study of the Maritime Provinces, annual and seasonal time series for the period 1944- 90 also indicate periods of high and low fluctuations. It is suggested that the index could be used as a tool in studies which attempt to correlate climate variability with forcing factors such as the North Atlantic Oscillation (NAO), the El Nino Southern Oscillation (ENSO) or major volcanic erruptions. The index could also be used for spatial comparisons of fluctuactions for differing climate regimes.

1D2.5
Evidence of Natural Variability in Climate Change during the Past Millenium and Its Possible Role in Current and Future Trends
M.R. Morgan (1) and R. Pocklington (2) ((1) CLIMARCON, Halifax, NS, (2) Bermuda Biological Station, Bermuda)

Temperature change in the Northern Hemisphere, in the past millenium, based on paleo-climate evidence and by instrumental observations, since the late 18th century, are examined. We show that periodic regional climate variability comparable with that experienced during this century has been naturally extant prior to the rise in man-made “greenhouse gas” emissions.

This brings into question just how much recent regional temperature trends comprise a naturally induced component and the latter’s role in future climate change.

Session 1-D3
Coastal Oc. Modelling

Monday June 1
15:20 - 17:00
Alderney Room

1D3.1
Tides of the Northwest Atlantic Calculated Using the CANDIE Circulation Model with a Free Surface Youyu Lu (1), Keith R. Thompson (1) and Jinyu Sheng (1) ((1) Dept of Oceanography, Dalhousie University, Halifax, NS)

The surface pressure formulation of the CANDIE ocean circulation model is improved to include changes in the height of the free surface. An implicit treatment of the surface elevation retains the numerical efficiency of the original rigid-lid code. Special attention

is paid in this talk to the treatment of open boundary conditions. An idealized model domain is used to test the free surface formulation. The model is then used to compute the three dimensional barotropic tide of the Northwest Atlantic with emphasis on the shelf seas. The boundary forcing is estimated by assimilating all coastal tide gauge data into a shallow water model with the open boundary conditions taken as controls. Further applications, which are now in progress, aim to improve the parameterization of vertical mixing in the simulation of seasonal variations in shelf circulation in this region.

1D3.2
Modelling Diurnal Tides and Coastal-Trapped Waves off Vancouver Island
Patrick F. Cummins (1) and Micheal G.G. Foreman (1) ((1) Institute of Ocean Sciences)

A three dimensional, baroclinic numerical model with realistic bathymetry is applied to study the characteristics of the K_1 tide over the continental shelf off Vancouver Island. The region is one of anomalously large diurnal tidal currents due to generation of shelf waves near the mouth of Juan de Fuca Strait. Several numerical experiments were conducted to assess the influences of density stratification and wind forcing on the K_1 tidal currents over the shelf. Comparisons are made with data obtained from a series of moorings, including a line extending for about 300 km in the alongshore direction over the shelf. The results show that inclusion of the stratification significantly improves the representation of K_1 currents in the model, particularly with respect to the alongshore phase propagation of the clockwise and counterclockwise rotary components of the motion. The results are consistent with theoretical models which indicate an increase in the phase speed of coastal rapped motions due to the stratification.

The seasonal variability of the K_1 currents is also examined from long records obtained at a number of sites over the shelf. The observations indicate a seasonal modulation in the phase of the rotary components which increase in amplitude with distance from the generation region of the shelf waves. Attempts to model the summer/winter phase difference by including a seasonal mean wind will be discussed.

1D3.3
Numerical Modelling of the Gaspe Current
Mateusz K. Reszka (1) and Gordon E. Swaters (1) ((1) Department of Mathematical Sciences, University of Alberta)

The Gaspe current in the St. Lawrence estuary is a mesoscale jet driven by freshwater runoff from the south shore, and marked by a pronounced salinity front. The variability observed in the Gaspe current, as well as its precursor, yields unstable waves and eddies, and is believed to be predominantly baroclinic in origin. We present numerical experiments of the Gaspe current instability, using a baroclinic, frontal geostrophic model. The model was derived in a systematic reduction of the appropriately-scaled two-layer shallow water equations. While previous studies assumed the quasigeostrophic approximation, our model does not require the stipulation of small interfacial deflections, and can accomodate frontal outcroppings. With parameter values chosen to reflect key characteristics of the Gaspe current, we show emergence of growing waves as well as

eddy detachment and interaction. The results are quantitatively compared with previous analyses and observational data associated with dominant length scales and growth rates. The role of bottom topography is investigated, in particular its ability to stabilize and destabilize a perturbed flow. Finally, we comment on the applicability of this model to other coastal/estuarine currents, and its relation to primitive equation models.

1D3.4
Seasonal-mean and tidal circulation on the eastern Scotian Shelf
Guoqi Han (1) and John W. Loder (1) ((1) Bedford Institute of Oceanography)

Seasonal-mean and tidal circulation on the eastern Scotian Shelf is studied using a prognostic finite-element model (QUODDY4; Dartmouth College). The model is three-dimensional, fully nonlinear, and closed with an advanced turbulence scheme. The seasonal-mean circulation for four bimonthly periods (January-February, April-May, July-August and October-November) shows dominant southwestward nearshore and shelf-break currents, embedded with anticyclonic (cyclonic) gyres over outer-shelf banks (inner-shelf basins) and cross-shelf exchange through deep channels. The model transport in the nearshore and shelf-break currents shows prominent seasonal and alongshelf changes. The baroclinic component dominates the nearshore current, while the shelf-break current is sensitive to barotropic boundary inflows through Cabot Strait and on the southern Newfoundland Shelf. Tidal mixing plays an important role over the outer shallow banks, even though tidal rectification is generally weak in the entire region. The solutions are in approximate agreement with observed transports and currents for the primary flow features.

1D3.5
What is the influence of indented walls on the oceanic circulation?
Frederic Dupont (1), David Straub (1) and Charles A. Lin (1) ((1) Atmospheric & Oceanic Dept, McGill, Montreal, QC)

In most oceanic models, complex basin geometries are approximated by well known step-like (or indented) boundaries. These boundaries present sharp corners at the resolution scale of the model. Thus, there is an unknown risk of amplifying small scale numerical noise. Extending the work of Adcroft and Marshall (1997), we examine if indented walls along the boundary are a suitable approximation for straight walls that are not aligned with one of the coordinate axes. Adcroft and Marshall (1997) used the Munk-Stommel problem as a test case. The physical problem remains identical except for an artificial rotation which only affects the discretization of the square basin. This artificial rotation creates indented walls and has an influence on the general ocean circulation. We propose a similar experiment which compares results from a rotated and non-rotated grid. Here, we consider the dependence of the influence of the grid orientation on the circulation as a function of Reynolds number. We are particularly interested in whether numerical problems associated with corners increase or decrease with Reynolds number as higher resolution permits the use of more realistic values for the eddy viscosity.
The experiments are performed using a shallow water finite difference code and consider statistical steady states under both slip and no slip conditions.

Session 1-D4
Radiation

Monday June 1
15:20 - 17:00
McNabs Room

1D4.1
A Review of Measurements of Surface Radiative Forcing by Greenhouse Gases
Wayne F. J. Evans (1) and Eldon Puckrin (1) ((1) Environmental Resource Studies, Trent University)

A review of our measurements of increases in surface radiation from greenhouse gases is presented. Global warming is driven by increases in the greenhouse radiation from the atmosphere. Atmospheric spectra of greenhouse radiation from the atmosphere have been measured at ground level from Peterborough at a resolution of 0.02 wavenumbers. This long wave radiation consists of thermal emission from natural gases such as CO2 and H2O as well as from many trace gases such as CH4, N2O, O3, CO, CFC11, CFC12, CFC22 and HNO3. These fluxes have been quantitatively measured. The forcing radiative fluxes from CFC11, CFC12, CCl4 and HCFC22 represent an absolute increase in the greenhouse radiation. A summary of the fluxes we have measured is presented. A flux imbalance of about 3 W/m2 has been created by anthropogenic emissions of greenhouse gases of which we have measured 1.1 W/m2. These measurements are compared with the radiation fluxes predicted by models. A simulation with a surface energy balance model indicates that a temperature increase of 0.5° C should have occurred at Canadian latitudes. Of this temperature increase, 0.2° C is due to the buildup of CFCs in the atmosphere.

1D4.2
Consequences of high Resolution Topography on Radiation Balance and Aerosol Circulation in NARCM
Fabien Zuretti (1), Jean-Pierre Blanchet (2) and René Laprise (2) ((1) Department of Earth Sciences, UQAM, Montréal, QC, H3C 3P)

Mexico city, the world largest city, has a high level of pollution due to human activities. Combined to the high population density, the particular topography of the area favors the increase of the pollution. At an average altitude of about 2200 m, Mexico is surrounded by high mountains on three sides, creating suitable conditions for thermal inversion and air stagnation. The atmospheric circulation is influenced by katabatic and kinematic flow altering the pollution dispersion. In this experiment, we take NARCM explicit aerosol model to investigate some aspects of this circulation on a typical winter day. The 3D topography modulate the absorption of solar radiation on the region, creating a particular diurnal circulation. Increase heating and shadow effects are evaluate at a resolution of 2 km on a domain of 240 by 240 km around Mexico. The katabatic flows also affect the drainage of pollution on some particular pathway. The main objective of the project is to

investigate the factor altering visibility in the city. Preliminary results will be presented and discussed.

1D4.3
Application of NARCM to the Earth Radiation Mission Measurement Synergetics
J.-P. Blanchet (1), M. Larocque (1), P. Park (2), S.R. Pal (3), L. Spacek (1), R. Girard (2), M.W.P. Cann (3) and D. Donovan (3) ((1) Université of Québec at Montreal, Montreal, Qc., (2) MPB Technology, Pointe Claire, Qc, (3) ISTS, York University, Toronto, ON)

The design of new satellite instruments requires synergetic instrument simulation for mission planning. In preparation to the ESA`s Earth Radiation Mission, NARCM is used as a framework to simulate high resolution atmospheric data fields including clouds and aerosols properties. This approach is applied to generate synthetic fixed frames at resolutions ranging from 50 to 1 km per pixel. The model simulation is done for a storm case near Halifax during the Space Shuttle LITE mission in September 1994. This data set is fed into a new satellite simulator, SYnergetic Passive and Active Instruments simulator (SYPAI), with the objective of retrieving 3D properties of clouds and aerosols. Modelling satellite instruments in climate and forecast models is a new approach for direct comparison and validation of models against satellite measurements. The method will be discussed with typical cases.

1D4.4
On the Coupling Aerosol Radiative Properties to Prognostic Aerosols in NARCM
J.S. Fontecilla (1), J.-P. Blanchet (1) and L. Spacek (1) ((1) Department of Earth Sciences, UQAM, Montreal, QC.)

The Northern Aerosol Regional Climate Model (NARCM) is used to investigate the coupling between absorbing aerosols with dynamics transport of particles. The smoke is treated as a 8 bins size segregated aerosol spectrum composed of a mixture of soot and sulfate. The parameterized aerosol microphysics includes coagulation, dry and wet deposition, and gravitational sedimentation. The dispersion, the concentration, and the deposition of smoke is investigated . Mie calculations are used to determine optical properties for each particulate size as a function of relative humidity. The aerosol optical properties are coupled with the solar and IR radiative processes. The regional climate forcing and its climate response are investigated. This study is used to validate the active aerosol treatment in NARCM project. The results are compared against available observed values from KUDA project taken during the Kuwait oil fire.

Session 2-A
Industry Day and Biological Cycles

Tuesday June 2
08:35 - 09:50
Lake City Ballroom

2A1.1
What the offshore industry requires from meteorologists and oceanographers
Cal Ross ((1) SOE Inc.)

During the life of an offshore oil project, various types of meteorological and oceanographic data are required. In the concept stage, data are needed to determine the type of drilling or production platforms most practical for the environment. These are usually "norms" or exceedance charts. During the design or rig selection process, wave spectra, extremes and period frequencies are required for structural and fatigue analysis. During operations, forecast products are required from a weather service. These forecasts range from the standard site-specific marine forecasts to answering long terms planning questions such as "How stormy is October going to be?"
At some time in the life of the project, almost all types of meteorological and oceanographic information will bw use for long and short term planning purposes. The service provider must be able to interpret the request from the non-specialist and provide the right data with the appropriate level of interpretation.

2A1.2
Food-web structure and fluxes of biogenic carbon in polar marine waters
Louis Legendre (1) ((1) Department of Biology ,Universite Laval, Quebec ,QC)

Polar marine waters are characterized by environmental characteristics such as an extreme seasonal cycle of solar radiation and submarine irradiance, low temperature, and a seasonal ice cover. These have major effects on the structure of pelagic ecosystems. The resulting food-web structure influences the channelling of biogenic carbon toward apex predators and the deep waters.

Session 2-B1
Biogeochemical Cycle

Tuesday June 2
10:10 - 12:10
Hawthorne Room

2B1.1
Abundance of bacteria in the Labrador Sea
W.K.W. Li (1) ((1) Bedford Institute of Oceanography)

The distribution of total heterotrophic bacteria in the upper water column of the Labrador Sea was surveyed in spring, summer and fall. The maximum abundance of bacteria varied only by a factor of about two in the seasons studied. Generally, bacterial abundance was of the same order (million cells per ml) as found in many mid- and low-latitude open ocean systems.

However, because phytoplankton concentrations in the Labrador Sea can attain seasonal values much higher than in many mid- and low-latitude oceanic waters, the relationship between phytoplankton and bacteria in the Labrador Sea appears different. In other words, the bacterial stock is not as high as might perhaps be sustainable by the phytoplankton stock. In an analysis of the global abundance of marine bacteria in diverse habitats at the annual climatological scale, a direct relationship was found between the annual average abundance and annual average temperature below 14C.
These results suggest that at the annual time scale, bacterial abundance in the Labrador Sea may be determined by temperature.

2B1.2
On the Ecology of Calanus SPP. in the Labrador Sea
Erica Head (1), Leslie Harris (1) and Robert Campbell (1) ((1) Bedford Institute of Oceanography, DFO, OSD, Dartmouth, NS)

Samples of zooplankton (0.2 mm) were collected in the near surface layers at stations of the L3 Section across the Labrador Sea (LS) in spring (‘94, ‘96, ‘97), summer (‘95) and fall (‘96). The samples were dominated by three species of copepod: Calanus finmarchicus, C. hyperboreus and C. glacialis. C. finmarchicus was numerically the most abundant species over the central LS, where the warm water of the Atlantic Ocean has its greatest influence. By contrast, the other two species generally showed higher abundances in the colder waters over the shelves. Highest abundances of C. finmarchicus were observed in the eastern LS in summer, apparently in association with inflowing Irminger Current waters. Biomass of C. finmarchicus was similar in spring and summer, when adults and younger stages dominated, respectively, but it was very low in the fall. By contrast, in the fall, large numbers of overwintering C. finmarchicus were found at depths of 100 m. The springtime abundance of C. finmarchicus apparently decreased over the ‘94 - ‘97 period. This decrease was not due to differences in reproductive rates, although it appears that survival of eggs and naupliar stages may be affected by predator abundance and food (i.e. phytoplankton) concentration.

2B1.3
Dissolved Organic Carbon (DOC) in the Labrador Sea
P.E.Kepkay (1) and J.B.C.Bugden (1) ((1) Bedford Institute of Oceanography)

DOC in the world’s ocean is a truly global reservoir of biogenic carbon - equal to the gigatons stored in soils and terrestial forests. It easily outweighs any other marine pool of biogenic carbon. In the Labrador Sea, the sheer size of the DOC pool means that any process regulating its size and reactivity will have a large effect on the cycling of carbon between atmosphere and surface ocean and the storage of carbon in the deep ocean.

Results obtained on the AR7W section during May of 1996 suggest that DOC concentrations are relatively high in surface waters (55-85 uM C), outweighing particulate organic carbon (POC) by a factor of about 5 in the middle of the section and a factor of 2-3 on the Labrador and Greenland shelves. The build up of substantial amounts of biogenic carbon on the shelves was primarily in the colloidal organic carbon (COC) size fraction and there was a close association between respiration and COC. Given that COC is the most bioreactive component of DOC, the combined measurements of DOC, COC and respiration provide key preliminary information on: 1. The rate at which DOC is processed by the biota in surface waters,and 2. The amount of DOC available for transport to the ocean interior by deep seasonal convection.

2B1.4
Modeling DOC export in the Labrador Sea
Rucheng Tian (1) and Alain F. Vezina (1) ((1) Fisheries and Oceans, Institut Maurice Lamontagne)

The traditional view is that organic carbon is lost from the upper ocean via sinking particles. However, increasing evidence suggests that substantial amounts are exported in the form of dissolved organic carbon (DOC). This DOC could be transported and sequestered to great depths in a convecting system like the Labrador Sea. Here we present preliminary results from a biogeochemical model that includes descriptions of the biological processes that produce and remove DOC in the water column. This model is embedded in a vertical mixing scheme parameterised from climatologies of the density structure. This allows us to compare the relative magnitude of DOC and POC export pathways and to evaluate the sensitivity of these pathways to small changes in the physical and biological parameters. Preliminary results suggest that DOC export is at least as important as sinking POC in removing organic carbon from the surface layer. Also, DOC tends to penetrate deeper into the water column than POC. However, the parameterisations of a number of biological processes in the model are crude and further field measurements are needed to improve the model and to increase confidence in its simulations.

2B1.5
Dynamics of Bacterial Dimethylsulfide (DMS) Production from Dissolved Dimethylsufoniopropionate (DMSPd) in the Labrador Sea
Sabine Schultes (1), Maurice Levasseur (1), Sonia Michaud (1), Guy Cantin (1), M Gosselin (2) and S J de Moral (2) ((1) Fisheries and Oceans, Institut Maurice Lamontagne, (2) Department of Oceanography, University of Quebec at Rimouski)

The dynamics of bacterial cleavage of dissolved DMSP (DMSPd) into DMS was measured in the surface waters of the Northwest Atlantic and Labrador Sea between May 9th and June 12th 1997. Surface water samples collected at 18 stations were amended with DMSPd (10 to 5000 nM) and incubated for 3 h at in situ temperatures. Control bottles were incubated without DMSPd additions. Changes in DMSPd and DMS were recorded hourly. At in situ DMSPd concentrations (control) , DMS levels usually did not change significantly during the time of incubation, indicating a balance between

production and consumption processes. However, three stations did show a clear tendency towards net DMS production. In DMSPd amended bottles, bacterial DMS production from DMSPd showed, as consistent with earlier findings, limitation by substrate yet the process does not seem to saturate even at additions of 5 mM DMSPd. The production rates of DMS as a function of substrate (DMSPd) concentration vary by a factor 10!
between the different stations. A preliminary analysis of the results indicates that changes in water temperature are responsible for about 50 percent of this variability. Results from incubations conducted in a Phaeocystis sp. bloom, a known strong DMS producer, revealed substantially altered DMS dynamics. Both natural and DMSPd amended systems showed rapid (h) alternation between net DMS production and net DMS consumption. A pr eliminary interpretation of the data indicates the presence of a bacterial community adapted to high levels of DMS production. This study provides the first set of data reporting on the dynamics of bacterial DMS production in cold water environments.

2B1.6
A tracer of anthropogenic CO2 in the Labrador Sea region
V. K. Tait (1), R. M. Gershey (1), E. P. Jones (2), I. Yashayaev (2) and I. J. R. N. Lazier (2) ((1) B.D.R. Research, (2) Bedford Institute of Oceanography, Dartmouth, Nova Scotia)

The intermediate and deep waters of the Labrador Sea are dominated by recently ventilated water masses (ventilation ages < 20 years). DSOW (Denmark Strait Overflow Water) and NEADW (North East Atlantic Deep Water) which enter the Labrador Sea from the North Atlantic, are overlain by Labrador Sea Water (LSW) which is formed within the Labrador Sea region itself. Atmospheric gases such as CO2 and chlorofluorocarbons are incorporated into these water masses at the time of formation and subsequently transported via boundary currents into the North Atlantic interior. Measurements of total alkalinity (ALK) and total carbonate (CT) have been made in the Labrador Sea annually since 1993. These 2 parameters can be used together to characterize the carbonate chemistry of the waters sampled. Total alkalinity and total carbonate, when normalised to a salinity of 35, are useful indicators of river water inputs, such as on the Labrador shelf. Increases in normalised alkalinity and total carbonate are also observed in some near bottom samples in areas of intense flow possibly due to interaction with sediments.

The measurements of ALK and CT have been used to construct a quasi- conservative tracer of dissolved anthropogenic carbon dioxide following the method outlined by Gruber et al. (1997) (Biogeochem. Cycles, 10, 809).
The advantages and limitations of the use of this tracer in the Labrador Sea region are discussed with reference to the observed temporal and spatial distributions and concurrent measurements of CFC-11.

Session 2-B2
Long-range Forecasting

Tuesday June 2
10:10 - 12:10
Sullivan Room

2B2.1
Surface temperature anomaly forecasts over periods ranging from five to ninety days
R. Verret (1), A. Bergeron (1), L. Lefaivre (1) and A. Plante (1) ((1) Atmospheric Climate and Water Systems Branch, Canadian Meteorological Centre, Dorval, Quebec)

Series of Perfect Prog (PP) simple linear regression equations relating observed temperature anomalies over 5-, 7-, 10-, 15-, 30- and 90-day periods and the corresponding analyzed mean 1000-500 hPa thickness anomalies have been developed at an ensemble of 240 Canadian stations. The dependent database covers 31 years from 1963 to 1993. Linear regressions have been developed to be used each day of the year to generate temperature anomaly forecasts over the following periods ranging from 5 to 30 days. The equations for the 90-day periods are available on the first day of each season only (December 1, March 1, June 1 and September 1) and are used to forecast temperature anomalies over the following three months. A window of plus or minus seven days centered on each Julian day of the year has been used to increase the number of time series available to derive the linear regressions. The statistical relationships have been calibrated such that the ordinate at the origin is zero. A bootstrapping technique has been applied to estimate the mean and standard deviation of the slope of the regression lines.

In forecast mode, the 1000-500 hPa thickness anomalies valid at 00 and 12 UTC provided by the driving model are averaged over the proper forecast periods and multiplied by the regression line coefficients to generate the mean surface temperature anomalies over the corresponding periods. The thickness climatology used for the forecast periods from 5 to 15 days has been calculated on the dependent sample from 1963 to 1993. This approach is based on the hypothesis that the model climatology does not differ significantly from the real climatology. The driving model for the temperature anomaly forecast over periods up to 15 days is the operational Canadian Global model with a spectral truncation at T199. Forecasts over the 30-day periods are driven by a lower resolution of that model with a spectral truncation at T63. The 30-day temperature anomaly forecasts are generated by averaging the 1000-500 hPa thickness valid at 00 and 12 UTC on each day of the valid period produced by six runs of the T63 model initiated 24 hours apart in a lagged average approach. The thickness climatology used is derived from the dependent sample, but a project is underway to replace it with the model climatology. In the current operational set-up, 30-day temperature anomaly forecasts are produced on the first and sixteenth days of each month. The temperature anomaly forecasts over 90-day periods are generated by averaging the thickness valid at 00 and 12 UTC on each day of the valid period produced by six runs of the T63 model and six runs of a General Circulation model (GCM) in a lagged average approach. The GCM has a

spectral truncation at T32. The thickness anomalies from both models are computed independently with their own model climatology and then averaged together. The lagged average approach used in the 30- and 90-day forecasts helps to reduce the noise level caused by unpredictable small scale features.

The temperature anomaly forecasts are generally categorized into three equiprobable classes. Forecasts have been verified at an ensemble of stations and show skill with respect to chance out to 90 days. Forecasts also show skill with respect to persistence over all forecast periods. Most of the skill of the temperature anomaly forecasts over 15-, 30- and 90-day periods comes from the first 10 days of the valid period.

2B2.2
Numerical Simulation of the Atmospheric Response to Middle Latitude SST Anomalies in the Northeast Pacific
Hua Sheng (1) and Harold Ritchie (1) ((1) Numerical prediction Research, Environment Canada)

Using RPN's global spectral model(SEF), we investigate the atmospheric response to middle latitude SST anomalies in the Northeast Pacific. A characteristic pattern with a positive SST anomaly gradient (PSST) in the east-central North Pacific, i.e., a warm water along the central west coast of North America in the area 45N-55N latitude and 130W-125W longitude and cold water in the east-central North Pacific in the area 30N-40N latitude and 165W-135W longitude, was added to climatological SST field. The negative SST anomaly gradient (NSST) is reversion as above. The five month runs for ten years, each starting from March 31, were performed for PSST and NSST respectively. The results were compared to a control integration with climatological SSTs (CSST). Difference fields between the experiments (PSST,NSST) and Control runs are statistically significant with negative geopotential height over west coast of North America, and positive height over the Labarador sea. As previous study, the response is equivalent barotropic structure. It is noteworthy that PSST and NSST response are quite similar. But the amplitude of PSST response is larger than NSST's and those at upper level is larger than those at lower level.

Examination of sensible heat flux, water vapor flux and momentum flux underly surface, it is demonstrated that the SST forcing influence on the air-sea exchange. This effect does not isolate on the prescribed SST anomalous area, it also spread over a globe through the atmospheric general circulation. A elongated negative anomalous precipitation belt appears along the 20N latitude from west Pacific to east Pacific, which is associated with storm track northward shift. It is consistent with negative vertically integrated vorticity belt along 30N latitude, positive vorticity and kinetic energy belt along 40N latitude from west Pacific to east Pacific. The strong positive anomalous precipitation reveals in gulf of Mexico, southeast United States, and Caribbean sea, another area in the Southeast Asia, except over the warm water area. The maximum positive value reaches to 31 mm/day. The most anomalous precitation attributes to the convective precipitation due to the SST forcing.

Vertically integrated budgets of energy show, for NSST expirement, it is clear that the positive energy budget appear over the warm water area, downstream over the Caribbean; the negative energy budget appear over cold water, downstream with positive value in east Canada. It indicates the sensible heat and latent heat play a crucial role in the atmospheric response to SST foring. However, for PSST expirements, the dominant mechanism appears to be positive latent heat release over the warm water.

2B2.3
A new predictor for winter conditions over the North Pacific and North America
Hai Lin (1) and Jacques Derome (1) ((1) Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Qc)

Using the 40-year NCEP reanalysis data, a significant long-term lag correlation is found between the amplitude of wintertime North Atlantic Oscillation (NAO) and the atmospheric anomalies over the North Pacific Ocean and western North America. A below (above) normal Icelandic low leads a below (above) normal Aleutian low by three years. This correlation is as strong as the correlation between the ocean temperature in the eastern tropical Pacific (El Nino region) and the North Pacific winter atmospheric anomalies. A statistical prediction model for mean-winter conditions is constructed based on the above new and previously known correlations. The prediction model is tested on 36 winters of the past. The model predictions are shown to be of remarkable quality over the North Pacific and western North America.

Sea level pressure data from 1899 is used to check the validity of the above correlation.

2B2.4
Long-Range Prediction of the Yield and Protein Content of Western Canadian Durum Wheat
J.C. Babb (1) and E.R. Garnett (2) ((1) Canadian Grain Commission, (2) The Canadian Wheat Board, Winnipeg, Manitoba)

It is well-established that wheat yields and protein content are inversely related and that both depend heavily upon seasonal weather. Large-scale atmospheric and oceanic circulation patterns associated with El Nino/Southern Oscillation (ENSO) events have been shown to impact upon seasonal weather over much of the world, including Western Canada. As well, it has been demonstrated that the Pacific North American (PNA) atmospheric oscillation is associated with seasonal weather over the Canadian prairie provinces.

In this study, data for for a 33-year period (1965-1997) is used to examine the relation of the yield and protein content of Western Canadian durum wheat to monthly precipitation and temperature over the growing region and to monthly indices of the PNA and ENSO teleconnections. Multiple regression methodology is applied to develop climate-based models for advance prediction of the yield and protein content of amber durum wheat.

Models based on regional precipitation and temperature data are compared to others supplemented with teleconnection indices. Cross-validation is used to assess predictive performance.

2B2.5
CLIMATE VARIABILITY IN A SIMPLE ATMOSPHERIC GCM WITH CONSTANT FORCING

Nick Hall (1) ((1) Department of Atmospheric and Oceanic Sciences, McGill University)

A dry spectral primitive equation model is used to form the basis for a `simple GCM'. The model consists of predictive equations for vorticity, divergence, temperature and surface pressure. Processes traditionally described as `model physics' are simulated through the addition of simple forcing and damping terms to the predictive equations. The damping is mostly linear in model variables and follows a prescribed vertical profile. A small horizontal hyperdiffusion term is also present. The forcing is constant in time, and acts on all model variables. It is calculated from a long time series of observational data in a way which is designed to represent the observed diabatic forcing.

This GCM captures the gross aspects of the atmospheric circulation including the mid-latitude jets and storm tracks. Output from a long integration will be compared with data.

An advantage of the primitive equation formulation is the ability to simulate tropical flows and the mid-latitude response to tropical forcing anomalies such as El Nino. Preliminary results from some linear and nonlinear simulations will be presented.

2B2.6
On the relationship between the PNA pattern and the atmospheric predictability
Jian Sheng (1) ((1) Canadian Centre for Climate Modelling and Analysis/AES, Victoria, BC)

Predictability experiments have been conducted using the CCC general circulation model. Forecasts are initiated when the PNA pattern is in strong positive or strong negative phases. For each forecast, an ensemble of six intitial conditions is generated with small random perturbations. A comparison of forecast skills shows that forecasts started from positive PNA phases tend to have smaller error growth rates than that started from negative PNA phases. Regional characteristics of the rms error are also examined. Similar experiments are performed to determine the relationship between the predictability and tropical SST anomalies. The results suggest that tropical SST has only secondary importance compared to the PNA pattern.

Session 2-B3
GLOBEC 1

Tuesday June 2
10:10 - 12:10
Alderney Room

2B3.1 & 2B3.2
U.S. GLOBEC - Climate Variability and Fisheries
David G. Mountain (1) ((1) NOAA/NMFS/Northeast Fisheries Science Center)

The U.S. GLOBEC Georges Bank program seeks to determine the effect of climate variability on the Georges Bank ecosystem, with particular interest in the developing year classes of cod and haddock, and on two zooplankton species which are important prey for the gadid larvae. The program is structured to integrate repeated population-scale (or Bank-scale) sampling, dedicated process studies and bio-physical modeling to develop a process-based understanding of how physical processes influence the population dynamics of the targeted organisms. Preliminary results, combined with historic data sets, suggest that large time- and space- scale atmospheric forcing and oceanographic variability may cause significant ecosystem variability. Discussion will focus on 1) how the program intends to determine the processes controlling the apparent climate-ecosystem relationships, 2) what implications these relationships may have for fisheries production and 3) how an understanding of these relationships could be utilized by fisheries management.

2B3.3
Interannual Variability of Boundary Fluxes and Water Mass Properties in the Gulf of Maine and on Georges Bank
Peter C. Smith (1), Robert W. Houghton (2), Richard G. Fairbanks (2) and David G. Mountain (3) ((1) Coastal Ocean Science, OSD, Bedford Institute of Oceanography, Dartmouth, N.S., (2) Lamont Doherty Geological Observatory, (3) National Marine Fisheries Service, NOAA)

Analysis of nearly four years (Oct.'93-June '97) of monthly mean current, temperature and salinity observations from moorings in the major Gulf of Maine (GOM) inflows off southwest Nova Scotia (C2) and in Northeast Channel (NECE) reveal interannual variability with magnitude similar to that of decadal variability recently analyzed on the Scotian Shelf. An episode of enhanced warm, saline, deep (>75m) inflow at NECE during the first part of the observation period (Oct.'93-Sept.'94) was followed by two later episodes (Nov.'94-Mar.'95 and Apr.- Feb.'97) of enhanced cold fresh inflow in the surface layers. The freshwater inflow pulses are traced at reasonable advection rates with hydrographic measurements from around the GOM and onto Georges Bank (GB), where surface layer salinities plummet in early 1997. Oxygen isotope analysis suggests that almost all of the fresh water present on the central cap of GB in '96 and early '97 is of northern (Scotian Shelf) origin as opposed to '94 and '95 when Maine River Waters contributed 33% and 25%, respectively, to the freshwater (relative to 34.8) on the cap.

Examination of possible local and remote sources confirms that the origin of the ‘96-’97 freshwater anomaly is in the northern Labrador Sea/Baffin Bay and results from exceptionally cold winters in the early ‘90s. Advection rates are found to be largely consistent with other direct and indirect observations. Similar events in the early ‘80s and ‘70s suggests their occurrence is part of a quasi-decadal climate signal which follows the North Atlantic Oscillation (NAO).

2B3.4
WATER AND CURRENT PROPERTIES ON WESTERN BANK
Gleb Panteleev (1), Brad deYoung (1), A. Bowen (2), C. Reiss (2) and C. Taggart (3) ((1) Physics and Physical Oceanography,Memorial University, (2) Department of Oceanography, Dalhousie University)

Temperature and salinity (TS) measurements in the Western and Emerald banks collected during the Summer-Fall period in 1991, 1992, 1997 and Western Bank were analysed together with current meter data from 1997. The distribution of the water masses in the upper layer is defined primarily by spreading of cold fresh water from the northeast and by penetration of warm salt water through the channel between Emerald and Western Banks and partly througth the Emerald Basin. The influence of the wind stress and St. Lawrence river discharge on these processes were investigated. The analysis of the long term current measurements on the Western bank revealed a persistent anticyclonic circulation with near zero mean current at the crest of the bank. The centre of the circulation defined as a zero velocity point drifted westward over the whole period with speed 5 and 20 km/month during the Summer and Fall respectively. Both TS and CM measurements showed two distinct (summer and fall) periods with an abrupt transition of wind stress around mid-October. The period of near-inertial oscillations varied by about 0.5 hours and the amplitude decreased from 20-30 cm/s in summer to about 5-10 cm/s in fall.

2B3.5
Prediction of surface currents on the northern British Columbia Shelf
William R. Crawford (1), Josef Y. Cherniawsky (1) and Patrick F. Cummins (1) ((1) Canadian Hydrographic Service, Institute of Ocean Sciences, Sidney, BC)

Between 1990 and 1995 the Canadian Hydrographic Service deployed surface drifters in the waters off northern Vancouver Island and around the Queen Charlotte Islands. These measurements are of use to evaluate dynamical models of surface currents. From the tracks of surface drifters in Queen Charlotte Sound in the summer of 1995 we have extracted daily average currents. These are compared with surface currents simulated by the Princeton Ocean Model (POM), forced by a wind field computed from weather buoy data. We compare these POM currents with currents computed from a least-squares fit (LSF) between drifter vectors and daily mean metbuoy winds, interpolated to the drifter positions. In general, POM vectors explain almost as much variance in the daily drifter vectors as does the LSF. However, POM model currents follow the coastline more faithfully than can be inferred from the LSF alone.

2B3.6
UW-NMS performance in the coastal waters and interior of British Columbia
Henryk Modzelewski (1) and Roland Stull (2) ((1) Department of Atmospheric Science and Geography, University of British Columbia, (2) Department of Geography, University of British Columbia)
The University of Wisconsin mesoscale Nonhydrostatic Modelling System (UW-NMS) is being used at UBC to simulate wind-stress over the coastal waters of British Columbia, in order to provide the driving force for an ocean-circulation model. Two types of studies have been conducted recently.

First, the reforecast was performed for the entire 1995 year at 30km resolution. This period is of interest because of the vast amount of special observations over the ocean collected during the GLOBEC project. The results obtained by UW-NMS were verified against observations collected at buoys located mainly around Vancouver Island.

Second, real-time forecasts are performed at 10km resolution. The performance of the model is compared with ongoing real-time validation against coastal and inland surface stations.

During the presentation the validation of the model over the ocean and the land will be presented and compared. The conclusions related to model performance in both environments, and the similarities and differences, will be presented. Potential improvements will be identified.

Session 2-B4
Atmosphere

Tuesday June 2
10:10 - 12:10
McNabs Room

2B4.1
The Canadian Middle Atmosphere Model
S.R. Beagley (1), J. de Grandpré (2), J.N. Koshyk (3), N.A. McFarlane (4) and T.G. Shepherd (5) ((1) Department of Earth and Atmospheric Science, York University., (2) Department of Earth and Atmospheric Science, York University, North York, Ontario, M3J 1P3, Canada., (3) Department of Physics, University of Toronto, Toronto, Ont., M5S 1A7,Canada., (4) CCCMA, AES, University of Victoria, P.O. Box 1700 MS 3339, Victoria, BC V8W 2Y2 , Canada., (5) Department of Physics, University of Toronto, Toronto, Ont., M5S 1A7, Canada.)

The Canadian Middle Atmosphere Model (CMAM) has recently been run for a 10 year simulation period. The CMAM has continued to develop over the years and now includes interactive chemistry and two alternative gravity wave drag schemes, allowing simulations of the radiative-dynamical-chemical system up to 100km. The interactive

chemistry is a fully online gas-phase chemistry module from which species tendencies are derived and combined with physics and transport tendencies to compute the tracer fields. Ozone and water are passed to the radiation and hence feedback on the model dynamics and physics.

Results will be shown of the latest CMAM multi-year simulations, together with experiments planned and in progress and future development tasks.

2B4.2
On the climatology of atmospheric constituents in the Middle Atmosphere.
J. de Grandpré (1), S.R. Beagley (1), J.C. McConnell (1) and J.W. Sandilands (1) ((1) Dept. of Earth and Atmospheric Science, York University, Toronto, ON)

The Canadian Middle Atmosphere Model (CMAM) has been used to investigate the annual and interannual variability of atmospheric constituents in the middle atmosphere region (0-95km). Multi-years simulation with a radiatively coupled chemical module have been performed to study the climatological distribution and variability of ozone and several long lived species such as N$_2$O, CH$_4$ and CO. The chemistry module includes a relatively complete set of constituents to solve ozone photochemistry including odd-hydrogen, nitrogen, chlorine, bromine families and methane related species.

We will present comparisons of model results with observations to assess the model capability to represent transport and photochemistry processes throughout the disparate conditions of the stratosphere and mesosphere regions. The impact of incorporating ozone radiative feedback in the model will be discussed.

2B4.3
Aircraft emission and its potential impact on the middle atmosphere ozone photochemistry.
J. de Grandpré (1), J.C. McConnell (1), S.R. Beagley (1) and D.J. Chartrand (1) ((1) Dept. of Earth and Atmospheric Science, York University)

The Canadian Middle Atmosphere Model (CMAM) has been used to investigate the long term impact of aircraft fuel emission on ozone and other species in the middle atmosphere. The continuous injection of hydrocarbons and nitrogen oxides among other species, has the potential to perturb the ozone layer and consequently the climatology of the region. The CMAM model has been run with a fully interactive ozone field that makes it suitable to simulate the various feedback processes involved. This experiment is part of an international study conducted under the auspices of IPCC to assess the potential impact of subsonic and supersonic aircrafts on the photochemistry processes occuring in the middle atmosphere. The importance of the anthropogenic signal introduced will be compared with the model variability to assess the climatological significance of the perturbation.

2B4.4
Heterogeneous chemistry modeling in the Chemistry Transport Model (CTM)
John C. McConnell (1), Darryl J. Chartrand (1) and Edna. Templeton (1) ((1) Department of Earth and Atmospheric Science, York University)

Heterogeneous reactions in and on stratospheric sulfate aerosols and polar stratospheric clouds are important in the photochemical balance of the stratosphere. Changes in ozone concentrations can lead to variances in dynamics and radiative heating which can further alter ozone levels. Therefore, we have incorporated a comprehensive heterogeneous chemistry module into the York University 3D chemistry transport model that includes reactions which occur on each of the above condensed-phase surfaces and we have used the CTM to evaluate the effects of these reactions on a global scale. Results will the show the effects on odd oxygen, NOx, ClOx, and BrOx concentrations over one year runs.

2B4.5
The role of an anisotropic gravity wave spectrum in maintaining the circulation of the middle atmosphere
A.S. Medvedev (1) and G.P. Klaassen (1) ((1) Dept. of Earth and Atmospheric Science, York University, Toronto, Ontario)

The spectral parameterization of gravity wave momentum deposition proposed by Medvedev and Klaassen has been incorporated into the Canadian Middle Atmosphere Model. Numerical experiments show that an anisotropic gravity wave source significantly improves the middle atmosphere circulation compared to an isotropic source. These results suggest that, at least in midlatitudes, the gravity waves primarily responsible for the momentum deposition at mesospheric heights are launched with observed phase velocities which are primarily in the same direction as the mean wind at tropospheric (source) heights.

Session 2-C1
GLOBEC 2

Tuesday June 2
13:40 - 15:00
Hawthorne Room

2C1.1
Seasonal Circulation on the Western Scotian Shelf
Jennifer A. Shore (1), Charles G. Hannah (1), John W. Loder (1), Shen Yingshuo (1) and Christopher E. Naimie (2) ((1) Fisheries and Oceans Canada, Bedford Institute of Oceanography, (2) Dartmouth College, Hanover, NH 03755-8000)

The seasonal variation in the circulation and drift on the Scotian Shelf is investigated using seasonal-mean and tidal circulation fields computed using a prognostic finite-element model. For each season the model is forced by the M2 tide, the seasonal-mean

wind stress and the seasonal-mean hydrographic fields estimated from historical observations.

The circulation fields contain the major large-scale features: the southwestward Nova Scotian and shelf-edge currents and the gyral circulation around Browns and Sable Island Banks. There is good agreement with observed currents for the Southwest Nova Scotia region but poorer agreement in the Sable Island Bank region where current and density observations are sparse and tidal influences weaker. Particle tracking is used to explore potential transport pathways between the Scotian Shelf and Browns Bank and from Browns Bank into the Gulf of Maine. Sensitivity to vertical position, season and unmodelled velocity fluctuations is examined.

2C1.2
Hindcasting Circulation over Eastern Canadian Shelves: Progress and Prospects
Jinyu Sheng (1) and Keith R. Thompson (1) ((1) Department of Oceanography, Dalhousie University)

We recently modified a three-dimensional primitive equation numerical model (now called CANDIE, CANadian version of the DIEcast model) and applied it to eastern Canadian shelves including the Gulf of St. Lawrence, Scotian Shelf, Gulf of Maine, and part of the Grand Banks. Our immediate goal is to simulate the multiple-year circulation of the region, allowing the density field to evolve with the flow. The model is driven by 12 hourly surface wind and air pressure fields. The sea surface temperature and salinity in the model are restored to the annual cycles determined from seasonal climatologies. We were encouraged to find the predicted circulation pattern reproduces many of observed features including relatively strong coastal currents over the Gaspe the Scotian Shelf, strong along-isobath shelf break currents and eddies in deep water spun off the Gulf Stream. Plans to use CANDIE in a study of interdecadal variability in the region, and as the basis for the operational system, will be discussed.

2C1.3
Influence of submarine canyons on zooplankton aggregation
Carine Vindeirinho (1), Susan E. Allen (1) and Richard E. Thomson (2) ((1) Earth and Ocean Sciences, University of British Columbia, (2) Institute of Ocean Sciences)

Barkley Canyon (off the West Coast of Vancouver Island) was surveyed extensively in 1997. Moorings were deployed inside the canyon at several depths from April to October and during a cruise in July, CTD casts and zooplankton tows were performed. The ultimate goal is to determine the flow structure and dynamics around the canyon and the response of its biological activity.

The water property data from the CTD survey showed enhanced upwelling over Barkley Canyon. The character of the upwelling is similar to that observed over Astoria Canyon but the effect of the canyon is strong up into the surface layer. An internal tide signal is clear. The data from the moorings show that upwelling is episodic over Barkley Canyon. Three episodes will be discussed, one of which occurred during the July cruise.

Zooplankton tows showed differences in aggregation between species in the canyon. These data will be presented and links between
biological and physical patterns will be analysed.

2C1.4
Comparison of Two Instruments and Methods for Estimating Turbulent Dissipation Rate
Barry Ruddick (1) and Dave Walsh (1) ((1) Department of Oceanography, Dalhousie University, Halifax, NS)

As part of a Canadian GLOBEC project, turbulent microstructure was measured in Bedford Basin, Nova Scotia, by two independent instruments. EPSONDE obtained 60 profiles of thermal and velocity microstructure, which gives direct measures of thermal dissipation (Chi) and turbulent kinetic energy dissipation (Epsilon). Within 100 m of these profiles, and coincident in time, the instrument SCAMP obtained 11 profiles of thermal and conductivity microstructure. These give direct measures of Chi and of overturn scales and statistics (Thorpe scales). In addition, spectral fits to segments of the data can be used to estimate the Batchelor wavenumber and hence give an indirect measure of TKE dissipation (Epsilon).

The promise of the SCAMP instrument is that it relatively inexpensive and requires little infrastructure support to obtain microstructure data. This makes the instrument potentially valuable in a variety of coastal oceanographic and limnological situations. The main disadvantage is that the measures of the key turbulence quantity, Epsilon are indirect, and may therefore be in error. We will report on the intercomparison — in particular, how close were the direct and indirect measures of Epsilon?

Session 2-C2
Ice Storm ‘98 1

Tuesday June 2
13:40 - 15:00
Sullivan Room

2C2.1
Synoptic Overview and Numerical Guidance Performance
Denis Bachand (1) ((1) Canadian Meteorological Centre, Dorval, Qc)

(unavailable)

2C2.2
The Ice Storm of 1998
John R. Gyakum (1) ((1) Department of Atmospheric and Oceanic Sciences, McGill University)

The Ice Storm of 5-9 January 1998 was an unprecedented meteorological event in terms of the intensity and duration of the freezing rain. The Montreal region, in particular, received in excess of 80 mm of freezing rain during a 96-h period.

We study the planetary-scale circulation anomalies that preceded the onset of the event, and examine their effects on the mesoscale convective precipitation structure. Additionally, the evolution of the surface-layer inversion is examined in terms of the large-scale and mesoscale thermodynamic processes. A crucial component in the intensity of the series of cyclonic events' precipitation is the latent heating. We show the water vapor transports that were responsible for the surface cyclones' moisture supply.

2C2.3
The Operational Forecasters' Challenge
Gilles Babin (1) and Jennifer Milton (1) ((1) Centre Météorologique de Québec, St. Laurent, Qc)

The presentation will deal with the Ice storm of 98 which hit southwestern Québec in January 98. The focus will be not on the meteorology as such, but on the activities which were going on in the Weather Centres in Quebec Region. The relationships with other partners such as the media, la "sécurité civile", etc... will be emphasized to show that the storm was not only a scientific or meteorological challenge but also and above all a social and communication problem. The difficulties encountered by meteorologists will be described as part of a comprehensive review of the work they did.

La présentation portera sur la tempête de glace qui a frappé le sud-ouest du Québec en Janvier 98. La présentation n'abordera pas exclusivement la météorologie, mais on s'intéressera aux activités qui se sont déroulées à l'intérieur des Bureaux de météo de la région du Québec pendant la tempête. Les relations avec les autres organismes tels que les médias, la sécurité civile, etc... seront abordés. On démontrera que cette tempête quoique représentant un défi météorologique important s'est révélé tout aussi bien un défi du côté social et des communications. Les difficultés rencontrés par les météorologistes ont renforcé l'esprit d'équipe et le travail qu'ils ont effectué est tout à leur honneur.

2C2.4
Canadian Freezing Drizzle Project III: More drizzle than we ever thought
G.A. Isaac (1), S.G. Cober (1), A.V. Korolev (1), J.W. Strapp (1), A. Tremblay (1) and D.R. Marcotte (2) ((1) Atmospheric Environment Service, Downsview, Ontario, (2) Institute for Aerospace Research, Ottawa, Ontario)

The Canadian Freezing Drizzle Experiment (CFDE) III conducted field work for approximately 6 weeks in the period from 11 December to 18 February. The project was based at the NRC/IAR hanger in Ottawa. The main goals of the project are to characterize clouds where icing associated with supercooled large droplets (SLD) occur, and to develop better forecasting techniques for helping pilots avoid such conditions. The Atmospheric Environment Service (AES) and the National Research Council (NRC) are cooperating to conduct this project with funding by the National Search and Rescue

Secretariat, Transport Canada, The Boeing Company and the Department of National Defense. The equipment in Ottawa included the AES upper air sounding system, the AES microwave radiometer, the McGill vertically pointing X-band radar, and the NRC Convair 580 instrumented to make in-situ measurements in-cloud. Measurements were also being made over the DND/DREV LIDAR located at Trenton and later Quebec.

For the whole project, 27 flights were flown for a total of approximately 105 flight hours. Excellent data were obtained which was quite different from conditions documented during CFDE1 out of Newfoundland in 1995. Initial impressions were that the clouds had higher liquid water contents. As in Newfoundland, freezing drizzle was not hard to find, but in contrast to the East Coast measurements, ice crystals often co-exited with the drizzle drops. Probably because of the higher liquid water contents, icing encounters were more severe than in Newfoundland, with many cases of runback icing being reported.

Convair 580 flights (16.6 in-flight hours) were conducted on Tuesday, Wednesday, Thursday and Friday during the week of the Ice Storm (5-9 January) which produced severe freezing precipitation over western Quebec and eastern Ontario, and where a State of Emergency was declared on because of the extreme icing conditions. On each day, regions of icing in freezing precipitation were characterized by special instrumention onboard the Convair, mainly by flying low approaches over airports. Several cases showing the transition of supercooled large drops into ice crystals were seen, which will help determine the lifetime of such “unstable” conditions. The NRC pilots reported that the Convair was in conditions of light to moderate icing on most of the occasions. No adverse performance effects were reported, although the aircraft tended to stay in icing for only brief periods, frequently melting off the ice by flying into warm layers. Most of the freezing precipitation during this period was formed through the classical mechanism. However, non-classical freezing precipitation events were observed.

The experimental forecasts of precipitation type being produced during the Ice Storm period using the MC-2 model were excellent. The model appeared to be identifying the zones of freezing precipitation aloft and at ground level. CFDE III is providing useful measurements for the validation of a new precipitation type parameterization scheme. The data obtained during this period will also help meteorologists analyze the very unusual severe weather event that occurred this week, and help improve our forecasts for the general public as well as the aviation community.

Session 2-C3
Data Assimilation 1

Tuesday June 2
13:40 - 15:00
Alderney Room

2C3.1
The CMC regional 3D variational data assimilation system

Stephane Laroche (1), Josee Morneau (2), Judy St-James (2) and Pierre Gauthier (1) ((1) Meteorological Research Branch, Environment Can ada, (2) Canadian Meteorological Centre, Environment Canada)

A Regional data assimilation system for the Global Environmental Multiscale (GEM) model has been implemented on 24 September 1997 at the Canadian Meteorological Center (CMC). For its regional application, we have adopted a discontinuous 12h data assimilation cycle. This cycle uses the same 3D variational analysis (3D-Var) system employed in the global forecasting system. This 3D-Var system is based on the incremental approach where the innovation vector is computed at the full resolution of the model in physical space, whereas the analysis increment is represented at a lower resolution.

The regional data assimilation system was evaluated using 33 cases over four seasons and during a 2 month parallel run before its operational implementation. A comparison between analyses and GEM model forecasts from the regional cycle against GEM model forecasts initialized from the global cycle has been made. The main impact of the regional assimilation cycle is a considerable reduction in the precipitation spin-up during the first 12 hour. Improvements were also noted in the geopotential height and temperature fields.

2C3.2
Background error statistics modelling in a 3D variational data assimilation scheme: estimation and impact on the resulting weather forecasts
Mark Buehner (1) and Pierre Gauthier (1) ((1) Meteorological Research Branch/ASES, Environment Canada)

Since June 1997, the Canadian Meteorological Centre has replaced its previous optimal interpolation (OI) scheme by a 3D variational data assimilation (3D-var) for its global analysis. The 3D-var offers the possibility to use a wider variety of background error covariance models. While the variances are defined in physical space, the background error correlations arre considered to be homogeneous, isotropic and non-separable and these assumptions yield a compact representation in spectral space. Recently, experiments have been carried out to study the impact of non-separable correlations on the analysis that results in sharper wind and temperature increments. The issue of accuracy of the estimation has to be raised especially when the estimates are obtained through a time series of lagged forecasts. The results have shown that the estimated correlations have an unrealistically long range which can be corrected by redefining the correlation functions through convolution of compactly supported functions. For the assimilation of surface winds measurements, it is necessary to introduce a realistic component of the correction to the divergent wind components. Some results will be presented on the impact of some covariance models for the divergent wind component of the error covariances.

2C3.3
Some Statistical Considerations Associated with the Data Assimilation of Precipitation Observations Luc Fillion (1), Ronald Errico (2), Douglas Nychka (2) and Zhan-Qian Lu (3) ((1) Atmospheric Environment Service, Dorval, Quebec, (2) National Center for Atmospheric Research, Boulder, Colorado, (3) Hong Kong University of Science and Technology, Hong Kong)

Bayes's theorem is applied to the problem of analyzing temperature and moisture in a volume of air given a single observation of precipitation amount, utilizing a model of non-convective precipitation and prior estimates of the fields. Results using different statistics and shapes of probability distributions are examined. These include normal, truncated normal, and log normal distributions with special treatment of the value 0. Application of Bayes's theorem demonstrates that uncertainty of the model's formulation should be considered in addition to uncertainty of observations. The posterior distribution is multimodal due to the model's formulation using a conditional expression. The dominant mode may be predicted as a non-precipitating state by the model, although the observation indicates precipitation is definitely present. Means and modes of posterior distributions depend sensitively on both the assumed statistics and shapes of the underlying distributions.

2C3.4
OCCURENCE AND IMPACTS OF DISCONTINUITIES OF THE RAS MOIST-CONVECTIVE PARAMETERIZATION SCHEME FOR VARIATIONAL DATA ASSIMILATION WITH PHYSICS
Jean-Marc Belanger (1) and Luc Fillion (2) ((1) Universite du Quebec A Montreal, Montreal, Quebec, (2) Atmospheric Environment Service, Dorval, Quebec)

In view of incorporating physical processes into three and four-dimensional variational data assimilation schemes, we examined the linearization properties of moist-convective parameterization as used in current numerical weather forecasting models.

The first step was to carefully examine the occurence and significance of discontinuities involved in such schemes. For this purpose, we have developed the "classical" tangent linear (TLM) and adjoint model codes of the Relaxed Arakawa-Schubert (RAS) moist convective parameterization scheme. The RAS scheme involve interactions among a rich spectra of entraining clouds and has a sound closure assumption based on the concept of Cloud Work Function as first suggested by Arakawa. As opposed to the original Arakawa-Schubert scheme, the RAS scheme performs the adjustment in a "relaxed" manner, i.e. the convective instability is not removed instantaneously but within a number of model timestep, thus producing a progressive equilibrium at a reasonable computational cost. This scheme is currently used operationally in major NWP centers for global modelling and is now available at AES for research on weather forecasting and data assimilation.

Different approaches were examined to quantify the degree of validity of the "tangent-linear approximation". We considered Monte Carlo methods together with perturbations

as suggested from the successive line-search occuring in a typical variational analysis,e.g. as in Fillion and Errico (1997). Discontinuities versus nonlinearities will be discussed. Results will be presented for a wide range of convective cases to support our conclusions.

Session 2-D1
GLOBEC 3

Tuesday June 2
15:20 - 17:00
Hawthorne Room

2D1.1
RECENT OBSERVATIONS OF THE DISTRIBUTION OF CALANUS FINMARCHICUS ON AND AROUND THE SCOTIAN SHELF IN SPRING
Erica Head (1), Leslie Harris (1) and Brian Petrie (1) ((1) Bedford Institute of Oceanography)

In April 1995, concentrations of Calanus finmarchicus were high at the shelf-break on the Halifax and Louisbourg sections and lower at stations on the shelf itself. By contrast, in April 1997, concentrations were similar and high at shelf-break and shelf stations of the Halifax section and similar and low at shelf-break and shelf stations of the Louisbourg section. In 1995, the near surface layers (0-50 m) at the shelf-break in both sampling areas were relatively warm and salty, suggesting a high contribution of slope water. In 1997, the near surface layers at the shelf-break of the Louisbourg section were cold and fresh, whereas at the shelf-break of the Halifax section they were warmer and saltier. High abundances of C. finmarchicus at the shelf-break thus appear to be associated with the presence of relatively warm salty water, suggesting that the animals derive from a population which overwinters in the deep water to the south and east. Climatological data suggest that intrusions of slope water on to the shelf occur every winter in the region of the Halifax section, but it appears that the degree of penetration or the timing of the intrusions differed in 1995 and 1997, such that the contribution of the large offshore population of C. finmarchicus to the shelf population was greater in 1997 than in 1995. At the shelf-break stations of the Louisbourg Line, the likely source of the water in the near surface layers is from off St. Pierre Bank. TS properties suggested a high contribution of offshore or slope waters to the near surface layers (0-50 m) in 1995, whereas in 1997, TS properties were similar to those characteristic of water in Halibut Channel (Newfoundland Shelf).

2D1.2
Long Term Changes in Zooplankton and Phytoplankton on the Scotian Shelf
Doug Sameoto (1) ((1) Bedford Institute of Oceanography)

Continuous Plankton Recorder data from the eastern and western Scotian Shelf were analyzed and contrasted for the period 1961 - 1975 and 1991 - 1994. They showed there have been significant changes in the abundances of some species of copepods between

the cold period in the early 1960s and 1991 - 1994 period. Phytoplankton color index (a proxy for phytoplankton biomass) was significantly higher in the 1991 - 1994 period. Marked changes in the climatology of a number of zooplankton species were found suggesting that production of these animals may be occurring early in the year during the 1990s than was the case in the 1960s.

2D1.3
Coupling of the life-cycle of Calanus finmarchicus with the hydrodynamics of the Gulf of St. Lawrence-Scotian Shelf System
B. Zakardjian (1), Y. Gratton (1), S. Plourde (2), J. A. Runge (2) and K. Thompson (3) ((1) INRS-Océanologie, Rimouski, Qc., (2) Pêches et Océans Canada, Institut Maurice Lamontagne, Mont-Joli, Qc., (3) Dalhousie University, Halifax, NS)

As part of the GLOBEC-Canada program we are studying the effect of circulation and water temperature on variation in the distribution and abundance of the planktonic copepod, Calanus finmarchicus, in the Gulf of St. Lawrence-Scotian Shelf (GSL-SS) system. Variations in the abundance of Calanus, a dominant member of the zooplankton community in eastern Canadian waters, may affect the growth and survival of early life stage of several commercial fishes. We are developing models to couple the life-cycle of Calanus with the hydrodynamics of the GSL-SS system as described by the Canada-Dietrich model (CANDIE). The life cycle model describes all life-stages of Calanus with stage specific growth and mortality rates as depending of the temperature. Preliminary 2D models show the importance of vertical migration behaviour for maintaining a Calanus population in the Lower St. Lawrence Estuary and seasonal, preadult diapause for simulation of its mean observed annual. The complete 3D model will be used to probe hypotheses about how the Calanus population maintains itself in the extended shelf system given the strong seasonal and inter-annual variations in the large-scale hydrography and circulation, and whether these variations result in significant fluctuations in Calanus abundance and distribution.

2D1.4
Larval fish assemblages on the Scotian Shelf: is spatial distribution a function of water mass characteristics or surface circulation patterns C. Reiss (1), G. Panteleev (1), C.T. Taggart (1), and B. deYoung (1) ((1) Department of Oceanography, Dalhousie University

Current hypotheses suggest that the distribution of ichthyoplankton (several species) on the Scotian Shelf and elsewhere reflect retention associated with marine banks and gyre-like features delineated by density fronts. We will describe results from a field study on the Scotian Shelf in November 1997 that examined both the broad scale and mesoscale distribution of several fish species in relation to both water-mass structure and the density driven currents. The density driven surface currents during the sampling period were inferred using the dynamics height method as describe by Sheng and Thompson (1996). Two larval assamblages representing demersal (esp. herring and capelin) and pelagic (es. cod and hake) spawning strategies were observed during the cruise. The pelagic assemblage (cod and hake) was associated with a water mass on the northern flank of Western Bank, reflecting a single spawning location. Herring were found in different

water masses, representing multiple spawning populations. The spatial distribution, size and abundance of fish larvae appears to be most easily explained by regions advection and retention as described by the current pattern. In contrast to predictions there was no evidence for retention of species (e. g. herring) that spawn on the southern edge of Western Bank at the shelf-slope. On the northern side of Western bank a region of relatively unorganized but counter-clockwise flow may responsible for maintaining larvae (all species) in the area of the cow pen and the Northern spur (Eastern Emerald Basin).

2D1.5
Climate Variability and Ecosystem Response in a Box Model of the Strait of Georgia and Juan de Fuca Strait
Ming Li (1), Ken Denman (1), Ann Gargett (1), Dave Mackas (1) and Dick Beamish (2)
((1) Institute of Ocean Sciences, (2) Pacific Biological Station)

North Pacific climate change influences the semi-enclosed estuary of the Strait of Georgia and Juan de Fuca Strait. In this paper we examine how the interannual variation of Fraser River runoff and ocean shelf water properties affects the circulation and low-trophic level ecosystem in the estuary.

A box model, which includes the effect of fresh water forcing and tidal mixing, is developed to simulate the estuarine circulation. The model predicts a seasonal cycle of salinities and water mass transports in reasonable agreement with observations. Multi-year calculations for successive years of high or low runoffs and for an abrupt change in the runoff show a rapid response of the estuarine circulation to the interannual variability in the fresh water forcing. The salinities and volume fluxes adjust to the new river runoff within a year.

The box model of estuarine circulation has been coupled with a biological model which has nutrients, phytoplankton and zooplankton compartments. For a typical set of parameters, the coupled bio-physical model predicts a large spring bloom and nutrient limitation in the Strait of Georgia but low phytoplankton production and high nutrient level in the Juan de Fuca Strait, in apparent agreement with biological observations in the Georgia-Fuca estuary. Plankton populations do not appear to be very sensitive to interannual change of estuarine circulation, with only a small decline in phytoplankton bloom size when the Fraser River runoff is reduced to a half. However, they are sensitive to variations in biological rate parameters. The model results point out the need to understand how climate change might affect the biology of plankton system.

Session 2-D2
Ice Storm ’98 2

Tuesday June 2
15:20 - 17:00
Sullivan Room

2D2.1
Storm Details
Stan Siok (1) ((1) Environment Canada, Ottawa Regional Centre, Ottawa, ON)

(unavailable)

2D2.2
Client Needs: Insurance Industry
Heather Auld (1) ((1) Environment Canada, Ottawa Regional Centre, Ottawa, ON)

(unavailable)

2D2.3
Direct Ice Measurements in Quebec
Jean Laflamme (1) ((1) Hydro-Québec, Montreal, Qc)

Instead of converting meteorological icing conditions into ice loads on structures, Hydro-Québec had decided in 1974 to take direct ice meaurements on a standard ice collector. A network of 145 passive ice meters was installed at meteorological and climatological stations in the province.
With such a fine grid and 23 years of observations, it is now possible to obtain valid statistical data on the frequency, the maximum intensity and on the persistence of icing. By comparing the extreme value distributions based on these data and the values ovserved during the ice storm of January 1998, it was possible to calculate a return period of the order of 300 to 500 years.

The passive ice meter measurements are converted into ice thickness and eventually into ice loads by using empirical formulae obtained at a well instrumented site at Mont-bélair near Quebec City airport. Measurements from load cells and measurements of ice fallen on the ground are compared with those obtained from ice collectors. The same site is equipped with standard meteorological instruments and with two automatic icing rate meters developed by Hydro-Québec. This instrument is the base of a real-time icing event analysis system, called Sygivre. This systems currently comprises a network of 23 icing rate meters and is used to maintain the stability of the electric transmission network. It is also useful to alert observers and to get them to collect detailed observations in the field, which are also very valuable in converting ice measurements into ice loads. One consequence of last January's ice storm is that top managers now want to keep the passive ice meter network to collect more statistics and they support the improvement of both the icing rate meters and the real-time analysis of icing events in order to better manage severe ice storms. It is now accepted that an ice storm is a rather slow process and that it can be managed with a reliable icing formation system. Hydro-Québec will consequently develop new techniques to de-ice conductors early in the storm as well as during the storm.

2D2.4
Return Period Analysis of the January, 1998 Ice Storm in Eastern Canada

Arnold Ashton (1) ((1) Acting Head of Engineering Climatology, Environment Canada, Ontario)

The ice storm which impacted significant portions of Eastern Canada on January 4-10, 1998 is unparalleled in its duration, scope and severity.
Ice accretion amounts are modeled for several sites most affected by the storm using a semi-empirical icing model. The model simulates ice accretion on horizontal surfaces to emulate observed freezing rain amounts, and on equivalent radial surfaces indicative of icing on overhead transmission line conductors. These results are then compared to modeled results from previous major icing events derived from observations from the Environment Canada digital archive dating back to 1953. Finally, comparison of the January, 1998 event is made to some other past severe Canadian ice storms.

2D2.5
El Nino and Climate Change as Possible Factors in the 1998 Ice Storm
Henry Hengeveld (1) and Amir Shabbar (1) ((1) AES Climate Research, Downsview, ON)

Extreme weather events usually occur when 2 or more weather variables undergo unusual anomalies at the same place and time. For example, with the 1998 ice storm, unusually mild conditions near freezing coincided with an unusual flux of moist air across the southern USA, a pressure anomaly over the North Atlantic that deflected the warm and moist air over the affected regions and kept it there for an extended period of time, and the presence of a colder air mass in the valley bottoms of the Ottawa/St. Lawrence Rivers. While each anomaly is unusual, their coincidence is very unusual. Hence, under normal climate conditions, events as extreme as this storm occur extremely rarely.

The paper will describe how the 1997-98 El Nino, itself rather unusual, increased the probability of anomalous behaviour of at least two of the variables involved (temperature and moisture), thus contributing too the severity of the event. It will further explore how climate change may affect El Nino behaviour and the probability/distribution of freezing precipitation in the decades to come.

2D2.6
AEP Program Assessment: How well did we do?
Joe Shaykewich (1) and Pierre Tourigny (2) ((1) Atmospheric Environment Service, Downsview, ON, (2) National Weather Services Directorate, AES)

Following the devastating ice storm that hit eastern Canada in January 1998, the National Weather Services Directorate took the lead for an assessment of how the AEP (Atmospheric Environment Program) performed its functions and delivered its services during that storm. This service assessment considered all aspects of the program, including monitoring and forecasting of weather, ice conditions and water levels, informatics, telecommunications, service delivery, and support to emergency measures organizations and to military operations. In addition, specific studies were undertaken to assess how the public and the media perceived AEP services immediately before, during

and after the storm. The service assessment and its related studies showed that while there are some areas that can be improved, there were no serious problems encountered during the storm and the media, the public and other clients were very satisfied with the service they received. These and other findings will be presented along with recommendations for surviving another such storm should one occur.

Session 2-D3
Data Assimilation 2

Tuesday June 2
15:20 - 17:00
Alderney Room

2D3.1
Statiform versus Convective Precipitation in the Contex of Variational Data Assimulation
Philippe Segers and Luc Fillion (2) ((1) Universite du Québec, à Montréal, Montréal, PQ,
(2) Atmospheric Environment Service, Dorval , PQ)

The availability of precipitation data derived from satellite observation systems represent an important source of information for atmospheric data assimilation. The improvement of precipitation location and intensity in NWPinitial condition is crucial for short terms precipitation forecasts. This challenging aspect for operational data assimilation schemes for NWP is curently being examined in most operational weatthre prediction centers.

The variational method for data assimilation offer a rigorous and very flexible approach for tackling such type of problems. The methodology must also be oriented towards adaptive solutions compatible with present day Kalman or 4D-Var assimulation methods currently being developed in operational NWP centers.

Our study concentrates on the basic features of the variational adjustment of vertical profiles of both temperature and specific humidity using the adjoint of parameterized moist-convective and non-convective (stratiform) schemes. This context is referred to as 1D-Var analysis with moist physics. It is found that both precipitation schemes are applied in sequence (as normally done. in NWP models), some care is necessary to guide the varational analysis towards the desired type of adjustment (i.e. precipitation type) over convective regions. Results of 1D-Var experiments with the Relaxed Arakawa-Schubert moist convective parameterization scheme will be shown for various types of convective cases.

2D3.2
Sensitivity analysis with the global variable resolution GEM model
Monique Tanguay (1) and Saroja Polavarapu (1) ((1) Meteorological Research Branch, Atmospheric Environment Service, Canada)

The Canadian Meteorological Centre is in the process of adopting a unified model (GEM) for the production of both global and regional forecasts. GEM is a global variable resolution, gridpoint, fully-implicit semi-Lagrangian primitive equations model (Cote et al., 1997) and will form the basis of a 4D-Var assimilation system. Such a system requires as tools the construction of additional models, namely, the tangent linear model and its adjoint. Those models are now available for GEM. As one more step toward a realistic 4D-Var system, the adjoint model can be used to investigate the sensitivity of forecast errors to initial conditions since it provides an estimate of the part of the analysis error which is largely responsible for short-range forecast errors. In this talk, we employ the adjoint of the tangent linear of GEM to examine the sensitivity of GEM forecast errors to its initial conditions.

Session 3-A
Education Day & Artic Chemistry

Wednesday June 3
08:45 - 09:50
Lake City Ballroom

3A1.1
Education Day
Steve Miller (1),((1)Atmospheric Environment Service Branch, Bedfors NS)

(Not available)

3A1.2
Contaminants in the Artic Ocean - the importance of pathway
Robbie MacDonald and J.N. Smith ((1)Institute of Ocean Sciences, Sidney, BC, Bedford Institute of Oceanography, Dartmouth NS.)

Concern about the contamination of the Artic marine ecosystem has fed accelerated research during the past decade. Coincident opportunities to conduct ocean-scale tracer studies, specifically using the icebreaker and submarine platforms, have led to remarkable advances in our understanding of the circulation of the Artic Ocean and its coupling to the oceans to the south. Ironically, much of our insight derives from transient tracers which include, among others, the organochlorines and radionuclides which are themselves priority contaminants. In particular, the contrast between the pesticide hexachlorocyclohexane (HCH) and the reprocessing plant radionuclides (137Cs, 129I) provides striking evidence of the importance of route of entry in determining the ultimate fate of a given contaminant in the Artic Ocean. Once contaminants enters this ocean, stratification, inter-basin coupling, boundary currents, particle reactivity, and facility for entering the food web then dominate the further transport and eventual pathway to sinks. We will discuss these two very different types of contaminants - organochlorines and radionuclides - to illustrate not only the transport pathways but the importance of understanding these to assess correctly the risk pose to humans.

Session 3-B1
Arctic Chemistry

Wednesday June 3
10:10 - 12:10
Hawthorne Room

3B1.1
An Arctic Haze Simulation with NARCM
J.-P. Blanchet (1), L. Barrie (2), H. Leighton (3), S. Gong (2), Q. Song (3) and L. Spacek (1) ((1) C2GCR and Department of Earth Sciences, UQAM, Montreal, QC., (2) Air Quality Research Branch, Atmospheric Environment Service, (3) Dept. of Atmospheric and Oceanic Sciences / C2GCR, McGill University)

Arctic haze is a well know feature of the Northern Polar region during winter and spring. The study by Barrie (1989 ? ?) provide comparison of aerosol horizontal and vertical distribution that are used for NARCM model validation. The transport is often thought as coming from central Europe when the circulation is from the South, providing a direct path to the Arctic. The Northern Hemisphere in early 1980 seems to be rather favorable for this type of pollution transport. For this comparison, the Northern Aerosol Regional Climate Model (NARCM) is driven in a 4 month continuous forecast mode over the hemispheric domain. The sulfur oxidation is not done by explicit chemistry but parameterized as a prescribed conversion rate. Other processes considered are in-cloud and below-cloud scavenging, dry deposition and coagulation. In-cloud SO2 oxidation is estimate from the preliminary version of a bulk oxidation scheme. The prognostic size distribution is represented by 8 size bins from .01 to 2.00 microns for SO4 and one for SO2. The results show periods of strong pollution inflow into the polar region and general agreement with observations.

3B1.2
The anthropogenic aerosols in Arctic
Eric Girard (1), Jean-Pierre Blanchet (2) and Universite du Quebec a Montreal (2) ((1) C2GCR, McGill University)

During Winter, the Arctic troposphere experiences hazy periods which are characterized by aerosol concentration of about 10 times the backgroud aerosol concentration. These new anthropogenic aerosols are transported from mid-latitudes and are mostly of acidic nature. These aerosols coagulate with other aerosols such as soil particles and organics which are potentially excellent IFN (Ice Forming Nuclei). It has been hypothesized that the net effect is to deactivate most of the prexisting IFN and then to reduce the number of aerosols that can act as IFN. This hypothesis is supported by Borys's laboratory experiment which has shown that IFN concentration is recduced by a factor varying between 1000 and 10000 during an Arctic haze
event. In this work, we investigate the effect of the reduction of IFN on the formation of the most frequent clouds being observed during Arctic Winter: Ice fog and clear sky precipitation. We use the NARCM model, a regional climate model which contains

explicit aerosol physics. We have parameterized physical processes such as aerosol activation, aggregation and sedimentation of ice crystals.

This model allows to simulate stable clouds like ice fog, thin stratus in which processes like turbulence and entrainment are negligible. A compa rison of observations and the column version of the model will be shown at Resolute and Alert in the Canadian Arctic.

It is shown that the model is able to reproduce adequately the observations (formation of clouds and precipitation). Furthermore, it is shown that IFN concentration plays a key role in the formation of clouds and precipitation. Finally, preliminary results of 3D simulations will be presented assuming various scenarios about the IFN concentration.

3B1.3
Circulation Features in the Western Arctic Ocean Revealed by Tracers from European Nuclear Fuel Reprocessing Plants
John N. Smith (1), Katherine M. Ellis (1) and Timothy Boyd (2) ((1) Bedford Institute of Oceanography, (2) Oregon State University, Corvallis, OR)

Measurements of the tracer radionuclides, 129I and 137Cs were conducted on seawater samples collected during a cruise to the Arctic Ocean of the US Navy nuclear submarine, USS Cavalla in 1995. During the past 40 years, large quantities of 129I and 137Cs have been released into Atlantic coastal waters from the Sellafield (UK) and La Hague (France) nuclear fuel reprocessing plants and subsequently transported into the Arctic Ocean through Fram Strait and the Barents Sea. 129I results from the surface mixed layer and halocline reveal a well-defined front between Atlantic-origin water having high 129I levels (> 100 x 107 at/l) and Pacific-origin water labeled mainly by fallout levels (< 5 x 107 at/l), which is aligned along the Mendeleyev Ridge and is displaced towards the Canada Basin with increasing water depth. Reduced 129I levels in halocline and Atlantic layer water in the interior of the Makarov Basin compared to those over the Eurasian continental slope reflect both mixing/dilution of the tracer signal and the longer transit times to the central regions of the Makarov Basin. 129I levels (< 2 x 107 at/l) measured in Atlantic layer water over the Alpha Ridge, indicate that ventilation rates for intermediate waters in this region are extremely low. However, higher 129I levels (> 40 x 107 at/l) detected in Atlantic layer water in the Central Canada Basin reflect the more efficient ventilation of the basin interior which probably occurs by lateral transport from boundary currents flowing over the continental margins. A simple transit time model applied to the 129I and 137Cs data provides estimates of 5-7 y for the passage of Atlantic halocline water from the Norwegian Coastal Current to the East Siberian Sea slope of the Makarov Basin. The model provides a lower limit of 8 y for transport to the interiors of the Makarov and Amundsen Basins.

3B1.4
Are polynyas a problem for high resolution sea ice models?
Halldor Bjornsson (1) and Lawrence A Mysak (1) ((1) Department of Atmospheric and Oceanic Sciences, McGill University)

Currently a large international research project is underway to study the Northwater Polynya which is situated in the northern end of Baffin Bay.
Part of this project involves modelling the polynya. The so-called Pease Model describes how wind-driven polynyas are maintained, as a balance between nearshore ice formation and offshore ice transport by the wind.
The Pease Model, which is highly idealized, has been generalized by several researchers, to include for example time dependence and the effects of a sensible heat flux into the mixed layer. To proceed further, it seems necessary to include in the model the pack ice whose motion is prescribed in the generalized Pease Model. However, although the necessary thermodynamics is included, standard sea ice models do not make a distinction between different ice types, such as the newly formed frazil ice and the more solid ice pack. We examine the differences in the results for a generalized Pease Model and a high resolution sea ice model for idealized polynya geometries.

3B1.5
Modelling the Interannual Variability of the Arctic sea ice cover
Gilles Arfeuille (1) and L. A. Mysak (1) ((1) Department of Atmospheric and Oceanic Sciences and Centre for Climate and Global Change Research, McGill University, Montreal)

A dynamic sea ice model based on granular material rheology (Tremblay and Mysak, JPO 1997) is used to study the interannual variability of the Arctic sea ice during the period 1954-1990. The sea ice model is coupled to both a mixed layer ocean model and a one-layer thermodynamic atmospheric model. The model uses monthly climatology for thermodynamic and dynamic components (air temperature, ocean temperature, ocean currents, wind stress...) to first reach a stable periodic seasonal cycle. For the 36-year run the monthly wind stress forcing is derived from analyzed sea level pressures from the Notional Meteorological Center; however, the thermodynamic forcing are based on monthly climatology. The objective here is to explore the high-latitude sea ice circulation and cover changes due to changes in the wind field. We focus our study on the interannual variability of the sea ice cover and the changes in export of sea ice from the Arctic basin into the northern North Atlantic. The latter is an important input of fresh water into the northern North Atlantic and therefore can be the origin of important ocean climate events like the Great and Ice Salinity Anomaly.

3B1.6
Singular Value Decomposition of Arctic Sea Ice Cover and Overlying
Dingrong Yi (1), L. A. Mysak (1) and S. A. Venegas (1) ((1) Atmospheric & Oceanic Sciences Department, McGill University)

The relationship between the Arctic and sub-Arctic sea-ice concentration (SIC) anomalies, particularly those associated with the Greenland and Labrador Seas' ``Ice and Salinity Anomalies (ISAs)'' occurring during the 1960s/70s, 1970s/80s, and 1980s/90s, and the overlying atmospheric circulation (SLP) fluctuations is investigated using the Empirical Orthogonal Function (EOF) and Singular Value Decomposition (SVD) analysis methods. The data used are monthly anomalies, cover the Northern Hemisphere

north of 45° and extend over the 38-year period 1954-1991. The SIC data are GISST2.2, the SLP data are GMSLP2.lf, and both data sets are available from the Hadley Centre in the UK.

It is found that the leading mode of the SIC anomalies has a clear decadal signal (superimposed on a decreasing trend), whereas the leading mode for the atmospheric fluctuations shows a weak decadal signal (with a decreasing trend) superimposed on a strong interannual signal. However, the decadal signal corresponds well with the decadal variability of the SIC anomalies. Secondly, we found that: in the North Pacific sector, there is a sea-saw pattern of SIC anomalies which is in phase with each of the ISA events in the North Atlantic sector. Thirdly: we showed that the SIC anomalies in the Arctic and sub-Arctic are mainly due to the anomalous atmospheric circulation fluctuation which occurs one to two months earlier. This is consistent with the result of Fang and Wallace (1994). Fourthly, we discovered that one ISA event might affect the atmosphere several years later. This is likely due to a short timescale positive feedback between the ice and the overlying atmosphere and the long time memory of the ice.

Session 3-B2
Education

Wednesday June 3
10:10 - 12:10
Sullivan Room

3B2.1
The InterMET Project: Using the Internet to Improve the Teaching of Meteorology in Quebec high schools
Nathalie Gauthier (1) ((1)Société Cyberscol Inc.)

The WEB site InterMET offers an environment for providing interactive multimedia instruction in Meteorology. InterMET gives 13- and 14-year-old students an opportunity to acquire knowledge and skills in the atmospheric sciences including the ability to read weather charts. All activities provided on the InterMET site are integrated in an amusing concept. The inside of a space station serves as the working interface and gives access to the various educational resources.

In real time, InterMET presents a set of visualization tools adapted to the level of the students, including satellite photos, radar images, and weather maps. Discussion groups, e-mail access to experts and virtual guided tours introducing people from the field of meteorology will soon complement the environment.

With the development of the new information and communications technologies, it is now possible to improve the level of instruction by combining judiciously these new methods with traditional techniques. However, experience has shown that using these new technologies for teaching confronts developers with the challenge of producing a

homogenous application on Internet, collaborating with parteners who have divergent interests, the organization of a large body of information, etc..

During this talk, the InterMet WEB site will be presented along with the principle challenges faced and their solutions.

Projet Intermet : L'utilisation Du Réseau Internet Pour L'amélioration Des Apprentissages En Météorologie Dans Les écoles Secondaires.

Le site WEB InterMET offre un environnement de formation multimédia et interactif en météorologie. InterMET permet aux jeunes de 13-14 ans d'acquérir des connaissances et des habiletés en sciences de l'atmosphère et dans l'interprétation des cartes météorologiques. L'ensemble des activités proposées s'articule autour d'un concept intégrateur ludique où l'intérieur d'une station orbitale sert d'interface et donne accès à différentes ressources pédagogiques. InterMet offre une approche alternative pour l'enseignement par laquelle l'élève participe plus activement à son processus d'apprentissage.

InterMet propose également, en temps réel, un ensemble d'outils de visualisation adaptés aux élèves tels que photos satellites, images radar et cartes météorologiques. Des forums de discussions, le courrier aux experts et des visites guidées virtuelles, présentant différents intervenants du domaine de la météorologie, viendront complèter cet environnement.

L'apparition des nouvelles technologies de l'information et des communications (NTIC) permet d'esperer que les apprentissages seront améliorés en arrimant de façon judicieuse les nouveaux outils aux méthodes traditionnelles. Il faut toutefois reconnaître que l'utilisation des NTIC pour l'enseignement amène de nouvelles réflexions et de nouveaux défis pour les développeurs, notamment, la production d'une application homogène sur Internet, la collaboration entre des partenaires ayant des intérêts divergents, la cueillette et l'organisation d'une masse importante d'informations, etc.

Lors de cette conférence, le site WEB InterMET sera présenté et la conférencière traitera des principaux défis et des moyens à prendre pour les relever.

3B2.2
Environment Canada's, Prairie and Northern Region, Warning Preparedness Meteorologist...A New Link to the Education Community.
John Parker (1) ((1) Environment Canada, Prairie and Northern Region)

Environment Canada's Prairie and Northern Region is developing a position whose task, among many others, will be to focus on strengthening the link between the Department and the education community. The Warning Preparedness Meteorologist will work to establish links with the science teachers' associations to foster a renewed sharing of information and expertise. Through involvement with teacher development days, participation in curricula development and regional science days, Environment Canada

aims to assist teachers in bringing the new atmospheric and environmental sciences to the classroom. The Warning Preparedness Meteorologists will participate with the education community through one on one presentations to groups of teachers to take advantage of the multiplier effect, development of in-class videos and computer materials, and the use of existing and development of new educational websites on the internet.
This presentation will demonstrate current activities, ! future projects and develop new ideas through discussion with the attendees.

3B2.3
"The Weather Forecaster" at Discovery Centre
Blair J. W. Greenan (1), Fred W. Dobson (1), Jim Abraham (2) and Steve Miller (3) ((1) Ocean Sciences Division, Bedford Institute of Oceanography, (2) Environment Canada Bedford, NS, (3) Maritimes Weather Centre, Environment Canada)

"The Weather Forecaster", an interactive multimedia weather-forecasting exhibit, was developed as part of a remote sensing exhibition that opened at Discovery Centre in Halifax, Nova Scotia in December 1994. The goal of this exhibit is to enable patrons of Discovery Centre to make their own short-term weather forecast by providing them with a sufficient amount of real-time data. Upon completing the exhibit, users can print out their forecasts and take them home for comparison to what actually happens. It is hoped that this exhibit will give the general public a better appreciation of what is involved in making a weather forecast.

The development of "The Weather Forecaster" was a collaborative effort between the Department of Fisheries and Oceans (Bedford Institute of Oceanography), Environment Canada (Atlantic Region), Hewlett-Packard Canada Limited, and Discovery Centre. The exhibit has proven to be reliable, robust and popular, and a traveling version has been developed for a touring exhibition.

3B2.4 & 3B2.5
What's up with the weather
Dave Phillips (1) ((1) Atmospheric Environment Service, Downsview, ON)

(unavailable)

Session 3-B3
GEWEX/MAGS

Wednesday June 3
10:10 - 12:10
Alderney Room

3B3.1
The Canadian Climate Research Network Land Surface Node — The First Three Years
Dr. Diana Verseghy (1) ((1) Atmospheric Environment Service)

This past year saw the end of the first three years of funding of the Canadian Climate Research Network. To mark the occasion, the co-investigators in the land surface node of the Network are assembling a suite of journal articles, which are being submitted to "Atmosphere-Ocean" for proposed publication in a dedicated issue. These papers focus on research that has been completed over this period, and which is being used to produce the next frozen version of CLASS ("Canadian Land Surface Scheme"), the land surface model in use in the Canadian GCM and in other Canadian atmospheric models. Basic improvements have been made to CLASS in the modelling of vegetation stomatal conductance; of snow accumulation and ablation processes; of wetland hydrological and thermal regimes; and in the incorporation of streamflow simulation. CLASS has also been tested against a variety of datasets representing the major Canadian ecosystems. This paper will present highlights of this research.

3B3.2
Predicting Monthly Energy and Water Budgets over the Mackenzie River Basin using the Canadian Land Surface Scheme
Ekaterina Radeva (1) and Harold Ritchie (1) ((1) Recherche en Prevision Numerique, 2121 Trans-Canada Highway #500, Dorval, PQ, H9P 1J3)

As part of the Mackenzie GEWEX Study, Canadian global spectral forecast model simulations of surface water and energy fields over the Mackenzie River basin (MRB) are examined. The objective of this work is to quantify how the improved treatment of land-surface processes via incorporating the Canadian Land Surface Scheme (CLASS) in our data assimilation and prediction system affects these fields. To this end, we complete evaluating CLASS impact on the predictability of monthly MRB budgets. The simulated budgets are then verified against data from the CMC GEWEX archive and observations.

The model, connected successively to the current operational force-restore land surface scheme and to CLASS, generates nine-member ensemble simulations of one month duration from analyses perturbed with the bred-mode technique, for spring, summer, fall and winter cases. The perturbations are comparable in magnitude to observational errors. As diagnostics we use the spatial averages, over the basin, of the forecast accumulated surface energy and water fluxes. We estimate the fluxes predictability from the ensemble standard deviation of the area- averages. As CLASS predictions proved to be sensitive to land-surface initial data, soil moisture in particular, we test initializing some of its soil-related and snow-related predictive variables with fields generated in a one-month spin-up simulation. The ensemble forecasts are then compared with monthly accumulations of surface energy and water fields constructed from 12-hour forecasts of the then operational RFE model and kept as part of the CMC GEWEX archive. Finally, we verify both the ensemble prediction and the CMC GEWEX archive precipitation against satellite-derived observations.

Spring and summer ensemble simulations of energy and water surface fluxes over MRB exhibit low to moderate sensitivity to uncertainties in the initial fields. CLASS shows slightly more uncertainty, due to initial conditions, than the operational force-restore

scheme. We observe good agreement between MRB monthly budgets that are produced by the model with CLASS, and their counterparts based on the CMC GEWEX archive, especially for the summer case. Better initialization of CLASS predictive variables has a significant impact on its performance. Results concerning fall and winter ensemble predictions as well as verification against observations will be presented at the Congress.

3B3.3
Atmospheric moisture budget over Mackenzie basin
Muyin Wang (1), Geoff Strong (2), Alan Barr (3) and Brian Proctor (3) ((1) Dalhousie University, (2) GEWEX/MAGS Secretariat, Saskatoon, Saskatchewan, (3) AES, National Hydrology Research Centre, Saskatoon, Saskatchewan)

The atmospheric moisture flux and flux convergence are calculated based on RFE/ GEM model analysis for the period of October 1996 to September 1997. The computation domain is carefully designed around the real basin boundaries based on model grid, with an area of about 2 million square kilometers.It is shown that the moisture flux convergence is positive for the whole year computed. A strong seasonal variation in the atmospheric moisture flux and flux convergence is found. The computation results are compared with the multi-year mean water runoff values observed at the arctic red above Mackenzie. A big difference is found between the estimated and observed runoff. The reason will be discussed.

We also tried to identify the atmospheric moisture sources and sinks for Mackenzie Basin based on the vertically integrated atmospheric moisture fluxes.

3B3.4
Diurnal Variations in Atmospheric Moisture during GEWEX/MAGS
G.S. Strong (1) ((1) GEWEX/MAGS Secretariat, Saskatoon, Saskatchewan)

A major goal of the Mackenzie Basin GEWEX Study (MAGS) is to quantify the hydrologic cycle of the Mackenzie Basin and to improve our modeling capabilities. This involves a better understanding of the links between the surface water balance and atmospheric moisture budgets. To date, however, estimates of annual runoff derived from computations of moisture fluxes from radiosonde data have been consistently higher (by 25-50%) than actual measurements of annual runoff from the Mackenzie. Possible sources of error for this bias include inaccuracies due to (1) radiosonde humidity sensors, (2) poor spatial resolution of radiosonde data, (3) lack of temporal resolution in sounding data (twice daily at 1200 and 2400 UTC), (4) river discharge measurements, especially during spring breakup, and (5) surface water storage.

It can be shown that (1) and (2) contribute to the problem, but are not the main source for the observed bias. A plan is in place to improve spring breakup estimates of discharge (4), but published error estimates for this as well as for (5) also do not account for the large bias. Regarding (3), the Mackenzie basin experiences significant convective precipitation during summertime, and approximately 50% of the total annual precipitation occurs during this period, suggesting an important contribution of moisture

from local evapotranspiration. This in turn implies a significant diurnal variation in the atmospheric moisture budget which might not be adequately sampled using only two soundings per day.

Two weeks of sequential sounding tests were therefore carried out during August, 1997. Results confirmed a significant diurnal signature in atmospheric vapour mass which was only occasionally picked up using only the two synoptic soundings. Moreover, comparisons with estimates based on output from the GEM model show that it also did not simulate the diurnal moisture cycle during this period.

3B3.5
Solar Radiation Budgets for MAGS
J. Feng (1) and H.G. Leighton (1) ((1) Atmospheric and Oceanic Sciences, McGill University)

One of the goals of the MAGS (Mackenzie GEWEX Study) is to improve understanding of the energy and water cycles of the MacKenzie Basin and specifically to improve the capability of modelling these cycles. An important component of the models is the solar radiation absorbed at the surface since it has a direct impact on the hydrology of these regions through its influence on melting of snow and on evaporation. Apart from being able to reproduce surface radiation fluxes correctly, the ability of the models to reproduce measured top-of-the-atmosphere fluxes provides an indirect measure of how realistically the models are able to simulate clouds in these regions.
The ScaRaB instrument on the Meteor-3 satellite measured narrowband and broadband radiances during the period March 1994 to February, 1995. These data can be combined with AVHRR data from the NOAA polar orbiting satellites to provide much better temporal coverage of the TOA radiation budgets over the MAGS and BALTEX regions than is obtained from ScaRab alone.

We will present solar radiation budgets from MAGS at the top of the atmosphere deduced from ScaRaB and AVHRR measurements. From the top-of-the atmosphere budgets we will present determinations of the net solar fluxes at the surface. In subsequent work these results will be compared with output from the Canadian regional climate model that is being used to study the energy transfers in MAGS and whose output is being used to drive the hydrology models. The surface solar fluxes will also be compared with local surface measurements of the incoming solar radiation.

3B3.6
An Enhanced Data Collection Period for the Mackenzie GEWEX Study
B. Kochtubajda (1) and G.S. Strong (2) ((1) Environment Canada , Edmonton, AB., (2) GEWEX / MAGS Secretariat, Saskatoon, Sask.)

The Mackenzie GEWEX Study (MAGS) is one of a collection of five major studies around the world, collectively called the Global Energy and Water Cycle Experiment (GEWEX). The major objectives of MAGS are to quantify all aspects of the hydrological cycle of the Mackenzie, to determine the effects which climate change will have on the

water budget of the Mackenzie, and to develop numerical modeling capabilities to be able to predict these processes and potential impact on the northern climate.

The Mackenzie Basin is poorly observed on an operational basis. As such, periods of enhanced observations that allow for greater confidence in the initialization and validation fields for modelling efforts and remote sensing studies have to be carried out. The Canadian GEWEX Enhanced Study (CAGES) is a modest enhanced data collection effort planned for the 1998/99 period, which should provide a higher degree of confidence in the water and energy budget parameters than available with routine measurements. CAGES should also provide valuable experience in preparation for a global GEWEX observational effort tentatively scheduled for 2001.

This presentation will review some highlights of scientific results to date, current uncertainties and scientific gaps, and upcoming CAGES plans to reduce these uncertainties.

Session 3-B4
Weather Forecasting

Wednesday June 3
10:10 - 12:10
McNabs Room

3B4.1
Efficiency through automation
R. Verret (1), D. Vigneux (1), F. Petrucci (1), L. Pelletier (1), J. Marcoux (1), C. Landry (1) and G. Hardy (1) ((1) Atmosphere, Climate and Water Systems Branch, Canadian Meteorological Centre, Dorval, Quebec)

An interactive expert system for composition of meteorological forecast products from weather element matrices available at an ensemble of stations or sample points is available to generate a full suite of products. The dynamic database includes a set of weather element matrices produced at approximately 600 points across Canada. These matrices include statistical and direct model output parameters at a 3-h time resolution. Upon reception of the matrices, the Knowledge Base System processes the data to extract the events or meteorological concepts that are the results of a semantic numerical analysis of the weather element matrices content. The concepts can be displayed on a graphical user interface for editing if needed and then the Knowledge Base System is called once more to generate the forecast products. It is possible to generate from the same data a multitude of products tailored to the needs of specific clients under a variety of formats including graphical packaging.

The system is file driven. A set of Product Description Files provide all needed instructions to generate the different products. The main component of the system is the Blackboard. Depending on the products to be generated, the Blackboard issues requests to the relational Database Management System that has been developed to manage the

static data, and also issues objectives to the Knowledge Base System which works on the dynamic meteorological data in the concepts file. The objectives are the goals that the Knowledge Base System must achieve to generate a particular forecast product and the results of the Knowledge Base System's work is returned to the Blackboard. The results of the objectives can be in textual and/or numerical formats. The system gives to the users the capabilities of defining the desired products, generating, managing and modifying them on site and as needed without relying on experts in development.

Efficiency is gained by working on a so called master product. After editing and quality controlling all needed weather elements included in the master product, series of derived products can be generated as defined in the Product Description Files, from extracted weather elements. The master product can then be considered as the working meteorological table, from which all other products can be derived without extra work. Consistency between different forecast products is also ensured.

3B4.2
An Interactive Aviation Weather Database
R. Verret (1), M.-F. Turcotte (1), V. Souvanlasy (1) and M. Baltazar (1) ((1) Atmospheric, Climate and Water Systems Branch, Canadian Meteorological Centre, Dorval, Quebec)

Despite all technological and scientific progresses made in analyzing and forecasting atmospheric conditions, the content and format of aviation weather information have not significantly evolved from the traditional alphanumeric bulletins that are still in use nowadays. However, computerization have brought forth new perspectives for producing and disseminating aviation weather information. The capacity of numerical atmospheric models to ingest an ever-increasing amount of data from various sources and to produce high-quality gridded forecasts in relatively short periods of time has prompted initiatives on the automated production of a new generation of aviation weather products. Other related initiatives include the development of user-friendly interactive systems to generate those products in graphic formats allowing a quick and intuitive understanding of actual and forecast aviation weather conditions.

The aviation weather database described here is the core component of a future aviation weather display system to be used as a briefing-aid tool. Development work has so far resulted in the creation of a database of gridded aviation-impact variables that can be interactively queried through a user-friendly JAVA based application. The driving model for the database is the operational Canadian Regional model. Variables are computed on the high resolution portion of the model's grid which covers all of Canada, adjacent waters as well as a significant portion of United States. Space and time characteristics of variables are similar to, or derived from, those of the model's actual operational outputs : 35 km horizontal resolution, 41 flight levels (from mean sea level up to 40 000 feet) interpolated from the 28 sigma levels of the model, and a 3-hour time resolution from zero to 48 hours. Most variables, including icing and turbulence, are calculated using algorithms that are adapted versions of pre-existing operational ones. The remaining variables were already available as standard outputs from the model. The database is

updated twice per day (00 and 12 UTC) in real time. In its current state the aviation weather database includes : temperatures, winds, icing, turbulence, cloud fraction, relative humidity, vertical velocity at 41 flight levels, every 3-hours from zero to 48 hours. It also includes : tropopause pressure and temperature, freezing level, total cloud cover, instantaneous precipitation rate at the surface and station pressure. The current icing algorithm used in based on supercooled liquid water content forecast by the driving model. The turbulence algorithm is based on the deformation vertical shear index. Real-time observation data will also be incorporated in the database. Utility programs have so far been developed for the treatment of METARs and TAFs. Future programs will be developed for other alphanumeric data as well as for satellite imagery, radar data, and others.

The AWeD database is made accessible on network through a users interface. This application allows the users to enter flight parameters, such as departure and arrival points, check points along the planned route, estimated elapse time of the flight and flight level. Series of meteorological products, all tailored to each particular flight, in plan view and vertical cross-section along the route can then be requested. It is the first known fully interactive system that can generate tailored meteorological aviation products from a numerical model gridded database. A verification system is also under development as part of the database, in order to assess the reliability and performance of the different aviation impact variable algorithms.

3B4.3
Aviation Weather Analysis and Forecasting for Airports Using a One-Dimensional Numerical Model
Robert Tardif (1), Peter Zwack (1), Anne Frigon (1) and (1) ((1) Université du Québec à Montreal, Earth Sciences Department)

Due to the continuing trend of increased air travel activities within the US airspace, efforts have been undertaken over the last few years toward the increase of airport capacity while maintaining the highest standards of safety for air travellers. An aspect playing an important role in determining airport capacity is the weather. Low ceilings and visibility as well as atmospheric conditions associated to the presence of long-lived aircraft-produced wake vortices are responsible for a reduced rate at which airplanes are being accepted for landing. The use of coupled 3D and column (1D) models is being investigated for the very short-term forecasting (1hr to 2 hrs) of weather elements over specific sites, such as airports.
Experiments have been performed using the high-resolution COBEL column model, driven by data from operational 3D mesoscale models, such as the ETA and GEM models. A real-time prototype of the coupled COBEL 1D model / operational 3D mesoscale model system has been tested during the Dallas-Fort Worth Wake Vortex Field Measurement Program in September 1997. The emphasis is now on the adaptation of this prototype for the very short-term prediction of low cloud burn-off as part of the US Federal Aviation Administration Marine Stratus Initiative at the San Francisco airport.

3B4.4
Normalization Techniques for the Verification of Aviation Forecasts
Kent A. Johnson (1) ((1) Mountain Weather Services Office Environment Canada)

For decades, different routines have been utilized for the evaluation of terminal aerodrome forecasts (TAFs). These routines generate scores for categorical forecasts which contain elements of uncertainty. Environment Canada (EC) presently produces TAFs as part of a commercial agreement with the Canadian air navigation system (NAV CANADA). An evaluation system is presently used to demonstrate TAF quality to NAV CANADA and its clients.

In any TAF verification scheme, accuracy and precision must be demonstrated. At the same time, meteorologists must be able to use the statistical values as a tool for determining trends and producing higher quality forecasts. A constant challenge exists due to the temporal and spatial variability of meteorological parameters. It would be useful to compare values from season to season, station to station or year to year. However, variability in frequency and duration of specific events complicates the issue considerably. Using a similar score to evaluate an event which might be rare at one location or in one season often renders comparison to a different location or season meaningless.

Several methods of normalization are possible although none is perfect and each have inherent limitations. Potential techniques include seasonally-adjusted statistics, normalization to long term verification statistics and standardization of all sites to national average scores.
Since the ceiling and visibility thresholds verified are relatively rare events, normalization to climatological frequency of these events is also discussed. A summary of the various techniques provides advantages, disadvantages and potential pitfalls of each while suggesting which scheme may be best suited to future implementation.

3B4.5
Verification
Phil Chadwick (1) ((1) Regional Weather Centre Toronto, AEP, DOE)

Verification is an important step in the predictive process. Clients and Program Managers require meaningful and representative quantities on which to base important operational decisions and to design improvements in the program.

Predictive skill is a strong function of event type and the space and time scale of the prediction. Message-Based (Spatial) Verification consider these dependencies and is suggested as an alternative to traditional event-based verification. Reproducible, accurate and unbiased measures of predictive skill are determined at telescoping scales of space and time. The characteristics of message-based verification are described and contrasted with those of event-based verifcation. Sample results and message based verification products are used to illustrate the main attributes of Spatial Verification using the Severe

Thunderstorm Program for Ontario Region. The requirements of clients and program managers at all scales, can be fulfilled using Spatial Verification.

Session 4-A1
Forecasting

Thursday June 4
09:05 - 09:50
Lake City Ballroom

4A1.1
Seasonal Prediction with a coupled Atmosphere-Ocean System at ECMWF
Tim Stockdale (1) ((1) European Centre for Medium-Range Weather Forecasts)

ECMWF as developed a coupled ocean-atmosphere seasonal forecasting system, which has now been running in real time for more than one year. The ocean model is global, and it is initialized using a OI sheme applied to all available sub-surface thermal data, together with a strong relaxation towards Reynold's SST analysis. The atmosphere models is identical to that used in ECMWF operational forecasts in December 1996, except that its resolution is T63L31. The coupled forecasts run without any artificial constraints except for the specification of sea ice at high latitudes. Typically 30 integrations, each of six months, are run each month.

Forecast products are generated by calibrating the model output against a set of forecasts covering an earlier period: in this way first order model biasesare removed. The rsults for 1997 and 1998 have been better than expected: the El Nino was nicely forecast, as were many of the resulting weather disturbances around the world. Initial impressions suggest that the model did better than simply reproducing the known "teleconnections" of El Nino; this maybe because of the global nature of the forecast system.

Session 4-B1
Forecasting

Thursday June 4
10:10 -12:10
Hawthorne Room

4B1.1
The Atlantic Environmental Prediction Research Initiative
Harold Ritchie (1) ((1) Recherche en prévision numérique)

The Canadian Atmospheric Environment Service (AES) has decided to establish a Climate and Atmospheric Research Directorate (CARD) presence in Halifax, Nova Scotia, to join with other partners in conducting research and development for an

environmental prediction capability in the Atlantic region on all time scales. This is considered to be now feasible for two main reasons. Firstly, in recent years major advances have been made in a variety of numerical modelling activities covering a wide range of space and time scales, and extending to new applications. Secondly, in parallel with these advances in our scientific knowledge and modelling capabilities, there has also been a rapid evolution in computer technology leading to the availability of ever increasing supercomputer power. As a result we now have the scientific and technical capabilities to build comprehensive environmental prediction systems integrating expertise from a wide range of disciplines and addressing important issues in both research and operational prediction modes. The Atlantic Region of Canada is considered to be an ideal location to undertake such an initiative. In addition to being a hyperactive environmental area, there is already a solid base of government and university expertise specializing in atmospheric and oceanic sciences, and operational meteorology.

Although it is intended to develop as comprehensive an environmental prediction system as possible, the research focus will be maritime environmental aspects such as regional atmosphere / ocean / ice / wave model coupling and the parameterization of related physical processes. The construction and testing of such an integrated regional prediction system is expected to be a major first step, and will require a close and productive collaboration of many key players. This should be accomplished in a phased manner, starting with the construction of a baseline system by combining prototype components that already exist for the synoptic (several days) time scale and the Atlantic Region space scale. The atmospheric component will be supplied by a more focussed version of the Canadian operational forecast model, which can be coupled with an ocean wave forecast model (work in progress) and a relatively simple ocean and ice data assimilation and prediction system that is running routinely at Dalhousie University. Coastal atmospheric and oceanic prediction and processes will be a major emphasis, particularly in the early phases of the initiative, with many potential applications for offshore activities.

4B1.2
Development of a 15 km Model at the Canadian Meteorological Center
Gérard Pellerin (1) André Methot (1) Richard Moffet (1) Alain Patoine (1) (1) Canadian Meteorological Centre, Environment Canada

The Canadian Meteorological Centre has implemented the Global Environmental Multiscale (GEM) Model for its operational short-range regional forecast on February 24, 1997. It replaced the Regional Finite-Element for the production of detailed and timely short-range (less than two days) forecasts over North America and some of its adjacent waters. The GEM model is integrated at a resolution equivalent to that of its predecessor, i.e. 0.33° versus 35km for the RFE.
Taking advantage of the flexibility afforded by the GEM model (Côté et al., 1997) in localizing its high resolution window, the following strategy has been adopted for the development of a 15 km version of the GEM. Two grids whose uniform high-resolution area cover the west coast of Canada and the St-Lawrence River valley respectively were designed. Taking into account computing resources and operational requirements they were selected to provide 24 hour high-resolution forecasts over most of the Canadian

territory south of 60° North in two separate integrations. This two-grid system (HIMAP) is now running in experimental mode within the operational suite at CMC.

The presentation will show the model characteristics and performances in comparison with the 35 km resolution model.

4B1.3
The Use of Coupled Meteorological and Hydrological Models at Regional Scale
Pierre Pellerin (1), H. Ritchie (2), R. Benoit (2), N. Kouwen (3) and R. Soulis (3) ((1) Division de Recherche en Prévision Numérique, Environnement Canada, Dorval, Québec, (2) Numerical prediction Research, Environment Canada, Dorval, Québec, (3) Department of Civil Engineering, University of Waterloo, Waterloo, Ontario)

Precipitation events, both observed and numerically modelled, are characterized by strong spatial variability and consequent uncertainties. This makes it difficult to verify precipitation forecasts using traditional methods.

The coupling of atmospheric and hydrological models provides a complementary tool that enables improved validation of numerical weather prediction by comparing runoff measurements and predictions from models based on distributed hydrologic water balance equations. Here results obtained for the Grand River Basin (southern Ontario) will be presented. The comparisons will include meteorological and hydrological observations, analyses radar data and mesoscale model predictions.

4B1.4
Water Level Forecast of the St. Lawrence River
D. Lefaivre (1), M. Gaulin (1), B. Tessier (2), B. Morse (3), G. Ouellette (1), N. Roy (1) and S. Dumont (3) ((1) DFO-Laurentian Region, Maurice Lamontagne Institute, 850 Route de la Mer, P.O. Box 1000, Mont-Joli, Qc. G5H 3Z4, (2) Canadian Hydrographic Service, Maurice Lamontagne Institute, Fisheries and Oceans, (3) Coast Guard, Fisheries and Oceans)

The Department of Fisheries and Oceans-Laurentian Region, in a joint effort of its Science branch with CHS and CG transmits daily the Water Level Forecast of the St. Lawrence River through the Coastal and Oceanic Water Level Information System (COWLIS) of CHS. A hydrological river model has been coupled to a hydrodynamical ocean model in order to forecast the water level between Montreal and Quebec City for periods up to 30 days. The coupled models integrate the bathymetry, bottom friction, tides and storm surge, freshwater runoff from lateral rivers, and from the Great Lakes and the Ottawa River basin. The forecast error for a 24 hour period is of the order of 8 cm at Montreal and 10 cm at Trois-Rivières. For a 30 day forecast, the error is 30 cm for the two regions. At Lauzon (Quebec City), where the water level fluctuation is tidally dominated, the error is in between 20 and 25 cm overall. These errors are caused by upriver fluctuation in flow, by rain events, and by ice cover, while down-river it is caused mostly by wind and atmospheric pressure. Since June 1997, the runoff of lateral rivers are assimilated in the model and used for the forecast. Wind and atmospheric pressure are

used since December 97 for the down-river boundary. This latter condition was used successfully on December 30, 97 to forecast overflow on the Gasp&eacute peninsula shoreline and in downtown Quebec City. The influence of this storm surge was observed up to Montreal. The ice-storm of January 5 to 9, 1998 had a more dramatic effect in the Montreal area. Its influence was also seen in the water levels. Rain increased the inflow while ice cover on the river hindered water flow. The overall result was an increase of 110 centimetres in seven days. Model results help quantify the relative contributions to the water level increase.

4B1.5
Application of A Direct Inverse Method to Tidal Modelling on the Newfoundland and Labrador Shelves
Zhigang Xu (1), Ross Hendry (1) and John Loder (1) ((1) Bedford Institute of Oceanography)

This paper describes an application of a newly developed data assimilation method, the direct inverse method, to remotely-sensed and in situ tidal data from the Newfoundland and South Labrador shelves and adjacent regions. The method seeks an explicit relationship between the interior solutions and boundary forcing via a finite element discretization of the linear 3D shallow water equations in the frequency domain. The explicit relationship is then used as a general regression model to assimilate the interior observations to produce an optimized boundary forcing.

The initial application is carried out for M2 and K1 tidal constituents. Remotely-sensed data from the TOPEX/POSEIDON satellite provide information on the tidal amplitudes and phase lags over a large area (about 1000 km x 2000 km). The in situ data include coastal tidal gauge data, offshore bottom pressure data, and moored current meter data. Constrained by more than 1400 data points distributed almost evenly in the entire domain, the optimized field of tidal elevation is believed to be highly realistic and the 3D current fields provide a high resolution representation of the flow over offshore topography and around coastal features.

4B1.6
An integrated forecast system for short-term ice-ocean forecasts
C.L. Tang (1) and B.M. DeTracy (1) ((1) Bedford Institute of Oceanography, Dartmouth, NS)

An automated system has been developed to produce daily forecasts of ice conditions and ocean currents for the eastern Canadian seaboard. The model used in the system is a coupled ice-ocean model consisting of a Hibler type ice model and a diagnostic ocean model coupled to sea-ice through an Ekman layer. Using appropriate boundary conditions, the ocean is spun up from rest to a steady state in about 10 days, which represents the mean circulation of the Labrador Sea. The boundary conditions and model parameters are tuned to obtain mean currents and volume transports comparable to

observations. Six hourly winds and barometric pressure from the Canadian Meteorological Centres are used as forcing for ice movement and wind-driven currents. In selected areas, tidal and inertial currents are computed separately and then added to the total currents. The ice model is calibrated against ice beacon and satellite data. In operational forecasts, the ocean model is run continuously, and ice concentration and thickness are updated daily using ice charts produced by Canadian Ice Services. The outputs include ice concentration, thickness and velocity, surface currents and surface trajectories. The system has been operated since January 1997 and are being improved on a continous basis. The forecasts are displayed on the Internet and can be viewed at the following address: http://dfomr.dfo.ca/science/ocean/ice_ocean_forecast.html

Session 4-B2
Boundary Layer Meteorology

Thursday June 4
10:10 - 12-10
Sullivan Room

4B2.1
Modelling longitudinal vortices in boundary-layer airflow over 2D wavy surfaces
Wensong Weng (1), Stefano Gallino (2) and Peter Taylor (1) ((1) Department of Earth and Atmospheric Science, York University, Toronto, Ontario, (2) Department of Physics, University of Genova, Italy)

Gong et al (1996) reported observations of the development of longitudinal vortices in a wind tunnel study of turbulent boundary- layer flow over 2D sinusoidal waves. Large eddy simulations of the same flow showed somewhat similar features but they were less regular or organised. Using a time dependent version of the 3D non- linear mixed spectral finite difference code (NLMSFD) for boundary- layer flow over topography we can simulate the development of similar vortex structures, but their rate of development tends to be rather slower that was observed in the wind tunnel.

Results will be presented showing, amongst other things, a strong dependency of growth rate on boundary-layer depth. So far these model predictions have not explained a significant disparity between wave crest velocity profile predictions with the 2D NLMSD model and the profiles measured in the wind tunnel. Potential application of the results to airflow over water waves and to wind wave generation will be discussed.

4B2.2
Stably-Stratified Flow Over Hills, and Wave Drag
Jingnan Zhou (1), Yoseph Mengesha (1), Peter A Taylor (1) and Ying Qi (1) ((1) Department of Earth and Atmospheric Science, York University, Toronto, ON)

Modelling studies of stably stratified planetary boundary-layer flow over topography are used as a basis for drag calculations. Cases with and without vertically propagating waves

are discussed with Froude number (F = Uk/N where k is the horizontal wavenumber of the topography) as the critical parameter. For stably stratified flow, linear inviscid theory provides a first estimate of the wave drag for cases with F < 1, but velocity and stratification in the outer flow, or at heights of order 1/k, are recommended in preference over values at lower "launching heights".
Difficulties in terrain representation are discussed and some results of an analysis of the "sandhills" area (Nebraska) are described.

4B2.3
Guidelines Model Developments
Joyce Kwan (1), James Salmon (2), Peter Taylor (1), John Walmsley (3) and Wensong Weng (4) ((1) Department of Earth and Atmospheric Science, York University, (2) Zephyr North, Burlington, ON, (3) Atmospheric Environment Service, Toronto, ON, (4) Department of Earth and Atmospheric Science, York University, Toronto, Ontario)

The "guidelines" for estimating wind speed variations in boundary-layer flow over hills and other terrain features as well as within internal boundary layers downstream of changes in surface roughness were developed by Taylor and Lee (1984) and Walmsley, Taylor and Salmon (1989). Since then there have been a number of improvements to make the guidelines more "user-friendly". A Windows 95 version has recently been developed.

In addition the basic guidelines have been extended to allow computations of humidity profiles within internal boundary layers and estimates of evaporation as a function of fetch over lake surfaces.

For flow over hills, guidelines for stably stratified flows have now been developed and some initial results will be used for illustration. These computations require additional input or assumptions to define the upstream, approach flow in a stable boundary layer. Methods for estimating these flows will be discussed.

4B2.4
A ONE-AND-A-HALF ORDER CLOSURE MODEL OF THE TRANSILIENT TURBULENCE MATRIX
Henryk Modzelewski (1) and Roland Stull (1) ((1) Department of Atmospheric Science and Geography, University of British Columbia)

The Transilient Turbulence (TT) closure model employs a non-local definition of turbulent fluxes and produces non-local mixing of physical quantities. Admitting the advective character of turbulent dispersion, the basic assumption of TT states that in certain conditions a matrix operator, called the Transilient Matrix (TM), may be used to represent the process of non-local turbulent mixing.

The previously developed parameterizations of TM are diagnostic. The most recent one used a diagnostic formula based on non-local analogue of the turbulence kinetic energy (TKE) budget equation. Proposed here is a 1.5 order model utilizing a non-local analogue of the TKE budget equation. Hence, it takes into account the evolution of the turbulence and its influence on the turbulent state of the atmospheric flow.

We will introduce the main ideas and the proposed new formulation of the TM parameterization. Then we will present the results of simulations, using a simple dispersion model, for which we will consider idealized cases with different types of forcing conditions and different types of atmospheric stability. Finally we will discuss turbulent dispersion and evolution of PBL as predicted by TT.

4B2.5
Boundary Layer Wind and Temperature Profiles in the Radix Layer
Edi Santoso (1) and Roland Stull (1) ((1) Atmospheric Science Program, UBC Department of Geography)

In the middle of the convective atmospheric boundary layer is often a deep layer of vertically-uniform wind speed (Mu), wind direction, and potential temperature (Tu). A “radix layer” (RxL) is identified as the whole region below this uniform layer (UL), where the winds are slower. The classical surface layer (SL), defined as the region where Monin-Obukhov similarity is valid, is a shallower subdomain of the radix layer. Radix is Latin for “root”, named because the roots of convective thermals are in this layer.

The depth of radix layer (zR) is determined as a function of the surface friction velocity, u*, the convective velocity scale, w*, and the mixed layer depth, zi, with relationship zR = C [(u* / w*)**B] zi where C and B are constants. Observations can then be plotted as (M / Mu) vs. (z / zi) (w* / u*)** B to get a non-dimensional similarity equation M / Mu = F(z / zR).

The profile function F that satisfies a smooth transition of the profile from RxL to UL is empirically found to be F =([(z / zR)**D]**A) * exp[A (1 - (z / zR)**D)] where A and D are constants. The same profile function F with different radix-layer depth and shape exponent is shown to describe the potential temperature profile (T - Tu) / (To - Tu) = 1 - F(z / zR), where To is the potential temperature near the surface. Results from the 1973 Minnesota data analysis give A = 1/4, B = 3

Session 4-B3
Air-sea Interaction 1

Thursday June 4
10:10 - 12-10
Alderney Room

4B3.1
ON THE CLIMATOLOGY OF SURFACE MARINE WINDS NEAR THE WESTERN COAST OF CANADA
Manon Faucher (1), Lionel Pandolfo (2) and William R. Burrows (3) ((1) Environmental Adaptation Research Group, Atmospheric Environment Service at the Sustainable Development Research Institute, University of British Columbia, (2) Earth and Ocean Sciences Department, University of British Columbia, (3) Atmospheric Environment Service, Downsview, Ontario)

An empirical-statistical technique named CANFIS (Burrows et al, 1998) was used to reconstruct six-hourly surface marine winds at 13 Canadian buoy sites along the western coast of Canada for the 40-year period 1957-1996. CANFIS combines Classification and Regression Trees (CART) and the Neuro-Fuzzy Inference System (NFIS) in a two-step procedure to build empirical relationships for continuous output. CART is a tree-based algorithm used to optimize the process of selecting a series of predictors from a large pool of potential variables. NFIS is used to do the modeling from subtractive clustering while removing CART discontinuities. This procedure links large scale atmospheric variables from the NCEP/NCAR 40-year reanalysis project and regional wind observations from the Canadian Atmospheric Environment Service (AES) buoy network during the learning phase from 1990 to 1995. The relationships are used to "hindcast" six-hourly wind data at the buoys prior to 1990 and in 1996.

Validation results with independent buoy data show a good performance of CANFIS. In particular, the correlation coefficient for 10 different events varies between 0.61 and 0.98. Histograms of the amplitude and direction of observed winds at 4 buoys in the inner and outer coast exhibit specific shapes, illustrative of the climatological characteristics of British Columbia coastal meteorology. Histograms of CANFIS winds for the same locations and periods reproduce observed wind distributions relatively well. By comparison, reanalyzed NCEP winds, interpolated to the shelf-buoys location, exhibit amorphous histograms. In most cases, NCEP reanalyzed winds, after height correction, are stronger than observed winds and are at an angle with respect to the latter. In all cases, CANFIS winds recover more than 60% of the observed variance. In addition, Hotelling's T^2 tests indicate no evidence of significant differences between CANFIS and observed winds at 95% confidence for at least 6 events.

Our results suggest that CANFIS is a successful downscaling method to reproduce the dynamics of surface marine winds, especially along the coast where ageostrophic effects are relatively important.

4B3.2

The Impact of Air-Sea Coupled Dynamics on Ocean Waves

William Perrie (1), Liangming Wang (2) and Bash Toulany (1) ((1) Bedford Institute of Oceanography, Dartmouth, NS, (2) Coupled Ocean Meteorology Enterprises)

Waves are generated by wind stress on the water surface. Waves grow and evolve in space and time, reflecting the structure and space - time development of the wind stress fields that generated them and that continue to influence them. In turn, the wind stress fields are themselves influenced by the waves, in an interactive process that continues throughout their entire history. This history extends from their beginning, when they are generated as tiny ripples and capillary waves, throughout their evolution, in which they may develop to huge 'Storm-of- the-Century' waves, to their progressive decay, as old swell waves, and their ultimate disappearance / dissipation, travelling global-scale distances from their point of generation. It is well know that many aspects of this wind and wave generation and evolution are poorly understood. For example, what is the correct theory and modelling of energy pumped into waves from the wind, or removed from waves by wave - breaking dissipation? What is the coupling of the wind and the atmospheric boundary layer to the waves? How is the evolution of the wind stress fields and the atmospheric model impacted by the waves and the ocean surface?

It is evident that ocean waves and boundary layer winds are coupled and interactive. Winds force waves and in turn are themselves impacted upon by the waves, by the sea surface roughness, by the maturity of the sea state.

There has been considerable discussion of sea surface roughness, Zo, in recent publications. Toba et al (1990) suggest that as waves become older and sea state matures, the ocean surface becomes rougher, and that young waves are relatively smooth. By contrast, Smith et al (1992) using HEXOS North Sea data, and Donelan et al (1993), using Lake Ontario data, suggest the opposite, that young waves are relatively smooth and that as waves become older and more mature, they become more smooth. Although field data tends to support the latter view of Smith et al (1992) and Donelan et al (1993), there has been some concern about depth dependence, as well as the influence of swell, which has not been resolved.

From an observational point of view, it is easier to measure the wind at a reference height, such as 10 meters U10, than friction velocity U*. A lot of empirical formulae trying to relate the drag coefficient Cd (or U*) and U10 have been produced by observations. However, equations for the atmospheric boundary layer relate wind speed U10, drag coefficient Cd, friction velocity and sea surface roughness, Zo. For neutral conditions, implementation of an empirical formula, such as Wu (1980), relating drag coefficient to wind speed U10, leads to an over-detemination of the atmospheric-boundary layer system of equations.

A given wind profile is specified by U*. However, at a given reference height such as 10 m, although the wind speed U10 may have a single value such as 20 m/s, there can be a myriad of differing possible wind profiles. Each wind profile is associated with a

different friction velocity U*, depending on the stability conditions. Each different U* drives different waves systems. Thus wave models should be driven by U*, as inferred from atmospheric models.

Empirical relations, try to express sea surface roughness Zo in terms of other marine boundary layer parameters. Smith et al (1992) and Donelan et al (1993) try to couple roughness to wave parameters, relating Zo to seastate. Within the context of models that couple the atmospheric boundary layer to the ocean-wave surface, specifically the WAM wave model, we show that the HEXOS results of Smith et al (1992) are significantly better respresented by a seastate-dependent Zo, rather than an uncoupled Cd relation, as suggested by Wu (1980), or similar relations suggested by Yelland and Taylor (1996) and others.

We present results for the Storm of the Century (March, 1993) and Hurricane Luis (Sept., 1995), both of which resulted in maximum waves of about 30 m, as measured at waverider buoys on the continental shelf.

4B3.3
Impact of a Coupled Atmospheric and Ocean Wave System on the atmospheric and ocean wave forecasts
Serge Desjardins (1), Jocelyn Mailhot (1), Roop. Lalbeharry (2) and Laurie Wilson (1)
((1) RPN,AES,Dorval, QC, (2) AES, Downsview, ON)

To take into account the change of surface roughness length induced by ocean waves, a coupled atmospheric and ocean wave system has been developed at AES. A bi-directional coupling is done between a mesoscale atmospheric model, MC2, and an oceanic wave model, a regional version of WAM Cycle-4.
Two different approaches, based on the wave-age and the wave-induced stress, respectively, are used to compute a coupling parameter called the Charnock parameter expressed as the nondimensional surface roughness length. The coupling between the two models is accomplished by the use of this parameter which is function of the sea state instead of a constant value obtained from empirical studies using the well-known Charnock relation. Both approaches are evaluated by comparing atmospheric outputs obtained from coupled and uncoupled model system, against buoy observations. Atmospheric and wave results of this bi-directional coupling will be shown for a few cases.

4B3.4
The influence of the mesoscale feature of the SST distribution on the marine boundary layer winds during the Storm of the Century
Serge Desjardins (1) ((1) AES,RPN,Dorval)

Can the Gulf Stream and its meanders, by its strong influence on the marine boundary layer, generate meso-scale features in the wind field?
Numerical simulations of the Storm of the Century of March 1993 were carried out using the MC2, a fully elastic non-hydrostatic model. Simulations were conducted at different

resolutions (50, 25, 10, 5 and 2-km) with both detailed and smoothed SST fields, so as to examine the influence of these parameters on the marine boundary layer winds. Results from these numerical simulations are compared with surface observations from buoys. The study revealed some meso-scale features in the surface wind field caused by the Gulf Stream's meanders and the warm eddies of the SST field. Most of the influence can be explained by the stability factor.

4B3.5
ON THE DYNAMICS OF SURFACE MARINE WINDS NEAR THE WESTERN COAST OF CANADA
Manon Faucher (1) and Lionel Pandolfo (2) ((1) Environmental Adaptation Research Group, Atmospheric Environment Service at the Sustainable Development Research Institute, University of British Columbia, (2) Earth and Ocean Sciences Department, University of British Columbia)

The objectives of this study are three-fold. Firstly, we describe the statistical and dynamical characteristics of oceanic surface winds for the western coast of Canada. Secondly, we relate the statistical descriptions to the climatology of the coastal regions of British Columbia. Thirdly, we estimate the accuracy of wind data over the western coast waters of Canada. The objectives are developed by comparing winds obtained from various data sets.

Observations from 13 AES weather buoys off the coast of British Columbia are used to characterize the surface winds on a spatial resolution of 50km to 75km. A second data set comes from the NCEP/NCAR 40-year reanalysis project. The surface NCEP winds are available on a grid with 2.5? resolution for the first sigma level (~45m). Histograms of the amplitude and direction of observed winds exhibit specific shapes, characteristics of British Columbia coastal meteorology. On the other hand, reanalyzed NCEP winds, interpolated to the shelf-buoys location, exhibit different histograms. In most cases, NCEP reanalyzed winds, after height correction, are stronger than AES observed winds and are at an angle with respect to the latter. In addition, an Hotelling's T^2 test indicates significant differences between NCEP and observed winds at 95% confidence. Discrepancies between wind observations from AES buoys and the NCEP reanalyzed winds are mostly due to the local topography.

Our results suggest that for the continental-shelf region of British Columbia, ageostrophic effects due to meso-scale weather events are not well represented by the NCEP surface winds. However, improvement is possible with speed and direction correction factors.

4B3.6

Wave Hindcasts Forced by Remotely-Sensed Wind Fields

William Perrie (1), Bash Toulany (1) and Michael Dowd (2) ((1) Bedford Institute of Oceanography, (2) Satlantic, Halifax, Nova Scotia)

Interpolation of remotely sensed SEASAT data, as suggested by Woiceshyn et al (1989), produced gridded wind fields at 1-degree resolution, as shown on the cover of Aviation Week & Space Technology (1989) Vol. 130, (11). The interpolation uses values from earlier/later swaths, to achieve synoptic wind maps. Alternate studies are by Bentamy et al (1996) using kriging methods, and Tang and Liu (1996), using succesive correction methods to get 12 hourly wind fields. Thus, wind fields with known/estimated errors and biases, can be constructed, without assistance of elaborate atmospheric models. In this study we use the ERS scatterometer data in conjunction with the ERS altimeter and TOPEX/POSIDON altimeter.

In this study we produce 1-degree spatial scale wind fields, synoptically every 6-hours, and every 12-hours for the North Atlantic ocean. We use optimal interpolation (specifically, “kriging”) as the objective analysis method, as suggested by Bentamy et al (1996). We confine the present study to the time period for 2 storms: (i) Storm of the Century in March’93, and (ii) Hurricane Luis in September’95.

Error maps are needed to understand the results from OI constructed wind fields. These are automatically produced as part of the kriging process and are constructed for the North Atlantic ocean, for 6-hourly and 12-hourly maps, for the periods for the 2 storms.

Verifications of OI constructed wind fields, are (i), with similar studies from operational AES studies, (ii) in situ measurements of wind from buoys and dedicated experiments, and (iii), kinematically constructed wind fields by Cardone.

Wave hindcasts were produced using the standard WAM wave model. For the storm events considered, we show that ERS scatterometer wind fields alone capture some features of AES analysis wind fields, whereas ERS-scatterometer + TOPEX/POSIDON-altimeter winds are qualitatively very close to AES analysis wind fields. By contrast, ERS-altimeter functions poorly, and in each case, degrades the features captured by the other two data sets. Associated wave fields are therefore analogous: waves from ERS scatterometer winds alone have some features of waves from ‘best’ AES analysis wind fields, whereas waves from ERS scatterometer + TOPEX/POSIDON altimeter winds are qualitatively very close to waves from the ‘best’ AES analysis wind fields. By contrast, results are degraded by ERS-altimeter wind data.

Presently we are doing an analysis of storms during the era of the NSCAT- scatterometer and plan to include the RADARSAT SAR, as well. We anticipate that resultant wind fields from these satellites, in conjunction with ERS-scatterometer and TOPEX/POSIDON-altimeter, will be quite competitive with ‘best’ AES analysis wind fields. Good results for ocean wave models are also anticipated.

Session 4-C1
Atmospheric Modelling 1

Thursday June 4
13:40 - 15:00
Hawthorne Room

4C1.1
Implementation of a new forecast and assimilation system based on the unified GEM model at CMC
Michel Roch (1), Stephane Laroche (1) and Sylvie Gravel (1) ((1) Meteorological Research Branch, Environment Canada)

The development phase of the Global Environmental Multiscale (GEM) model was completed 2 years ago. The objective of this work was to replace the functions of the two numerical models used at the Canadian Meteorological Center (CMC) to provide forecast guidance to Canadian weather offices. This new model, when run at uniform resolution, can be used to drive the global assimilation system and to provide medium-range forecasts at the global scale. When configured to have variable resolution, it can also be used to make short-term high resolution forecasts at the continental scale. Both of these applications are made within a single dynamical framework.

The first operational phase was completed in February 1997 when the GEM model operationally replaced the Regional Finite Element (RFE) model at the Canadian Meteorological Centre. A further step forward was the operational introduction of an intermittent regional 3-d variational (3dvar) data assimilation spin-up cycle. The third and last stage, the replacement of the Spectral Finite Element (SEF) model by the GEM model in its uniform-resolution configuration is now reaching completion.

The GEM model has been validated as a driving model for a 3dvar system with long data assimilation periods characteristic of all seasons of the year, and also as a medium-range forecast model that uses analyses derived from its own self-consistent data assimilation cycle.

Validation results will be presented together with an evaluation of the new system performed during a pre-implementation parallel run.

4C1.2
Applications of Ensemble Forecasts at the Canadian Meteorological Centre
Louis Lefaivre (1), Peter L. Houtekamer (2), Alain Bergeron (1) and Richard Verret (1) ((1) Canadian Meteorological Centre, Environment Canada, (2) Recherche en prevision numerique, Environment Canada)

Ensemble Prediction is part of the operational suite at the Canadian Meteorological Centre since late Winter 1998. Based on the experience of more than two years of

experimental runs, a number of products have been produced and evaluated. The purpose of the talk will be to present and review them.

The ensemble system consists of a set of eight member forecast runs done every day up to 10 days, using a T95 version of the spectral model (SEF). Each set of forecasts are launched from pertubed analyses obtained from independent assimilation cycles. The cycles use perturbed sets of observations and are driven by models that differ in their physical parameterizations.

Ensemble outputs have been used to generate the following products: spaghetti plots of the 500mb height and of high and low pressure systems; forecast charts of precipitation amount probability at various thresholds; forecast daily maximum/minimum temperatures out to day 10 at various locations. Examples of improvement of the mean of the ensemble over the deterministic high resolution model (T199) will be shown, along with examples of the use of probability distributions coming from the individual members.

4C1.3
Ensemble Forecast Generation by Selective Introduction of Hazardous Modes
Joshua Hacker (1) and Roland Stull (1) ((1) Atmospheric Science, Geography, UBC)

Three classical methods of adding perturbations to an analysis to generate an ensemble of initial conditions are Breeding of Growing Modes, Linear Tangent, and Random. Most of these methods have been applied to global or hemispheric models. Our goal is to design a perturbation generation method tailored to the needs for regional forecasting for W. Canada, where two major difficulties are the complex topography, and the upstream Pacific data void.

The method we have designed is called Selective Introduction of Hazardous Modes (SIHM), where the upstream flow is seeded with insipient cyclones of size of the most energetic wavelengths in that region of the world. The seeds are planted as 3-D coherent structures at regions of large-scale dynamic instability, such as where there is low altitude or stratospheric potential vorticity, or jet-stream divergence. SIHM creating a five-member ensemble has been tested at 100 km resolution over the N. Pacific Ocean and W. North America, for eight days during 21-31 January 1990. SIHM is shown to have desirable characteristics similar to the other classical methods of generating ensembles.

4C1.4
SocioEconomic Benefit of Ensemble Weather Forecasts in SW British Columbia
Sarah Lowes (1) and Roland Stull (2) ((1) UBC, (2) Department of Geography, UBC)

Strategies of business leaders depend on the accuracy of weather forecasts. Unfortunately, forecasts in BC are less accurate than elsewhere in Canada, due to the complex topography and the upstream data void over the Pacific.
To counteract these predictability problems, two new forecast methods are being utilized at UBC: higher spatial resolution and multiple (ensemble) forecasts. A byproduct of the ensemble forecast is a measure of forecast reliability.

When put into the proper socio-economic context, business decision makers can utilize this reliability information for strategic planning of resources, tactical planning of daily operations, and improved profitability. The first stage of this project began during summer 1997, to probe the nature of forecast usage in two economic sectors: coastal shipping/towing, and agriculture in BC. Twenty-one companies in the above sectors were interviewed. Based on these screening interviews, we identified those types of businesses that could utilize the new type of forecasts to beneficially alter their operations. The next stage of this research will begin in summer 1998, when we explore other sectors and types of companies affected by weather. We will also develop decision trees and contingency diagrams for specific businesses, and provide them with probabilistic forecasts to study how they are best utilized.

Session 4-C2
Cloud & Precipitation Physics

Thursday June 4
13:40 - 15:00
Sullivan Room

4C2.1
Blowing Snow Modelling with Pietuk-Comparisons with Schmidt's Field Data
Jingbing Xiao (1), Stephen Dery (2) and Peter Taylor (1) ((1) Department of Earth and Atmospheric Science, York University, (2) Department of Atmospheric and Ocean Sciences, McGill University)

Using a fetch-dependent blowing snow model, which we call PIEKTUK, that incorporates prognostic equations for a spectrum of sublimating snow particles, plus temperature and humidity distributions, it is found that the sublimation of blowing snow can lead to temperature decreases of order 1C and significant water vapour increases in the near-surface atmospheric boundary layer, particularly at long fetches. This causes sublimation rates to reduce significantly with fetch despite ongoing transport of snow by wind and snow removal rates due to sublimation are significantly less than the rate given by some other models. This has proved a somewhat controversial issue and there is a clear need for careful comparison between model predictions and field observation.

As a first step in model validation we are attempting detailed comparisons with the field observations reported by Schmidt (1982) of the vertical distribution of particle numbers and size distributions, temperature and humidity during blowing snow events from southeastern Wyoming. Predictions with our standard model give lower particle concentrations above the surface than were reported. This is presumed due to the snow particle size distributions assumed for the lower boundary. Adjusting the shape and scale parameters in the two parameter gamma distribution allows the model to be tuned to give better agreement with the observations. Sensitivity to various model parameters and

unreported observational parameters (e.g. upstream temperature and humidity) will be discussed.

4C2.2
Joint Distributions of Temperature and Moisture in the Convective Planetary Boundary Layer, A Cumulus Population Factor Larry Berg (1) and Roland Stull (1) ((1) Atmospheric Science Programme, Department of Geography, UBC)

We have constructed joint frequency distributions (JFDs) of temperature and moisture at five different heights in the CBL using data collected over three different surfaces (crops, pasture, and forest) in the central great plains of the United States. These JFDs can be used to forecast cumulus onset, coverage, and size distributions, which are important for climate, radiation, and boundary layer studies.

We compare the JFDs from the central United States to those from France. The general features of the JFDs from the two locations are similar: strong central tendency around a dominate mode, sharply pointed peak, asymmetric tails, finite range, and an irregular perimeter. We will relate features of the JFDs to the three different land surfaces. In addition to the JFDs collected during clear conditions we will show JFDs collected on days with some cloud cover.

4C2.3
Measurement of Water Vapour Mixing Ratios Using the Purple Crow Raman Scattering Lidar C. Bryant (1), S. Argall (1), R. J. Sica (1) and R. M. Hoff (2) ((1) Department of Physics and Astronomy, University of Western Ontario, London, Ontario, (2) Atmospheric Environment Service)

The University of Western Ontario's Purple Crow Lidar currently measures temperature and density using Rayleigh scattering. Modifications are coming online that will allow continuous nighttime collection of water vapour data concurrently with Rayleigh and sodium measurements. The water vapour measurements are important for climate and weather modelling, gravity-wave-source studies, and understanding stratosphere-troposphere exchange.

Raman-scattered photons from the 532 nm Nd:YAG laser beam are used to measure molecular nitrogen at 607.3 nm and water vapour at 660.3 nm in order to determine the mixing ratio. Measurements were obtained on 15-16 December, 1997 by manually swapping in the required filters. This data is being processed and will be compared to radiosonde data obtained from Detroit and Buffalo over the same time period.

4C2.4
Cloud droplet spectra formation by ripening process
Fikrettin Celik (1) ((1) Atmospheric and Environmental Research Ltd.)

Updraft during the initial stage of a cloud forms an unstable cloud droplet size spectrum that changes with time by transfer of liquid water from small droplets to large droplets

("ripening process"). This process is shown to be a potential physical mechanism for the droplet spectra broadening, formation of large droplets, and changes in the droplet concentration in stratiform clouds. Internal mixing may result in immediate broad droplet spectra depending on the droplet spectra in the cloud parcels which are mixing with each other. Numerical simulations show that following internal mixing, depending on the characteristics of the droplet spectra in the parcels which are mixing with each other, the resulting droplet spectrum may broaden to large sizes or narrow to smaller sizes with time. These results suggest that the ripening process with internal mixing may have significant roles on the initiation of precipitation, changes in cloud albedo (climate), and aircraft icing.

4C2.5
Ripening process in polluted and clean stratiform clouds
Fikrettin Celik (1) (1) University of Alberta, Dept. of Earth and Atmos. Sci.)

Cloud droplet size spectra formations in marine and continental stratus clouds are numerically simulated. The ripening process, the process of transfer of water vapor from evaporating small droplets to large droplets, is shown to be strongly dependent on the cloud condensation nuclei (CCN) spectra.

The major findings are as follows.

1) The rate of droplet size spectra broadening to large sizes increases with increasing slope parameter of the CCN spectrum (k).

2) In the presence of large CCN in the polluted continental air, droplet size spectra broadening to large sizes in polluted continental stratus clouds can be significantly faster than broadening in clean continental stratus.

3) In a heavily polluted marine stratus, large number of haze particles form and the mean droplet sizes significantly decrease. The ripening process becomes insignificant.

4) In a clean marine stratus with a large k, droplet spectrum broadening to large sizes by the ripening process is significantly faster than in broadening in polluted marine stratus clouds.

Session 4-C3
High Latitude Processes

Thursday June 4
13:40 - 15:00
Alderney Room

4C3.1
Sea-ice anomalies and atmospheric circulation in the Arctic Ocean

S. A. Venegas (1) and L. A. Mysak (1) ((1) Centre for Climate and Global Change Research, McGill University)

The Complex Empirical Orthogonal Function (CEOF) analysis method is used to analyze 40 years (1953-1992) of simultaneous annual sea-ice concentration (SIC) and winter sea level pressure (SLP) anomalies. In order to concentrate on the low-frequency variability, the SIC and SLP anomalies are low-pass filtered so as to retain only periods greater than 4 years.

The first CEOF joint mode, which explains 44% of the covariance between the two fields, identifies cyclic patterns in the coupled SIC and SLP data which have a period of approximately 10 years. The evolution of the SIC anomalies during a typical decadal cycle can be described as a clockwise propagation of the signal around the Arctic Ocean. During the same decadal cycle, the winter SLP anomalies fluctuate between configurations which strongly resemble the positive and negative phases of the North Atlantic Oscillation (NAO) pattern. A series of dynamic and thermodynamic interactions between sea-ice and atmosphere are proposed in order to explain the observed decadal oscillations in the coupled atmosphere-ice-ocean system.

4C3.2
Modelling Flow Through the Arctic Archipelago
David A. Greenberg (1) ((1) Coastal Ocean Science, Ocean Sciences Division, Bedford Institute of Oceanography)

Much of the low salinity water in the Labrador Current is known to come from the Arctic Ocean. Early theories suggested that most of that was water that came around Greenland. As more data are analyzed, it is becoming clear that a significant portion of the fresh water flow is coming through the Arctic Archipelago. In this study, a finite element model of the Archipelago is formulated to resolve the flows through the many complex channels. The existing sparse bathymetry information needed for the model has been augmented with recent data collected jointly by the Geological Survey of Canada and the Canadian Hydrographic Service for Law of the Sea requirements. The initial examination will concentrate on the barotropic response to sea level pressure differences between the Arctic and the Atlantic Oceans.

4C3.3
Thermohaline Intrusions in the Arctic Ocean
Brian D. May (1) and Dan E. Kelley (1) ((1) Department of Oceanography, Dalhousie University)

Thermohaline intrusions are a wide-spread feature of the Arctic Ocean. With the goal of determining the driving mechanism of the intrusions, we analyse CTD profiles collected in a frontal zone north of Svalbard.

Tracking intrusions from profile to profile, we show that they slope upward toward the cold fresh side of the front, relative to horizontal surfaces.

This cross-front slope is in the sense expected for driving by buoyancy fluxes from salt fingering, in the wrong sense for driving by buoyancy fluxes from diffusive convection. The intrusion slope lies between the slopes of horizontal and isopycnal surfaces, in the wedge of baroclinic instability. This cross-front slope is consistent with baroclinic driving of the intrusions. Based on the observed cross-front slopes, we suggest the intrusions are driven by salt fingering and baroclinicity, opposed by diffusive convection.

Assuming a steady-state balance, we estimate the relative magnitudes of the baroclinic and salt-finger driving terms. The calculations indicate that the intrusions are driven 70% by baroclinicity and 30% by salt fingering.
This suggests that baroclinicity is the dominant driving mechanism of the Arctic thermohaline intrusions.

4C3.4
A dynamical model for ice drift based on the air-ice-ocean momentum exchange
Will Perrie (1) and Yongcun Hu (2) ((1) Bedford Institute of Oceanography, Dartmouth, Nova Scotia, (2) Forrest Numerical Modelling Research, Dartmouth, Nova Scotia)

A model was constructed to estimate ice floe trajectories and ice edge evolution, for a given ice floe field. The model considers the balance of atmosphere and ocean drag forces, including skin and body drag forces from wind, waves and currents. Explicit consideration is given to air-ice and water-ice skin stresses, water-ice form stress and wave radiation stress. Estimates are presented for ice drift in a variety of hypothetical situations: (i) as a function of ice floe diameter, thickness and concentration, (ii) in “wave” and “no-wave” situations, and (iii) in constant wind forcing and time-varying wind forcing situations.

Combining this model with an explicit model for the wave-scattering formulation of Perrie and Hu (JPO: 1996, vol. 26, 1705-1720) allows consideration of (1) the effect of wave scattering attenuation on ice floe trajectories and ice edge evolution, and (2) the effect of ice edge drift on the wave spectra. Thus an enhanced modelling of both wave and ice dynamics is achieved. The model is shown to be consistent with wave and ice observations collected during the Labrador Ice Margin Experiment 1987 on the Grand Banks, during relatively high wind situations.

This model is presently being combined with elements of the Canadian operational ice forecast model (Tang and Gui, JGR: 1996, vol. 101, 28,343-28,364) which is a three-dimensional coupled ice-ocean model for short-term ice motion over the eastern Canadian continental shelf, consisting of a Hibler ice model and a diagnostic ocean model.

Session 4-D1
Atmospheric Modelling 2

Thursday June 4
15:20 - 17:00
Hawthorne Room

4D1.1
On the Baroclinic Response of Spatially-Averaged Eulerian and Semi-Lagrangian Treatments of Mountains Harold Ritchie (1), Monique Tanguay (1), Real Sarrazin (1) and Jocelyn Mailhot (2) ((1) Recherche en prévision numérique, (2) Canadian Meteorological Centre)

It has previously been shown that a spatially-averaged Eulerian treatment of mountains can significantly reduce the severity of the spurious topographically-induced resonance problem in semi-implicit semi-Lagrangian models (Ritchie and Tanguay, 1996). This was demonstrated by a linear one-dimensional analysis of the shallow water equations, as well as in integrations of nonlinear shallow water and baroclinic global spectral models. The benefits of this treatment of mountains should be even greater in high resolution regional forecast models operating over mountainous terrain where the high resolution might be expected to aggravate the resonance problem. This is examined here in connection with the development of a 35 km version of a regional model which was implemented at the Canadian Meteorological Centre (Mailhot et al., 1996).

A one-dimensional linear analysis of the forced baroclinic equations is presented and confirms the results obtained in the shallow water analysis of Ritchie and Tanguay (1996) that the resonance is less severe with a spatially-averaged Eulerian treatment of mountains compared to a semi-Lagrangian treatment of mountains and hence can be suppressed with a weaker first-order off-centering. However, this baroclinic analysis does not exhibit the serious truncation problem that was found to be present in the middle of the twin resonances with the semi-Lagrangian treatment in the former shallow water case. The superior behaviour of the spatially-averaged Eulerian treatment is illustrated in idealized baroclinic problems including a comparison of the analytic and numerical linear solutions for the forced baroclinic equations reconstituted for the case of constant advected flow across an isolated bell-shaped Witch of Agnesi mountain. Tests in a high resolution regional forecast model, with a focus on the impact of the first-order off-centering, are also presented.

4D1.2
Lake Breeze Modelling with MC2
Ying Qi (1), Xin Qin (1), David Sills (1) and Peter Taylor (1) ((1) Department of Earth and Atmospheric Science, York University)

Computations of lake breeze and other summer, lake-affected mesoscale circulations in southern Ontario have been performed with the MC2 model.

Typical runs nest from a 24 hour simulation on a 100 km North America grid, down to 25 km and finally a 12 hour run on a 5km grid over the lake under consideration (Erie or Ontario). Different strategies have been tested for nesting and the choice of vertical levels, and for the selection of options and parameters within several versions of MC2. Results from simulations for selected dates from the SONTOS and ELBOW experimental periods will be compared with observational data, including satellite data for cloud cover, in order to illustrate effects of different modelling choices.

In these simulations different model versions result in significant differences in the predicted near surface wind fields and cloud cover predictions are sensitive to a number of parametrization options. The specification of horizontal diffusion coefficient can also have a significant impact on model predictions, especially in regions with topography.

Model performance in terms of predictions of lake breeze penetration and depth will be discussed.

4D1.3
Comparison and Validation of the RPN-MC2 and UW-NMS Mesoscale Weather Forecast Models for Spring 1997
Henryk Modzelewski (1), Joshua Hacker (1) and Roland Stull (1) ((1) Department of Atmospheric Science and Geography, UBC)

Since March 1997, we have been running both the RPN-MC2 and the Univ.of Wisconsin-NMS realtime to produce daily 48 hour research forecasts from the 00 UTC initializations. These are nested regional forecasts, with the largest domain of 90 km resolution covering most of W. Canada and the N.E. Pacific Ocean, the 30 km nest covering all of BC and coastal waters, and the 10 km nest covering the southern half of BC and the whole BC coast.
Samples of these research forecasts are available on the web at http://spirit.geog.ubc.ca/~model/.

Verification against both coastal stations and the Eta 00 h forecast indicate that both models behave similarly. Model errors generally decrease with finer grid resolution, except for coastal stations near steep topography. The high-resolution land-sea mask creates sharp boundaries between continental and marine air masses, which are difficult to handle by the boundary-layer parameterizations in both models.

4D1.4
Improvements to the Canadian Global Spectral Forecast Model in Support of the Middle Atmosphere Initiative
Harold Ritchie (1), Nils Ek (1) and Christiane Beaudoin (1) ((1) Recherche en prevision numerique)

The current operational version of the Canadian global spectral forecast model uses a conventional sigma vertical coordinate on a regular (unstaggered) grid. Presently the representation of the stratosphere is rather coarse, with the uppermost model sigma levels

being .010, .045, .090, .140, .190. The forecast range for this global system now extends to monthly and seasonal scales, and the global system based on this model is also being used to do stratospheric data assimilation and prediction of ozone within the Middle Atmosphere Initiative.

In support of these activities, modifications have been made to introduce a hybrid vertical coordinate, raise the model top to approximately the stratopause with an associated increase in the number of vertical levels, improve the vorticity and energy spectra, and implement a quasi-monotone semi-Lagrangian advection option.

Here we present results for a series of experiments that have been performed in order to assess the incremental impact of the sequence of steps in preparing the improved model. Various versions have been compared using five day forecasts on test cases that span the year and 3-D variational data assimilation cycles in summer and winter. In all cases the horizontal spectral representation uses a triangular truncation at 199 waves. Our control model corresponds to the operational model with its 21 sigma levels and a three-time-level semi-Lagrangian scheme using a 30-minute time step. A second version has 27 sigma levels with a finer stratospheric resolution and a top at 0.05, the third one uses additionally the hybrid coordinate, and the fourth version takes advantage of a two-time-level formulation with a 60-minute time step. We compare the root-mean-square temperature errors of the forecasts with respect to radiosonde observations. In progressing from one version to then ext, we note an improvement, particularly in the stratosphere, with the total impact from the control to the fourth version being very significant. The impacts of the quasi-monotone semi-Lagrangian scheme and the improvements for the spectra will also be illustrated.

Session 4-D2
Gravity Waves & Mixing

Thursday June 4
15:20 - 17:00
Sullivan Room

4D2.1
Linear Stability of Inertio-gravity Waves
Ka-Hing Yau (1), Gary Klaassen (2) and Len Sonmor (3) ((1) Centre for Research of Earth and Space Science, York University, (2) Earth and Atmospheric Science, York University, (3) Department of Oceanography, Dalhousie University)

We demonstrate the general trend of the dominant instability for a large amplitude monochromatic inertio-gravity wave (IGW) propagating in a stationary Boussinesq fluid under the influence of Coriolis forces. A linear Floquet stability analysis is employed. The advantage over earlier stability studies is that the propagating nature of the basic wave is treated exactly and three-dimensional instabilities are considered. The effects of Coriolis forces on the stability of IGW are assessed by comparing with the corresponding analyses for plane, non-rotating internal gravity waves. We found that Coriolis forces

have a surprisingly large effect on the stability of IGW, including wave periods from about 0.05% to 0.95% of the inertial period, assuming the Coriolis parameter (f) is one hundredth of the buoyancy frequency (N), i.e. f/N=0.01.

Previous studies have implied that a particular mode of instability, namely Kelvin-Helmholtz, should be favoured. However, we find that the nature of the dominant instability changes as the wave period varies while the wave amplitude is fixed. In general the growth rates decrease with increasing wave period. The preferred orientation of the disturbance rolls rotates from parallel to the major-axis of the wave velocity polarization at low wave periods, to oblique orientation, becoming parallel to the minor-axis of the wave velocity polarization for intermediate to high wave periods. For the highest range of wave periods that we have explored, the orientation preference diminishes, resulting in an weakly anisotropic instability.

Besides the growth rate and preferred orientation, the scale, frequency, Floquet modulation and the energy budget of the dominant instability also change with wave period. These fundamental changes in stability properties are due to the fact that, as the wave frequency approaches the local Coriolis frequency, the basic wave buoyancy decreases and the wave velocity field tends to become isotropic. These complicated properties will be explained in our presentation.

4D2.2
Broad-spectrum effects on gravity-wave interactions
Len Sonmor (1) and Gary Klaassen (2) ((1) Oceanography Department, Dalhousie University, (2) Earth and Atmospheric Science, York University)

There is a growing consensus that interactions within the gravity-wave spectrum play a key role in dissipation and mean-flow acceleration (wave drag) in the middle atmosphere. However, much of what is known regarding these interactions derives from highly idealized studies or models that feature restrictive assumptions. Hines' Doppler-spread wave-drag parameterization achieves computational efficiency in middle atmosphere models largely by ignoring the temporal fluctuations of the waves. This constraint has profound implications on wave dissipation. In particular, it ties wave action density uniquely to vertical group speed, which limits focusing to critical levels, and at the same time maximizes dissipation in those locations. Oceanic studies have shown that time dependence relaxes both of these limitations, yielding non-critical focusing and leaky critical levels. These effects have the potential to dramatically change wave drag profiles, mean winds and the temperature distribution in the middle atmosphere. Recent modelling experiences with the Hines scheme in the Canadian MAM suggest that it could benefit from inclusion of these effects. Nevertheless, simple action-conservation arguments have been used in the past to dismiss the applicability of non-critical focusing in the middle atmosphere, in which wave energy propagates preferentially upward. We show that these arguments do not follow from action conservation except in the most idealized models of wave interaction, in which the background is nearly monochromatic. We use a hierarchy of models of increasing complexity to demonstrate that focusing arises under the relaxation of any of a number of constraints required to prevent it. These results imply

that atmospheric researchers must confront the challenge of accounting for temporal focusing and de-focusing by wave interactions in the broad gravity-wave spectrum. As a step in this direction, we have developed a ray-tracing model that attempts to represent typical atmospheric conditions, designed for the realistic investigation of wave interactions in the middle atmosphere. It includes a broad spectrum of gravity waves and a CIRA mean zonal wind, as well as exponential density diminution. The rms fluctuations increase, and the peak vertical wavenumber decreases, with altitude; tail slopes are realistic. Special care is taken to account for WKB considerations. We use this model to investigate the incidence and detailed nature of quasi-critical approaches and focusing of wave energy in the middle atmosphere.

4D2.3
Shear Excitation of Large Amplitude Internal Waves Observed in the Laboratory
B.R. Sutherland (1) and P.F. Linden (2) ((1) University of Alberta, (2) Department of Applied Mathematics and Theoretical Physics, University of Cambridge, England)

Linear theory and the results of nonlinear numerical simulations have shown that strong coupling between radiating internal gravity waves (IGW) and unstable stratified shear flow is anticipated if the stratification is sufficiently weak where the shear is strong and the stratification is sufficiently strong elsewhere. We examine the behavior of IGW under such circumstances in laboratory experiments. A continuous shear flow is established near the surface in a recirculating tank by an Odell-Kovasznay drive in which two sets of intermeshed horizontally rotating disks drive flow with a small amount of vertical mixing. In the test section of the tank the flow passes over a thin barrier generating stationary lee waves. Depending on the speed and local stratification of the flow, spanwise- coherent vortical structures develop from the growth of small scale instabilities in the lee. These structures act to periodically deform the base of the mixing region and, under suitable conditions, IGW are excited. Profiles of the perturbation density and horizontal velocity are measured using a conductivity probe and by tracking vertical dye lines, respectively. In addition, a new “synthetic schlieren’’ system has been developed to determine quantitatively and non-intrusively the streamwise structure and amplitude of the IGW.

We find that if the stratification is strong in the mixing region, short lived small amplitude IGW are generated due to either transience or superharmonic excitation (that is, due to vortex pairing). However, if stratification in the mixing region is weak, large amplitude IGW are generated continuously by coupling directly with coherent structures in the flow. If the stratification in the mixing region is negligible, the effectiveness of the coupling is reduced and IGW of smaller amplitude are excited. The observed behavior leads us to propose that large amplitude IGW are not passively generated but that a feedback between the mixing region and radiating waves enhances IGW excitation.

4D2.4
An airborne case study of evolving Kelvin-Helmholtz waves
Fikrettin Celik (1) ((1) University of Wyoming, Dept. of Atmos. Sci.)

Breaking of Kelvin-Helmholtz (KH) waves is an effective mechanism for generation of clear air turbulence (CAT) and mixing in a stably stratified atmospheric layer. A KH wave train showing all the stages in the evolution of a KH wave was documented by the Wyoming King Air during the Atmospheric Utilities Signatures Predictions Experiment (AUSPEX). The large and micro scale structure of the waves at different stages were analyzed. A conceptual model of secondary instability is proposed for the transition to turbulence.

4D2.5
Mixing in a Coastal Environment
Neil S. Oakey (1) and Blair J. W. Greenan (1) ((1) Fisheries and Oceans Canada, Bedford Institute of Oceanography)

The Coastal Mixing and Optics experiment is an oceanographic program designed to study the mixing of ocean water on the continental shelf, and the effect of the mixing on the transmission of light through the water. A field experiment was carried out in 1996-97 southeast of Montauk Point, Long Island.

As part of this experiment, concurrent measurements of vertical mixing rates have been obtained using an integrated tracer (J. Ledwell) and microstructure profiler (N. Oakey). This is the first time that mixing has been studied with tracers and microstructure on the same length and time scales. In the current paper, measurements obtained from the vertical microstructure profiler, EPSONDE, will be described for two field programs, one in September, 1996 and the second in August, 1997. During each of these two field experiments measurements from temperature gradient microstructure and turbulence shear probes, obtained with EPSONDE, were used to determine vertical diffusivities. These rates of vertical diffusion will be compared to those obtained from the dispersion of a tracer.

Session 4-D3
Air-sea Interaction 2

Thursday June 4
15:20 - 17:00
Alderney Room

4D3.1
Estimation of Ocean Waves using SAR Image Cross-Spectra
Michael Dowd (1), Paris W. Vachon (2), Fred W. Dobson (3) and Richard B. Olsen (4) ((1) Satlantic, Inc., Halifax, Nova Scotia, (2) Canadian Centre for Remote Sensing, Ottawa, ON, (3) Bedford Institute of Oceanography, Dartmouth, NS)

It is well established that synthetic aperture radar (SAR) ocean imagery contains valuable information on the surface wave field. Quantitative studies generally rely on inversion of the nonlinear transform of Hasselmann and Hasselmann (1991), which maps the ocean wave spectrum to the SAR image spectrum. Recently, it has been suggested (Engen and

Johnsen 1995) that image cross-spectra using independent looks of the same ocean scene (separated by a time lag of O(1s)) be used for ocean wave estimation from SAR. Advantages include reduced speckle noise and the resolution of the wave propagation direction. In this work, we outline a potentially useful inversion approach for determining directional wave spectra from SAR image cross-spectra. Coherency and phase based spectral filtering are first used to separate (wave) signal from the (speckle) noise. A variational inversion procedure then estimates the unknown parameters governing the wave spectral shape. This is illustrated withs ome case studies based on Radarsat SAR, and compared against co-located wave buoy data.

4D3.2
Validation of ERS-2 scatterometer winds in Storm Wind Study II
Yuri S. Geshelin (1) and Fred W. Dobson (2) ((1) IMPROC Co., (2) Bedford Institute of Oceanography)

The wind speed data collected on the Hudson 97-069 cruise are analyzed and compared with the ERS-2 satellite scatterometer-derived data. The field data set includes the data obtained from a) buoys of different shapes and sensor heights, and b) onboard anemometers: RM Young and the Gill “Solent” sonic anemometer. The noise level due to instrumentation error is assessed. The effects of atmospheric stability and adjustment of wind speeds to 10-m level are investigated. The time correlation and spectra of wind speeds are compared with those derived from buoys of different shapes. The time series of horizontal gradient of wind speed is assessed and its behaviour is studied at the times of the frontal passages.

4D3.3
On the Relationship Between Ship and Buoy Wind Speeds
Bridget Thomas (1) ((1) Atmospheric Environment Service)

Homogeneous marine winds are important for air-sea flux calculations used to drive atmosphere-ocean models, for climate analyses, for input into numerical weather prediction and ocean wave models, and for wind diagnosis in forecasting. However, the wind fields may be inhomogeneous due to different measuring or observing methods used by ships and buoys. Buoy wind speeds may be reduced in high wave conditions. Results of this study will contribute to improved techniques for adjusting wind speeds to reduce these errors, and to increased understanding of marine wind fields. The data span an 8 year period on Canada’s east coast, and a 16 year period on Canada’s west coast, up to the end of 1995. The ship data are from the Comprehensive Ocean-Atmosphere Data Set (COADS), Release 1a, and the buoy data are from the Environment Canada Operational Data Acquisition System (ODAS) as archived by the Canadian Marine Environmental Data Service, and in COADS Release 1a.

The buoy reports are paired with ship reports that are close in space and time. Standard descriptive statistics and distributions are calculated separately for measured and for estimated ship wind speeds, and for moored buoy wind speeds. Measured wind speeds are adjusted for anemometer height and method of calculating mean wind, and estimated

ship wind speeds are converted using an improved Beaufort equivalent scale. The relationship between the individual paired adjusted wind speeds is determined. I also examine the effect of sea state and atmospheric stability, on the relationship between the paired ship and buoy wind speeds.

4D3.4
Shipboard measurements of air-sea fluxes in the Labrador Sea
Robert J. Anderson (1) and Fred W. Dobson (1) ((1) Fisheries and Oceans Canada)

We describe a set of air-sea flux measurements taken in February-March 1997 in the Labrador Sea during a period of intense surface cooling, leading up to a documented oceanic deep convection event. We make a simple estimate of the overall effect of all surface processes (including precipitation and the melting of pack ice) on the location and intensity of the deep convection. There are indications that the location of the convection is partially controlled by processes locked to the geometry of the Labrador Sea itself.

4D3.5
Wind stress and wave measurements in storm force winds
Fred W. Dobson (1), Robert J. Anderson (1), Peter K. Taylor (2) and Robin Pascal (2) ((1) DFO/BIO/OSD/Ocean Circulation Section, (2) York University)

We describe a set of wind stress and directional wave spectra taken during two storms in the period 20 November - 6 December 1997 at the “Hibernia” site on the Grand Banks of Newfoundland. The measurements were made by groups from the Southampton Oceanographic Centre (SOC) and BIO, as part of the joint EC/SOC/DFO “Storm Winds Study II”. The measurements were made using a variety of platforms: several buoys, the Coast Guard Ship “Hudson”, and Radarsat and ERS-2 satellites. One of the buoys, a “NOMAD” meteorological buoy of the type used operationally by the Weather Service, was equipped with motion package and a fast-response sonic anemometer for “dissipation technique” wind stress measurement. Two further wind stress systems were mounted on a bow mast on “Hudson”. Wave data were available from a Directional Wave Rider buoy, the Nomad buoy, and a shipboard radar.

Initial analysis indicates all the ship and Nomad buoy mounted sensors that survived performed well and give consistent results; in particular, the winds from the sensors on the “NOMAD” buoy agreed closely with the measured winds from the ship. However these calibrated wind measurement systems produced, at the height of the storm, wind speeds significantly lower than those estimated by the bridge officers for the WMO reports. In contrast, a smaller buoy (the BIO “Minimet”) underestimated winds at the height of the storm.

Abstracts for Posters

Résumés des affiches

P1

Variability in Phytoplankton Biomass on the Scotian Shelf as Viewed from Space

Glen Harrison (1), Trevor Platt (1), John Loder (1) and Brian Petrie (1) ((1) Fisheries & Oceans Canada)

746 high-resolution (2 km) images of the Gulf of Maine/Scotian Shelf region from the Coastal Zone Color Scanner (CZCS) mission that flew from 1978-1986 have been processed as part of the retrospective data analysis activity in the Atlantic component of GLOBEC Canada. Interpretation of these images with regard to regional, seasonal and interannual variability in phytoplankton biomass fields will be presented and related to regional hydrography and nutrient concentrations. The derivation of primary production rates from ocean colour data will be discussed.

P2

Remote Sensing of Ocean Color and Sea Surface Temperature in the Labrador Sea

Glenn F. Cota, Trevor Platt, Shubha Sathyendranath and Glen Harrison ((1) Center for Coastal Physical Oceanography, Old Dominion University, Biological Science, Bedford Institute of Oceanography, Dartmouth, NS, Bedford Institute of Oceanography)

Bio-optical validation cruises were conducted in fall 1996 and spring 1997 coinciding with the beginning and end of Ocean Color and Temperature Sensor (OCTS) observations. Phytoplankton chlorophyll biomass levels were very low during the fall except in Greenland coastal waters. In spring, biomass encompassed most of the natural range in a highly complex mosaic. Compared with observations on and models of lower latitude systems, colored dissolved organic material is more abundant and chlorophyll-specific diffuse attenuation is lower particularly in the blue.

Most 2- and 3-band bio-optical algorithms provide poor chlorophyll retrievals at high latitude, usually underestimating biomass unless tuned with high latitude observations. The current SeaWiFS algorithm underestimates low to moderate biomass (<1 to 10 mg chlorophyll/m3), but overestimates high biomass (> 10 mg chlorophyll/m3). Kishino's 3-band OCTS algorithm provides reliable retrievals over most of the natural range. Observations are compared to an analytic ocean color model.

Images from AVHRR (Advanced Very High Resolution Radiometer) and OCTS reveal that the region is extremely complex with numerous mesoscale features including eddies and fronts. There does not appear to be any simple relationship between chlorophyll biomass and temperatures. High biomass retrievals occurred in some cold coastal waters and some warm core eddies, but not others.

P3
Near-Surface Measurements of Ocean Turbulence with a Tethered Free-Fall Glider
Blair J. W. Greenan, Neil S. Oakey and Fred W. Dobson ((1) Bedford Institute of Oceanography, Fisheries and Oceans Canada)

Measurements of ocean microstructure and directional wave spectra were complemented with wind stress and sensible heat flux estimates in the atmospheric boundary layer during a field experiment carried out on the Scotian Shelf in June 1996. A tethered free-fall microstructure glider was designed to sample the horizontal and vertical variability of mixing processes along a gradually descending flight path in the ocean mixed layer. The payload of the glider consisted primarily of the EPSONDE vertical microstructure profiler. The vehicle attained a 4:1 glide ratio.
The study was designed to determine the relationship of intermittency of mixing processes in the ocean surface layer to atmospheric forcing. Results indicate that the glider provides a low-noise platform for near-surface dissipation measurements.

P4
Computer Atlas of the North-West Atlantic
Igor Yashayaev and Allyn Clarke ((1) Bedford Institute of Oceanography, Dartmouth, NS, Canada)

New powerful personal computers (PC) offer new opportunities to analyze hydrographic data. Such analyses include storing and accessing large volumes of both historical and recent observations; data quality control; creating subsets of selected data types in any specified spatial and temporal domain (including user-defined section and surface); performing various statistic and oceanographic analyses; and girdding and visualizing data and results. All these features were embedded in a system, known as computer atlas of the north-west Atlantic, used in BIO for data analysis and preparation of initialization fields for hydrodynamic models.

The Atlas operates with different types of oceanographic data: conductivity-temperature-depth (CTD), water bottle, expendable bathythermograph (XBT), current meter, floats, etc. The major datasets presently loaded into the Atlas were created from historic and WOCE BIO archives, Russian data collected in the "SECTIONS" program, data from NOAA National Oceanographic Data Center (USA), Marine Environmental Data Service (Canada) and Obninsk World Data Center (Russia).

The Atlas locates data from a simple query, produces plots (field, section, etc.), and runs different statistical and oceanographic applications. A user has the freedom to choose among various procedures for objective analysis, interpolation, averaging, smoothing and subsampling. Datasets, regions and procedures can be easily added, replaced or altered. Scale-independence is one of its features, allowing the user to work on different spatial and temporal scales, and adjust the working environment for his own needs and requirements. There is no need in finding a compromise for processing and viewing data in deep and shallow areas: the system will build the grid in consistency with vertical, horizontal scales and data distribution.

A comparison of unevenly distributed in space and time observations is a task usually requiring a fair amount of effort. The computer atlas solves this problem, by creating time series in certain locations, areas, sections and within defined time intervals, and performing decomposition of the series onto the seasonal component, interannual and mesoscale variability. Fractions of the seasonal cycle, short and long term components in the total variance present a good indicator of dominant processes in the system.

As an example, we examine the seasonal cycle in the Newfoundland Basin. Its magnitude is greatest at the surface in the areas inshore from the Subpolar Front. The seasonal cycle penetrates much deeper in the waters to the south of the Subpolar Front. Propagation of the seasonal cycle is visualized through displaying its phases on a section or plane.

Removing the seasonal cycle from historic data allows one to reconstruct temperature and salinity anomaly time series. These series reveal two major patterns: one is typical for the Subpolar Gyre and characterizing by quasi-decadal oscillations, another patter seen in the warm sector of the Newfoundland Basin indicates a steady warming over, at least, two decades. This ability to estimate the seasonal cycle helped us with the detection of climatic variability from the hydrographic data (WOCE & history) collected in different seasons.

P5
Remote Video Acquisition System-A Canadian Approach
David Wartman and Ben Hunter ((1) Environment Canada)

There is increased importance placed on the role automated weather observation stations (AWOS) play as an integral part of meteorological observing networks. However, in some cases it is desirable and even necessary to augment and validate the remote information on a routine basis with other tools. The Remote Video Acquisition System (RVAS) is a modular system developed in Canada in the early 1990's and used Atlantic Canadian Weather Centres to provide up-to-date information to operational weather forecasters. It allows forecasters to view full color video images from up to four cameras at a remote meteorological observation site and ascertain such parameters as visibility, sky condition and occurrence of precipitation. The system is fully automated, obtaining images from 1 or all remote stations and copying them to the forecaster's workstation. It has also been adapted for use in many locations in western Canada and at a number of locations in the northwestern United States.

The RVAS is based upon commercially available technology and the application software developed by Environment Canada, utilizing CCD color cameras installed in outdoors-environmental housing and connected to a PC. This capture PC continuously acquires still video images in compressed format, stored locally, which are available via modem by a user equipped with another PC at a different location. This user has full control of the remote machine through a commercial telecommunication package and can maintain the remote system or even boot it remotely.

The attributes and flexibility of the application software are explored along with details regarding the hardware requirements and the cost, in terms of capital and maintenance. The use and value of the RVAS in an operational weather forecast setting are discussed.

P6
Filling the Pacific Data Void with Tethered Guided Balloons (TGBs)
Roland B. Stull and Ron McTaggart-Cowan ((1) Department of Geography, UBC)

Numerical weather forecasting in the Pacific Northwest is severely limited by the dearth of upstream data. To address this problem, we are starting a 5-year effort to design and deploy tethered guided balloons (TGBs) to make hourly synoptic weather observations over the NE Pacific Ocean.

These will be pressurized, carbon-composite skinned, 6 m long, streamlined balloons with an active guidance system attached to the elevator to maintain a constant altitude of roughly 2 km (just above the top of the boundary layer). The lightweight, plastic tether will be anchored to the sea floor. There will be no buoy or float at the sea surface, to avoid the extremely harsh environment there. Hourly observations will be relayed via neighboring TGBs to shore, where they will be quality checked and assimilated into an analysis field. During high winds, an onboard program will reconfigure the flight parameters to a lower-altitude, lower-drag configuration to enhance survivability. Nonetheless, we anticipate that these will be quasi-expendable, with design lifetimes of about a year.

P7
Weather Prophecies of E. Stone Wiggins
John D. Reid ((1) Canadian Meteorological and Oceanographic Society)

In the 1880s an official of the Department of Finance in Ottawa, Ezekiel Stone Wiggins, gained an international reputation for his predictions of storms, floods and earthquakes, and some unusual beliefs about the natural environment on which they were based. The paper will verify his prophesies, focussing on his most well known, a six-month prediction for an East Coast storm on March 11th, 1883 for which record high tides were recorded at Halifax. It will attempt to explain his astronomical methods, and discuss contemporary criticism of them. Finally it will show, through some recently discovered correspondence, how his opinions evolved from being a public critic to covert supporter of Canada's fledging weather service.

P8
Climate-Driven Variability of Primary Productivity in the Northwest Passage on Interannual and Seasonal Scales
Glenn F. Cota and W. Glen Harrison ((1) Center for Coastal Physical Oceanography, Old Dominion University, Bedford Institute of Oceanography)

Primary productivity was measured during August 1994-1996 near the center of the Northwest Passage off Resolute Bay, NWT, Canada. This region is typically completely

ice-covered with 1-2 m of landfast first-year sea ice for 9-10 months per year and attains a seasonal minimum ice cover of 10% in August. However, there are large interannual variations of ice cover, extent, and thickness. Some years such as 1986 and 1996 much of Barrow Strait remains ice-free all winter. Over seasonal scales there are also large differences in when the ice breaks out or when freeze-up occurs, and the amount of residual pack ice cover moving around the area or landfast ice in embayments.

This region is highly productive with mean values ranging from 1.9 to 6.0 gC/m2/ d for the three years. Chlorophyll stocks averaged 111 to 363 mgChl/m2. The phase of the phytoplankton bloom appeared to be different in each year. The blooms were increasing in 1994, declining in 1995 and near its peak in 1996. However, this system is highly advective and variability is not easily partitioned into biological vs physical components.

P9
The North Atlantic Ocean
Robert J. Anderson, Fred W. Dobson and Albert J. Hartling ((1) Fisheries & Oceans Canada)

We display the conditions encountered during two field experiments, one in the Labrador Sea in Feb-March 1997 and one on the Grand Banks at the Hibernia site in Nov-Dec 1997. We will present a collection of annotated photographs and a 20-min video.

P10
Global Ocean Ecosystem Dynamics (GLOBEC) Canada: Northewest Altantic and Northeast Pacific Studies.
Not available

P11
Modelling the vertical transport of trace gases in reservoir
Nathalie Barrette, René Laprise and Marc Lucotte ((1) Department of Earth Sciences, University of Québec at Montreal, Montreal, Quebec)

Since 1993, hydroelectric reservoirs have been examined closely by environmentalists to study their contribution on global greenhouse gases emissions. Our research is integrated into a large monitoring project on production and emission of the greenhouse gases (CO2 and CH4) by hydroelectric reservoirs of the boreal region. We propose to study the annual variation of the CO2 and CH4 fluxes emited at the water-air interface of the reservoir with a diffusive-convective lake model. This lake model will be coupled with atmospheric Local Climate Model (MLC) to study how certain meteorological conditions (ex. heavy winds) influence the vertical transport of trace gases in the reservoir.

We will present preliminary results concerning the annual variation of CO2 and CH4 fluxes emited at the surface of the reservoir and we will discuss the contribution of certain meteorological events on the total annual emission of CO2 and CH4. The reservoir under study will be Laforge 1 (James Bay) which was flooded in 1993.

P12
Characteristics of Winter Leads and Polynyas over the Arctic Basin from 85.5 GHz DMSP SSM/I and NOAA/AVHRR Imagery
T.A Agnew, L. Le and M. Shokr ((1) Environment Canada)
Animation of the 10-year record of 85.5 GHz SSM/I brightness temperature imagery, from 1987 to the present, is used to describe some general characteristics of lead formation over the Arctic Basin and to identify extreme lead formation events. Two particular events are investigated in detail using estimates of ice motion from SSM/I imagery, NOAA AVHRR brightness temperature information and nearby weather station observations.

The first event occurred in early November, 1988 when the sea ice pack was forced up against the Canadian Archipelago and fractured. Surface wind forcing then opened up what is probably the largest lead formed over the SSM/I 10-year record. The second event occurred when the western half of the Arctic ice pack shifted away from the Canadian Archipelago towards the Siberian side of the Arctic Basin. This produced one of the largest wind driven coastal polynyas which formed off Banks Island and Prince Patrick Island.

A simple wind-driven coastal polynya model is applied and ice production rates and the thickness of newly formed ice, as the polynya re-freezes, are estimated.
Heat lost to the atmosphere during this 10-day event was estimaged to be 22.7x10^11 MJoules and total volume of sea ice produced was 7.4 cubic kilometres.
Pour décrire certaines caractéristiques générales de formation de chenaux dans le bassin Arctique et déterminer les phénomènes extrêmes de formation de chenaux, on a animé le relevé sur dix ans, de 1987 à aujourd'hui, des images de températures de luminance SSM/I à 85,5 GHz. On a étudié en détail deux phénomènes particuliers, en se fondant sur l'estimation du mouvement des glaces d'après les images SSM/I, les données de températures de luminance AVHRR de la NOAA et les observations des stations météorologiques voisines. Le premier phénomène est survenu au début de novembre 1988, quand la banquise de mer fut plaquée de force contre l'archipel canadien et s'est fracturée. Le foréage opéré par les vents de surface a ensuite engendré ce qui est sans doute le plus grand chenal enregistré dans le relevé sur dix ans du SSM/I. Le second phénomène est survenu quand la moitié ouest de la banquise de l'Arctique s'est éloignée en dérivant de l'archipel canadien et en s'approchant du côté sibérien du bassin Arctique. Il en est résulté une des plus grandes polynies côtières entraînées par les vents qui se soient formées au large de l'Île Banks et de l'Île Prince Patrick. On a utilisé un modèle simple de polynie côtière entraînée par les vents et estimé les taux de production des glaces et l'épaisseur de la glace nouvellement formée, comme les regels de polynies. On a estimé la perte de chaleur cédée à l'atmosphère, pendant ce phénomène de 10 jours, à 22,7 x 1011 Mjoules et le volume total de la glace de mer produite à 7,4 km à 3.

P13
An Interactive Aviation Weather Database
R. Verret, M.-F. Turcotte, V. Souvanlasy and M. Baltazar ((1) Atmospheric, Climate and Water Systems Branch, Canadian Meteorological Centre, Dorval, Quebec)

Despite all technological and scientific progresses made in analyzing and forecasting atmospheric conditions, the content and format of aviation weather information have not significantly evolved from the traditional alphanumeric bulletins that are still in use nowadays. However, computerization have brought forth new perspectives for producing and disseminating aviation weather information. The capacity of numerical atmospheric models to ingest an ever-increasing amount of data from various sources and to produce high-quality gridded forecasts in relatively short periods of time has prompted initiatives on the automated production of a new generation of aviation weather products. Other related initiatives include the development of user-friendly interactive systems to generate those products in graphic formats allowing a quick and intuitive understanding of actual and forecast aviation weather conditions.

The aviation weather database described here is the core component of a future aviation weather display system to be used as a briefing-aid tool. Development work has so far resulted in the creation of a database of gridded aviation-impact variables that can be interactively queried through a user-friendly JAVA based application. The driving model for the database is the operational Canadian Regional model. Variables are computed on the high resolution portion of the model's grid which covers all of Canada, adjacent waters as well as a significant portion of United States. Space and time characteristics of variables are similar to, or derived from, those of the model's actual operational outputs : 35 km horizontal resolution, 41 flight levels (from mean sea level up to 40 000 feet) interpolated from the 28 sigma levels of the model, and a 3-hour time resolution from zero to 48 hours. Most variables, including icing and turbulence, are calculated using algorithms that are adapted versions of pre-existing operational ones. The remaining variables were already available as standard outputs from the model. The database is updated twice per day (00 and 12 UTC) in real time. In its current state the aviation weather database includes : temperatures, winds, icing, turbulence, cloud fraction, relative humidity, vertical velocity at 41 flight levels, every 3-hours from zero to 48 hours. It also includes : tropopause pressure and temperature, freezing level, total cloud cover, instantaneous precipitation rate at the surface and station pressure. The current icing algorithm used in based on supercooled liquid water content forecast by the driving model. The turbulence algorithm is based on the deformation vertical shear index. Real-time observation data will also be incorporated in the database. Utility programs have so far been developed for the treatment of METARs and TAFs. Future programs will be developed for other alphanumeric data as well as for satellite imagery, radar data, and others.

The AWeD database is made accessible on network through a users interface. This application allows the users to enter flight parameters, such as departure and arrival points, check points along the planned route, estimated elapse time of the flight and flight level. Series of meteorological products, all tailored to each particular flight, in plan view and vertical cross-section along the route can then be requested. It is the first known fully interactive system that can generate tailored meteorological aviation products from a numerical model gridded database. A verification system is also under development as

part of the database, in order to assess the reliability and performance of the different aviation impact variable algorithms.

P14
BiNet Xplorer: A software to explore radar bistatic data.
Christian Page (1), Isztar Zawadzki (1) and Alain Protat (1) ((1) Department of Meteorology, McGill University, Montreal, QC)

An X-Window software was developed at McGill University to explore McGill Bistatic Network Data. This software can be used to explore raw bistatic radar data, generate and explore a 3D wind field as well as many derived variables from this wind field. Also, pressure and tempaerature perturbations can be calculated from the bistatic data and displayed with the software.

Furthermore, BiNet Xplorer can show cross-sections, animations, and display in a 4-panel or 1-panel layout, among other functions.

This software is a must to explore the structure of mesoscale processes, thunderstorms and mesocyclone structures.

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Theme/Thème

Environmental Prediction

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