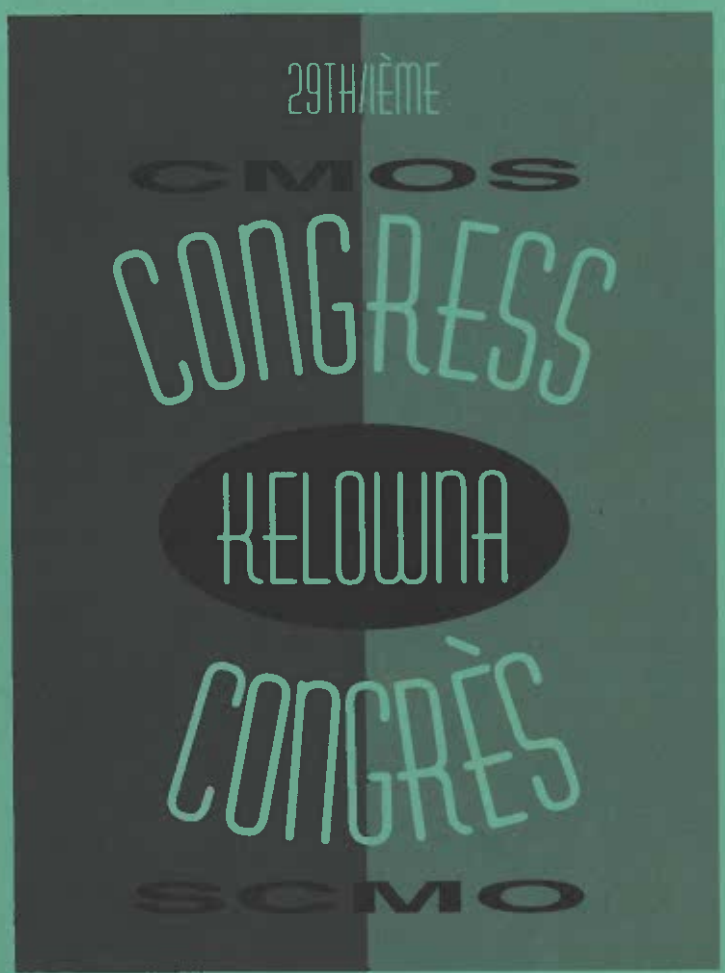
N. J. Campbell

Program and Abstracts
Programme et Résumés

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

Environmental Services: Clients, Innovation and Commercialization

Les Services Environnementaux: Clients, Innovation et Commercialisation.



MAY 29 TO JUNE 2 1995 • 29 MAI AU 2 JUIN 1995

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

La Société Canadienne de météorologie et d'océanographie a pour but de stimuler l'intérêt pour l'avancement des sciences de la météorologie et de l'océanographie au Canada.

Panel of Energy, Research and Development:
Coastal Current Models for Continental Shelves

Co-Editors: W. Hsieh
A. Wallace

Editorial Assistants: J. Shore
D. Laplante

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Welcome to Kelowna

Welcome to the 29th Annual Congress of the Canadian Meteorological and Oceanographic Society. The following is some information about the city and the Okanagan Valley region of British Columbia. A complete information package will be provided to all Congress attendees upon arrival and registration.

About Our City
Kelowna is located in the Okanagan Valley, in the interior of British Columbia. The climate is semi-arid, ideal for growing of many varieties of fruit. The Okanagan is best known for its apples, pears, peaches, apricots and grapes. At the time of the Congress, none of this fruit will yet be ripe.

Arrival into Kelowna
The Kelowna Airport is located 15 kilometres north of downtown. Taxi (approximately $20) or shuttle bus (approximately $8) transportation is readily available. The Okanagan University College has two campuses in Kelowna, the North Campus is the site of the Congress. The North Campus is only 2 km from the airport.

Accommodation
Accommodation has been reserved, for the CMOS Congress, in two locations, the North Campus residences and the Coast Capri Hotel. There are also many other available accommodations in Kelowna. Information was placed in the most recent CMOS Bulletin. Further details are available from the Local Arrangements Committee.

Local Transportation
Although public transportation is available between the North Campus and Downtown Kelowna, it is strongly recommended that attendees staying off the North Campus rent an automobile. Free parking is available at the North Campus. The Local Arrangements Committee will be supplying limited local transportation as well as facilitating carpool arrangements.

Meals
Cafeteria services will be available during the Congress for breakfast and lunch. We anticipate that a sufficient number of attendees will rent automobiles in order to provide transportation into town for supper. In addition, the Local Arrangements Committee will have access to a passenger van for the week of the Congress.

Bienvenue à Kelowna

Bienvenue au 29ième Congrès Annuel de la Société Canadiènne de Météorologie et d'Océanographie. L'information qui suit se rapporte à la ville de Kelowna ainsi qu'à la région de la vallée de l'Okanagan en Colombie Britannique. De l'information plus complète sera présentée à tous les participants au Congrès dès leur arrivée et enregistrement.

A propos de notre ville
Kelowna est située dans la vallée de l'Okanagan en Colombie Britannique. Le climat est semi-aride et idéal pour la culture d'une variété de fruits. L'Okanagan est reconnue principalement pour ses pommes, poires, pêches, abricots et raisins. Cependant, au moment du Congrès, aucun de ces fruits ne sera mûr.

Arrivee à kelowna
L'aéroport de Kelowna est situé à 15 kilometres au nord du centre-ville. Taxis (approximativement $20) et navettes (approximativement $8) sont disponibles. Le Collège Universitaire de l'Okanagan possède deux campus à Kelowna, le Campus Nord étant le site du Congrès. Le Campus Nord n'est qu' à deux kilomètres de l'aéroport.

Logement
De l'espace de logement fut réservé pour le Congrès CMOS à deux endroits; aux résidences du Campus Nord et à l'Hotel Coast Capri. Plusieurs autres options de logement sont aussi disponibles à Kelowna. De l'information détaillée a été placée dans le plus récent bulletin du CMOS. De plus amples renseignements sont également disponibles auprès du Comité du Logement Local.

Transport local
Même si il exite un système de transport en commun entre le Campus Nord et le centre-ville de Kelowna, il est fortement recommendé aux participants du Congrès demeurant en dehors du Campus Nord de louer une voiture. Du stationnement gratuit sera disponible au Campus Nord. Le comité Local du Logement procurera également un service limité de transport local et facilitera le co-voiturage.

Repas
La cafétéria sera accèssible aux participants pour le déjeuner et le diner et ce pour la durée du Congrès. Nous esperons qu'un nombre suffisants de participants loueront une automobile de sorte à pouvoir se rendre au centre-ville pour le souper. De plus, le Comité du Logement Local aura accès à un mini-bus pendant la semaine du Congrès.

Useful information for participants

Scientific Program

Papers are described by their code number, e.g. 3aPL2, 4cPO9, etc. Examining the code from left to right:

The first digit gives the day of the presentation (e.g. 2 = Tues., 3 = Wed., 4 = Thurs., 5 = Fri.).
The second digit is a small Roman letter indicating the time period of the day (a = 8:45-10:15, b = 10:40-12:20, c = 13:10-15:10, d = 15:40-17:40, e = evening).
The next 2 digits in Capital Roman letters indicate the session, e.g. PL = Plenary, PO = Poster, etc. (see the List of Sessions).
The final digit indicates the sequence of your paper in that session (e.g. 2 means the second paper in the session).

For example, a code number of 3aPL2 means that this paper will be given on Wednesday, in Period a (from 8:45-10:15), in the Plenary Session, as the 2nd paper to be presented.

In the abstracts, the name of the speaker is underlined, and the e-mail address for the speaker is provided in <...> for future correspondence. At the end of this book, a Name Index is provided, where the papers associated with each person is listed. If the person is also the speaker, the paper is underlined.

Registration Desk
The registration desk, located in the Student Centre, will be open throughout the Congress beginning at 5:00 PM on Monday (29 May) and 7:00 AM on Tuesday (30 May).

Social Program

1) ICEBREAKER: Monday, 29 May @ 18:00 @ OUC CLUB (Student Centre)

2) WINE & CHEESE: Tuesday, 30 May @ 17:45 @ Multi-purpose Room

3) PATTERSON LUNCHEON: Wed., 31 May @ 12:00 @ OUC CLUB

4) BANQUET: Thurs., 1 June @ 19:00 @ Capri Hotel

Companions Program
Details will be available at the Congress.

Information utile aux participants

Programme scientifique

Les articles sont décrits par leurs numéros de code, e.g. 3aPL2, 4cPO9, etc. Les numéros de code se lisent de gauche à droite comme suit:
Le premier caractère donne la date de présentation (e.g. 2 = Mardi, 3 = Mercredi, 4 = Jeudi et 5 = Vendredi).
Le second caractère est une minuscule en caractère Romain indiquant la période du jour (a = 8:45-10:15, b = 10:40-12:20, c = 13:10-15:10, d = 15:40-17:40 et e = soirée).
Les deux caractères suivants sont des caractères Romains majuscules indiquant la session, e.g. PL = Pléniaire, PO = Affiche, etc. (Prière de se réfférer à la section Liste des Sessions).
Le dernier caractère indique l'ordre des articles à l'intérieur de la session (e.g. 2 indique que l'article est le deuxième de la session).

Par exemple, le numéro de code 3aPL2 indique que l'article auquel il est attaché sera présenté le Mercredi durant la période "a" (de 8:45-10:15), pendant la session Pléniaire, et sera le deuxième article présenté.

A l'intérieur du résumé, le nom du présentateur est souligné. Son adresse électronique se trouve entre <...> afin de faciliter toute correspondance future. A la fin de ce livre on retrouve un Index des Noms contenant une liste des articles associés à chaque participant. Si une personne présente un article, le titre de l'article sera souligné.

Bureau d'enregistrement
Le bureau d'enregistrement, situé au Centre Etudiant, sera ouvert pendant la durée du congrès à partir de 5:00 PM le lundi (29 Mai) et à partir de 7:00 AM le mardi (30 Mai).

Programme social

1) Cocktail de bienvenue : Lundi, 29 Mai @ 18:00 @ OUC Club (Centre Etudiant)

2) Vin & Fromage : Mardi, 30 Mai @ 17:45 @ Multi-purpose Room

3) Diner en l'honneur de Patterson : Mercredi, 31 Mai @ 12:00 @ OUC Club

4) Banquet : Jeudi, 1 Juin @ 19:00 @ Capri Hotel

Programme d'accompagnement
Les détails seront disponibles lors du congrès.

Committee Meetings
A complete list and locations will be available at the Congress. Committee Chairs are encouraged to make contact with the Local Arrangements Committee Facilities Coordinator, as soon as possible. Contact Brian Bowkett at 604-491-1507 or e-mail "bowkettb@ylwkstn2.kelowna.bc.doe.ca".

Réunion des Comités
Une liste complète des différents endroits où s'effectueront les réunions sera disponible au congrès. Les présidents de Comités sont encouragés à contacter le coordonateur du Comité Organisateur Local aussitôt que possible. Prière de contacter Brian Bowkett au 604-491-1507 ou par poste électronique à "bowkettb@ylwkstn2.kelowna.bc.doe.ca".

Local Arrangements Committee / Comité Organisateur Local

Al Wallace Chair / Président
Brian Bowkett
Kent Johnson
John Mullock
Peter Schwarzhoff
Brad Snyder

Scientific Program Committee / Comité du Programme Scientifique

Chair / Président
William Hsieh, Dept. of Oceanography, Univ. of British Columbia

Members / Membres
Phil Austin, Dept. of Geography, Univ. of British Columbia
Howard Freeland, Dept. of Fisheries and Oceans
Mert Horita, Environment Canada
Kirk Johnstone, Environment Canada
Paul LeBlond, Dept. of Oceanography, Univ. of British Columbia
Ian McKendry, Dept. of Geography, Univ. of British Columbia
Tom Pedersen, Dept. of Oceanography, Univ. of British Columbia
Kelsey Spring, Environment Canada
Al Wallace, Environment Canada

Many other colleagues helped us in the organization of the scientific program, among them: Ralph Adams, Mike Foreman, John Fyfe, Barry Goodison, Madhav Khandekar, Norman McFarlane and Sara Pryor.

On the technical side, Internet magic was provided by Denis Laplante, abstracts sorting and printing in Latex was done by Jennifer Shore, and displaying CMOS congress information on World Wide Web and gopher systems, by Mark Allen.

CMOS 1996 Annual Congress in Toronto

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Invited Speakers and Panelists

David Battisti, Dept. of Atmospheric Sciences, Univ. of Washington

James Bruce, Canadian Climate Program Board

Ian Campbell, Canadian Forest Service

Gregory Carmichael, Center for Global & Regional Environmental Research and the Department of Chemical & Biochemical Engineering, University of Iowa

Nancy Cutler, Environment Canada

Gail Gabel, G S Gabel Corporation

W. John Gould, WOCE International Project Office

Jochem Marotzke, Dept. of Earth, Atmospheric, and Planetary Sciences, MIT

David Schindler, Department of Biological Sciences, University of Alberta

Gary Wells, Environment Canada

Ron Woodward, B.C. Science Council

List of sessions / Listes des sessions

AD Atmospheric Dynamics = Dynamique de l'atmosphère
AM Atmospheric Modelling = Modélisation de l'atmosphère
AQ Air Quality = Qualité de l'air
AR Sea Ice & Arctic Studies = Glaces de mer et Études de l'Arctique
AW Atmospheric Waves = Ondes atmosphériques
BM Boundary Layer Meteorology = Météorologie de la couche limite
BO BOREAS
CC Client & Commercial Services = Services aux clients et commerciaux
CI Coastal Ocean & Inland Waters = Océan côtier et eaux intérieures
CL Climate & Paleoclimate = Climat et paléoclimat
CO Chemical Oceanography & Limnology = Océanographie chimique et limnologie
CP Cloud & Precipitation Physics = Physique des nuages et des précipitations
CS CSAM/ Agricultural & Forest Meteorology = Météorologie agricole et forestière
DA Data Assimilation = Assimilation des données
FB Fisheries & Biological Oceanography = Océanographie biologique et des pêches
FD Geophysical Fluid Dynamics = Dynamique géophysique des fluides
IV Interannual Variability = Variabilité interannuelle
LR Long Range Forecasting = Prévisions à long Terme
MA Middle Atmosphere = Atmosphère moyenne
OC Ocean Circulation = Circulation océanique
PB Public Lecture = Conférence publique
PD Congress Theme Panel Discussion = Discussion Thème du Congrès
PE PERD = GRDE
PL Plenary Session = Assemblée Plénière
PO Poster = Affiche
WF Weather Forecasting = Prévisions météorologique
WO WOCE

Schedule of presentations

Tuesday a.m.					
	Plenary Session (Multi-purpose Room)				
8:30-8:45	Opening Remarks				
8:45-9:10	2aPL1: Commercialization of Weather Services -- Innovation, Aggravation or Speculation (**Wells,** G) ***invited***				
9:10-9:55	2aPL2: Modeling Air Quality : A View from the Trenches (**Carmichael**, Gregory R.) ***invited***				
9:55-10:15	Empress Software presentation: A Heterogeneous Distributed Database for Meteorological Applications (Geerts, Anita)				
	Health Break				
	2bCC: Client & commercial Services (Arts 108) [Chair: Spring]	2bCI Coastal Oc. & Inland Waters (Multi-purpose Rm) [Chair: Freeland]	2bCP Cloud & Precipitation Physics (Arts 116) [Chair: Austin]	2bCS CSAM (Auditorium) [Chair: Adams]	2bDA Data Assimilation (Arts 118) [Chair: Hsieh]
10:40-11:00	2bCC1:The City of Edmonton's Watering Index (Paruk, B.J.)	2bCI1:Surface thermal structure in Hecate Strait (Jardine, I.; LeBlond, P.H.)	2bCP1:Effects of mesoscale convergence on convective precipitation (Xin, Lingyan; Reuter, G. W.)	2bCS1:Studies of Canopy Atmosphere Interactions in an Electrochemical Water Tunnel. (Smyth, C.; Leclerc, M.Y.; Tremblay, C.; Schuepp)	2bDA1:Construction of a fully reversible global linear balance equation using SVD methods with application... (Daley, R.)
11:00-11:20	2bCC2:Regulation and the Economic Benefit of Aviation Terminal Forecasts (Doyle, C.J.)	2bCI2:Internal Tides in Dixon Entrance (Carrasco, A.C.; Leblond, P.; Crawford, W.; Marsden, R.F.)	2bCP2:Relative contributions of sensible heat, latent heat and pollution emitted from an industrial complex ...(Guan, Shucai; Reuter, Gerhard W.)	2bCS2:Estimating Regional Surface Bowen Ratios from Radiosonde Soundings in the Atmospheric Surface Layer (Barr, Alan G.; Strong, Geoff)	2bDA2:The system meteodata assimilation for Siberian region (Rivin, G.S.)
11:20-11:40	2bCC3:Coastal and Oceans Monitoring Capabilities of RADARSAT (Staples, Gordon C.; Nazarenko, Dennis)	2bCI3:A Numerical Modeling Study of the Circulations along the Westcoast of Vancouver Island (Pal, B. K.; Holloway, G.)	2bCP3:A numerical study of frontal inversion and precipitation (Szeto, K.K.; Stewart, R.E.)	2bCS3:Growing season water deficits in Ontario (Brown, D.M.; de Jong, R.; Bootsma, A.)	2bDA3:Determining empirical parameters of simple equatorial coupled atmosphere-ocean models by adjoint method (Lu, J.; Hsieh)

11:40-12:00	2bCC4:Modernization and Commercialization Efforts at the Northern Alberta Environmental Services Centre (Ricketts, S.C.)	2bCI4:Modeling upwelling over Juan de Fuca Canyon (Chen, X.; Allen, S.E.)	2bCP4:Relationships between cloud type and amount, precipitation and surface temperature (Isaac, G.A.; Stuart, R.A.)	2bCS4:Measurement and Modelling of Micro-Scale Advection Between Straw Mulch and Bare Areas (Novak, M.D.; Chen;....)	2bDA4:Data assimilation algorithm of the meteor. observations based on the simplified variant of Kalman filter (Klimova E.G.)
12:00-12:20		2bCI5:Satellite AVHRR observations of a summer upwelling event off Vancouver Island (Staples, Gordon C.; Hsieh, W W.)			2bDA5:An analysis of sea surface temperature for numerical weather prediction (Brasnett, B. A.)
Tuesday p.m.					
:	2cAD Atmos. Dynamics (Arts 118) [Chair: Fyfe]	2cAQ Air Quality (Arts 108) [Chair: McKendry]	2cCP Cloud & Precipitation Physics (Arts 116) [Chair: Austin]	2cCS CSAM (Auditorium) [Chair: Adams]	2cOC Ocean Circulation (Multi-purpose Rm) [Chair: Ruddick]
13:10-13:30	2cAD1:The atmospheric response to the average transient-eddy forcing during PNA anomalies (Sheng, J.; Klasa, M.; Derome, J.)	2cAQ1:Wind Observations over Complex Terrain (Lauzon, L.; Rawlings, M.; Petersen, J.)	2cCP1:Condensational growth of an ensemble of cloud droplets in a turbulent velocity field. (Vaillancourt, P.A.; Yau, M.K.)	2cCS1:Wind Tunnel Measurements of Turbulent Wind Regimes Associated with Forest ...(Orchansky, Alberto L.; Novak, ; Ketler,)	2cOC1:Sensitivity of the circulation and large scale water mass properties in a global ocean GCM to stability ... (Reason, C.J.C.)
13:30-13:50	2cAD2:The Mixing of Mass and Momentum by Kelvin-Helmholtz Billows (Scinocca, J.F.)	2cAQ2:Atmospheric Concentrations of PAHs, PCDDs and PCDFs in Suburban Kamloops, British Columbia (Reid, P.D.)	2cCP2:The impact of clouds on absorption of solar radiation by the atmosphere (Li, Zhanqing; Barker, Howard W.; Moreau, L.)	2cCS2:Measurement of Sensible Heat Flux Using the Nonsymmetric Structure of Turbulent Air Temperature ...(Chen, Wenjun; Novak,)	2cOC2:Passive tracer uptake by an ocean general circulation model during climate...(Gough, W. A.; Allakhverdova, T.)
13:50-14:10	2cAD3:Major Teleconnection Patterns and their Synoptic-Scale Eddy Forcing (Sheng, J.)	2cAQ3:The Effect of Large Regional Forest Fires on Particulate Air Quality in the Southern Interior of British Col. (Reid, P.D.; Josefowich)	2cCP3:Optical depth and effective radius variability in marine stratocumulus clouds (Szczodrak, G.; Austin, P.)	2cCS3:Evaluation of the Ultrasonic Depth Gauge for Determining Snow Water Equivalent at Remote Locations (Spittlehouse, D.L.)	2cOC3:A Finite Element Semi-Lagrangian Barotropic Ocean Model (Le Roux, D. Y.)
14:10-14:30	2cAD4:Application of Empirical Normal Mode Analysis to Shallow Water Model Data (Tran, D. H.; Derome, J.; Brunet, G.)	2cAQ4:An Evaluation of the Canadian Smog Advisory Program (Paola, Jasmin)	2cCP4:The Role of Drop Size Distributions in The Acoustic Measurement of Rainfall Rate (Waddell, S.R.)	2cCS4:Influence of a forest canopy on snow melt (Spittlehouse, D.L.; Winkler, R.D.; Adams, R.S.)	2cOC4:The effect of momentum dissipation parameterizations in thermohaline circulation models (Huck, Thierry; ...)

14:30-14:50	2cAD5:Diagnostic study of the summer Southern Hemisphere planetary wave circulation in the CCC GCM (Lin, C.; Béland; Lambert,)	2cAQ5:A computer-assisted synoptic climatology of ozone in Montreal. (Stephens, K.; McKendry, I.)	2cCP5:Solar radiative transfer for inhomogeneous clouds: The gamma function approximation (Barker, H.W.)	2cCS5:Identifying critical phenological periods affecting fruit crop production using long-term weather/crop-yield (Caprio,; Berard; Quamme,)	2cOC5:An OGCM for Coupling to the CCCMA AGCM (Lee, Warren G.; Weaver, Andrew J.)
14:50-15:10	2cAD6:Necessary conditions for mesoscale cyclogenesis in the Labrador Sea (Moore, G.W.K.)	2cAQ6:A Simple Numerical Multiple-Box Model of Atmospheric CO_2 Over an Urban Environment (Reid, K. H.; Steyn, D. G.; McBean)	2cCP6:Inferring cloud optical depth from surface pyranometer data (Curtis, T.J.; Barker, H.W.)	2cCS6:Methane and nitrous oxide exchange from a boreal forest in Saskatchewan. (Simpson, I.J.; Edwards, G.C.; Thurtell, G.W.; Kidd; Lee)	2cOC6:An Operational Oceanographic Model for the Northeast Pacific (Bancroft, D.W.)
			Health Break		
	2dAM Atmos. Modelling (Multi-purpose Rm) Sc 1 [Chair: McFarlane] 134	2dAQ Air Quality Barthelmie (Arts ~~108~~) 112 [Chair: McKendry]	2dBO BOREAS (Auditorium) [Chair: Goodison]	2dCI Coastal Ocean & Inland Waters (Arts ~~116~~) [Chair: Crawford] 108	2dOC Ocean Circulation (Arts 118) [Chair: Hsieh]
15:40-16:00	2dAM1:Numerical Simulation of a Secondary Cyclogenesis Event during CASP II (Zhang,Da-Lin; Radeva, Ekaterina; Gyakum)	2dAQ1:Ozone and Meteorological Profiles in the Lower Fraser Valley, B.C. (Thomson, R.B.; Evans, C.E.; Froude, F.; Martin, B.)	2dBO1:Overview of Twin Otter Flux Measurements in BOREAS (MacPherson, J.I.; Desjardins, R.L.; Schuepp, P.H.)	2dCI1:Hydrodynamics of a Large-Scale Estuarine System: The St. Lawrence (Chassé, J.; El-Sabh, M.I.; Murty, T.S.; Stronach, J.A.)	2dOC1:Measuring skill of ocean models against direct current observations (Sou, T.; Eby, M.; Holloway, G.)
16:00-16:20	2dAM2:On the sensitivity of gcm climate simulation to the parameterization of surface fluxes (Abdella, K.; McFarlane, N.)	2dAQ2:Down-mixing of elevated pollutant layers over the Lower Fraser Valley - a case study (McKendry, I.; Steyn, D.; Lundgren, J.)	2dBO2:On determination of surface source and sink distribution of energy and ... (Ogunjemiyo, S.; Schuepp, P.H.; Mitic, C.M.; Desjardins, R.L.; MacPherson, J.I.)	2dCI2:On the Separation/ Intrusion of the Gaspe Current and Variability ... (Gan, J. P.; Ingram, R. G.; Greatbatch, R. J.)	2dOC2:Veronis effect diagnostics in ocean general circulation model (Gough, W. A.; Welch, W. J.)
16:20-16:40	2dAM3:An upgrade of the Canadian Global Spectral Forecast Model (Ritchie, H.; Beaudoin, C.; Leduc, A.-M.)	2dAQ3:Aircraft surveys of ozone in a tributary valley of the Lower Fraser Valley (O'Kane S.; McKendry, I.; Zawar-Reza, P.)	2dBO3:A new bulk aerodynamic formulation for heat flux constructed from BOREAS Electra data. (Mahrt, L.; Sun, Jielun)	2dCI3:Heterogeneity of Tidal Flow Structure Near a Promontory (Bang, Bohyun; Ingram, R. G.; Laval, B. E.)	2dOC3:Generalized two-layer models of the North Atlantic/Caribbean (Ford, Rupert.; Salmon, R.)

16:40-17:00	2dAM4:Atmospheric energetics of a fully compressible model: Preliminary results (Thurre, Ch.; Laprise, R.)	2dAQ4:Predicting surface ozone concentrations in southwestern British Columbia based on readily ... (Pryor, S.C.; Pottier, J.)	2dBO4:Relationship of the heat flux to microscale temperature variations: Application to BOREAS (Sun, Jielun; Mahrt, L.)	2dCI4:The modification of tidal currents by a small bay in the St. Lawrence Estuary (Laval, B.E.; Bang, B.; Archambault, P.; Ingram)	2dOC4:On the climatological heat and salt budgets at OWS Papa. (Large, W.G.)
17:00-17:20	2dAM5:Fine-scale modelling of intense orographic precipitation over the Columbia River Basin (Benoit, R.; Pellerin, P.; ...)	2dAQ5:Combined meteorological and photochemical modelling of ozone ... (Steyn, D.G.; Suzuki, N.M.; Cai, X.; Pryor, S.;...)	2dBO5:Tower flux measurements at the BOREAS Old Aspen Tower Site (Neumann, Harold H.; den Hartog, G.; Staebler, ...)	2dCI5:The response of Baie des Chaleurs to the passage of a strong storm. (Lavoie, D.; El-Sabh, M.I.)	2dOC5:On the Spatial and Temporal Variability of Surface Heat Fluxes over the North Atlantic During Winter (Moore, G.W.K.)
17:20-17:40	2dAM6:The performance of semi-Lagrangian transport scheme for the advection-condensation ...(Pellerin, P.; Laprise, P. R.; Zawadzki, I.)	2dAQ6:Measurements of biogenic volatile organic compound emissions from (Gillespie, T.J.; Curren, K.; Steyn, D.G.; Drewitt; Niki,)	2dBO6:Eddy correlation measurement of carbon dioxide fluxes beneath a boreal aspen forest canopy (Yang, Paul C.; Black; ..)	2dCI6:Modeling the mean circulation of the Labrador and Newfoundland shelves (Tang, C.L.; Gui, Q.; Peterson, I.)	2dOC6:Seasonal variation of the 3-D circulation over the eastern Scotian and southern Newfoundland Shelves (Han, G.; Hannah, C.G.; Loder, ...)

Wednesday a.m.

Plenary Session (Multi-purpose Room) [Chair: Freeland] Gymn.

8:45-9:30 3aPL1: Environmental and economic perspectives on climate change (**Bruce**, James P.) ***invited***

9:30-10:15 3aPL2: The World Ocean Circulation Experiment - its achievements and its remaining challenges (**Gould**, W.J.) ***invited***

Health Break

	3bAW Atmos. Waves (Arts ~~108~~) 112 [McFarlane]	3bBO BOREAS (Auditorium) [Chair: Goodison]	3bCI Coastal Ocean & Inland Waters (Arts ~~118~~) [Chair: Allen] 106	3bCL Climate & Paleoclim. (Multi-purpose Rm) SC1 [Chair: ~~McKendry~~ Renson 134]	3bWF Weather Forecasting (Arts 118) [Chair: Wallace]
10:40-11:00	3bAW1:Evolution of gravity wave spectra with height and the parameterization of associated wave drag (Medvedev, A.S.; Klaassen,)	3bBO1:Eddy-correlation measurement of water vapour fluxes beneath a boreal aspen forest canopy (Blanken, Peter D.; Black, T. A.; Yang, ...)	3bCI1:Tidal mixing in Sechelt Inlet, B.C. (Tinis, S.W.; Pond, S.)	3bCL1:Can runoff regulation in Hudson Bay really affect the climate of the North Atlantic ? (LeBlond, P.H.; Weaver, A.J.; Lazier, J.R.N.)	3bWF1:Next operational version of the regional finite element model (Sarrazin, R.; Brunet, N.; Bilodeau, B.; Pellerin, G.; Mailhot, J.)

Regional scale simulations of mountain waves over the Rockies
Baljii Klausen, Laprise.

11:00-11:20	3bAW2:Manifestation of the baroclinic-wave life-cycle in TOMS column ozone data. (Reader, M. C.; Moore, G. W. K.; Belanger, K.)	3bBO2:Measured and modelled isoprene emissions from as aspen boreal forest (Fuentes, Jose D.; Neumann, H.H.; den Hartog, G.; Wang)	3bCI2:Logarithmic layer observed in a tidal channel using an acoustic Doppler current profiler (Lueck, R.G.; Lu, Youyu)	3bCL2:Atmospheric moisture transport into the Arctic and its variability (Holzer, Mark)	3bWF2:New statistical methods for weather forecasting developed at RPN (Bourgouin, P.; Vallee, M.; Wilson, L.)
11:20-11:40	3bAW3:Predicting a shallow-water model and the atmospheric slow variability with an empirical normal mode ... (Brunet, G.)	3bBO3:Seasonal and Geographic Variations in the Atmospheric Boundary Layer Above Boreal Forest (Barr, Alan G.; Betts, Alan K.)	3bCI3:An Evaluation of Environment Canada's Operational Ocean Wave Model Based on Moored ... (Lalbeharry; Khandekar)	3bCL3:Decadal climate variability in the subpolar North Atlantic (Wohlleben, Trudy M.H.; Weaver, Andrew J.)	3bWF3:SCRIBE Verification System (Verret, R.; Babin, G.; Parent, R.)
11:40-12:00	3bAW4:Envelope Radiation of Internal Gravity Waves by Kelvin-Helmholtz Billows (Ford, R.; Scinocca, J.F.)	3bBO4:Doppler radar observations of boundary layer turbulence and clouds during BOREAS (Martner, B.E.; Frisch, A.S.; Banta)	3bCI4:Turbulence measured with moored instrument in tidal channel (Lueck, Rolf G.; Huang, Daiyan) A moored instrument for turbulent measurements	3bCL4:Recent climatic variability and associated effects and interactions with Hudson Bay and James Bay (Skinner; Jefferies)	3bWF4:Description and verification of a new technique to forecast precipitation type at CMC (Bourgouin, P.; Desautels, G.)
Wednesday p.m.					
	3cAM Atmos. Modelling (Arts 118) [Chair: McFarlane]	3cBM Boundary Layer Meteorology (Arts ~~108~~ 112) [Chair: Austin]	3cBO BOREAS (Auditorium) [Chair: Goodison]	3cCI Coastal Ocean & Inland Waters (Arts ~~116~~ 106) [Chair: Marsden]	3cWO WOCE ~~(Multi-purpose Rm)~~ SC1 [Chair: Freeland] 134
13:10-13:30	3cAM1:Role of turbulence and surface properties in cold front evolution. (Pagowski, Mariusz Z.)	3cBM1:Coastal wind power - how advantageous is going offshore? (Barthelmie, R.J.)	3cBO1:Field Test Results using the Vaisala Radiosonde System during BOREAS (Strong, G.S.; Barr, A.G.)		3cWO1:Inferring meridional mass and heat transports of the Indian Ocean by combining a GCM with climatolog. data (Lee, T.; **Marotzke, J.) *invited***
13:30-13:50	3cAM2:Climatology in ECSib general circulation model (Krupchatnikoff, V.N.; Fomenko, A.A.)	3cBM2:Scaling sea breeze flows (Steyn, D.G.)	3cBO2:The surface mesoscale meteorological system for BOREAS (Shewchuk, S. R.)		
13:50-14:10	3cAM3:MC2 Contribution to the COMPARE 2 Experiment - A Mountain Wave Simulation (PYREX IOP 3) (Benoit, R.; Desgagne, M.)	3cBM3:Parameterization of vertical turbulent transfer in stable stratification (Delage, Yves)	3cBO3:Influence of leaf development on the radiation regime beneath a boreal aspen forest canopy (Blanken, Peter D.; Black, T. A.; Nesic,...)	3cCI1:Oceanic tides over the Newfoundland and Scotian Shelves (Han, G.; Ikeda, M.; Smith, P.C.)	3cWO2:JEBAR, Bottom Pressure Torque and Gulf Stream Separation (Myers, Paul G.; Fanning, Augustus F.; Weaver, Andrew J.)

14:10-14:30	3cAM4:Numerical Convergence in AGCMs (Boer, G.J.)	3cBM4:Lake-breezes in Southwestern Ontario with Implications for the Transport of Ground-Level Ozone (Sills, D.M.L.; Taylor, P.A.)	3cBO4:Climate and tree growth in the BOREAS allometry stands (Campbell, Ian D.; Varem-Sanders, Thierry; Grewal, Harjit; ...)	3cCI2:Improvement of tidal predictions using multiple years of tidal analyses (Crawford, William R.)	3cWO3:Sensitivity of an ocean model to sub-grid mixing schemes (Robitaille, Daniel Y.; Weaver, Andrew J.)
14:30-14:50	3cAM5:A numerical study of the along-line variability of a frontal squall line during PRE-STORM (Bélair, S.; Zhang, D.-L.)	3cBM5:A model of stably-stratified surface boundary-layer flow in two dimensions (Chan, L.)	3cBO5:Estimation of the Photosynthetically Active Radiation Absorbed by Canopy from Satellite Measurements (Li; Moreau)	3cCI3:Near-shore characteristics of the Great Whale River under-ice plume (Seifert, K.H.; Ingram, R.G.)	3cWO4:Model spin up and meridional overturning in OGCMs (Cherniawsky, Josef)
14:50-15:10	3cAM6:A statistical model for UV radiation at the ground in the presence of cloud (Burrows, William R.)	3cBM6:Open-water Evaporation: The Swift Current Water Balance Study (Strong, G.S.; Granger, R.G.)	3cBO6:Investigation of snow cover variations in the boreal forest during the BOREAS 1994 winter ...(Walker, Anne E.; Goodison, Metcalfe)	3cCI4:A sediment and carbon budget for the Mackenzie Shelf of the Beaufort Sea; (Macdonald, Robie W.; Solomon, Steve M.; ...)	3cWO5:an estimate of advective heat flux in the northeast pacific ocean from satellite-tracked drifters (Bograd; LeBlond; Thomson)
			Health Break		
	3dAM Atmos. Modelling (Auditorium) [Chair: McFarlane]	3dBM Boundary Layer Meteorology (Arts ~~108~~ 112) [Chair: Austin]	3dFB Fisheries & Biol. Oceanography (Arts 118) [Chair: LeBlond]	3dLR Long-Range Forecasting (Arts ~~116~~ 106) [Chair: Khandekar]	3dWO WOCE SCI (~~Multi-purpose~~ Rm) [Chair: Cummins] 134
15:40-16:00	3dAM1:A Numerical Study of Mesoscale Flow over the Canadian Southern Atlantic Region During a Ground-Level Ozone Episode (Gong)	3dBM1:A preliminary study of surface effects within Avalon Peninsula winter storms (Déry, S. J.; Stewart, R. E.; Taylor, P. A.)	3dFB1:Dissolved and particulate nucleic acid in the Okhotsk Sea during the Summer seasons, 1992-1994 (Agatova, Alina; Dafner)	3dLR1:Ensemble Forecasting at the Canadian Meteorological Centre (Lefaivre, L.; Houtekamer, P.L.; Derome, J.; Ritchie, H.)	3dWO1:Trends in Properties at Ocean Station Papa and B.C. Coastal Stations (Freeland, Howard)
16:00-16:20	3dAM2:Tropospheric Distributions of NMHC in Winter using a 3-D SL Chemical Transport Model (Templeton,; McConnell, ...)	3dBM2:Incorporation of a simple land surface processes scheme into a mesoscale non-hydrostatic model (Bélair, S.)	3dFB2:The Distribution and Variability of Dissolved Oxygen in the Gulf of St. Lawrence (Galbraith, Peter S.; Lefaivre, Denis; Bugden,)	3dLR2:Long lead Seasonal Prediction of Canadian Surface Temperature by Canonical Correlation Analysis (Shabbar, A.)	3dWO2:Mixing in the main thermocline of the North Atlantic (Ruddick, Barry; Oakey, Neil)
16:20-16:40	3dAM3:Numerical Modelling of Flow and Dispersion around a Building in neutral and non-neutral conditions (Shopov, P.J.)	3dBM3:A 2D finite difference numerical model on evaporation from lakes (Kwan, Joyce)	3dFB3:Acoustic Measurement of Net Avoidance (Mihaly, Steve)	3dLR3:ENSO Prediction Using Neural Networks (Tangang, F.; Hsieh, W.W.)	3dWO3:Near-surface circulation in the Newfoundland Basin (Hendry, R.M.; Clarke, R.A.)

16:40-17:00	3dAM4:Analytical solutions to Newtonian nudging model (Cai, X.-M.; Steyn, D.G.; Uno, I.)	3dBM4:Experiments with the land surface scheme CLASS in the MC2 model (Belanger, Jean-Marc; Delage, Yves; Benoit, Robert; Mailhot)	3dFB4:Effects of the alaska gyre circulation on fraser river sockeye salmon return times (Thomson, Keith A.; Blackbourn, David; ...)	3dLR4:EOFS, Detection of Regional ENSO Signals, and Network Designs (Wohlleben, Trudy M. H.; Shen, Samual S.)	3dWO4:A new instrument for measuring temperature and salinity profiles from underway vessels. (Clarke, R.A.; Dessureault, J.G.)
17:00-17:20	3dAM5:A case study of mobilization and transport of the east asia dust (Tan, Jiqing)	3dBM5:A Study of One Case of High Concentrations of Wood Smoke Particulates in the River Valley at Whitehorse. (Wiens, Brian J.)	3dFB5:Those missing sockeye and the environment (LeBlond, P.H.)	3dLR5:Variation in Predictability in Relation with the Pacific-North American Pattern (Lin, H.; Derome, J.)	3dWO5:Dynamics of circulation in Okhotsk Sea using multiple chemical tracers of chlorofluocarbons (Wong, C.S.; Whitney, F.;...)
17:20-17:40		3dBM6:Adaptation of a boundary layer column model for terminal area short term ceiling \& visibility prediction (Tardif; Zwack; Beauchemin)	3dFB6:The Effects of the Hudson Strait Outflow on the Biology of the Labrador Shelf (Drinkwater, K.D.; Harding, G.C.)	3dLR6:Climatic Teleconnections from the Pacific Ocean to the Canadian Prairies -... (Babb, J.; Garnett, E. R.; Khandekar, M. L.)	
19:30-20:30	CMOS Public Lecture:The Little Ice Age in Canada (**Campbell,** I.D.) ***invited*** (Auditorium) [Chair: LeBlond]				
	Thursday a.m.				
	Plenary Session (Multi-purpose Room) [Chair: Austin]				
8:45-9:30	4aPL1: Effects of Climatic Warming on the Physics, Chemistry and Biology of Freshwater Lakes (**Schindler**, D. W.) ***invited***				
9:30-10:15	4aPL2: Low Frequency Variability in the Arctic Atmosphere/Sea Ice/Ocean Climate System (**Battisti**, D.S.; Bitz, C. M.; Moritz, R. E.; Beesley, J. A.) ***invited***				
	Health Break				
	4bAR Sea Ice & Arctic Studies (Arts ~~116~~) [Chair: LeBlond] 106	4bCL Climate & Paleoclim. ~~(Multi-purpose Rm)~~ 501 [Chair: McKendry] 134	4bCO Chem. Oceanogr.& Limnology (Arts ~~108~~) [Chair: Pedersen] 112	4bPE PERD (Auditorium) [Chair: Lynch]	4bWF Weather Forecasting (Arts 118) [Chair: Wallace]
10:40-11:00	4bAR1:The Sea-ice Budget of the Arctic: Models and Observations (Flato, G.M.)	4bCL1:Measurements of the Forcing Radiation of Global Warming (Evans, W.F.J.; Puckrin, E.)	4bCO1:The Seasonality of Diagenetic Trace Metal Profiles in a Seasonally Anoxic Lake (Martin, A. J.; Pedersen, T. F.)	4bPE1:Shelf Circulation Models and the Real World (Thompson, Keith R.; Sheng, Jinyu)	4bWF1:Composite Analyses of Large-Scale Circulation Fields Associated with ... Cyclones in Atlantic Canada (Gyakum, J. R.; Renaud,...)

11:00-11:20	4bAR2:Observed and Modelled Interannual Variability in Landfast Sea-ice (Brown, R.B.; Flato, G.M.)	4bCL2:Parameterizations of the microphysical and thermodynamical characteristics of clouds (Gultepe, I.; Isaac, G. A.; ...)	4bCO2:Cadmium in shelf and slope sediments from the Canada Basin (Arctic Ocean) (Gobeil, Charles; Macdonald, Robie W.; Sundby, Bjorn)	4bPE2:A Model Comparison of Baroclinic Instability in the Presence of Topography (Griffiths, C.; Ikeda, M.; Wang, J.; Smith, P.C.)	4bWF2:Coupling of a Synoptic-Dynamic Diagnostic Package (DIONYSOS) with a Regional Climate Model (RCM) (Zwack, P.; Pagé, ...)
11:20-11:40	4bAR3:Sea ice response to wind forcing on the Labrador shelf (Greenan, B.J.W.; Prinsenberg, S.)	4bCL3:Current developments in land surface modelling within the Canadian Climate Research Network (Verseghy, Diana L.)	4bCO3:Silver geochemistry and the potential of silver as an indicator of sewage in the Strait of Georgia (Gordon, K.; Pedersen, T.F.; Macdonald)	4bPE3:A 3D coupled ice-ocean model applied to Hudson Bay, Canada: ... (Saucier, Francois J.; Dionne, Jacques)	4bWF3:On the application of climatic data to estimate on-ground icing at selected airports ... (Stuart, R.A.; Isaac, G.A.)
11:40-12:00	4bAR4:A Dynamical Model of Sea-Ice Based on Quasi-Static Granular Flow Theory (Tremblay, B.; Mysak, L.A.)	4bCL4:Multidecadal climate variability in the Indian Ocean/Australasian region during the austral summer (Reason, Allan; Lindesay)	4bCO4:Seasonality of Trace Metal Reactivity in an Estuary (Chrétien, Rémy; Pedersen, Tom F.; Orians, Kristin J.)	4bPE4:Simulation of the climatological seasonal cycle of northern B.C. coastal waters with the Princeton Ocean Mod. (Cummins; Oey)	4bWF4:Diagnostic Analysis on Forecast Skill (Tan, Jiqing)
12:00-12:20		4bCL5:Cyclic Spectral Analysis of Fluctuations in A GCM Simulation (Huang, Jian-Ping; North, Gerald R.)		4bPE5:Three-dimensional prognostic modelling of the Georgia-Fuca basin using GF8 (Stronach, James A.; Hodgins, Donald O.)	
Thursday p.m.					
13:10-15:10	4cPD: Congress Theme Panel Discussion ~~(Multi-purpose Rm)~~ Sc1 134 [Chair: Cutler]	4cPO Poster session (Main Foyer, Student Services Building)		4cPE1: PERD Panel Discussion of Coastal Ocean Models and Applications. (Arts 118) [Chair: Mycyk]	
Health Break					
	4dAQ Air Quality (Multi-purpose Rm) [Chair: Pryor]	4dCO Chem. Oceanogr. & Limnology (Arts 108) [MacDonald]	4dFD Geophysical Fluid Dynamics (Auditorium) [Chair: Swaters]	4dPE PERD (Arts 118) [Chair: Foreman]	4dLR/4dIV Long-Range Forecast/ Interannual Variability (Arts 116) [Chair: Khandekar]

15:40-16:00	4dAQ1:An Updated Gas-Phase Chemistry Mechanism for Regional Pollution Modelling. (Makar, Paul A.; Li; Bottenheim; Shepson,)	4dCO1:Redox behaviour and speciation of chromium in Saanich Inlet, B.C., Canada. (Mugo, R.K.; Orians, K.J)	4dFD1:On the baroclinic stability of ocean surface fronts (Karsten, Richard H.; Swaters, Gordon E.)	4dPE1: Turbulent dissipation measurements applied to models of shelf seas (Crawford, William R.; Simpson; Rippeth; Campbell)	4dLR1:Past Practice and Prospects for Climate forecasting in Canada (Saulesleja, Andrej; Dawson, D.K.)
16:00-16:20	4dAQ2:Measurement of Ozone Dry Deposition in the Lower Fraser Valley (Kellerhals, Markus O.B.; Steyn D.G.)	4dCO2:Interannual climate variability reflected in laminated sediments of an anoxic basin, saanich inlet, b.c. (Collins, A.D.)	4dFD2:On the Finite Amplitude Instability of Geostrophic Fronts (Slomp, Carol G.; Swaters, Gordon E.)	4dPE2: Oil Spills in Open and Ice-Infested Waters: A Comparative Need for Data on Water Currents(Venkatesh, S.)	4dLR2:Teleconnections between ENSO events and growing season extended dry spells on Canadian Prairies (Bonsal;Lawford;Chakravarti)
16:20-16:40	4dAQ3:Investigating a Multi-Layer dry deposition Model Against Single Layer Models and O_3 Measurements from ... (Zhang, L.; Padro; Walmsley)	4dCO3:Estimating particle decay in the water column from sediment trap data (Timothy, D.A.; Pond, S.)	4dFD3:On the Weakly Nonlinear Baroclinic Instablility of a Mesoscale Gravity Current in a Channel (Mooney, Curtis J.; Swaters)	4dPE3:Tidally forced under-ice Ekman Layers observed by an acoustic Doppler current profiler (Marsden, R. F.; Ingram, R. Milinazzo...)	4dIV1:Interannual variability of SST and the overlying atmospheric circulation in the western South Atlantic. (Venegas; Mysak; Straub,)
16:40-17:00	4dAQ4:A Clean Air Day in the Lower Fraser Valley of British Columbia (di Cenzo, C.S.)	4dCO4:Annual Variations of d13C and d15N of particulate organic matter in La Perouse Bank off Vancouver Is. (Wu, Jinping.; Calvert, S.E.; Wong)	4dFD4:Strongly Curved Flow Profiles In Quasigeostrophic Stability Theory (MacKay, M.D.; Moore, G.W.K.)	4dPE4:Vertical structure of the currents off Newfoundland (Narayanan, S.; Colbourne, E.; Helbig, J.)	4dIV2:Intense Extra-Tropical Northern Hemisphere Winter Cyclone Events: 1899-1991 (Lambert, Steven J.)
17:00-17:20	4dAQ5:Visual Air Quality in Waterton and Glacier Parks (McDonald, Karen)	4dCO5:Methane, molecular nitrogen and production-destruction processes in ecosyst. of Okhotsk & Bering Seas (Dafner, Vereshagina)	4dFD5:Nonlinear Stability of Generalized Phillips Model (Yang, Li; Mu, Mu)	4dPE5:Internal wave directional spectra using an acoustic Doppler current profiler (Marsden , R. F.; Juszko, B. A.; Ingram, R. G.)	4dIV3:Interannual Atmosphere-Ocean Coupled Variability in the North Atlantic: Observations & Modelling (Fyfe, J.C.; Peng)
17:20-17:40	4dAQ6:The Effects of Stable Stratification on the Flow and Dispersion Within Idealized Urban Street Canyons (Zhang, YanChing Q.)	4dCO6:Modelling of barium - barite cycling in the oceanic water column - (Shopova D.; Dehairs, F.)	4dFD6:Linear Stability Analysis of a Frontal Oceanic System over a Submarine Ridge (Déry, Francis)	4dPE6:Intercomparison of surface wind data off the BC Coast (Cherniawsky, Josef; Crawford, William R.; Brown, Robin M.)	4dIV4:An ecologically-based regionalization framework for regional and national climate data analysis in Canada (Gullett, D.; Malone, L.)

Friday a.m.					
	5aAR Sea Ice & Arctic Studies (Arts ~~118~~ 106) [Chair: Flato]	5aCL Climate & Paleoclim. (Multi-purpose Rm) Weaver [Chair: ~~McKendry~~ 134]	5aFD Geophysical Fluid Dynamics (Auditorium) [Chair: LeBlond]	5aMA Middle Atmosphere (Arts 108) [Chair: Fyfe]	5aPE PERD (Arts 118) [Chair: Crawford]
8:45-9:05	5aAR1:Sea-ice, polar amplification and Arctic climate warming (Gaumont-Guay, Stephan; Blanchet, Jean-Pierre)	5aCL1:Climate Variability in a Low-Order Coupled Atmosphere-Ocean Model (Roebber, P.J.)	5aFD1:Does the two constituent nature of seawater affect its potential vorticity dynamics? (Straub, David N.; Warn, Tom)	5aMA1:The Canadian Middle Atmosphere Model :Some Results from Multi-Year Simulations. (Beagley, S.R.; de Grandpré, J.; Koshyk,...)	5aPE1:Model Simulations for Dixon Entrance and the North Coast of British Columbia (Ballantyne, V.A.; Foreman, M.G.G.; Crawford Lee)
9:05-9:25	5aAR2:Arctic climate sensibility to the alteration of CCN/ICN and the water vapor cycle (Girard, Eric; Blanchet, Jean-Pierre)	5aCL2:for the Ocean's Thermohaline Circulation (Hughes, T.M.C.; Weaver, A.J.)	5aFD2:A Semi-Geostrophic Model of the Leeuwin Current off West Australia (Oxilia, David M.; Straub, D.N.)	5aMA2:The Canadian Middle Atmosphere Model: Sensitivity of the SH General Circulation ... (Koshyk, John N.; Beagley, Stephen; ...)	5aPE2:Study of Mean Water Circulation in Dixon Entrance Region (British Columbia) (Jacques, Renée; LeBlond, P.H.; Foreman; Crawford)
9:25-9:45	5aAR3:BASE special model performances and analysis of mesoscale weather with MC2 model advanced output (Benoit R.; Pellerin, S.)	5aCL3:A discussion of mode transitions in a simple global ocean model (Wright, D.G.)	5aFD3:Variability in forced/dissipative barotropic flow over topography (Merryfield, William J.; Holloway, Greg)	5aMA3:Towards Dynamic Stratospheric Ozone Analyses and Forecasts for Canada (Dastoor, A.; Ritchie, H.; Gauthier, P.; Vallée; Dion)	5aPE3:Numerical Modeling and a Comparison to Observations of Flow around Canyons (Allen, S.E.)
9:45-10:05	5aAR4:An oil spill tracking component for the Multi-category Particle-In-Cell (McPIC) sea-ice model. (van Hardenberg, Bon; Holloway)	5aCL4:The stability of a zonally-averaged thermohaline circulation model (Schmidt, G.A.; Mysak, L.A.)	5aFD4:Asymmetric geopotential height fluctuations from symmetric winds (Holzer, Mark)	5aMA4:The Upward Propagation of Planetary Waves Forced by Tropospheric Baroclinic Eddies (Scinocca; Haynes)	5aPE4:A Model for Suspended Sediment Transport in the Benthic Boundary Layer (Hannah, C.G.; Loder; Muschenheim)
10:05-10:25	5aAR5:Contaminant study in the Arctic Ocean (Eby, M.; Sou, T.; Holloway, G.)	5aCL5:Flux corrections in coupled ocean-atmosphere models (Weaver, A.J.; Hughes, T.M.C.)	5aFD5:Relative angular momentum balances of quasi-geostrophic circulation models (Cummins, P.F.)	5aMA5:Comparisons of Gravity Wave Drag Parameterization Schemes in a Simplified Model of the Middle Atm.(McLandress, C.)	5aPE5:A case study of wave-current interaction in a strong tidal current (Masson, D.)
Health Break					

	5bCL Climate & Paleoclim. (Multi-purpose Rm) [Chair: Weaver]	5bFD Geophysical Fluid Dynamics (Auditorium) [Chair: LeBlond]	5bIV Interannual Variability (Arts 116) [Chair: Hsieh]	5bMA Middle Atmosphere (Arts 108) [Chair: Fyfe]	5bPE PERD (Arts 118) [Chair: Thompson]
10:40-11:00	5bCL1:A Coupled Ocean-Atmosphere Model for Climate Studies (Fanning, Augustus F.; Weaver, Andrew J.)	5bFD1:The slow manifold and initialization for the shallow water equations on f-plane (Medvedev, S.B.)	5bIV1:A 3-D empirical normal mode comparative study of a numerical AMIP integration with the NMC analysis. (Brunet, G.; Dugas)	5bMA1:A Comparison of Middle Atmosphere Model Fields with TOMS Ozone (Evans, W. F. J.; Fox, D.)	5bPE1:Comprehensive Finite Element Model for Continental Shelf Circulation (Lynch, D.R.)
11:00-11:20	5bCL2:Late Quaternary Geochemical and Stable Isotopic Records from the Gulf of Alaska (McDonald, D.W.; Pedersen, T.F.)	5bFD2:Beyond ... the speed of gravity currents in a rotating frame (Allen, Mark)	5bIV2:Progress on AMIP-like integrations with the RPN Spectral Forecast Model (Dugas, B.; Brunet, G.)	5bMA2:The Observation of Polar Stratospheric Clouds with the WINDII Instrument on UARS (Alfred, Jerome, M.; Evans, W.F.J.; Gattinger)	5bPE2:Weakly Nonlinear Oscillatory Flow Over An Isolated Seamount (Shore, J. A.; Allen, S. E.)
11:20-11:40	5bCL3:Dendroclimatic records of climate change over last millennium at high-elevation sites in Vancouver Is.(Smith, Laroque)	5bFD3:In search of Holmboe's instability (Lawrence, G. A.; Zhu, Z.; Haigh, S. P.)	5bIV3:A study of the interannual variability (1948-1994) of the CIL core temperature in the Gulf of St. Lawrence(Gilbert; Pettigrew)	5bMA3:The Canadian Middle Atmosphere Model: The Chemistry Module. (Sandilands; de Grandpré; McConnell; Beagley,)	5bPE3:A 3-D diagnostic model of the Labrador and Newfoundland and shelves (Tang, C.L.; Gui, Q.)
11:40-12:00	5bCL4:The effects of duration of record and of method of analysis on climate change conclusions ... (Pocklington, R.; Morgan, ...)	5bFD4:Large amplitude internal gravity waves: comparison between weakly nonlinear theory and a primitive equation model (Lamb, K.G.)	5bIV4:Explosive cyclogenesis over the North Atlantic: Some results based on a new long term climatology (Moore, G.W.K.)	5bMA4:Thermal and Chemical Impacts of Large Volcanic Eruptions (Blanchette, C.; Liu, Qijun; Barker, Howard; Blanchet)	5bPE4:Seasonal Baroclinic Circulation in the Scotia-Maine and Grand Banks Regions (Hannah, C. G.; Greenberg, D. A.; Loder; Xu)
12:00-12:20	5bCL5:A technique for the identification of inhomogeneities in annual temperature series. (Vincent, Lucie)		5bIV5:Effects of Circulation Anomalies on the Hydrology of the Mackenzie River Basin (Lawford, R. G.)	5bMA5:Matrix parameterization of the 15 micron CO_2 and cooling in the middle atmosphere ... (Fomichev; Turner, Blanchet)	

Week at a glance

Monday	Tuesday	Wednesday	Thursday	Friday
Committee Meetings	8:30-10:15 Plenary Session (PL)	8:45-10:15 Plenary Session (PL)	8:45-10:15 Plenary Session (PL)	8:45-10:25 Sea Ice & Arctic (AR) Climate & Paleocl.(CL) Geop. Fluid Dyn. (FD) Middle Atm.(MA) PERD (PE)
Committee Meetings	10:40-12:00 or 12:20 Client&Commerc.(CC) Coastal Oc./Inland (CI) Cloud & Precip. (CP) CSAM (CS) Data Assimil. (DA)	10:40-12:00 Atmos. Waves (AW) BOREAS (BO) Coastal Oc./Inland (CI) Climate & Paleocl.(CL) Weather Forecast.(WF)	10:40-12:00 or 12:20 Sea Ice & Arctic (AR) Climate & Paleocl.(CL) Chem.Oc.& Limn.(CO) PERD (PE) Weather Forecast.(WF)	10:40-12:00 or 12:20 Climate & Paleocl.(CL) Geop. Fluid Dyn. (FD) Interannual Variab (IV) Middle Atm.(MA) PERD (PE)
		Patterson Luncheon		
Committee Meetings	13:10-15:10 Atm. Dynam (AD) Air Quality (AQ) Cloud & Precip. (CP) CSAM (CS) Ocean Circulation (OC)	13:10-15:10 Atm. Model.(AM) Bdy Layer Met.(BM) BOREAS (BO) Coastal Oc./Inland (CI) WOCE (WO)	13:10-15:10 Congress Theme Panel Discussion (PD) Poster Session (PO) PERD Discussion (PE)	13:00-14:00 PERD Summary
Committee Meetings	15:40-17:40 Atm. Model.(AM) Air Quality (AQ) BOREAS (BO) Coastal Oc./Inland (CI) Ocean Circulation (OC)	15:40-17:40 Atm. Model.(AM) Bdy Layer Met.(BM) Fish.& Biol. Oc. (FB) Long-Range Fore.(LR) WOCE (WO)	15:40-17:40 Air Quality (AQ) Chem.Oc.& Limn.(CO) Geop. Fluid Dyn. (FD) PERD (PE) Long-Range Fore.(LR) +Interannual Var.(IV)	
	17:45- Wine & Cheese		19:00- Banquet	
18:00- Icebreaker reception	20:00- Ann.Gen.Meeting (Auditorium)	19:30-20:30 Public Lecture (Auditorium)		

Aperçu de la semaine

Lundi	Mardi	Mercredi	Jeudi	Vendredi
Réunions des comités.	8:30-10:15 Session Plénière (PL)	8:45-10:15 Session Plénière (PL)	8:45-10:15 Session Plénière (PL)	8:45-10:25 Glaces & Arctique(AR) Climat & Paléocl.(CL) Dyn. Fluid. Géop. (FD) Atmos. Moyenne(MA) GRDE (PE)
Réunions des comités.	10:40-12:00 ou 12:20 Clients&Commerc.(CC) O.Côtiers/M.Intér. (CI) Nuages & Précip. (CP) CSAM (CS) Assim. de Données(DA)	10:40-12:00 Ondes Atmos. (AW) BOREAS (BO) O.Côtiers/M.Intér. (CI) Climat & Paléocl.(CL) Prévisions Météo.(WF)	10:40-12:00 ou 12:20 Glaces & Arctique(AR) Climat & Paléocl.(CL) Oc. Chim. & Limn.(CO) GRDE (PE) Prévisions Météo.(WF)	10:40-12:00 ou 12:20 Climat & Paléocl.(CL) Dyn. Fluid. Géop. (FD) Var. Interann.(IV) Atm. Moyenne(MA) GRDE (PE)
		Déjeuner Patterson		
Réunions des comités.	13:10-15:10 Dynam. Atm. (AD) Qualité de l'air (AQ) Nuages & Précip. CP) CSAM (CS) Circulation Océan.(OC)	13:10-15:10 Modél. Atm. (AM) Météo. Aéronaut.(BM) BOREAS (BO) O.Côtiers/M.Intér. (CI) ECOM (WO)	13:10-15:10 Discussion Thème du Congrès (PD) Séance d'affichage (PO) Discussion GRDE (PE)	13:00-14:00 Sommaire GRDE
Réunions des comités.	15:40-17:40 Modél. Atm. (AM) Qualité Air (AQ) BOREAS (BO) Côtiers/Intér. (CI) Circulation Océan. (OC)	15:40-17:40 Modél. Atm. (AM) Météo. Aéronaut.(BM) Oc. Biol. & Pêches(FB) Prév. Long Terme(LR) ECOM (WO)	15:40-17:40 Qualité Air (AQ) Oc. Chim. & Limn.(CO) Dyn. Fluid. Géop. (FD) GRDE (PE) Prév. Long Terme(LR) +Var. Interan.(IV)	
	17:45- Vin et Fromage		19:00- Banquet	
18:00- Réception de bienvenue	20:00- Assemblée Générale Annuelle(Auditorium)	19:30-20:30 Conférence Publique (Auditorium)		

Room/Salle: Multi-purpose Room [2aPL] Tuesday/Mardi

PLENARY
ASSEMBLÉE PLÉNIÈRE

Chair/Président: William Hsieh

[2aPL1] Commercialization of Weather Services – Innovation, Aggravation or Speculation

Wells G
AES, Environment Canada, 200 - 1200 West 73rd Ave., Vancouver, B.C. V6P 6H9

"I walk around with my wallet open because I expect some change in the weather"

The Weather Service of Environment Canada has maintained a long tradition of providing weather services primarily aimed at the safety and security needs of Canadians. As a result of the large and complex infrastructure required to maintain this "basic" service, opportunities arose to be able to provide additional services for very little, if any, incremental costs.

BUT the world it is a-changing. With increased debt and deficits, maintenance of the basic infrastructure is becoming very difficult. Many countries are already converting their weather programs to business enterprises. Canada likewise intends to follow suit and this has created a growing rift that commercial services from a government service is unacceptable.

This discussion will address these issues.

[2aPL2] Modeling Air Quality : A View from the Trenches

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Center for Global & Regional Environmental Research and the Department of Chemical & Biochemical Engineering University of Iowa. Iowa City , Iowa 52240

A detailed understanding of the relationships between the emissions and the resulting distribution of primary and secondary species in the atmosphere is a requisite to designing actions for the maintenance of a healthy environment. Scientific efforts to understand the atmospheric processes governing these relationships involve a combination of laboratory experiments, field studies, and modeling analysis. Laboratory experiments provide basic data on individual physical and chemical processes. Field studies are designed to investigate a limited number of processes under conditions in which a few processes dominate. Unlike controlled laboratory experiments, field studies can not be parametrically controlled. Since laboratory experiments and field studies by themselves can not fully elucidate complex atmospheric phenomena, comprehensive air quality models that allow multiple processes to occur simultaneously are required for data analysis and scientific inquiry. These models treat transport, chemical transformations, emissions and deposition processes in an integrated framework, and serve as representations of our current understanding of the complex atmospheric processes. They provide a means to perform parametric studies for quantitative analysis of the relationships between emissions and the resulting distribution, and they can also be used to study the response of the pollutant distributions to system perturbations. The evaluation of emission reduction strategies is an important example. The scientific issues associated with analysis of chemically perturbed atmospheres using air quality models are dominated by a number of underlying considerations. Several of the more important are: (a) the anthropogenic sources of trace species are quite localized and occur only over a fraction of the Earth's land area; (b) natural sources of trace species are, for the most part, very disperse and are not in the same areas as the anthropogenic sources (although this trend may be changing in regions such as tropical rain forests and the savannas); (c) in virtually no case can an individual species be studied in isolation from other species; (d) many of the mechanisms that effect transformation of the species are non-linear (e.g., chemical reactions and nucleation processes); and (e) species of importance have atmospheric lifetimes that range from milliseconds and shorter to years (e.g., OH radical to CH_4). Modern air quality models have been developed to address these issues and are now in wide-spread use for applications spanning the spectrum from basic to applied science. Air quality models have also become an integral part of environmental policy analysis. In this paper the present "state" of air quality modeling (as viewed by the author) is presented. The focus of the paper will be on the "current" state-of-affairs.

The present strengths and shortcomings of the models will be illustrated through discussion of successes and failures of modeling applications. The paper will close by looking at what the future may hold for air quality models (and modellers as well).

Room/Salle: Arts 108 [2bCC] Tuesday/Mardi

CLIENT AND COMMERCIAL SERVICES
SERVICES AUX CLIENTS ET COMMERCIAUX

Chair/Président: Kelsey Spring

[2bCC1] The City of Edmonton's Watering Index

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The source of water for the City of Edmonton is the North Saskatchewan whose headwaters are glacial melt in the Rockies. There are dams upstream that regulate the flow of water through the City. Thus, water itself, is not a problem.

Some of the City sewage and storm runoff outlets are located upstream of one water treatment plant intake. Because capital projects (re-locating intakes further upstream) take years to complete, there are concerns about water treatment, especially if too much water is pushed through the system. Nonetheless, water pressure must be maintained for fire fighting and emergencies.

During the summer period, a public advisory aimed at changing behavior patterns was considered. Because at this time major usage is watering the grass, a watering index was developed: WI(today) = WI(yesterday) + SMI(today) - SMI(climate) - P where WI is Watering Index, SMI is Soil Moisture Index, and P is downward percolation.

The 1994 season was wet. Most of the region received 100 mm more rain than normal. Thus, most of the City didn t water. The typical large draw-down of reservoirs didn t happen.

Comparing Watering Index values with water demand shows a correlation that is negative, as expected, but small. The coefficient was minimized when Index values were compared to demand for the following day suggesting some watering may have occurred about 24 hours after dry days.

The City has shown interest in pursuing this project through 1995. Hopefully, the precipitation regime will be closer to normal to allow a better assessment.

[2bCC2] Regulation and the Economic Benefit of Aviation Terminal Forecasts

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This paper demonstrates a method to model the economic impact of decisions made on the basis of aviation terminal forecasts, on a specific route, over a short period. Costs are determined by Transport Canada's regulations concerning the airlines' decision, based on aviation weather forecasts, whether to carry sufficient fuel to reach an alternate in case of adverse weather. The regulations are designed to maintain an acceptable level of safety while recognising the costs that over-prescribing safety measures would create. The airlines use these rules to their best advantage by attempting to maximise revenue and minimise costs while maintaining safe operating practices. Forecast accuracy determines, to a great extent, the success of the airlines' strategy. This work is the first stage of a project to estimate the economic benefit of terminal forecasts to airlines under Transport Canada's weather-related rules for the selection of alternates.

[2bCC3] Coastal and Oceans Monitoring Capabilities of RADARSAT

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RADARSAT, which is scheduled for launch in early 1995, will have the capability of providing operational re-

source and environmental monitoring of the coastal zone and the oceans. The operational nature of RADARSAT stems from the all-weather, day/night image acquisition ability of Synthetic Aperture Radar (SAR), and RADARSAT's variable incidence angles and beam modes. Operational monitoring in the coastal zone and oceans includes activities such as coastal zone features-mapping, aquaculture site detection, mesoscale ocean-features mapping, oil spill detection, and ship detection.

Coastal zone features-mapping, aquaculture site detection, and mesoscale ocean-features mapping will probably have a limited need for data delivery in near-real-time. Instead, these activities will benefit from RADARSAT's variable incidence angles and beam modes; for example, increased spatial coverage at a reduced resolution will permit efficient coastal zone features-mapping, and high resolution imagery at a reduced spatial coverage will aid in the detection of the small-scale aquaculture sites. On the other hand, oil spill detection, and ship detection will require data delivery in near-real-time, where near-real-time is application specific, but generally will be within 12 to 24 hours following acquisition. Near-real-time data acquisition activities usually require multiple images of the same area, which is difficult given the relatively small scene size (100 100 km) of a standard SAR image; however, by combining RADARSAT's variable incidence angles and beam modes, the effective number of re-visits for a given area is greatly increased.

In a recent study, RADARSAT-simulated imagery was used to study ocean features in the Strait of Georgia, British Columbia. Numerous features including ships, internal waves, thermal fronts, and regions of reduced backscatter were detected. The regions of reduced backscatter, which were generally along the coastline, were due to an attenuation of ocean surface-roughness that was related to biologically-derived slicks. Since a similar attenuation of the surface roughness occurs after an oil spill, it appears that RADARSAT imagery will be effective for oil spill detection and monitoring.

[2bCC4] Modernization and Commercialization Efforts at the Northern Alberta Environmental Services Centre

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Environment Canada, Room 200, 4999 98 Ave, Edmonton, AB, T6B 2X3

In January 1995, the Alberta Weather Centre in Edmonton became the Northern Alberta Environmental Services Centre, in conjunction with the opening of the new Southern Alberta Environmental Services Centre in Calgary. Having to plan for operating a smaller weather centre has meant making significant changes in the way the centre operates. Old manual labour-intensive procedures are gradually being replaced by new systems to monitor the weather and produce forecasts, and hard-copy maps are being replaced by software to display information on-screen. The NAENSC also has been aggressively pursuing new commercial clients (such as the City of Edmonton, ITV and CBC television stations, Northwestern Utilities), and has developed some new systems to produce graphical products for them (most notably, using Paradox for Windows).

Room/Salle: Multi-purpose Room **[2bCI]** Tuesday/Mardi

COASTAL OCEAN AND INLAND WATERS 1
OCÉAN CÔTIER ET EAUX INTÉRIEURES 1

Chair/Président: Howard Freeland

[2bCI1] Surface thermal structure in Hecate Strait

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Dept. Oceanography, University of BC, Vancouver, B.C. V6T 1Z4

The thermal history of surface waters in Hecate Strait has been documented through temperature recorders moored below navigation buoys and on a ferry that traverses Hecate Strait daily. This information has been combined with that routinely collected at lighthouses and weather stations, and used with satellite imagery to produce temperature maps of Hecate Strait surface waters with greater temporal and spatial resolution than hitherto available. The talk will describe the observation program and results for the first year of observations.

[2bCI2] Internal Tides in Dixon Entrance

Carrasco AC[1], Leblond P[1], Crawford W[2], and Marsden RF[3] <carrasco@ocgy.ubc.ca>
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[2]Inst. Ocean Sciences, P.O.Box 6000 Sidney, B.C. V8L 4B2, Canada
[3]Royal Roads Military College, Victoria B.C. V0S 1B0, Canada

Dixon Entrance is a coastal oceanic region, east-west oriented, located on the west coast of Canada, with strong, principally semi-diurnal M2, tides. Local bathymetry and strong stratification are favorable to the generation and propagation of internal tides.

Using observations, from current meters and CTD's, from the North Coast Oceanic Dynamics Experiment (NCODE) during the period 1984-85 a horizontal baroclinic field of motion at M2 and K1 is estimated. An Empirical Orthogonal analysis over such baroclinic field is performed, detecting the temporal and spatial variability of these waves. The results show a strong signal at the M2 frequency and a modal propagation pattern associated with Poincaré and Kelvin waves. Also a discussion related to the possible generation regions is presented.

The subsequent goal is to develop a numerical model of the scattering of these waves in a simple basin and compare the model results to the data.

[2bCI3] A Numerical Modeling Study of the Circulations along the Westcoast of Vancouver Island

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Institute of Ocean Sciences, P.O. Box 6000, Sidney, B.C. V8L 4B2.

The Princeton Ocean Model of Blumberg and Mellor (1987) is used to examine the dynamical balances in the 3-D summer and winter mean circulations along the west coast of Vancouver Island. The model domain is 445 km in alongshore length and 145 km along cross-shore direction with a grid spacing of 7 km by 4.5 km. The model is initialised with horizontally averaged temperature and salinity fields from the seasonal Levitus compilation. A uniform summer and a uniform winter wind are used to force the model. The discharge from the Juan de Fuca Strait is simulated by relaxing the initial salinity field along the mouth of the Juan de Fuca. The model is also modified to include "topographic stress" following Ebby and Holloway (1990).

In the absence of buoyancy forcing and topographic stress, the summer mean circulation is dominated by an equatorward flow over the shelf and slope. As we introduce the topographic stress, a poleward coastal jet developes over the inner shelf and an equatorward flow over the outer shelf and slope. When the initial salinity field is relaxed, an eddying motion is developed on the shelf across the mouth of the Juan de Fuca Strait. For the winter mean circulation, the flow is always toward the pole for all situations of topographic stress and buoyancy forcing. These features are in qualitative agreement with the observations.

[2bCI4] Modeling upwelling over Juan de Fuca Canyon

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Juan de Fuca canyon is about 250 m deep and 7 km wide. It cuts the continental shelf from the slope to and actually continues into the Strait of Juan de Fuca. Summer Northwesterly winds drive the southward flowing shelf break current. The interaction of the current with Juan de Fuca canyon has been observed to produce deep upwelling (Freeland and Denman, 1982) and appears to be associated with a cyclonic, surface trapped eddy, the Tully eddy.

A hierarchy of analytic and numerical models have been developed to investigate the circulation in the vicinity of Juan de Fuca canyon due to the shelf current. Many of the observed features, including the Tully eddy, can be simulated using a barotropic model, but the details and the effect of the California undercurrent require a stratified numerical model. A comparison with Astoria canyon, which ends on the shelf, demonstrate the significance of the geometry of this canyon.

[2bCI5] Satellite AVHRR observations of a summer upwelling event off Vancouver Island

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AVHRR satellite imagery during July 1984 was used to investigate the spatial and temporal variability of the shelf-break current during an upwelling event which lasted about 10 days off Vancouver Island. The onset of the upwelling event initially appeared as a plume of cool water at the tip of Brooks Peninsula. As the winds intensified, the plume of cool water migrated equatorward as jet centered just seaward along the shelf-break. As the winds dramatically weakened near the end of the upwelling event, there was warming of the surface waters along the shelf, though a band of cool water persisted along the shelf-break. A correlation square of around 0.85 was found between the AVHRR SST in situ temperature measurements in the upper 3 m of the water column. The temporal variations in the SST structure were related to temporal variations of the longshore coastal wind, and the temperature from coastal lightstations and subsurface moorings.

By the calculating the apparent equatorward velocity in the sequential satellite images using a feature-tracking method and comparing with current meter measurements, we concluded that when the upwelling favourable winds were intensifying, the apparent equatorward velocities in the images were much larger than the measured currents, hence shelf-break upwelling would be the major mechanism in creating the apparent equatorward migration of the jet. But once the winds weakened, the apparent velocity and the measured velocity were similar, suggesting that shelf-break upwelling had ceased (as expected from the theory of Johnson and Nurser, 1984), and that advection by the main currents was responsible for the equatorward migration of the jet.

Room/Salle: Arts 116 **[2bCP]** Tuesday/Mardi

CLOUD AND PRECIPITATION PHYSICS 1
PHYSIQUE DES NUAGES ET DES PRÉCIPITATIONS 1

Chair/Président: Phil Austin

[2bCP1] Effects of mesoscale convergence on convective precipitation

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Division of Meteorology, Dept. of Geography, University of Alberta, Edmonton, AB T6G 2H4, Canada

An axis-symmetric cloud model is used to examine how convective precipitation is affected by the profile of the mesoscale convergence. Warm-rain processes are included in the model using a bulk-water parameterization scheme. The initial conditions for our simulation case were taken from the sounding and Doppler velocity-deduced convergence profile sampled on 19 August 1992 in central Alberta. The simulated precipitation field closely resembles radar observations.

The quantitative effects of the convergence profile on precipitation are investigated by comparing model experiments that differ in the convergence magnitude, depth of convergent layer and vertical distribution of the convergence. Increasing the strength and depth of convergence result in stronger convection and more precipitation. Rainfall increases monotonously but nonlinearly with convergence magnitude. Doubling the convergence magnitude from 1.0x10-4 to 2.0x10-4 s-1 causes an increase of rainfall by a factor of 2.5, whereas rainfall increases about 130 % for convergence from 1.25x10-4 to 2.5x10-4 s-1. The nonlinear effects become more apparent when changing the depth of convergent layer. This is related to the moisture stratification that varies markedly with height. Rain reaches the surface at 70 min when using a convergence magnitude of 2.5x10-4 s-1, but after 275 min for 2.5x10-5 s-1. Similarly, increasing the depth of convergent layer from 0.5 to 4.0 km speeds up the initiation of surface rainfall from 130 to 38 min. The relative contribution of increasing the magnitude of convergence versus its depth indicates that convergence magnitude is the dominant factor for the first hour. After 2.5 hour, the intensity of convection and associated rainfall is controlled largely by the depth of the convergent layer.

[2bCP2] Relative contributions of sensible heat, latent heat and pollution emitted from an industrial complex to a convective rain shower

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Large industrial complexes emit waste energy as sensible heat and vapour, as well as industrial aerosols that act as efficient cloud condensation nuclei. Each of these three factors can contribute to cloud formation and rainfall. However, the relative contributions of the three factors and their possible interactions are not obvious. An axisymmetric cloud model is used to investigate the role of waste heat, vapour and pollution on rain enhancement for short-lived cumuli developing within industrial plumes. Using the Factor Separation Method, we isolate the pure contribution of each of the three factors and their mutual-interactive contributions towards the total integrated cloud mass, rain mass, and accumulated rainfall.

The simulations show that the sensible heat provides the major stimulus to cloud development, rain formation and rainfall at the surface. The pure contribution of the industrial aerosols is to enhance the condensation and result in larger total cloud mass; however, its contribution to rainfall is insignificant. Vapour contributes only a marginal increase in cloud and rainfall. An important finding is that the contributions due to the mutual interactions between waste energy and industrial aerosols are quite large.

[2bCP3] A numerical study of frontal inversion and precipitation

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Frontal inversion layers have significant effects on the dynamics of the parent frontal system, the form of surface precipitation and gravity wave propagation. In this study, idealized warm-frontal precipitation systems are simulated with a 2-d cloud model. The effects of background flow conditions, frontal dynamics, precipitation physics and boundary layer processes on the development of frontal inversion are investigated. The results will be compared to those of previous studies and available observations.

[2bCP4] Relationships between cloud type and amount, precipitation and surface temperature

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Hourly data from climatological stations in the Mackenzie Valley - Beaufort Sea area of northern Canada have been examined to determine the relationships between cloud type and amount, precipitation and surface temperatures. During all seasons, stratocumulus is the dominant cloud type for both precipitating and non-precipitating hours. More stratocumulus cloud occurs when temperatures are warmer in the winter and colder in the summer. Similarly, precipitation occurs more frequently and the total amount is greater when temperatures are warmer in the winter and colder in the summer. Overcast skies are dominant in all seasons when precipitation is falling. During the winter, during non-precipitating hours, clear skies are most frequent. During the summer, during non-precipitating hours, some cloud is usually present. Surface temperatures are warmer in the winter with overcast skies, and warmer in the summer with clear skies. All of the above conclusions have been quantified. Comparisons are also made with data from several U.S. stations in much different climates.

Room/Salle: Auditorium [2bCS] Tuesday/Mardi

CSAM/AGRICULTURAL AND FOREST METEOROLOGY
CSAM/MÉTÉOROLOGIE AGRICOLE ET FORESTIÈRE

Chair/Président: Ralph Adams

[2bCS1] Studies of Canopy Atmosphere Interactions in an Electrochemical Water Tunnel.

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Given the current interest on the impact of greenhouse gases on climate change, the determination of moisture, carbon dioxide, and trace gas fluxes from vegetated surfaces is necessary. The presence of a canopy influences the nature of the flow in and above the canopy, and complicates the gaseous transfer between the vegetation and the atmosphere. Large strong bursts, which are coherent in both space and time, contribute a large portion of the total energy exchange between the canopy layer and the air above it. This study uses a model canopy placed in a water tunnel to investigate this phenomenon by measuring turbulent velocities near the canopy interface. Turbulent velocities are measured with split film anemometry, and turbulence statistics are calculated as a function of canopy characteristics. This study will examine the depth and angle of penetration of coherent structures inside the canopy as a function of its geometrical configuration using an electrochemical simulation technique. This technique involves adding electrochemicals and measuring the rate of mass transfer to conducting elements which have been placed selectively within the canopy.

[2bCS2] Estimating Regional Surface Bowen Ratios from Radiosonde Soundings in the Atmospheric Surface Layer

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This study assesses the use of radiosonde soundings of temperature and humidity in the atmospheric surface layer for estimating the surface Bowen ratio at a regional scale. High resolution soundings were made at 2 or 3 h intervals between 0630 and 1800 CST on 18 fair-weather days at Kenaston, SK, between 24 June and 31 July, 1991. The region was homogeneous cropland. Surface climate was measured simultaneously on a 4x4 square grid mesonet at 25 km station separation, and included four sites with radiation measurements. The surface-layer Bowen ratio was estimated from surface and surface-layer measurements of potential temperature and water vapour mixing ratio. Three estimates were compared, differing in: estimation by linear regression or finite difference; surface-layer delineation; and surface measurement (local manual, mesonet mean, or excluded). The surface-layer Bowen ratio was sensitive to the estimation method on a case-to-case basis. However, when stratified by time of day, mean and median values from the three methods had a similar diurnal variation. The surface-layer Bowen ratio compared closely with two independent estimates, one based on an upper-air budget method and the other estimated from the Priestley-Taylor equation. The three estimates had large root-mean-squared differences, but the means compared closely. The ratio of mean sensible to mean latent heat flux density was 0.39 (surface-layer Bowen ratio - energy balance), 0.39 (Priestley-Taylor), and 0.34 (upper-air budget).

[2bCS3] Growing season water deficits in Ontario

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Historically, average water deficits have often been calculated from a balance between average monthly pre-

cipitation and estimated evapotranspiration (ET) using the original (1948) Thornthwaite method. This study compares average Thornthwaite deficits for the 1961-90 period with deficits calculated by a validated daily soil water flow model (SWACROP) for the same period and the 1921-90 period.

SWACROP simulated transient vertical soil water flow using Richard's equation. Daily potential ET was based on the Priestly-Taylor energy budget approach, and daily actual ET on the soil-water pressure head distribution and the root proliferation in the soil profile. SWACROP simulations were made for a perennial forage crop cut for hay two to four times per season, depending on location and year, and for three soils, namely, a Caledon sandy loam, a North Gower clay loam and a Rideau clay. Daily differences between PET and AET were accumulated to provide seasonal water deficits for each year from 1921-90.

Results showed that yearly SWACROP deficits calculated for all 3 soils (assuming free drainage) exceeded the 30-year mean Thornthwaite values for a soil with 100 mm available water capacity in 95 % or more of the years. Average SWACROP deficits were comparable to values computed by a validated forage model (FORYLD) using 30-year normal climatic data for several locations in Ontario. We conclude that yearly deficits should be calculated using well-validated soil water/crop growth models rather than average values only for irrigation planning and other climatic risk assessments.

[2bCS4] Measurement and Modelling of Micro-Scale Advection Between Straw Mulch and Bare Areas

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Conservation tillage practices, which maintain the soil surface covered with plant-residues, are becoming more common in agriculture and silviculture because of their effectiveness in decreasing soil loss by water and wind erosion. Such 'mulching' also moderates soil temperatures and conserves soil moisture. As a compromise between the advantages of bare and mulched surfaces, partial coverage, as in strip tillage, is often used. Our group has shown previously that advection between adjacent mulch and bare strips can enhance temperatures and evaporation in the bare strips. This paper reports measurements of the surface energy balance components, soil temperatures, and air temperature and vapour density profiles in and above a small circular bare area surrounded by a large circular area of straw so as to understand and quantify the turbulent transfer occurring between mulch and bare areas. The circular design eliminates variability due to changes in wind direction. These measurements are compared to a first order advection model and a Lagrangian diffusion model.

Room/Salle: Arts 118 **[2bDA] Tuesday/Mardi**

DATA ASSIMILATION
ASSIMILATION DES DONNÉES

Chair/Président: William Hsieh

[2bDA1] Construction of a fully reversible global linear balance equation using SVD methods with application to the generation of balanced global error covariances

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In modern data assimilation methods such as OI, 3DVAR, 4DVAR or the Kalman filter, it is usually necessary to specify some form of forecast (or model) error covariance. For the OI schemes, which were generally implemented in local form, it was relatively easy to generate balanced error covariances using the geostrophic approximation. For global schemes such as 3DVAR, the geostrophic approximation is not appropriate and it has been necessary to resort to either Rossby-Hough expansions (ECMWF) or the (forward) global linear balance equation (NMC). These techniques are somewhat awkward to use and ad hoc approximations have been resorted to. Here we intoduce a somewhat different technique, based on the singular value decomposition of the spherical harmonic form of the linear balance equation. We show that the modes corresponding to the eigenvalues of the symmetric eigenvalue problem can be broken into two classes - balanced extratropical modes and tropical modes. We show that the balance in the tropics implied by a Rossby-Hough expansion or strict application of the (forward) linear balance equation is not supported by data. Global error covariances are constructed from these new modes,

in which there is a multivariate balance in the extrapropics, while the tropical covariances remain essentially univariate.

[2bDA2] The system meteodata assimilation for Siberian region

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A regional system of data assimilation as principal part of system mathematical modelling of atmospheric processes is in the process of development at the ICT of SD RAS.

The basic components of this system are the following: task management, scheme of numerical analysis of the observed meteorological data; initialization scheme; model of the atmosphere described by the hydrodynamic equations. The scheme of numerical analysis uses the box-variant of the method for the three-dimensional optimal multivariate interpolation. A modification of the implicit initialization method is applied by using the condition of slow-mode conservation obtained by the solution of variational problem with the geostrophic constraint. The economic numerical model (15 levels from 1000 to 10 gPa and the horizontal grid D in the notations of A.Arakawa) of the atmosphere for region was developed on the basis of the G.I.Marchuk's splitting-up method.

The solution of system of hydrodynamic equations is reduced to the succesive solution of the equations of advection on the intervals $(t_n, t_{n+1/2})$ and the solution of the system of adaptation equations on the intervals $(t_{n+1/2}, t_{n+1})$. In its turn, the solution of the advection equations is based on the splitting-up method. The solution of the system of adaptation equations is based on the biortogonalization method with use of the vertical normal modes.

Description of this system, methods of solution and the rezults of experiments with real data are presented in the report.

[2bDA3] Determining empirical parameters of simple equatorial coupled atmosphere-ocean models by the adjoint method

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Simple equatorial coupled atmosphere-ocean models have been used for seasonal forecasts of El Nino. We explore the possibility of determining the empirical parameters used in these coupled models by the adjoint data assimilation method. Our coupled model has the atmosphere and the ocean each represented by a single-layer shallow water model. The adjoint method is used to successfully retrieve the 6 damping and coupling parameters from a two-month identical twin experiment. Other tests include (a) the use of sparser data sets both spatially and temporally, (b) the addition of noise, and (c) parameter retrieval when only sea level height and wind data are available.

[2bDA4] Data assimilation algorithm of the meteorological observations based on the simplified variant of Kalman filter

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The problem of the data assimilation based on the estimation theory is examined. The algorithm of extended Kalman filter is used for obtaining the best estimate of atmospheric state. The behavior of forecast error covariances calculates with the use of two-dimensional linear advection model. In numerical experiments the 15-level regional model of the atmosphere described by primitive equations is used.

Two-dimensional multivariate analysis of data is made for the coefficients of vertical normal modes of atmospheric model.

The results of preliminary numerical experiments with real data are demonstrated.

[2bDA5] An analysis of sea surface temperature for numerical weather prediction

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The new global analysis of in situ observatons of sea surface temperature (SST) in use at the Canadian Meteorological Centre is described. The analysis uses the optimum interpolation formalism but emphasis has been placed on the quality control of the observations. The data are analyzed daily on a 0.9 degree latitude-longitude grid and the correlation e-folding distance is 200 km. Climatology is incorporated in data void regions by analyzing the anomaly from climatology of SST, rather than analyzing the SST directly. The anomaly analysis is then added to climatology to produce the SST field used by the numerical weather prediction model. The background field is the previous anomaly analysis, a strategy which exploits the observed tendency of anomalies to persist over long periods. A special version of the analysis which used only data from ships and moored buoys was produced daily for a four month period. Verification of this special analysis against unassimilated drifter data demonstrates that the ship and moored buoy data contain sufficient information to improve upon climatology by 25 % in the northern hemisphere, but the improvement is a modest 5 % in the data sparse southern hemisphere. It is intended to use satellite data to improve the analysis. The analysis of in situ data described here will be an essential component of an algorithm to debias the satellite SST observations.

Room/Salle: Arts 118 **[2cAD]** Tuesday/Mardi

ATMOSPHERIC DYNAMICS
DYNAMIQUE DE L'ATMOSPHERE

Chair/Président: John Fyfe

[2cAD1] The atmospheric response to the average transient-eddy forcing during PNA anomalies

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In light of the recent advances in long-lead forecasts, the predictability of the Pacific/North American (PNA) pattern is of interest. However, the degree of predictability of the PNA pattern depends in part on its interactions with higher-frequency transients. This study investigates the barotropic and baroclinic interactions between the monthly-mean PNA anomaly pattern and the submonthly transients. The study is based on 23 winters of NMC tropospheric data. The time mean of the vorticity forcing by the transient eddies during months with strong PNA anomalies is calculated at the 250, 550 and 850 hPa levels. The vorticity forcing is displayed as a monthly-mean geopotential tendency, which is found to be spatially in phase with the PNA height anomaly throughout the troposphere. The corresponding eddy thermal forcing (displayed as a monthly-mean temperature tendency) is calculated at the 400 and 700 hPa levels. This temperature tendency is found to be of opposite sign to the PNA temperature anomaly at the two levels. In order to verify how the eddy forcing is affecting the structure of the PNA pattern, the atmospheric response to the forcing is simulated using a linear steady-state model with a non- zonal basic state. The amplitude of the height response is found to be weaker than the observed PNA anomaly. For example, about 40 % of the observed PNA amplitude is simulated at 250 hPa.

[2cAD2] The Mixing of Mass and Momentum by Kelvin-Helmholtz Billows

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The mixing of mass and momentum induced by the full life cycle of stratified shear instability is considered. In particular, the nonlinear numerical simulation of a stratified shear layer that is unstable to Kelvin-Helmholtz waves is undertaken in three spatial dimensions. The numerical experiments are designed to model the secondary convective instability of the K-H billow previously indicated by linear stability analyses and identified in tilted-tank experiments. The initial parallel flows considered in the present study allow for the presence of constant stratification external to the shear layer. For weakly unstable stratified shear layers good agreement

is found between the numerical simulations and similar physical (tilted-tank) experiments. For strongly unstable stratified shear layers the final state of the numerical simulations is a long-lived two-dimensional vortex associated with the primary K-H instability. Quantitative estimates of the efficiency of mixing are made by calculating the flux Richardson number of the modeled mixing events. It is found that the flux Richardson number can strongly depend on the relative strength of the stratification external to the shear layer.

[2cAD3] Major Teleconnection Patterns and their Synoptic-Scale Eddy Forcing

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The interaction between five major teleconnection patterns (PNA, EA, WP, WA and EU) and the synoptic-scale eddies is studied. By calculating the geopotential tendency and the heat flux convergence it is demonstrated that all five teleconnection patterns are supported barotropically and dissipated baroclinically by the synoptic-scale eddies. Spatially each teleconnection pattern is closely collocated with the corresponding forcing. Temporally each pattern index is well correlated with the two indexes determined from the forcing terms.

[2cAD4] Application of Empirical Normal Mode Analysis to Shallow Water Model Data

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The Empirical Normal Mode (ENM) analysis procedure has an advantage over the more standard Empirical Orthogonal Function (EOF) analysis in that the ENMs are the eigenfunctions of dynamical equations. The conservation property of the pseudomomentum is used to construct the angular pseudomomentum operator (similar to the covariance matrix in EOF theory). In this study we perform an ENM analysis on the output of a shallow water model integration. The model is run with small-amplitude perturbations added to a basic state at rest, and the goal is to see how well the ENM analysis can recover the known properties of the Hough modes. Of particular interest is the sensitivity of the results to the length of the data record used for the analysis. The method is also used to obtain the normal modes for the stratosphere based on 13 winters of observational global daily NMC data up to 1 hPa. Some preliminary results of this analysis will be presented.

[2cAD5] Diagnostic study of the summer Southern Hemisphere planetary wave circulation in the CCC general circulation model

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Medium scale waves, consisting largely of zonal wavenumber 5-7, frequently dominate the summer Southern Hemisphere tropospheric circulation. Observational and theoretical studies show that these waves are a baroclinic instability with a sharp zonal scale selection. The first generation CCC general circulation model simulates well this wave regime. We diagnose the planetary wave structure in the second generation version of the CCC model, in both the normal CO2 and doubled CO2 climates. The simulated eddy energetics and transports, together with their relation to changes in the zonal mean meridional temperature gradient are described. This is of particular interest as it is known that the cyclone frequency and intensity in both the Northern and Southern Hemispheres change in the doubled CO2 climate of the CCC model.

[2cAD6] Necessary conditions for mesoscale cyclogenesis in the Labrador Sea

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In the past several years, it has been recognized that the Labrador Sea is a region in which small and short lived mesoscale cyclones known as polar lows often develop. In this presentation we use an existing climatology

of these events to develop a better understanding of the synoptic scale environment in which these disturbances develop. As will be discussed, 3 statistically significant synoptic scale anomalies were found. It appears that the existence of all three anomalies are necessary for the development of a polar low in the Labrador Sea. The role that each of these anomalies plays in the development of polar lows will also discussed. Evidence will also be presented that there is a sub-class of mesoscale cyclones whose development is markedly different from that usually associated with Labrador Sea polar lows. The paper concludes with a brief discussion of the factors that control the inter-annual variability in the number of polar lows that form in the Labrador Sea.

Room/Salle: Arts 108 **[2cAQ]** Tuesday/Mardi

AIR QUALITY
QUALITÉ DE L'AIR

Chair/Président: Ian McKendry

[2cAQ1] Wind Observations over Complex Terrain

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In order to evaluate the dispersion of sulphur dioxide emitted by a pair of natural gas processing facilities, two specialized meteorological stations were installed in northeastern British Columbia. Both sites are characterized by a complex topography, with river valleys, hills and mountains in the vicinity. Because of the complex nature of the terrain, surface and low level observations cannot be used to determine the atmospheric conditions at higher elevations where the emissions from the facilities are likely to disperse. Accordingly, the meteorological stations were designed to take measurements at several heights up to and including the expected plume elevation using a combination of tower-based instruments and a Doppler acoustic SODAR. The data collection period covered more than a year of meteorological conditions, specifically from October 1993 to November 1994, giving unique and exhaustive data sets representative of the atmospheric behaviours in complex terrain. Relationships between wind and turbulence observations at various heights have been analyzed for both locations and compared between the two sites which are characterized by diverse levels of roughness.

[2cAQ2] Atmospheric Concentrations of PAHs, PCDDs and PCDFs in Suburban Kamloops, British Columbia

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In 1992 BC Environment ran a PS-1 PUF sampler in an isolated suburb of Kamloops, British Columbia coincident with the 6-day NAPS PM10 sampling schedule. The goal of this year-long study was to measure atmospheric concentrations of polycyclic aromatic hydrocarbons, polychlorinated dibenzodioxins and polychlorinated dibenzofurans (PAH, PCDD/PCDF) in a residential setting. This systematic assessment of air toxics follows two years of event- based sampling aimed at determining extreme and background values of PAH, PCDD and PCDF in a variety of settings. In this paper results from the 1992 program are presented. Comparisons are made to extreme and background values, as well as values reported in the literature. The QA/QC program is also described.

Regional sources of these compounds potentially include; primary clarifier sludge burning at a bleached Kraft pulp mill, coal burning at a Portland cement manufacturing plant, back-yard domestic refuse burning, residential woodburning appliances, internal combustion engines, and long-range transport.

It is well known that PAH's are produced when biomass is open burned. These were expected, and indeed detected, during the local back-yard burning season. Finding substantial quantities of PCDDs and PCDFs coincident with back-yard burning was somewhat surprising. Indeed, the highest concentrations were detected on one day when back-yard burning was taking place, and the pulp mill had been shut down for 10 days. The literature states that when materials containing chlorinated compounds are burned at low temperatures PCDDs and PCDFs are likely to form. Local residents have been observed to burn waste oil, tires, plastic and other domestic refuse in backyard fires. Reports of people burning railroad ties and domestic refuse in woodstoves

have also been received. These results suggest that casual burning of deleterious materials by local residents contributes substantially to the total air toxics burden.

[2cAQ3] The Effect of Large Regional Forest Fires on Particulate Air Quality in the Southern Interior of British Columbia

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This paper summarizes the meteorological and air quality features of the mid July to early August period in the Southern Interior of British Columbia. This period was marked by some of the most extreme forest fire conditions ever recorded in the Interior of BC. Several large regional forest fires burned throughout the period, inundating many valley-bottom communities with smoke.

Of the urban locations monitored continuously by BC Environment in the Southern Interior, Penticton had by far the worst air quality during the height of the fires. Somewhat less impacted was Kelowna, followed by Kamloops. Concentrations of Inhalable Particulate (PM10) in Penticton were high enough to warrant the Medical Health Officer issuing a Health Alert advising those with respiratory problems to take precautions.

Hourly and 24-hour PM10 data from all three sites are presented, along with ground level ozone and nitrogen dioxide data from the air quality monitoring station in Kelowna. BC Environments new TEOM (Tapered Element Oscillating Microbalance) continuous PM10 sampling technology are described. Photographic slides taken at the Vernon RACS (Remote Automated Camera Site) during that period are also presented.

[2cAQ4] An Evaluation of the Canadian Smog Advisory Program

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This paper will explore the results of separate surveys administered in the summer/fall 1994 in four different areas where Environment Canada issues SMOG Advisories. These four areas are: Southern New Brunswick, Greater Vancouver, Greater Toronto, and a rural site in Southern Ontario - Haldimand-Norfolk County. The federal government established the Canadian Smog Advisory Program in 1993 in four Environment Canada regions which experience recurrent episodes of elevated levels of ground-level ozone. With this program in its second year, Environment Canada in partnership with Health Canada produced an initial evaluation of the program to assess its effectiveness to date and identify how it might be improved further. Included in this paper are: the results of the public's awareness and understanding of the program and its impact on attitudes and behaviours; Canadian's current awareness and understanding of the smog problem and its effects on the environment and human health; and ways to better inform the Canadian public about the program and the hazards associated with smog.

[2cAQ5] A computer-assisted synoptic climatology of ozone in Montreal.

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The Kirchhofer computer-assisted map-typing technique is used to classify MSL pressure and 500 hPa height fields into map types which are then related to surface ozone concentrations in Montreal 1980-92. Residual cumulative dose analysis confirms that "back of the high" synoptic types are responsible for above average concentrations in summer. However in winter such conditions are conducive to stable conditions, ozone scavenging and below average concentrations. In contrast, cyclonic types contribute to above average wintertime concentrations possibliy as a result of stratospheric intrusions. Synoptic sequencing confirms the importance of stagnating anticyclonic conditions to the development of elevated ozone concentrations in Montreal. Finally a "declimatizing" technique is evaluated as a means of removing the synoptic signal from pollutant time series. Results of the study are in broad agreement with similar investigations elsewhere in northeastern North America

[2cAQ6] A Simple Numerical Multiple-Box Model of Atmospheric CO_2 Over an Urban Environment

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Few measurements of atmospheric CO_2 concentrations have been conducted near urban areas. In June 1993 a LICOR infrared gas analyzer was operated at the Sunset tower in a suburban region of Vancouver to sample the air at two heights, 10.0 and 27.5 metres, every 20 seconds. No distinguishable difference was observed for the main diurnal features of the CO_2 trace between these heights. The observed concentrations show a clear diurnal signal around the expected upwind background concentration, and are described by a late afternoon minimum, and overnight maximum. The afternoon CO_2 minimum is attributed to the strength of biospheric photosynthesis and strong mixing of local anthropogenic sources. Poor nighttime mixing, lower mixed depth heights, and biospheric respiration account for the observed nighttime maximum, often more than 80 ppmv greater than the background concentration.

A simple numerical multiple-box transport model was developed to simulate the observed diurnal pattern of CO_2 concentration at the tower site. CO_2 emissions inventories for important mobile sources, stationary sources, and biospheric sources and sinks are calculated as input to the model for upwind fetch areas. Other CO_2 inputs include advection of background concentration and entrainment from above the mixed layer. The mixing volume for CO_2 is calculated by an advective model for determining mixed layer heights, coupled to the transport model.

A description of the CO_2 observations will be presented, along with the model results and a discussion of boundary layer influences on CO_2 concentrations.

Room/Salle: Arts 116 [2cCP] Tuesday/Mardi

CLOUD AND PRECIPITATION PHYSICS 2
PHYSIQUE DES NUAGES ET DES PRÉCIPITATIONS 2

Chair/Président: Phil Austin

[2cCP1] Condensational growth of an ensemble of cloud droplets in a turbulent velocity field.

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Before reaching a radius of approximately $25\mu m$ cloud droplets grow mainly by condensation. The condensation rate of an individual droplet is a function of the temperature and the vapor pressure in its immediate environment. These quantities are time dependent and vary from droplet to droplet in a turbulent medium such as a cumulus cloud. In most theoretical and numerical studies of clouds, it is assumed that these variations are negligible in calculating the growth of a large ensemble of droplets. However, the validity of this assumption has not been thoroughly examined. The objective of this work is to determine the importance of these neglected effects using two numerical models. The first model simulates a turbulent velocity field and computes the advection and diffusion of heat and water vapor. The second calculates the growth of each individual droplet considering its trajectory under the action of the velocity field and gravity. Results of these calculations will be presented.

[2cCP2] The impact of clouds on absorption of solar radiation by the atmosphere

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The ratio R of shortwave cloud radiative forcing at the surface to that at the top of the atmosphere indicates the effect of clouds on atmospheric absorption: $R > 1$ implies clouds warm the atmosphere while the converse is true

for R < 1. Recent observational analyses suggest that R is near 1.5. On the other hand, many GCMs, and other radiative transfer models, tend to produce R near 1.1. This discrepancy implies that models underestimate cloud absorption by by about 25 Wm-2. In addition, other studies indicate that clear-sky atmospheric absorption is also underestimated by a similar amount. If both findings are true, the relative error in atmospheric absorption of solar radiation estimated by GCMs can be as high as 100 %! This study examined R using four years worth of global monthly-mean solar flux data obtained from ERBE satellites and the global surface radiation observation network. R is highly variable with a median of about 1.5 in the tropics, less variable in the midlatitudes with a median near 1.1, and less than 1 in polar regions. Large values of R in the tropics and midlatitudes during summer are correlated well with occurrences of convective clouds. By means of radiative transfer simulations using both plane-parallel and Monto Carlo methods, it was demonstrated that conventional radiation models are likely to do well in the extra-tropics but poorly in the tropics. Cloud droplet absorptances for towering 3-D clouds with thin overlying cirrus can exceed absorptances for corresponding plane-parallel clouds by more than 100 %.

[2cCP3] Optical depth and effective radius variability in marine stratocumulus clouds

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scenes acquired by the polar-orbiting Advanced Very High Resolution Radiometer (AVHRR) during the First ISCCP Regional Experiment (FIRE). The method, developed by Nakajima and Nakajima (1995), uses 3 AVHRR channels to simultaneously retrieve optical depth, effective radius (ratio of the third and the second moment of the cloud droplet size distribution) and cloud top temperature. Careful treatment of atmospheric absorption, cloud emission and surface reflection in AVHRR channel 3 allows for retrieval of effective radii as small as 4 μm with an accuracy of 1-2 μm.

We retrieved optical depth and cloud droplets effective radius for cloud scenes of about 200 km by 200 km or larger. We have found evidence of:

1. A positive correlation between optical depth and effective radius of the cloud droplet distribution for clouds with optical depth $< 15 - 20$. We see this positive correlation in two images of a precipitating layer.
2. A larger range of effective radii in optically thinner clouds. Clouds of optical depth less then 10 have effective droplet radii between 4 and 16 μm, whereas optically thicker parts of the same scene show radii in range of 8 to 11 μm.
3. A sharp transition in the size of cloud droplet effective radii in boundary layer clouds off the Californian coast (from 4-5 μm in near the shore clouds to 8-12 μm and larger some 200 km further towards open ocean).

We are currently adapting the retrieval method to measurements taken with the Landsat Thematic Mapper (TM) (channels 2 and 7). We are looking at mesoscale organization patterns in precipitating and non precipitating clouds, and are using Landsat imagery to study variability in cloudiness on scales smaller than the AVHRR resolution.

References:
Nakajima, T.Y. and T. Nakajima, 1995: Wide-area determination of cloud microphysical properties from NOAA AVHRR measurements for FIRE and ASTEX regions. *J. Atmos. Sci.*, accepted.

[2cCP4] The Role of Drop Size Distributions in The Acoustic Measurement of Rainfall Rate

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Acoustic spectra and simultaneous rain drop size distribution data observed at Mara Lake, B.C. during a 90-minute convective rain event were analyzed. During this event a wide range of drop size distributions was observed. Short term (2 min.) rainfall rates varied from 0.001 mm/hr to 30 mm/hr while the drop size distributions varied on temporal scales of a few minutes. Simultaneous acoustic spectra were calculated at 12 second intervals then, suitably averaged and compared with the rainfall rates determined from the drop size

distribution data. The expected 15 kHz peak in the acoustic spectra was seen in only some of the records, being totally absent in others. The simple correlation of rainfall rate with ambient sound level, although significantly worse than values previously reported by other authors, was shown to depend critically on drop size distribution. Previous work did not have the benefit of simultaneous acoustic and drop size distribution measurements and the drop size variation within the data sets was limited. The inclusion of drop size distribution data, presented here, significantly improves the correlation between rainfall rate and the ambient sound level over a wide range of drop size distributions. The estimation of drop size distribution from the acoustical spectral data is an essential first step to the inference of rainfall rate from acoustic data.

[2cCP5] Solar radiative transfer for inhomogeneous clouds: The gamma function approximation

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A new method of computing radiative fluxes for inhomogeneous clouds is presented. The method assumes that the probability density of cloud optical depth τ is approximated by a gamma distribution function and that horizontal transport of photons between columns of cloud, approximately one photon free-pathlength wide, is negligible. Several cloud fields are shown whose distribution of τ followed closely a gamma distribution. 3-D Monte Carlo photon transport simulations were used to demonstrate predictable, and thus adjustable, biases for solar fluxes inherent to this method.

The gamma approximation demonstrates that solar albedo and absorptance biases incurred by use of plane-parallel, homogeneous (pph) models are expected to exceed 15 %. The impact of the gamma approximation on GCM heating rates was examined using the CCC-GCM radiation codes. Relative to pph models, solar heating of cloud was enhanced slightly and IR cooling was, surprisingly, reduced much. Currently, a cloud water scheme is being developed for the CCC-GCM which estimates the mean and variance of liquid water content LWC. The gamma approximation requires mean and variance of vertically integrated LWC and thus is an attractive candidate for use in the GCM. It is important to note that the gamma approximation requires only a small amount of additional computation time relative to the current homogeneous models.

[2cCP6] Inferring cloud optical depth from surface pyranometer data

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There have been several studies aimed at inferring mean cloud optical depth τ using surface, broadband pyranometer data and plane-parallel, homogeneous (pph) solar flux models. Nevertheless, it is well known that the assumption of cloud homogeneity is incorrect and yields systematic underestimates of τ. As yet, however, the magnitude of the biases are unknown. By applying the gamma function approximation (presented in this session) to one minute pyranometer data (as archived in Canada), both τ and the variance of optical depth were estimated for periods of one hour for several Canadian sites.

The inversion process is limited by having just one minute integrated fluxes. When the minute-mean, -variance, -minimum, and -maximum values bases on one second flux data are archieved, results are less ambiguous. For some time there has been a move afoot in AES to archieve these flux statistics. This study lends support to that cause as routine information regarding cloud optical thickness and variability may be helpful for assessing aspects of climatic change and climate model performance.

Room/Salle: Auditorium **[2cCS] Tuesday/Mardi**

CSAM/AGRICULTURAL AND FOREST METEOROLOGY
CSAM/MÉTÉOROLOGIE AGRICOLE ET FORESTIÈRE

Chair/Président: Ralph Adams

[2cCS1] Wind Tunnel Measurements of Turbulent Wind Regimes Associated with Forest Openings and Topography

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Although presently under review because of environmental concerns, clearcut timber harvesting remains a common practice in British Columbia and elsewhere. Two major associated problems are the resulting harsh microclimates for tree seedlings and windthrow along cut block edges. Both these are largely influenced by wind and turbulence regimes in the clearcut and adjacent forest. These in turn depend upon factors such as clearcut size, shape, tree density, and topographical changes. Because field measurement of these effects is difficult and expensive we have been systematically studying them in a large wind tunnel at 100:1 scale using a Dantec model 5600 3-dimensional hot-film anemometer. Model trees are 15 cm high artificial Christmas tree branches placed at densities up to 500 stems per m^2. This paper reports measurements in some of the configurations studied to date, which include forest/clearcut edge, uniform thinning, longitudinal and transverse strips, circular patches, clearcut/forest corners, and ridges.

[2cCS2] Measurement of Sensible Heat Flux Using the Nonsymmetric Structure of Turbulent Air Temperature Fluctuations

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Measurement of sensible heat flux above rough surfaces and within plant and mulch canopies is often difficult, requiring complex and expensive eddy correlation systems. It has been suggested that sensible heat flux can be determined from high frequency measurements of air temperature coupled either with similarity methods or coherent eddy structure functions. In this paper, we report application of an extended version of Van Atta's cubic order ramp structure model of temperature fluctuations to determine sensible heat flux above bare and straw mulch surfaces and within straw mulch and forest canopy layers. Comparison is made between these calculated values and measurements from either energy balance or eddy correlation methods. The results show that the technique works well above the surface and within surface layers after minimum calibration. Within the straw mulch the method appears to predict the direction of the sensible heat flux even without calibration.

[2cCS3] Evaluation of the Ultrasonic Depth Gauge for Determining Snow Water Equivalent at Remote Locations

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The Campbell Scientific Inc. ultrasonic depth gauge can be used to measure the distance to surfaces below the sensor. Thus, it can be attached to a datalogger for use at remote locations to monitor snow fall and changes in snow-pack depth. However, many hydrologic applications require snow water equivalent (SWE) rather than depth of snow. Two winters of snow depth data were converted to SWE using a snow settling equation to calculate density. Occasional manual measurements of SWE and snow density, and continuous measurements of solar radiation, air temperature, wind speed and precipitation were also obtained. The settling equation does not work well during warm periods or rain that rapidly increase snow density. Occasional manual measurements of snow density are required to correct settling estimates and to allow reliable estimates of SWE and of snow melt. The manual measurements are required once near the time of maximum snow pack and once or twice during the melt season.

[2cCS4] Influence of a forest canopy on snow melt

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Theory indicates that the downward longwave radiation flux should dominate the energy balance of a snow surface below a mature forest canopy during the melt phase. Removal of the canopy by harvesting changes the magnitude of the energy fluxes, with the solar, sensible and latent heat fluxes becoming significantly larger and the longwave balance becoming negative. Greater rates of snow melt are predicted to occur in the open. Measurements to be made in the spring of 1995 in a mature forest and recent clearcut will be used to test the theory. Measurements of the short and longwave radiation balances, soil heat flux, snow temperature and melt water runoff, and eddy correlation measurements of the sensible and latent heat fluxes will be presented.

[2cCS5] Identifying critical phenological periods affecting fruit crop production using long-term weather/crop-yield associations in the Okanagan Valley.

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Fruit crop production in the Okanagan Valley of British Colombia is sensitive to weather conditions occuring at various phenological periods throughout the entire year. A statistical procedure, originally developed for assessing the impact of weather on the incidence of winterkill in winter wheat, was adapted to study the impact of weather on fruit crop production in the Okanagan Valley. Using 76 years of production data, the analysis consisted of seperating the data into quartiles of good, normal, and poor yield years and then using a chi-square analysis procedure to determine significant weather/crop yield associations. The procedure is useful in identifying critical phenological periods where weather conditions can have a significant impact on final crop yields.

[2cCS6] Methane and nitrous oxide exchange from a boreal forest in Saskatchewan.

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Methane (CH_4) and nitrous oxide (N_2O) exchange from a boreal forest was measured between October 15 and November 15, 1993 and from April 15 to September 15, 1994. The tower-based fluxes were measured both above and within an old aspen canopy in the Prince Albert National Park, Saskatchewan. The research was conducted as part of the Boreal Ecosystem-Atmosphere Study (BOREAS). The fluxes were determined micrometeorologically using a flux-gradient relationship, whereby the concentration gradient of each trace gas was measured using a tunable diode laser trace gas analysis system (TGAS), and the eddy diffusivity was determined from sonic anemometer data. The TGAS is a fast response instrument capable of resolving CH_4 concentration differences to 100 pptv, and N_2O concentration differences to 10 pptv based on half-hour sampling periods. Above canopy CH_4 fluxes averaged 22 +/- 4 μg/m2s from April to September, 1994. Thus, the aspen stand appears to be a net source of CH_4. These results are surprising since the aspen site was one of the drier sites at BOREAS, yet several researchers have reported CH_4 uptake in well aerated temperate and tropical soils. We are currently investigating possible explanations for the observed CH_4 emission at old aspen. N_2O fluxes averaged 1.4 +/- 0.7 $\mu g/m^2s$ during the same interval. Soil analyses indicated that there is very little available nitrate (NO_3) at this site, which helps explain the small fluxes.

Room/Salle: Multi-purpose Room **[2cOC] Tuesday/Mardi**

OCEAN CIRCULATION 1
CIRCULATION OCÉANIQUE 1

Chair/Président: Barry Ruddick

[2cOC1] Sensitivity of the circulation and large scale water mass properties in a global ocean GCM to stability dependent vertical mixing parameterisations

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The sensitivity of the circulation and water mass properties in a global ocean circulation model (OGCM) to various stability dependent parameterisations of vertical mixing is investigated. The resolution is similar to that typical of OGCM being coupled to atmospheric GCM in climate models and the parameterisations investigated are all computationally inexpensive enough to allow for integrations on long time scales.

Under the assumption of constant vertical eddy coefficients (control case), the model climatology displays North Atlantic Deep Water (NADW) formation at a rate of 14 Sv, an Antarctic Circumpolar Current (ACC) of 124 Sv, Indonesian through- flow of 19 Sv and an excessively deep and diffuse pycnocline structure with weak stratification in the deep ocean. It is found that these circulation and water mass properties are sensitive to the choice of parameterisation of vertical mixing and that determining a scheme which works satisfactorily over all regions (tropical, mid-latitude, and polar) of the domain is not straightforward. Richardson number dependent schemes developed to improve the representation of the tropical currents and thermocline appear to lead to significant weakening (by up to a factor of 2) in the NADW formation and ACC intensity. Schemes involving a parameterisation of internal wave breaking through the Brunt-Vaisala frequency lead to small improvements in the model NADW, ACC and poleward heat transport when compared to the control case. Various other schemes which include parameterisations of processes thought to be important in interior mixing in the ocean are considered but identification of one that consistently performs better than constant eddy coefficients over all regions has not been possible to date.

[2cOC2] Passive tracer uptake by an ocean general circulation model during climate change scenarios

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The impact of changing ocean circulation on the distribution of a surface released tracer is examined. An idealized basin geometry is used with the Bryan-Cox ocean general circulation model. Several mixing parameterizations are used: lateral, isopycnal and GM90 (Gent and McWilliams, 1990). Changing ocean circulation is produced by warming and cooling scenarios. Two tracer release strategies are employed, gradual and sudden release to mimic natural and anthropogenic tracer release from the atmosphere. This provides a simple, first order surrogate for carbon dioxide release. It is found that the transient response of the ocean to a warming scenario suppresses the sequestering of a passive tracer. The transient response to a cooling scenario has the opposite effect.

[2cOC3] A Finite Element Semi-Lagrangian Barotropic Ocean Model

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We use for the first time in ocean modelling the combination of the finite element and semi-Lagrangian methods. The barotropic two dimensional flow is simulated by discretizing the shallow water equations.

The finite element method has many advantages in ocean modelling: precision, conservation of energy and

enstrophy, and especially the flexibility of triangulation in the natural treatment of boundary conditions. A triangular unstructured mesh is used to obtain an homogeneous grid.

To avoid a severe time step restriction due to the presence of high speed surface gravity waves, the semi-Lagrangian treatment of advection is combined with a semi-implicit treatment of gravitational oscillations. The two-time level advection scheme used is second-order accurate in time, and allows stable integrations with Courant numbers that exceed unity. The accuracy of the treatment of Rossby waves, which should be at least to fourth order, is determined by the precision of the advection. Thus a major difficulty is to find an interpolator which is at least fourth order accurate in an unstructured mesh. We have developed such a scheme, using a dual kriging interpolation which gives better precision than $O(\Delta x^4)$. Furthermore, mass conservation is well satisfied.

To remove the spurious oscillations of the shallow water equations, we use a staggered grid with linear non-conforming elements for the velocity variables and linear conforming elements for the height variables. For boundary nodes the direction of the normal is defined without ambiguity and free slip boundary conditions are used.

Preliminary results are shown for the eddy shedding phenomenon in the Gulf of Mexico.

[2cOC4] The effect of momentum dissipation parameterizations in thermohaline circulation models using the Planetary Geostrophic equation.

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A hierarchy of simplified thermohaline circulation models are used to show how boundary layer structure can influence the large-scale oceanic circulation and thermohaline oscillations. A three-dimensional ocean-circulation model is developed in idealised geometry using diagnostic planetary geostrophic dynamics and fully prognostic equations for temperature and salinity. Horizontal momentum dissipation is parameterized by linear Rayleigh friction, and different methods are used to solve for the non-hydrostatic boundary layers. The results are then compared to those obtained using traditional Laplacian dissipation and also using fully prognostic dynamical equations. The comparison is based on very similar atmospheric forcing, in order to analyse the effect of only the parameterization change in each run.

[2cOC5] An OGCM for Coupling to the CCCMA AGCM

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An Ocean General Circulation Model (OGCM) based on the GFDL MOM code is modified for coupling to the CCCMA Atmospheric General Circulation Model (AGCM). The OGCM has 29 vertical levels and at $1.875° \times 1.855°$, it has twice the horizontal resolution of the AGCM. Ocean-only experiments are conducted with annual mean forcing to examine the sensitivity of various choices of external forcing, internal parameters and topography. To minimize the use of computing resources, a standard asynchronous timestepping scheme is used in these tests, which involves integration for thousands of model years.

In preparation for the coupling of the OCGM to the AGCM, a climatology based on a time-varying forced OGCM with synchronous timestepping is required. To avoid the larger amounts of computer time needed to integrate for thousands of years with synchronous timestepping, a technique is developed by starting from an equilibrium annual mean climatology and adapting to time-varying forcing, with synchronous timestepping. First, time-varying relaxation fields of temperature and salinity are introduced, after that timestepping is made synchronous. Finally, windstress is allowed to vary in time as well.

[2cOC6] An Operational Oceanographic Model for the Northeast Pacific

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Oceanographic analyses are performed by naval Meteorology and Oceanography (METOC) Centres. The principal result of this work is an ocean feature description, or "nowcast", that is used to predict the performance of acoustic detection systems. There was a requirement to enhance the quality and flexibility of these analyses, and to direct output of physical oceanographic fields to acoustic models. This was accomplished by the integration of observations into an objective analysis (OA) program, coupled with a sophisticated visual display of both observational data and the objective analysis results.

There was also a need to generate oceanographic forecasts out to seven days. A prototype modelling capability has been recently implemented using the "Princeton Oceanographic Model" (POM), also referred to as the Mellor-Blumberg three-dimensional finite-difference ocean model. The specific domain is the Northeast Pacific north of 45xN, east of 150xW, using a curvilinear, 5km grid.

The paper will review the results achieved to date; describe interfaces for obtaining meteorological forcing data from the Canadian Meteorological Centre (CMC); and detail how initial oceanographic conditions are specified. Finally, intentions for future development of this ocean modelling system at the METOC Centre will be discussed.

Room/Salle: Multi-purpose Room **[2dAM]** Tuesday/Mardi

ATMOSPHERIC MODELLING 1
MODÉLISATION DE L'ATMOSPHÈRE 1

Chair/Président: Norm McFarlane

[2dAM1] Numerical Simulation of a Secondary Cyclogenesis Event during CASP II

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Although there have been marked improvements in the model predictability of rapidly deepening extratropical cyclones, many operational models still have great difficulties in predicting secondary cyclogenesis that often begins as a mesoscale vortex embedded in a larger-scale cyclone. furthermore, little attention has been paid in the past to the understanding of these baroclinically driven mesoscale phenomena, owing partly to the lack of high-resolution observations and partly to the coarse grid resolution used in operational numerical weather prediction models. Of particular interest is that under certain circumstances, these baroclinically driven mesovortices can deepen rapidly and eventually overpower the primary cyclonic system.

There are several instances of secondary cyclogenesis that occurred during CASP II (Canadian Atlantic Storms Program); the 13 - 15 March 1992 case is just one of the samples. In the present study, a 48-h real-data numerical simulation of the 13-15 March secondary cyclogenesis has been carried out using a mesoscale model with a grid size of 30 km. The model we used includes i) the Fritsch-Chappell convective scheme; ii) an explicit moisture scheme containing the prognostic equations for cloud water (ice) and rainwater (snow); and iii) a realistic boundary-layer parameterization scheme.

The model reproduces very well the secondary cyclogenesis from a mesotrough over the southeastern U.S., that is superposed on a north-south-oriented large-scale cold front. The system deepens 30 hPa into an intense cyclone within 48 h as it propagates northeastward over the Atlantic ocean. In contrast, the simulated primary cyclone, which is nearly quasi-stationary over central Quebec, weakens 6 hPa during this period. Both the simulated track and intensity of the primary and secondary cyclones compare favorably to the analyzed. The model also reproduces very well the structure and evolution of the cold front, its interaction with the secondary cyclone, and the associated mesoscale cloud systems, as verified against available observations.

Then, a series of sensitivity simulations and diagnostic analysis have been conducted to gain insight into the dynamical and physical processes leading to the secondary cyclogenesis. It is found that i) the baroclinic forcing helps initiate the vortex circulation; ii) the weak surface drag over the ocean accounts for a large portion of the rapid deepening; and iii) the intense surface heat and moisture fluxes, and latent heat release help enhance the

development of the secondary cyclone.

[2dAM2] On the Sensitivity of GCM Climate Simulation to the Parameterization of Surface Fluxes

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new simple surface-flux parameterization is presented and its impact on climate simulations with the Canadian Climate Centre GCM is discussed. The parameterization is based on the Monin-Obokov similarity theory with flux-profile relationship of Dyer(1974) for the unstable conditions and Beljaars and Holtslag(1991) for the stable conditions. The proposed flux parameterization yields surface transfer coefficients that are considerably different from those used in the standard flux formulation of the GCM for conditions away from neutral. The impact of this parameterization and its sensitivity to vertical resolution will be discussed using seasonal climate simulations. For stable conditions over land marked differences are found in the surface heat and moisture fluxes and surface temperatures. In general however the two formulations produce similar results over-all.

[2dAM3] An upgrade of the Canadian Global Spectral Forecast Model

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In June 1993 the horizontal resolution of the global spectral model used for data assimilation and medium range forecasts at the Canadian Meteorological Centre (CMC) was increased from a triangular 79-wave (T79) truncation to a T119 truncation. At the same time significant modifications were introduced in the physical parameterizations. The conventional scores have indicated that the medium range forecasts continue to compare quite favourably with those produced by other leading forecast centres. Nevertheless, some specific weaknesses have been noted by operational meteorologists at CMC and elsewhere, and preliminary tests indicated that further increases in resolution should lead to more improvement in the meteorological performance. Consequently an improved version of the model has been prepared.

The Canadian global spectral forecast model was the first spectral model to use a semi- implicit semi-Lagrangian time integration scheme. This enables increased efficiency by taking advantage of larger time steps, but also can lead to a fictitious topographic resonance problem, especially at high resolution. For this reason, we incorporated an improved treatment of the mountains before increasing our spectral resolution to beyond T119. By increasing the spectral resolution to the limit of the waves that can be resolved on the "linear Gaussian grid", it is possible to cure another weakness that has been observed in the relative humidity forecasts in very cold air masses. A vertical decoupling problem that was noted in operations at CMC and has been greatly reduced by changing the vertical advection operator used in the model. Some of the physical parameterizations have also been updated to correspond with the versions used in the operational regional finite element model. Tests on a set of six cases have shown that the upgraded model gives improved forecasts, especially during the first three days of the medium-range forecast period.

[2dAM4] Atmospheric energetics of a fully compressible model: Preliminary results

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The atmosphere is a stratified compressible medium. Solving the set of governing equations with a fully compressible model leads to different type of waves, such as internal gravity waves and compression waves. The latter are often considered as beeing meteorologically irrelevant and are either filtered by an anelastic approximation (e.g., the Boussinesq approximation) or slowed down by using the semi-implicit integration scheme.

The importance of thermally forced compression waves in the upscale transfer of total energy from a localized heat source (e.g., latent heat released by a thunderstrom) has recently been emphasized by Nicholls and Pielke (1994).

Simulations that resemble those conducted by Nicholls and Pielke are performed with the fully compressible

nonhydrostatic MC2 (Mesoscale Compressible Community) model. The results show that the effect of compressibility is closely related to a term in the mass conservation equation which is proportional to the diabatic heating rate . The role played by this term from an energetic point of view, as well as its sensitivity to the semi-implicit scheme are discussed.

Reference: Nicholls, M.E., and R.A. Pielke, 1994: Thermal compression waves. Part I: Total energy transfer. Quart. J. Roy. Meteor. Soc., 120, 305-332.

[2dAM5] Fine-scale modelling of intense orographic precipitation over the Columbia River Basin and coupling with distributed hydrology models

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The simulation of precipitation occurring over complex and high-ampli- tude topography regions is still very difficult to achieve properly due to the large disturbances of the airflow over the mountains. The Colum- bia River Basin on the windward side of the Canadian Rockies is a local maximum in the monthly climatological precipitation maps. Several large hydro-electric dams occur along the Columbia downstream of Mica Dam. The present study is part of an integrated precipitation-runoff modelling ac- tivity that is testing a new generation of models for parts of the manage- ment of this important watershed. Large economic benefits are related to the potential improvements in the reliability and accuracy of these modelling tools. The forecasts from high-resolution mesoscale atmospheric models are coupled with distributed hydrology models. Two atmospheric models are used ; the first one is a 15 km version of the operational Canadian regional finite element (RFE) model. The other model (MC2) is a new non- hydrostatic finite-difference semi-Lagrangian nested model; the MC2 equations are more accurate and can be used at very high resolution. In the present study, the MC2 model is integrated on a sequence of spatial re- solution down to 5 km and the results are compared with the RFE. The preci- pitation and surface temperature fields are coupled with two distributed hydrologic models, SLURP and WATFLOOD; these models use a satellite-derived land cover classification and have spatial resolutions compatible with the RFE and the MC2 respectively. The precitation forecasts together with synthetic hydrographs for the Columbia affluents are compared with available observations.

[2dAM6] The performance of semi-Lagrangian transport scheme for the advection-condensation problem.

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A series of numerical experiments are carried out solving a coupled set of equations for advection and condensation with a semi-Lagrangian (SL) transport scheme. Canonical validation tests in one dimension show that SL suffers less numerical aberrations than most other Eulerian schemes. Some monotonic transport constraints are experimented with. These tests confirm for SL transport, the statement first enunciated by Grabowski and Smolakiewicz (1990) within the context of Eulerian transport, that monotonic transport constraints are not sufficient to prevent the devel- opment of false ripples when integrating coupled field equations. A constraint is developed and succesfully applied to the simplified ad- vection-condensation problem. A two-dimensional dynamical model based on the Euler equations solved with semi-implicit semi-lagrangian scheme is used to simulate the classical moist bubble convection problem; these SL solutions are compared to published results obtained with Eulerian models. The problem of downward convection caused by evapora- ting cloud water is also modelled, and the numerical results are compa- red with those obtained in a laboratory experiment. These experiments show that (1) the original (unsconstrained) SL trans- port scheme does produce some small ripples, (2) these ripples are smaller than with most Eulerian schemes, but (3) they may be amplified through the interaction with the condensation microphysics when abrupt concentration changes occur; however (4) in most applications, these ripples do not seem to contaminate unduly the results of SL simulations.

Room/Salle: Arts 108 [2dAQ] Tuesday/Mardi

AIR QUALITY
QUALITÉ DE L'AIR

Chair/Président: Ian McKendry

[2dAQ1] Ozone and Meteorological Profiles in the Lower Fraser Valley, B.C.

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Atmospheric profiles of tropospheric ozone, temperature, humidity and winds were obtained from two sites in the Lower Fraser Valley of British Columbia during several days in the summers of 1992 and 1993. These profiles highlight the importance of mesoscale meteorology and the formation of low level inversions on the concentration of ground level ozone. The behaviour of the ozone profiles in the lowest layers of the atmosphere were observed to follow the expected diurnal cycling. Above the low level inversion, concentrations of ozone during the 1992 study increased during the study in response to a subsidence inversion capping the Valley. This subsidence inversion was not present for most of the 1993 program. However, on the 4th and 5th of August, 1993, a transient subsidence inversion did develop and concentrations of ozone above the low level inversion did increase. This behaviour demonstrates the importance of the subsidence inversion in capping the valley, promoting a return circulation of pollutant.

[2dAQ2] Down-mixing of elevated pollutant layers over the Lower Fraser Valley - a case study

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During Pacific'93 (an intensive field study investigating the photochemistry and meteorology of summertime air pollution episodes in the LFV) elevated pollutant layers were a commonly observed phenomenon. Layers could be attributed to a number of formative mechanisms including the ejection of material aloft from heated valley side-walls and the injection of material into the boundary layer capping inversion from convective activity. The mechanism contributing to an elevated layer that developed at the end of a mild photochemical episode is described and vertical tethersonde profiles of ozone during subsequent daytime down-mixing are presented. A simple model based on transilient theory provides an estimation of the contribution of non-local vertical mixing (as opposed to advection and ozone formation) to the observed temporal variation in ground-level ozone concentrations.

[2dAQ3] Aircraft surveys of ozone in a tributary valley of the Lower Fraser Valley

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Previous studies suggest that the Pitt Lake Valley represents a major sink for ozone emanating from metropolitan Vancouver. A simple, cheap method of investigating horizontal and vertical variations of ozone in the lower troposphere using a light aircraft and fast response chemiluminescent sensor is described. Comparisons of aircraft concentrations with those from surface based and tethersonde borne instruments show good agreement and confirm the accuracy of the method. Low-level flights in the the vicinity of Pitt Lake reveal a consistent pattern of concentrations that increase with distance up the tributary valley. Similar patterns were observed during Pacific'93 and suggest that advection of pollutants into the tributary valleys of the LFV may have significant impacts on local ecology and visibility.

[2dAQ4] Predicting surface ozone concentrations in southwestern British Columbia based on readily available meteorological parameters.

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The Lower Fraser Valley (LFV) British Columbia episodically experiences periods of elevated ozone concentrations. Pryor et al. (1994) report that the 82 ppb National Ambient Air Quality Objective (NAAQO) was exceeded for at least one hour at one or more of the 24 monitoring sites in the LFV on 70 of the 828 days (8.5 %) during July to September, 1984-1992. It has previously been shown that synoptic scale meteorological conditions exert a profound influence on the daily maximum ozone concentrations in the region (e.g. McKendry 1994), and that inter-annual variations of synoptic scale meteorology are partially responsible for the observed inter-annual variation in the frequency of exceedence of the NAAQO (Pryor et al. 1994). The scheme currently used to predict ozone concentrations in the Vancouver region, whilst accurate, requires a large number of input parameters related to prevailing meteorology and precursorconcentrations to ensure reliable forecasts. In this paper we examine the potential for using four predictors; (i) location of the 500mb ridge, (ii) thickness of the 1000-500mb layer, (iii) maximum northward extension of the 100C isotherm at 700mb, (iv) maximum northward extension of the 200C isotherm at 850mb, to forecast surface level ozone concentrations by examining the historical record from the summers of 1984-1992.

References. McKendry I. G. (1994): Synoptic circulation and summertime ground-level ozone concentrations at Vancouver, British Columbia. Journal of Applied Meteorology 33 627-641. Pryor S. C., McKendry I. G. and Steyn D. G. (1994): Synoptic-scale meteorological variability and ozone concentrations in Vancouver, B.C.. In press, Journal of Applied Meteorology.

[2dAQ5] Combined meteorological and photochemical modelling of ozone episodes in the Lower Fraser VAlley, B.C.

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The Lower Fraser Valley of B.C. frequently experiences episodes of tropospheric ozone pollution in excess of Federally established guidelines. In order to guide the development of an air management plan for the region, we are applying a regional air quality modelling system to selected episodes in the valley. The modelling system consists of the EPS-2 emissions model, the Colorado-State University Regional Atmospheric Modelling System and version IV of the Urban Airshed Model. Air quality and meteorological data from existing networks, augmented by additional data collected as part of an intensive study of mixing heights in the summer of 1985, form the basis of a three-day modelling study of the episode extending from July 18th - 20th. We highlight important features of local emissions and meteorology, and difficulties encountered in integrating the two models. Paired and unpaired peak accuracies for hourly averaged ozone are shown to be within acceptable limits, but the modelled position of the urban plume is shown to be displaced eastward from its measured position. Sensitivity analyses are used to explore the causes of this deficiency.

[2dAQ6] Measurements of biogenic volatile organic compound emissions from agricultural surfaces in the lower Fraser valley.

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Volatile organic compounds (VOCs) participate in the oxidation of NO to NO2, and hence in the formation of ground-level ozone. A knowledge of the relative contributions of biogenic and anthropogenic VOC sources is essential to the design of control strategies for ozone. Measurements of VOC fluxes from several important agricultural crops in the lower Fraser valley (potatoes, pasture, raspberries, blueberries, cranberries) were made using a micrometeorological gradient technique. These data were combined with previous measurements from

additional important crops (eg. corn) to conclude that agriculture does not appear to be a strong contributor to the VOC load in this region. Comparisons will be made between fluxes from agricultural surfaces and emissions from tree species that are know to be strong VOC producers.

Room/Salle: Auditorium [2dBO] Tuesday/Mardi

BOREAS 1
BOREAS 1

Chair/Président: Barry Goodison

[2dBO1] Overview of Twin Otter Flux Measurements in BOREAS

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From May to September 1994, the NRC Twin Otter atmospheric research aircraft was flown as one of the trace gas flux measuring aircraft during the Boreal Ecosystem/Atmosphere Study (BOREAS). The aircraft was fully instrumented to measure the mean and turbulent components of atmospheric motion, the vertical fluxes of sensible and latent heat, momentum, C02, and ozone, as well as supporting meteorological and radiometric data. A total of 57 project flights were flown in the vicinity of Prince Albert Park, Saskatchewan and Thompson, Manitoba, and on transects between these sites. Over 16,000 km of wind, turbulence and flux data were collected at altitudes of 30 -100 m during this program.

Preliminary analysis of data collected on repeated grid flights has revealed relatively high Bowen ratios (sensible/latent heat flux), which were related to the development of deeper boundary layers than anticipated. During these flights, the aircraft encountered a significant number of strong, coherent vortices, one of which produced a vertical gust of 11.4 ms-1, the largest measured by this aircraft in 20 years of research flying. It is thought that these vortices were a result of the rapid development of the deep boundary layers. The grid flight data also suggests a de-coupling between the radiometrically sensed surface temperature and the measured sensible heat flux, implying that estimating sensible heat fluxes from satellite radiance data may be difficult for the boreal forest. On the other hand, C02 fluxes measured on long transects between the study areas appear to be well-correlated with the aircraft-measured ratio of near-infrared to red radiation. This result shows promise for estimating CO2 exchange rates from satellite-derived spectral data.

[2dBO2] On determination of surface source and sink distribution of energy and gases from airborne observations in BOREAS

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Correct prediction of source and sink distribution is of interest in the estimation of regional energy-, hydrological- and trace gas balances. In BOREAS, which attempts to link remote sensing radiometric data to forest-atmosphere exchange processes, aircraft were used to observe surface source and sink distributions at scales commensurate with remote sensing observations. During BOREAS 1994, the Canadian Twin Otter flux aircraft flew 23 grid flights, each consisting of 18 lines over a 16 km x 16 km area. Attempts at 'mapping' surface source and sink distributions for sensible heat, latent heat, carbon dioxide and ozone over these areas are complicated by the complexity of large-scale turbulent structures encountered over the sites. These are related to the high Bowen ratios, leading to rapid development of deep convective boundary layers, and make objective determination of averaging and detrending procedures for eddy correlation flux estimates, and objective separation of local from mesoscale transfer processes, very difficult. Our tentative solution to this problem is based on optimizing the ratio of gradient to counter-gradient transfer processes detected in the flight data. The potential and limitations of relating the resulting 'flux maps' to maps of radiometrically observable surface characteristics

will be discussed.

[2dBO3] A new bulk aerodynamic formulation for heat flux constructed from BOREAS Electra data.

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This study analyzes NCAR Electra measurements of surface radiation temperature, air temperature and the turbulent heat flux during the Boreal Ecosystem-Atmospheric Study (BOREAS). To prevent negative, or extremely large values of the exchange coefficient, the spatially averaged surface radiation temperature is replaced by an effective surface temperature which includes the influence of spatial variability of the surface radiation temperature. As an instructive side study, the relationship of the surface radiation temperature and heat flux to the Normalilzed Difference Vegetation Index is examined. This is carried out after the radiometer measurements are subjected to calibration procedures and a model of downward spectral transfer to convert reflected limited band width radiation to reflectances.

To correct for erratic behavior of the exchange coefficient under light wind conditions, a generalized velocity scale is used based on the work Godfrey and Beljaars (1991), Stull (1994) and Mahrt and Sun (1995). A new bulk aerodynamic formulation is offered which avoids erratic behavior of the exchange coefficient ocurring with application of the traditional bulk aerodynamic relationship over the boreal forest and also corrects for defficiencies encountered in other flow situations.

[2dBO4] Relationship of the heat flux to microscale temperature variations: Application to BOREAS

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The surface heat flux is normally parameterized in terms of the difference between the air temperature and the surface radiative temperature, or equivalently, the temperature computed from the surface energy balance. In this study, the relationship between the heat flux and the air-surface temperature difference is shown to be sensitive to the microscale variability of the surface radiation temperature and transfer efficiency. These conclusions are based on surface and aircraft data collected during the Boreal Ecosystem-Atmosphere Study (BOREAS).

Preliminary observations of the microscale distribution of surface radiation temperature and Twin Otter aircraft measurements imply that the upward heat flux over the boreal forest is due almost exclusively to the sunny sides of the tree tops and sunny open ground. Shaded ground and moist surface areas, seen by the downward looking radiometer, decrease the spatially averaged surface radiation temperature and cause the spatially averaged surface temperature to be close to, or even cooler than, the spatially averaged air temperature. This occurs in spite of significant upward heat flux, As a result, the exchange coefficient must be much larger than typically predicted by similarity theory or even negative.

In order to predict the upward surface heat flux, the bulk aerodynamic formula must be generalized to include information on the microscale spatial distribution of the surface radiation temperature and transfer efficiency. In the present study, the bulk aerodynamic relationship and gradient flux are restored by weighting the surface temperature according to the efficiency of heat transfer.

[2dBO5] Tower flux measurements at the BOREAS Old Aspen Tower Site

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As part of BOREAS, an eddy flux tower site was established in an 80-yr old aspen stand in the southern part of Prince Albert National Park, Sask. These measurements were made to address specific scientific objectives formulated by the Old Aspen Tower Site (OATS) research group (comprised of ourselves and colleagues from the

Department of Soil Science, U.B.C. and the Department of Land Resource Science, U. of Guelph) and to satisfy the needs of the BOREAS climate modellers. Our particular objectives were to quantify the energy budget and the carbon exchange above the canopy over a annual cycle, including an examination of the controlling processes. A description of the site and the suite of measurements is provided. In addition to eddy correlation flux measurements above the canopy, supporting meteorological and concentration measurements were made above and within the canopy as well as from a tethered balloon. Measurements were made from early October 1993 to late September 1994. Selected results are presented to illustrate changes in fluxes and climatic variables over the annual cycle and the changes associated in going from a leafless to a fully developed canopy. Carbon dioxide fluxes were small upward through the winter period with little diurnal variation. In the spring, these upward fluxes increased until leaf-out. After leaf-out strong diurnal patterns developed with large downward fluxes during daylight and moderate upward fluxes at night. Integration of the fluxes over our measurement period provided an estimate of the annual carbon uptake by the aspen ecosytem.

[2dBO6] Eddy correlation measurement of carbon dioxide fluxes beneath a boreal aspen forest canopy

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The eddy-correlation technique was used to continuously measure carbon dioxide exchange just above the hazel understory of an 80- year old boreal aspen forest. These measurements were a part of a BOREAS project at the Old Aspen Tower Site (OATS) in Prince Albert National Park, Saskatchewan. Researchers participating in this project were from the Atmospheric Environment Service, the University of Guelph and U.B.C. Measurements were made during October and November 1993 and from April to September 1994. A 3- dimensional Solent model 1012R2A sonic anemometer was used with a closed-path CO2/H2O infrared gas analyzer (LI-COR model 6262) with air drawn at 8.5 L/min down a 3-m long, heated sampling tube. Leaf area index of the aspen and hazel canopies reached 1.9 and 3.5, respectively, by mid-summer. Downward fluxes of CO2 above the hazel were only observed during the daytime during June and early July. Nighttime fluxes, for which the standard deviation of the vertical velocity was greater than 0.15 m/s, were used to obtain an exponential relationship between soil CO2 efflux and soil temperature at the 2-cm depth. Fluxes calculated using this relationship agreed well with daytime measurements of soil CO2 efflux using the transient-chamber technique. These fluxes increased from 0.02 mg/m2/s in late winter to 0.35 mg/m2/s in mid-summer. Gross photosynthesis of the hazel was estimated as the difference between calculated soil CO2 efflux and the above-hazel eddy correlation CO2 flux. The cumulative value of gross hazel photosynthesis for the 1994 growing season was approximately 0.3 kg C/m2 or about 30 % of that of the aspen-hazel ecosystem.

Room/Salle: Arts 116 **[2dCI]** Tuesday/Mardi

COASTAL OCEAN AND INLAND WATERS 2
OCÉAN CÔTIER ET EAUX INTÉRIEURES 2

Chair/Président: William Crawford

[2dCI1] Hydrodynamics of a Large-Scale Estuarine System: The St. Lawrence

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A full three dimensional non-linear prognostic model was developed to study the hydrodynamics and water circulation in the St. Lawrence estuary. The model is based on a fine mesh (2 km by 2 km) finite difference grid in the horizontal and 20 levels of variable thickness in the vertical. It is semi-implicit and the surface elevation is obtained by iteration. This approach allows the barotropic mode to be independant of the CFL criterion, so that larger time-steps could be used (of the order of 10 minutes). The vertical eddy viscosity coefficient

depends on both shear and Richardson number (baroclinic cases). When operating in prognostic mode, the horizontal advection of density is done along characteristics. The model is used to simulate the five major tidal constituents in the study area, namely M2, S2, N2, K1 and O1. Good agreement was obtained when comparing the calculated tidal elevations and streams with observed data from tide gauges and current measurements. The model is also used to simulated wind induced circulation in the estuary. Diagnostic simulations (using fixed density fields) are carried out to study the residual circulation, and prognostic simulations are used to better understand the relative effects of tide, wind and density variations (including river discharges) on the water circulation. The results suggest that the instantaneous circulation in the entire estuary is governed by tidal processes. Tides also drive the long-term residual circulation in the upper estuary, while density gradient control the long-term residual circulation in the lower part of the estuary. On some occasions, strong winds blowing steadily for long periods can contribute to the overall residual circulation in the lower part of the study area.

[2dCI2] On the Separation/Intrusion of the Gaspe Current and Variability in Baie des Chaleurs: Observations and Modelling

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Hydrographic and current meter data are used first to study the variability of both dynamics and thermodynamics in the Baie des Chaleurs (BdC, Gulf St. Lawrence) and its relation to the separation/intrusion of the unsteady Gaspe Current. A numerical model is then applied to gain insight into the problem. The model developed is an eddy-resolving upper ocean model and has primitive equation dynamics with two active layers embedded with a Kraus-Niiler type mixed layer model at the top.

Both observations and model results indicate that seasonal variations in the BdC are strongly related to the characteristics of separation/intrusion of the Gaspe Current (GC), which is mainly controlled by its transport magnitude as well as phase, duration and strength of its acceleration (or deceleration). The separation occurs when (adverse) vorticity having an opposite sign from that existing upstream is generated near the separation area. Although the separation can be generated in a decelerating GC, it can also occur in an accelerating GC when the GC is strong enough to advect upstream vorticity necessary to form a recirculation and the related adverse vorticity downstream. The GC intrudes either along the coastline (attachment) into the bay in a non-separated GC or following the separated GC (reattchment). Effects of various physical processes on the separation/intrusion and variability of eddies in the BdC are examined.

[2dCI3] Heterogeneity of Tidal Flow Structure Near a Promontory

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To investigate the heterogeneity of flow structure around coastal promontories, a shipboard ADCP and moored current meters (RCM-4 and 7) were used in the vicinity of the Anse du Petit Mitis bay in the lower St. Lawrence Estuary during summer 1994. The scale of the promontory is approximately 2 km. Six moorings were deployed in and outside the bay during July and August. Ten daily operations of the ADCP provided 3 dimensional flow measurements along one of 4 different tracks (2 closed and 1 open), with each operation lasting ~ 8 to 9 hours for repeated traverses. The two closed tracks covered a hypothesized zone of flow transition (coastal boundary), while the other consisted of straight transects parallel to the shore at a constant separation of ~ 1 to 2 km from the shore. In the bay, mean-flow estimates over the mooring period were estimated to be relatively small (~ 1 cm/s) in the bay, compared to the magnitude of the low-frequency fluctuations (~ 5 - 10 cm/s). This indicates the eddy circulation driven by tidal current interaction may not be easily identified from subtidal flow signals in the bay. Meanwhile, outside the bay were estimated mean flows of 5 - 6 cm/s. The results of tidal analysis on ADCP measurements were used to determine the crosschannel variation of alongchannel tidal currents and the vertical vorticity. Using the closed track patterns, the vorticity was computed using the Stoke's circulation theorem on the estimated tidal currents. Higher vorticity estimates ($\sim 1 * 10^{-3} s^{-1}$) were located near the tip of promontory, while lower ones ($\sim 10^{-4} s^{-1}$) in the bay. A significant crossshore transition of alongshore current was identified along an isobath between ~ 5 and 10 m, by which two different dynamic regimes can be defined.

[2dCI4] The modification of tidal currents by a small bay in the St. Lawrence Estuary

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Data were collected at L'Anse du Petit Mitis, a bay 5km in extent on the south shore of the lower St. Lawrence Estuary, during July and August of 1994. Water velocity data from 6 moored RCM's are analysed to describe the effect a bay has on tidal currents and possible retention of water within the bay over several tidal cycles.

Harmonic analysis was performed on the data set. Currents were strongly semi-diurnal with the M2 tide predominating. Outside of the bay more than 75 % of the statistical variance was attributed to tidal frequencies, whereas inside the bay less than 45 % of the statistical variance was due to tidal frequencies. Outside of the bay tidal currents were oriented alongshore, while inside the bay there was no such orientation. Current magnitudes are an order of magnitude weaker within the bay.

An analytic model for estimating the residence time of conservative and non-conservative tracers in the bay is developed. Average mass fluxes out of the bay are estimated using Eulerian averages of the data plus a Stokes' drift correction. Residence times on the order of 10 days are estimated for conservative tracers. Critical values for doubling time were computed for non-conservative tracers with first order growth rates. Concentration of tracers with doubling times less than the critical value increased exponentially within the bay, whereas the concentration of tracers with longer doubling times decreased exponentially.

[2dCI5] The response of Baie des Chaleurs to the passage of a strong storm.

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The main objective of this study is to better understand the importance of water temperature and circulation variability on the spawning, larval drift and settlement of the giant scallop population in the Baie des Chaleurs. Strong storms are one mechanism that can cause wide variations in temperature and currents due to upwelling/downwelling and high level of vertical mixing. These events are thought to be a major link between scallop spawning and the physical environment. Earlier investigations show good relations between storm frequency and recruitment. In the present study, we describe the response of the bay to the passage of Bertha, a hurricane that traveled up the east coast of the United-States and propagated across the Gulf of St.Lawrence as a strong extratropical system in August 1990. Preliminary results based on time series and Fourier analysis show a strong response of the current field to the cyclonically rotating winds and wide variations of temperature along the north shore of about 9 degrees Celsius during a time interval of about 2 days. We also investigate the response of the bay to the passage of an extratropical cyclone which is very frequent in the region and generates the westerly winds that prevail over the bay.

[2dCI6] Modeling the mean circulation of the Labrador and Newfoundland shelves

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The mean circulation of the Labrador and Newfoundland shelves is investigated using a linear three-dimensional diagnostic model. The model domain is a rectangle encompassing the Labrador Sea and the Grand Bank, and the grid size is 20 km. Seasonal mean density data with a resolution of 1/6 degree compiled by DeYoung et al. (1994) were used to compute the pressure gradient terms in the momentum equations. The circulation is forced by a sea surface elevation at the northern boundary, which was tuned to produce a 35 Sv transport across the Hamilton Bank section. A comparison of the model results with observations indicates that model is able to reproduce the main features of the observations. The circulation in the northern Labrador Sea is characterized by a basin scale cylonic barotropic flow, a strong Labrador Current over the shelf edge and a strong Greenland Current off the Greenland coast, and a broad and weak baroclinc currents over the continental shelve. In the southern Labrador Sea, the circulation pattern is more complex and buoyancy effects become more important.

Several eddies exist off the shelf and in the central Labrador Sea, and a branch of the Labrador Current separates from the shelf edge and flows off-shore east of the Hamilton Bank. The winter surface currents computed from the model are in good agreement with currents derived from ice beacon trajectories. The calculated southward transport at the Hamilton Bank section in winter is greater than the summer transport. The difference in transport between winter and summer is much greater than that calculated from barotropic models. This suggests that density cannot be neglected in transport calculations using vorticity conservation.

Room/Salle: Arts 118 [2dOC] Tuesday/Mardi

OCEAN CIRCULATION 2
CIRCULATION OCÉANIQUE 2

Chair/Président: William Hsieh

[2dOC1] Measuring skill of ocean models against direct current observations

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We obtain measures of the skill of a global ocean model against a global inventory of long term, deep (>100 m) current meters. Skills include a measure of error kinetic energy and a measure of directional skill only (inner product of unit vectors). Results indicate that these skills are different from null and that refinements of model dynamics can improve the skills.

[2dOC2] Veronis effect diagnostics in ocean general circulation model

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Five tunable input parameters are varied in 26 simulations of an idealized ocean basin using the GFDL ocean general circulation model. The analysis consists of two parts. The first is an examination of the flow using familiar 0-dimensional measures such as the average kinetic energy density, etc. The model behaviour is consistent with earlier, less comprehensive, work. The second part of the of the analysis is an examination of various diagnostics of the Veronis effect as proposed in Gough and Lin (1995). These include the zonal overturning streamfunction, the number of downwelling points in the basin and in a localized sector, and the volume transport in the basin and sector. The net volume transport was found to be dependent on both the horizontal diffusivity (as expected) and the horizontal viscosity, a result not detected in earlier work. Implications of this are presented.

[2dOC3] Generalized two-layer models of the North Atlantic/Caribbean

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New solutions for non-inertial barotropic and baroclinic flow in the North Atlantic/Caribbean are presented using realistic bathymetry, and using a technique which enables relaxation to solution at much smaller values of friction than have previously been presented. The technique consists in exploiting the dynamical significance, in the barotropic case, of contours of h/f, where h is the depth of the ocean and f is the Coriolis parameter. A triangulation of the entire domain based upon points which lie on a small finite number of these contours is constructed. The result is a hybrid advection-diffusion upwind–finite-element scheme, in which the advective upwinding part is substantially less numerically diffusive than standard advective upwinding methods for finite-element schemes. In particular, in the absence of closed contours of h/f, and with no explicit diffusion, the scheme would be exactly hyperbolic, in that the solutions on neighbouring contours of h/f would be independent of each other. Following Salmon (1994; *J. Mar. Res.*, **52**, 865–908), baroclinicity is introduced in an idealized way, in which the potential vorticity is taken to be an arbitrary function of buoyancy. This constitutes a generalization of the concept of models of the large-scale circulation based on two immiscible layers, which can be recovered for discontinuous choices of the arbitrary function. The influence of baroclinicity and topography

on the separation of the Gulf Stream and the flow through the Florida Straights will be discussed.

[2dOC4] On the climatological heat and salt budgets at OWS Papa.

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Different hypotheses of the climatological heat and salt balnces at OWS Papa are tested using a one-dimensional model of vertical mixing with prescribed horizontal and vertical advection. Model computed vertical diffusion accounts for all but about 40 mm/yr of the estimated 137 mm/yr excess freshwater flux, but only about 2 W/m2 of the estimated 25 W/m2 excess surface heating. Assumming that the flux estimates are in error and flux correcting both the heat and freshwater fluxes leads to a systematic erosion of the main pycnocline and deepening of winter mixed layers, such that the surface waters become too cold and too salty. These trends are reduced but not eliminated by including vertical diffusion and a steady vertical advection due to Ekman pumping in the salt and heat budgets. Balancing the remaining heat by horizontal advection throughout the water column, results in a local minimum of too cold water at about 165m depth. However, acceptable long term simulations are achieved if the required cold water is advected into the seasonal thermocline and mixed layer only during the fall and winter months. Observations supporting this scenario are reviewed. Finally it is concluded that flux correction as practiced in many climate models can lead to erroneous oceans in cases where it is trying to account for oceanic transport deficiencies that are not both concentrated in the mixed layer and steady throughout the year.

[2dOC5] On the Spatial and Temporal Variability of Surface Heat Fluxes over the North Atlantic During Winter

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The exchange of sensible and latent heat across the air-sea boundary represents an important coupling between the ocean and atmosphere. The energy transferred by these fluxes plays a crucial role, on a variety of spatial and temporal scales, in the atmospheric and oceanic circulation. Traditional climatologies of the oceanic surface heat flux, based on marine ship reports, have been unable to give reliable estimates as to the magnitude of the fluxes in data sparse regions such as the high latitude marginal seas of the Arctic Ocean. In additional, they lack sufficient temporal resolution to provide an estimate as to the variability of the fluxes on timescales of one month or less. In this paper a new technique that does not suffer from these short comings will be introduced. It makes use of the ECMWFUs archive of objectively analysed fields to diagnose the surface heat flux fields. As will be shown, this new approach allows one to estimate the temporal and spatial variability of surface heat fluxes over the North Atlantic on both the fast, i.e. less than one month, and slow, i.e. greater than one month, timescales. With regards to the mean values of the sensible and latent heat fluxes, there is good agreement with the conventional climatologies in the mid-latitudes. The mean values derived are also consistent with the long-term climatologies for the various Ocean Weather Ships stationed in the North Atlantic, including those at high latitude locations in the Labrador and Norwegian Seas. It will be shown that the transfer of heat and moisture across the air-sea interface is a highly episodic process with the variance about the mean of the same order as the mean itself. It will also be shown that the occurrence of extreme events characterized by large fluxes of heat from the ocean to the atmosphere are not uncommon. Evidence will be presented that supports the hypothesis that there is a relationship between the North Atlantic Oscillation and the low-frequency variability in the surface heat flux fields. The implications that these results have with respect to such processes as water mass transformation and deep water formation will also be discussed.

[2dOC6] Seasonal variation of the three-dimensional circulation over the eastern Scotian and southern Newfoundland Shelves

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The seasonal mean circulation over the eastern Scotian and southern Newfoundland shelves is studied numerically using a three-dimensional diagnostic circulation model. The model is forced by seasonal mean baroclinic

pressure gradients and barotropic upstream inflows. An extensive set of density data is used to determine climatological mean forcing. The barotropic upstream inflows are specified at the applicable open boundary either as an along-boundary elevation gradient or a depth-integrated normal velocity. Emphasis is placed on the seasonal variation of 3-d velocity fields and depth-integrated transports. The numerical solutions, in conjunction with other observations and previous interpretative studies, support the conventional understanding that circulation over the Scotian Shelf is dominated by the southwestward flow of relatively cool and fresh shelf water from the Gulf of St. Lawrence and Newfoundland Shelf. Moreover, pronounced "topographic-scale" influences of submarine banks, basins and cross-shelf channels on the circulation, such as Slope-Water inflows in channels, and anticyclonic (cyclonic) circulation tendencies over banks (basins), are revealed. The solutions are also compared with available current meter data over the Scotian Shelf.

Room/Salle: Multi-purpose Room **[3aPL]** Wednesday/Mercredi

PLENARY
ASSEMBLÉE PLÉNIÈRE

Chair/Président: Howard Freeland

[3aPL1] Environmental and Economic Perspectives on Climate Change

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The 1994 Special Report of the Intergovernmental Panel on Climate Change, and the draft set of 1995 Second Assessment Reports provide some new "consensus" perspectives on anthropogenically-driven climate change. These reports contain up-dated information on the natural sciences and sectoral impacts, but also include an overview of the social sciences and economics literature, developed by the newer Working Group III. Highlights of these reports will be presented. In addition, some observations will be offered on the possible relationships between climate change and increased frequency and severity of climate related disasters.

[3aPL2] The World Ocean Circulation Experiment - its achievements and its remaining challenges

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WOCE is arguably the most ambitious oceanographic experiment ever undertaken. Planned in the mid 1980s, its observations, started in 1990 will end in 1997. The completion of the observational phase is not expected to mark the end of the project but it will mark the start of the synthesis phase.

Major challenges remain, not least of which will be the assembly, quality control and synthesis of the diverse WOCE data sets into basin-wide and global WOCE climatologies for the 1990s. The assimilation of these data sets into models and the further development of ocean circulation modelling will continue to be a major activity of the international WOCE community.

The paper will summarise the major achievements of the programme to date, both in observations and numerical modelling, and will outline the strategy to be adopted by WOCE to meet the remaining challenges.

Room/Salle: Arts 108 [3bAW] Wednesday/Mercredi

ATMOSPHERIC WAVES
ONDES ATMOSPHÉRIQUES

Chair/Président: Norm McFarlane

[3bAW1] Evolution of gravity wave spectra with height and the parameterization of associated wave drag

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A parameterization of gravity-wave momentum deposition based on an extension of Weinstock's theory of nonlinear wave spectra has been developed. Unlike Weinstock's original formulation, our approach treats the low frequency part of the gravity wave spectrum as an additional background flow for higher frequency waves. The combined technique allows one to calculate frequency shifting and wave damping produced by this spectrum-induced background wind. The theory to be presented combines results of Weinstock's theory of nonlinear wave diffusion and Hines' Doppler spreading theory. For a monochromatic wave the formulae for wave drag reduce to those of Lindzen (1981). It is shown that two processes should be distinguished: the wave breaking due to instability-type interactions and the saturation due to nonlinear diffusion-like processes. The criteria for wave breaking and wave saturation in terms of wave spectra are derived. For a saturated spectrum the PSD dependence $S(m) = AN^2/m^3$ is obtained, where m is the vertical wavenumber, N is the Brunt-Vaisala frequency. and the coefficient of proportionality A is a slowly varying function of m and mean wind. For vertical wavelengths ranging from 10 km to 100 m and for typical wind shears A varies from 1/2 to 1/9. Results of calculations of spectral evolution with height as well as related profiles of wave drag and its spectral composition will be shown. These results reproduce variation of vertical wavenumber spectral tail slopes near the -3 value.

[3bAW2] Manifestation of the baroclinic-wave life-cycle in TOMS column ozone data.

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It has been demonstrated (see, for example Mote et al. JAS 48, (1991)) that synoptic-scale baroclinic waves are evident in TOMS column ozone data. We examine TOMS ozone composites for various stages and several categories of cyclones. These illustrate, in more detail, the ozone signature of cyclogenesis.

We use the NMC archive of 5 degree resolution sea-level pressure data to track, from 1979 to 1988, winter lows in the North Atlantic and characterize them by depth and rate of deepening. Corresponding TOMS ozone "storm centred" composites are then produced for several days surrounding the times of first appearance of the low, deepest, and most rapidly deepening points as well as subsets with constraints on depth, deepening rate and geographical region. Areas of statistical significance are determined using the t-test.

Composites constructed using all stages of development show a clear wave pattern with approxmately 50 degree wavelength, similar to that observed by Mote et al. Composites based on various stages in cyclogenesis illuminate the development of the disturbance in column ozone. Our preliminary results indicate that further subdivision according to depth and deepening rate will shed light on tropopause features relating to differences in these quantities, though for some categories, they are hampered at present by limited statistics.

[3bAW3] Predicting a shallow-water model and the atmospheric slow variability with an empirical normal mode auto- regressive model

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Long time series of a randomly forced shallow water model have been diagnosed with the empirical normal mode (ENM) method (Brunet 1994, JAS) for different forcing amplitudes. We then generate an auto- regressive

model using the ENM principal components. Prediction experiments show that the use of the mean state in constructing the empirical normal mode is a better choice when compared with other basic states. It is argued that the predictive skill of a model based on ENMs is better than other classical methods because of the monochromatic time behavior of this basis set. Motivated by these simple experiments, we tentatively show similar properties for the atmospheric winter slow variability using long time series of 3-D analysis.

[3bAW4] Envelope Radiation of Internal Gravity Waves by Kelvin-Helmholtz Billows

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It is now believed that stratified shear instability provides a significant source of internal gravity waves in the atmosphere. However, dynamically important gravity waves – those that propagate up into the the middle and upper atmosphere – possess horizontal scales that are more than an order of magnitude larger than the horizontal scales that are typical of stratified shear instability. A mechanism whereby modes of stratified shear instability can stimulate internal gravity waves of such greater horizontal scale has been proposed by Fritts (1982; 1984) and Chimonas and Grant (1984). This mechanism is referred to as envelope radiation and essentially involves the nonlinear interaction of modes of shear instability of varying horizontal scale. The viability of this mechanism has been demonstrated numerically by Fritts (1984).

In the present study we investigate the enelope radiation mechanism by allowing its natural development in numerical simulations of an unstable parallel shear flow. This is achieved by employing a model domain that accommodates and resolves 32 horizontal wavelengths of the fastest growing mode of Kelvin-Helmholtz instability. The flow is initialized with small-amplitude white-noise perturbations which allow a spectrum of unstable modes to initially develop within the shear layer. The initial evolution displays the spontaneous production of envelope structures of 5-10 waves of K-H instability. Eventually, internal gravity waves propagate away from the shear layer into the external flow. The horizontal scale of the radiated gravity waves closely matches the scale of the envelope structures initially present in the shear layer. One of the most striking results of this study is that the amplitude of radiated gravity waves is much smaller than suggested by the study of Fritts (1984). In addition, it is not clear if the radiated waves are forced by the initial envelope modulation of the modes of K-H instability or are forced by localized pairing events of K-H billows which occur at later stages in the development. In order to address this question, and better characterize the internal wave radiation, we have undertaken a Lighthill (1952) analysis of this problem in which Greens function techniques are employed to reproduce the internal wave response in the external flow from the localized nonlinear forcing within the shear layer.

Room/Salle: Auditorium **[3bBO]** Tuesday/Mardi

BOREAS 2
BOREAS 2

Chair/Président: Barry Goodison

[3bBO1] Eddy-correlation measurement of water vapour fluxes beneath a boreal aspen forest canopy

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Eddy-correlation measurements above the hazel understory of a mature aspen stand were made during October and November 1993 and from April to September 1994. This was part of the BOREAS project at the Old Aspen Tower Site (OATS) involving researchers from the Atmospheric Environment Service, the University of Guelph and U.B.C. The eddy-correlation sensors were a 3-dimensional Solent model 1012R2A sonic anemometer, a LI-COR model 6262 closed-path infrared gas analyzer with a 3-m long heated sampling tube and an open-path Campbell Scientific model K20 krypton hygrometer. The latter was used to evaluate the vertical wind velocity-humidity covariance spectrum obtained from the closed-path system and to determine the time delay

of the sampling tube. Energy-balance closure was evaluated using measurements of the sensible heat flux, net radiation, soil heat flux and heat storage in the hazel canopy. Net radiation was measured using a tram that travelled back and forth along a 100-m long transect carrying a Swissteco S-1 net radiometer and a S-14 miniature net radiometer. Fluxes were very small when snow was on the ground and before leaf-out of the hazel. After leaf-out, water vapour fluxes were close to zero at night and were well correlated with above-aspen net radiation during the daytime. Daily-average water vapour fluxes from the understory after leaf-out were approximately 30 % of the forest evapotranspiration. Lysimeter measurements showed that evaporation from the forest floor was < 5 % of the water vapour flux from the hazel.

[3bBO2] Measured and Modelled Isoprene Emissions from an Aspen Boreal Forest

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Isoprene was the dominant non-methane biogenic hydrocarbon measured within and above an aspen forest during the growing season of 1994. Maximum ambient isoprene mixing ratios reached 10 parts per billion during the mid-growing season (July). The peak values coincided with maximum solar radiation and canoopy temperature. Substantial isoprene concentration gradients existed above the forest canopy to estimate canopy flux densities using the gradient diffusion approach. Canopy isoprene fluxes ranged from 15 to 50 nanomoles (isoprene) per metre squared per second. The amount of carbon in these isoprene fluxes represented approximately 2 % of the photosynthetically fixed carbon by the aspen forest canopy. Using foliage isoprene emission rates and locally measured plant microclimate data, canopy isoprene emission rates were modelled and compared to the values derived from the gradient-diffusion approach. Comparisons revealed that modelled canopy isoprene emissions were consistently overestimated by a factor of two. The reasons for the discrepancies between modelled and measured canoopy isoprene fluxes will be presented.

[3bBO3] Seasonal and Geographic Variations in the Atmospheric Boundary Layer Above Boreal Forest

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The 1994 BOREAS field campaigns included upper-air soundings at seven sites which spanned the boreal forest between spring and early autumn. Serial soundings were made every 2 h between 12 and 24Z at the northern and southern study sites, and at five additional sites at 12, 18 and 24 Z. The day-time evolution of the mixed-layer will be analyzed and will be related to surface forcings and the upper-air budgets of heat and water vapour.

[3bBO4] Doppler radar observations of boundary layer turbulence and clouds during BOREAS

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NOAA/ETL operated a ground-based 35 GHz Doppler radar in the forest of northern Manitoba during the summer of 1994 as part of BOREAS. Although the radar was designed primarily for cloud detection, it can also measure winds and turbulence in the clear convective boundary layer, using floating insects and bits of vegetation as the microwave scatterers and air motion tracers. The radar has excellent sensitivity and resolution which allow fine- scale measurements to be obtained of very weak cloud features, including multiple layer situations. Measurements from BOREAS were obtained with 37.5 m range resolution from about 100 m AGL to near the top of the mixed layer for clear air targets and to 12.5 km for clouds. The radar operated continuously for 24 hour periods or longer in either a conical-scanning or a fixed-beam zenith-pointing mode. The conical mode provided 10 profiles per hour of boundary layer mean winds, momentum flux, and higher-order turbulence terms as well as the overlying cloud structure. The vertical mode allowed uninterrupted detailed measurements of the evolution of boundary layer vertical velocity fluctuations and the simultaneous cloud layer structure and kinematics. The radar observations complement those of the BOREAS flux towers, which were limited to much lower heights, and those of the research flux aircraft, which were much more episodic. They will be used in

conjunction with these in situ data to examine how motions in the outer boundary layer (above about 100 m) are related to surface layer fluxes. The radar data are also being used to investigate how cloudiness may affect turbulent boundary layer motions. Initial analyses to be presented will focus on the daily evolution of profiles of vertical velocity variance under different cloudiness conditions.

Room/Salle: Arts 116 **[3bCI]** Wednesday/Mercredi

COASTAL OCEAN AND INLAND WATERS 3
OCÉAN CÔTIER ET EAUX INTÉRIEURES 3

Chair/Président: Susan Allen

[3bCI1] Tidal mixing in Sechelt Inlet, B.C.

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The sill at the entrance to Sechelt Inlet, 50 km northwest of Vancouver, is tuned almost perfectly to extract the maximum power from the barotropic tide. However, despite the enormous up-inlet energy flux from the barotropic tide (~40 MW), the diffusive processes in the deep water of the inlet basin are weak, and the energy flux of the internal tide generated at the sill is relatively small (< 200 kW). The large tidal energy flux is almost completely dissipated at the sill, and most of the energy that manages to excape the sill region does so in the form of a turbulent jet that dissipates at mid-depths near the sill; very little energy is left over for mixing the deep water. Using estimates of the change in potential energy of the water column from vertical diffusion, the mixing efficiency (flux Richardson Number) of the breaking internal tide is determined to be between 3 and 8 %.

Because the transfer of energy to diffusive processes is so inefficient, the vertical diffusion of salt decreases the deep water density by only ~0.01 kg m^{-3} per month. The decrease of the deep water density conditions the inlet for eventual deep water replacement; however, hydrographic surveys in Sechelt Inlet suggest that while the mid-depth basin water is replaced once a year, the deep water (below 150 m) is replaced only once approximately every five years.

[3bCI2] Logarithmic layer observed in a tidal channel using an acoustic Doppler current profiler

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Tidal current in Cordova Channel, B.C., is measured using a broadband acoustic Doppler current profiler (ADCP) mounted on the bottom of the channel. The 20-minute smoothed velocity profiles reveal a logarithmic layer, the height of which varies tidally and reaches up to 15 meters above the bottom (about one-half of the water depth). Friction velocity is determined from the slope of the logarithmic profile and is then used to obtain the drag coefficient. Reynolds stress estimated from velocity correlation agrees well with the friction velocity squared obtained from fits to the logarithmic profiles.

[3bCI3] An Evaluation of Environment Canada's Operational Ocean Wave Model Based on Moored Buoy Data

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An operational wave model called CSOWM (Canadian Spectral Ocean Wave Model) has been implemented in the operational forecasting system of the Atmospheric Environment Service (AES) since early 1991. The CSOWM operates over two separate oceanic regions,namely,the northwest Atlantic and the northeast Pacific. The model is run twice daily at the Canadian Meteorological Centre (CMC) in Montreal and is driven by surface level winds obtainable from the operational weather prediction models of CMC.

The wave model's most important output parameter, namely, the significant wave height has been evaluated

against the buoy measured wave heights at several locations in the Canadian Atlantic as well as in the Canadian Pacific. The evaluation is based on a recent one year period from July 1993 to June 1994 and is presented in terms of scatter plots of model versus buoy value and also in terms of verification statistics such as mean error, root-mean-square error, etc., calculated over four seasons of the verification year.

The verification results will be presented and discussed in the context of wave model physics.

[3bCI4] Turbulence measured with moored instrument in tidal channel

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A moored microstructure instrument was used to measure the rate of dissipation of kinetic energy with conventional airfoil shear probes. Tidal currents were weak, reading only 0.15m/s, and comparable to open ocean conditions. Dissipation spectra were obtained for flows as weak as 0.03m/s. The lower limit of resolution was $6x10^{-10}$ W/kg set mainly by electronic noise rather than body vibrations.

Room/Salle: Multi-purpose Room [3bCL] Wednesday/Mercredi

CLIMATE AND PALEOCLIMATE 1
CLIMAT ET PALÉOCLIMAT 1

Chair/Président: Ian McKendry

[3bCL1] Can runoff regulation in Hudson Bay really affect the climate of the North Atlantic ?

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In response to claims that freshwater regulation arising from hydroelectric developments in the basins of Hudson and James bays might affect deep-water formation in the North Atlantic, and thus northward heat transport by ocean currents, which in turn might lead to a cooling of western Europe, we have examined in some detail the oceanographic consequences of changes in the timing of the freshwater runoff regime in that area.

We have critically reviewed the information available on the sequence of phenomena linking anthropogenic changes in runoff to a possible impact on the North Atlantic thermohaline circulation: enhanced spreading of estuarine plumes under ice; the effect of lowered salinity on the rate of ice formation; regional effects on the scale of Hudson Bay; the export of fresh water to the Labrador Sea; its impact on deep convection in that area; the relative importance of such changes to the North Atlantic circulation. At each step of this chain of events, we have attempted to compare anthropogenic effects with other factors and to place them within the perspective of natural variability.

Our conclusion is straightforward and unambiguous: a closer examination of the oceanic response does not support the contention that freshwater runoff regulation in the basins of Hudson and James bays could have a significant, perhaps even a detectable effect on the climate of the North Atlantic.

[3bCL2] Atmospheric moisture transport into the Arctic and its variability

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We analyze an ensemble of ten-year GCM runs for the atmospheric moisture flux into the Arctic. This study is motivated in part by the fact that the net flux of fresh water into the Arctic is balanced by oceanic outflow into the regions of the North Atlantic associated with the sinking branch of the thermo-haline circulation. Hence, the variability of the Arctic fresh water budget has implications for the forced variability of the thermo-haline circulation.

The simulated moisture flux across 70N compares well with recent observational studies of the same quantity.

However, the Arctic fresh water budget must take river runoff into account, which is done by computing the moisture transport across the associated continental drainage divides. This gives a mean net flux which can exceed that across 70N by more than a factor of two. The interannual fluctuations of the moisture flux into the Arctic will be characterized in terms of their statistics and spatial and temporal structures. The ultimate goal of this study is to gain a dynamical understanding of the statistics of the atmospheric component of the Arctic moisture budget.

[3bCL3] Decadal climate variability in the subpolar North Atlantic

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The cyclic nature of observed decadal to interdecadal climate variability of the subpolar North Atlantic is re-examined in terms of six separate climate components of this air-sea-ice system: 1) sea surface temperature; 2) atmospheric sea level pressure; 3) sea surface salinity; 4) sea ice extent; 5) Gulf Stream transport of heat and salt into this region; and 6) deep water formation within this region (especially within the Labrador Sea). Sea surface temperature anomalies concentrated in the Labrador Sea region are found to have an impact upon atmospheric sea level pressure anomalies over Greenland, which in turn are believed to influence the transport of freshwater (salinity anomalies) and ice anomalies out of the Arctic Ocean, via the Fram Strait. Such sea surface salinity and ice anomalies are advected around the subpolar gyre into the Labrador Sea affecting convection and the formation of Labrador Sea Water. This has an impact upon the transport of Gulf Stream water into the subpolar gyre and thus, also has an effect upon sea surface temperatures in the region. A decadal climate loop is therefore proposed as an internal source of decadal to interdecadal climate variability within the subpolar North Atlantic region. Through the lags associated with the correlations between the different climate components, observed horizontal advection timescales, and the use of Boolean Delay Equation models, the timescale for one cycle of this loop is determined to have a natural range extending from approximately 15 years to approximately 21 years.

[3bCL4] Recent climatic variability and associated effects and interactions with Hudson Bay and James Bay coastal ecosystems

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Recent evidence suggests that variations in climatic conditions over the past few decades in northern Canada, in addition to other important factors, have strongly influenced trophic interactions along the shores of Hudson and James Bays between a herbivore population (lesser snow geese) and the coastal vegetation on which the birds feed. Northern Hemisphere seasonal temperature changes from 1961 to 1990 indicate a steep southwest to northeast spatial gradient during winter and spring between a large region of strong positive anomalous warming in west- central and northwestern North America, and a smaller region of strong negative anomalous cooling in northeastern North America. Colder than normal conditions to the northeast of Hudson Bay has resulted in the delayed migration of snow geese and prolonged staging of northward- bound birds along the southern shores of Hudson and James Bays, in addition to the presence of breeding populations of snow geese along the coastline.

Air temperature and 50 % snow clearance time series during spring are examined and compared to a long-term goose dataset from La Perouse Bay near Cape Churchill to determine the influence of climate on the migration and breeding patterns of goose populations in the region. Intensive, destructive foraging by breeding and staging geese, and intense summer grazing due to colony expansion, have occurred at numerous sites for a distance of 2500 km along the coastlines of Ontario, Manitoba and the Northwest Territories. Aerial surveys and LANDSAT imagery demonstrate the extent of the biomass destruction both along the coasts of Hudson and James Bays in

general and at specific sites, in particular. This mesoscale loss of vegetation is termed desertification. Future work will focus on the relationships between these surface changes and atmospheric feedbacks that can affect regional climate. Changes in coastal zone evapotranspiration, soil moisture, and albedo must be determined for energy balance considerations and regional climate modelling studies.

Room/Salle: Arts 118 **[3bWF]** Wednesday/Mercredi

WEATHER FORECASTING
PRÉVISIONS MÉTÉOROLOGIQUE

Chair/Président: Al Wallace

[3bWF1] Next Operational Version of the Regional Finite Element Model

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The regional forecast system of the Canadian Meteorological Centre, used for data assimilation and short-range numerical weather prediction, is based on the 50-km version of the Regional Finite Element (RFE) model. The presentation will focus on the current development effort that will lead to the implementation of the next operational model.

One of the objective of the development work is to improve the forecast of the surface variables: temperature, dew-point and surface wind. Two modifications contribute to the changes in the forecast of these surface fields. The first one is a new formulation of the turbulent vertical transfers of heat, moisture and momentum. Among other things, the formulation allows for a roughness length for heat and moisture that is different from the one used for momemtum. The second modification is an improvement to the parameterization of land surface processes. This modification will address the main sources of errors in the surface temperature and dew-point forecasts. It includes: a change to the surface evaporation, new types of soil (snow and ice), a snow-melting effect and a modified soil-moisture content.

Another objective is to improve the cloud and precipitation forecast. For the stratiform cloudiness, we are experimenting with the predictive cloud water/ice scheme proposed by Sundqvist. The first experiments with the new scheme show slightly better precipitation forecasts. Also, we intend to replace the current Kuo-type convection scheme by one proposed by Fritsch and Chappell and designed for the prediction of mesoscale convection. The scheme has shown its ability to refine the mesoscale precipitation and circulation details when compared to the current parameterization.

The presentation will highlight the differences of formulation between the current 50-km RFE and the new version, and on the impact of the new formulation on the operational numerical guidance.

[3bWF2] New statistical methods for weather forecasting developed at RPN

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The operational statistical approach used at CMC to forecast such fields as surface temperature, wind, and precipitation (POP) is based on the perfect prog technique. The main advantage of this technique comes from the fact that it is not model-dependent. On the other hand, the drawbacks are that the method does not account for model biases (model errors decrease accuracy) and that it must use relatively low spatial and temporal resolution observational (analysis) data for equation development. In this presentation, we will introduce two new statistical approaches, the Kalman filter (KF) and Updatable MOS (UM). The KF is essentially a recursive model error correction procedure, while UM is a method for fast-response updating of MOS equations. Both techniques produce forecasts based on model data, therefore any model bias is included in the equations and the data resolution is higher. This gain is achieved while minimizing the model-dependency problem by automatically redeveloping the statistical equations to take account of any change to the driving numerical model. Encouraging preliminary results will be shown. These methods will become operational in the near

future.

[3bWF3] SCRIBE Verification System

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SCRIBE is the system developed at the Canadian Meteorological Centre with inputs from the Regions to assist the operational forecasters in the production of a variety of worded forecast. One of the components of SCRIBE is the Verification module.

The SCRIBE Verification module, still under development, is based on the following framework. All available surface observations, synoptic, hourly and supplementary aviation observations are used to create a truth file at a set of stations. The truth file is basically a matrix which includes all observed weather elements with a time resolution of one hour, taking into account the special observations produced at non-standard times. The weather elements are cross-checked between themselves to validate the observations and thus create the truth, assumed to be the actual representation of the weather that really occurred. For instance, the temperature observations available at each hour, are cross- referenced against the maximum/minimum temperatures reported in the synoptic observations, to establish the true maximum/minimum temperatures on a local time window and to identify inverse temperature trends. Similar treatment is done to assess occurrences of precipitation. The truth files are generated once a day at each station, for the past 24 hours. The truth files can be downloaded to the Regional Weather Centres for their own use.

On the other hand, a similar set of matrices are generated from the forecasts. The forecast matrices and the truth matrices can then be compared and the validity and skill of the forecasts assessed.

The verification system is flexible enough to be used to verify specific events, that meet specific threshold criteria. It will be able to verify any weather element (or derived wether element such as the drying index, relative humidity, wind chill, etc..) that can be forecasted and observed. The system has been designed to be used at the national, regional and individual levels. It can provide answers to the management question of how good the forecasts are at the national level (results measurement). It can also help to answer the same question at the regional level, but can also help to find ways to improve the forecasts within a Regional Office. Finally, it can be used as a tool to improve the forecasts on an individual basis. A graphical interface will be developed so that the verification system can be used efficiently.

Verification scores for the SCRIBE forecasts generated in an automated mode will be shown. The SCRIBE Verification module has also been used to verify the public forecast data that are decoded and processed in the National FP Verification System. Comparisons will be made with the SCRIBE forecasts. The verification results presented will mainly concentrate on the maximum/minimum temperature forecasts and on the probability of precipitation forecasts. The verifcation will be stratified according to seasons and also according to specific events departing significantly from climatology.

[3bWF4] Description and verification of a new technique to forecast precipitation type at CMC

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Following a subjective evaluation by operational meteorologists, from across the country, during the cold season of 1993-94, CMC decided to use a new technique to forecast the precipitation type, the Bourgouin technique. This method is based on measurements of negative and positive areas, as seen on a tephigram. A brief description of the method will be made, followed by a verification of the technique. This verification will cover the first period of operational application, the cold season of 1994-95. The method will also be compared to three other methods (Koclas, Baldwyn-Contorno, Ramer).

Suite a une evaluation subjective faite par des meteorologistes operationels a travers le Canada durant la saison froide de 1993-94, le CMC adoptait une nouvelle technique de prevision du type des precipitations, la technique Bourgouin. Cette technique repose sur la mesure d'aires positives et negatives, tel que vue sur un tephigramme. Une breve description de la methode sera faite puis une verification de la technique suivra. Cette verification portera sur la premiere periode de prevision operationelle, soit la saison froide de 1994-95. La methode sera

egalement comparee a trois autres techniques (Koclas, Baldwyn-Contorno, Ramer).

Room/Salle: Arts 118 [3cAM] Wednesday/Mercredi

ATMOSPHERIC MODELLING 2
MODÉLISATION DE L'ATMOSPHÈRE 2

Chair/Président: Norm McFarlane

[3cAM1] Role of turbulence and surface properties in cold front evolution.

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A two-dimensional hydrostatic model of a cold front has been developed to investigate effects of PBL on frontal evolution. High vertical and horizontal resolution and 1.5 order turbulence closure as well as parameterization of soil-atmosphere interaction yielded results which remain in qualitative agreement with observations of Frank(1994) and Berger and Friehe(1994) and modelling work of Becker(1994). Realistic features such as maximum strength of turbulent fluxes of heat and momentum at the head of a front, strong stability of atmosphere with capping inversion behind the front, vertical jet at the top of PBL above the pressure trough, prefrontal jet splitting and separation of the lower and upper fronts have been reported. Currently effects of changing roughness on the behaviour of the front are being studied. Further development of the model to include moist processes is in hand.

[3cAM2] Climatology in ECSib general circulation model

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In this report the global atmosphere general circulation model ECSib (Dynamics - Siberian general circulation model, Physics - European Centre model) and its performance in simulating the present - day climate is presented.

The model has the horizontal resolution 5° × 4° and 15 non-uniform distributed in vertical sigma-levels. Prognostic variables are velocities, temperature, surface pressure, specific humidity. The model contains parameterizations of radiation, cloudness, precipitation, convection, vertical and horizontal diffusion and land surface processes. The monthly-mean climatic values of the ocean surface temperature, the ice-cover distribution, the underlying surface albedo are given as input parameters . The annual cycles of solar radiation, sea surface temperature and sea-ice distribution are prescribed as lower boundary condition.

The model simulates a realistic mean climate state, which is close to the observations.

[3cAM3] MC2 Contribution to the COMPARE 2 Experiment - A Mountain Wave Simulation (PYREX IOP 3)

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The COMPARE (Comparison Of Mesoscale Prediction And Research Experiment) project is an international community effort in mesoscale modelling whose main goals are to further understand the predictive capability at mesoscale and identify important issues of mesoscale research. The first case that was selected for the COMPARE 1 project is an explosive marine cyclogenesis case which occurred during March 6-8 1986 of the North America east coast. (Chouinard et al., 1994, Monthly Weather Review). The Mesoscale Compressible Community (MC2) model was one of the few non-hydrostatic models among the 12 models of the international modelling community (7 countries) participating to this first COMPARE experiment. The proposed set of experiments were aimed at studying the issues of vertical and horizontal resolution (up to 25 km). The MC2 performance at synoptic and meso-alpha scale was very good and compared very closely to that of other models.

The COMPARE 2 experiment focuses on a mountain wave event observed during the field phase of the Pyrenees

Experiment (PYREX) (Bougeault et al., 1993, Annales Geophysicae). The very well documented IOP 3 case of October 14-15 1990 was selected because it corresponds to a very typical, strong lee wave event during which regional winds (Foehn and Autan) of up to 16-20 m/s were recorded. Models are requested to complete a set of runs similar to those for COMPARE 1 and are also allowed to run at the highest possible resolution in order to capture the chronology of most mesoscale features of this event such as the formation and dissipation of a very small scale lee vortex, the occurence of non-hydrostatic lee waves, the history of the surface pressure drag and wave momentum flux. MC2 simulations at 10 km horizontal resolution (and at higher resolution) will be presented. Non-hydrostatic effects will be discussed and issues such as the performance of the semi-implicit semi-Lagrangian (SISL) scheme in presence of intense gravity waves and sensitivity to the terrain height and roughness will be investigated.

[3cAM4] Numerical Convergence in AGCMs

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The intercomparison of AGCM results, both in a forecasting and climate mode, is aimed at identifying and ultimately removing model deficiencies. In a standard intercomparisons, results are from AGCMs which differ in their horizontal and vertical resolution, in their numerical methods and in their physical parameterizations. The strong and non-linear interaction between physical parameterizations and numerical aspects of models complicates the interpretation of differences between results.

As part of an investigation undertaken for the WGNE, we investigate the convergence of model "numerics" which largely avoids the strong interaction between numerical formulation, resolution and parameterized physics. In particular the "physics" are largely removed by: (1) using a "dry" model and dry convective adjustment (replaces the moisture equation),(2) specifying a heating field together with a weak relaxation on [T] (replaces radiative, latent and sensible heat forcing), (3) using a simple surface stress approach (replaces boundary layer calculations), but (4) horizontal and vertical diffusion is retained as part of the model numerical formulation.

Results using the CCC GCM are discussed as a function of resolution and compared and contrasted with the results of Held and Suarez (1994) which arose in an independent but similar investigation. Both our approach and the results differ in important ways.

[3cAM5] A numerical study of the along-line variability of a frontal squall line during PRE-STORM

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In this study, the roles of large-scale and mesoscale circulations in the generation of along-line variability of squall lines are investigated, using an 18-h prediction of a frontal squall line that occurred during 26-27 June 1985 PRE-STORM, with the Canadian regional finite-element (RFE) model. It is shown that the model reproduces reasonably well the initiation, propagation, and disintegration of the squall system, as well as a number of the associated surface and vertical circulation structures, as verified against available network observations. The vertical circulations at the northern segment of the squall line are found to differ significantly from those at its southern segment, including the absence of a rear-to-front (RTF) flow and midlevel mesolow, the early dissipation of deep convection, and different types of stratiform precipitation. The along-line variability of the squall's internal circulations results primarily from the interaction of convectively generated pressure perturbations with a midlevel baroclinic trough. The large-scale trough provides and extensive RTF flow component in the southern portion of the squall system and a front-to-rear (FTR) flow component in the north, whereas the midlevel mesolow tends to enhance the RTF flow to the south and the FTR flow to the north of its location during the mature stage. This along-line variability of the squall's circulations appears to be partly responsible for the generation of varying weather conditions along the line.

[3cAM6] A statistical model for UV radiation at the ground in the presence of cloud

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The Canadian operational procedure for predicting total ozone and UV radiation (Burrows et al, 1994) was implemented in June, 1993. Forecasts of stratospheric ozone for the northern hemisphere are made from upper troposphere-lower stratosphere meteorological variables with a regression relation, then clear sky UV radiation at local noon is derived from the relation of Kerr et al (1994). Presently a crude adjustment is made for cloudiness to give the final maximum UV forecasts for sites in Canada. A new method for obtaining the UV radiation at the ground in the presence of cloud has been developed and tests are underway. Hourly UV measurements for the Toronto Brewer instrument have been archived since 1989 in the World Ozone/UV Data Base at Downsview. The UV data for all available times and days were matched with observed weather for Pearson airport and fitted with CART, a recent non-linear tree-based regression technique. Trees are validated with independent data to give an honest result. About 91 % of the variance in the UV data is explained with only 2 predictors: clear-sky radiation and total cloud opacity. By adding temperature, relative humidity, visibility and liquid- precipitation predictors another 1 % of the variance was explained. Linear regression with the same predictors explains approximately 84 % of the variance. CART has similarity to a feed-forward neural network with a hard-limit transfer function. Using the CART tree structure and a fuzzy set membership function, a feed- forward back-propagation neural network can be designed that performs at near the same error level (Jessup and Burrows, 1995). This allows continuous variation of prediction within and between decision tree nodes.

Room/Salle: Arts 108 [3cBM] Wednesday/Mercredi

BOUNDARY-LAYER METEOROLOGY 1
MÉTÉOROLOGIE AÉRONAUTIQUE 1

Chair/Président: Phil Austin

[3cBM1] Coastal wind power - how advantageous is going offshore?

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Wind power is a major alternative energy source in Denmark and its use is expanding rapidly in other parts of Europe. One of the obstacles to further expansion is the lack of high wind speed sites which are acceptable to the public. Placing wind farms offshore overcomes acceptability problems and has the added advantage that wind speeds over the sea tend to be higher than those over nearby land surfaces. Test programs are already underway in Denmark, Holland and Sweden. A number of models exist which predict offshore wind speeds based on geostrophic, upper air or near-surface coastal (land) wind speed data. In the coastal zone, where the wind field is adjusting between different roughness and stability climates, the predictions are less accurate. This is partly because there is a general lack of data from the offshore coastal zone for developing and validating models. Most models suggest that the increase in wind speed moving offshore is initially large but after this rapid readjustment the wind speed tends toward an equilibrium value. As the distance from land increases so do the costs of wind farm installation and maintenance. There is therefore an optimal distance from the coast for installing a wind farm where the maximum wind speed is obtained with minimum operation and maintenance costs. Here, a number of models are tested and validated against meteorological data from the Vindeby offshore wind farm in Denmark and the importance of stability on the modification of the wind field is examined.

[3cBM2] Scaling sea breeze flows

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Scales governing dynamics of the fully developed sea breeze circulation are derived from the governing equations. These scales are used to non-dimensionalize observed profiles of the fully developed sea-breeze circulation. Observations representing pure sea breeze circulation are selected from a large set of tethersonde profiles taken

in the Lower Fraser Valley, B.C. over a five year period. Pure sea-breeze conditions are presumed to be represented by profiles exhibiting flow reversal with height. It is shown that these profiles collapse to a single "universal" profile when non-dimensionalized with the dynamical scales. Modelled profiles derived from runs of a 3D fully nonlinear mesoscale model are scaled in the same manner and collapse to the scaled observed profiles, thus substantiating the claim that they are "universal".

[3cBM3] Parameterization of vertical turbulent transfer in stable stratification

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This presentation deals with the effects of simple formulations of vertical turbulent transfer in NWP and climate models in the particullar case of stable stratification. A few issues are addressed: 1) the continuity between the surface layer and the Ekman layer, 2) the validity of the surface layer assumptions, 3) the relative rate of transfer of heat and moisture versus that of momentum, and 4) the opportunity of including a critical value of the Richardson number Ri in the formulation.

If we adopt vertical diffusion as the mechanism for vertical turbulent transport, it is appropriate to define the coefficient as a local function of Ri, while for the surface layer it is more convenient to have it as a function of height and of surface fluxes. The two expressions must, however, be consistent to avoid discontinuities at the top of the surface layer. Also, the thickness of the surface layer in NWP and climate models is often a sizeable fraction of that of the boundary layer for the stable case, and we can question the wisdom of neglecting the variation of the fluxes with height in this case. Alternative assumptions are discussed; it appears that the error associated with the assumption of constancy of the fluxes with height increases with the depth of the surface layer, as expected, but also depends on the actual formulation of the stability functions.

The spectral model is used to investigate the effects of various formulations, including one in which the diffusion coefficients are set to zero for Ri above a critical value.

[3cBM4] Lake-breezes in Southwestern Ontario with Implications for the Transport of Ground-Level Ozone

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The synoptic meteorological conditions favourable for the development of lake-breezes in southwestern Ontario on summer days are also those that can lead to episodes of elevated tropospheric ozone. Lake-breezes are found to be capable of reaching most inland localities in this region, and thus are thought to play a critical role in the transport of ozone near the surface. A good understanding of the development and interaction of these lake-breezes is needed to elucidate this role. Well-developed lake-breezes were accompanied by elevated levels of ground- level ozone in southwestern Ontario on August 14, 1993. The Mesoscale Compressible Community (MC2) model, developed by Environment Canada's Atmospheric Environment Service, was run for this case and resolved the lake-breezes and their temporal evolutions. Some of the more general details of the lake-breeze fronts, such as temperature gradients and wind profiles, were also captured. Output from MC2 was compared to GOES 1km resolution visible satellite imagery, maximum reflectivity radar data and high-resolution surface meteorological observations to assess the model's accuracy. A preliminary analysis of the effect of these lake-breezes on ground-level ozone transport is conducted.

[3cBM5] A model of stably-stratified surface boundary-layer flow in two dimensions

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A model of two-dimensional, turbulent boundary-layer flow over periodic, sinusoidal terrain has been developed for stably-stratified conditions. It seeks the steady-state solution to the Reynolds averaged equations of motion by use of a finite-difference numerical scheme which is integrated forward in time until steady-state is achieved. The terrain shape is assumed to deviate only slightly from a flat surface, so the model is initiated with a flat-surface steady-state solution. Numerous tests have been performed with initial, basic states corresponding to constant turbulent flux layers implementing rigid lid upper boundary conditions. Results, however, were only obtainable for weak stratifications because at stronger stratifications numerical instability is unavoidable in the

upper domain where a large horizontal velocity, U, has been specified by the constant flux initial conditions. In addition to the stability problem, the constant flux assumption and rigid lid upper boundary inhibit all upward propagating internal waves. This is confirmed by streamline plots of obtained results and Froude number, Fr, calculations showing Fr>1. To expand the model usage to strong stratification and simultaneously address the problem of upward wave propagation, new initial states yielding Fr<1 are introduced. The new initiating velocity and temperature are such that U=constant and the buoyancy frequency N=constant in the upper flow; and this initial state alteration is produced by the insertion of artificial momentum and heat sources into the boundary layer. This change is justified because it gives more realistic basic profiles which coincide with the nocturnal confinement of turbulence to the near-surface. Results of this expanded model using wave-transmitting upper boundary conditions will be presented.

[3cBM6] Open-water Evaporation: The Swift Current Water Balance Study

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Water balance estimates of evaporation from two lined dugouts are being used to evaluate and fine-tune semi-empirical operational methods for estimating open-water evaporation over small water bodies. The two dugouts, provided by PFRA in Swift Current, Saskatchewan, are 30 m by 55 m by 4 m deep. During 1994, both were instrumented to provide detailed half-hourly basic-state meteorological data, as well as precipitation, water levels, and water temperatures. Daily evaporation pan data were also recorded.

Evaporation determined from the water balance will be compared with estimates from pan data, Meyer's mass transfer method, and Morton's complementary relationship applied to small water bodies. Other results from and problems encountered during the 1994 field season will be discussed.

Room/Salle: Auditorium [3cBO] Wednesday/Mercredi

BOREAS 3
BOREAS 3

Chair/Président: Barry Goodison

[3cBO1] Field Test Results using the Vaisala Radiosonde System during BOREAS

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Most Canadian radiosonde sites have now been converted to the Vaisala. During early processing of upper air data from the 1994 BOREAS radiosonde network, some unusual-looking wind profiles from the Vaisala sites were occasionally noted. Relative humidity values also appeared to be negatively biased. The possibility of data errors necessitated field tests to verify and quantify any such problems.

Vaisala and Airsonde sondes were released simultaneously at two- hour intervals on three consecutive sunny days during late-July, 1994 at Candle Lake, Saskatchewan. The Vaisala system employs a Loran tracking system for winds, while Airsonde sondes were tracked manually using an optical theodolite system. A second theodolite was used to track the Vaisala balloon, and extensive manual surface observations of temperature and humidity were recorded on site during soundings.

Analyses of these field data will be presented, together with some later results carried out under controlled laboratory conditions. Slight biases in Vaisala humidity and geopotential height data are noted, while the wind data prove to be surprisingly good.

[3cBO2] The surface mesoscale meteorological system for BOREAS

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The Saskatchewan Research Council (SRC), Atmospheric Sciences Section was awarded a contract from NASA

to provide the surface meteorological network to support the BOREAS project. Ten fully automated above-the-canopy meteorological stations were specifically designed for the BOREAS project. A description of each station and locations within the Boreal forest are outlined. The main components of the BOREAS network include specific components of the radiation balance over the project area and various parameters to monitor above-the-canopy mesoscale flows. Data is received daily at SRC. It is then processed and packaged, according to NASA's specifications, and sent monthly to BORIS.

[3cBO3] Influence of leaf development on the radiation regime beneath a boreal aspen forest canopy

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This study was part of a BOREAS project that took place at the Old Aspen Tower Site (OATS) in Prince Albert National Park, Saskatchewan. The aspen trees were 21-m high with a 2-m high hazel understory. The primary objective was to obtain accurate diurnal spatially-averaged measurements of net radiation to the hazel understory before and after leaf-out. These measurements are needed to assess the energy-balance closure of below-canopy eddy-correlation measurements and for the development of an evapotranspiration model for the understory. Measurements were made using a tram that moved horizontally back and forth at 10 cm/s on a pair of steel cables 100-m in length, 4-m above the ground. The tram carried a Swissteco S-1 net radiometer and a Swissteco S-14 miniature net radiometer, a shaded and unshaded Kipp and Zonen CM-5 pyranometers and upward and downward facing LI-COR LI-190SB quantum sensors. The pyranometer and quantum measurements were made to determine radiation transmission characteristics of the overstory and the photosynthetically active radiation (PAR) absorbed by the understory. A stationary Swissteco S-1 and quantum sensor were placed beneath the hazel canopy to assess the daily average ratio of below to above hazel understory net radiation and PAR fluxes. In addition, a LI-COR LAI-2000 plant canopy analyzer was used to determine the course of the leaf area development for both the aspen and hazel throughout the growing season. The leaf area indices of the aspen and hazel reached a maximum of 1.9 and 3.5, respectively. Before leaf-out, the ratios of below to above aspen net and solar radiation were 0.48 and 0.60, respectively. By mid-summer, these ratios had fallen to 0.37 (net radiation) and 0.32 (solar radiation). These ratios were relatively insensitive to the time of day. Extinction coefficients for net, solar and PAR after leaf-out were lower than before leaf-out. Similar results have been found in an oak-hickory forest in Tennessee and in an oak forest in Russia. It is partly attributed to the lower solar elevation in early spring as compared to most of the growing season.

[3cBO4] Climate and tree growth in the BOREAS allometry stands

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The BOREAS project included allometric sampling of trees at four sites in the northern study area and six sites in the southern study area. At each site, a number (usually ten) of trees were felled, and various measurements taken; disks were also collected at several positions along the stem. X-ray densitometry of these disks shows not only annual volume increment, but also non-volatile mass increment - essentially annual carbon storage. By relating volume increment and mass increment to climate, it is possible to describe the sensitivity of tree growth to climatic change. Trees at the southern sites are shown to be most sensitive to drought, and trees in the northern region, although also sensitive to drought, are more sensitive to temperature. There are differences between the responses of volume and mass increment, implying that at the scale of individual annual increments, they must be treated as separate variables. Although volume is measured more readily than mass, mass is the more important variable for modelling forest carbon storage and its response to climate (or other) change.

[3cBO5] Estimation of the Photosynthetically Active Radiation Absorbed by Canopy from Satellite Measurements

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Photosynthetically Active Radiation (PAR) absorbed by Canopy (APAR) is essential to the vegetation photo-

synthesis, net primary productivity and the carbon cycle. Due to the paucity of ground-based measurements, global monitoring of APAR can only be achieved by means of space-borne remote sensing. So far, APAR has been estimated from the retrievals of the incoming PAR at the surface and the fraction of the PAR intercepted by vegetation (FPAR). Derivation of downwelling PAR from satellite data entails the determination of cloud properties, which is generally a difficult and error-prone task. We proposed a new approach to retrieve APAR that is defined as the product of the PAR absorbed by the surface layer below the top of canopy and the fraction of PAR absorbed by green foliage only. Since clouds do not absorb solar radiation in the PAR spectral region, it is much easier and more accurate to estimate the PAR absorbed by the surface layer than the incoming PAR at the surface. Comprehensive atmospheric radiative transfer modelling was conducted to establish the relationship between surface absorbed PAR and the visible albedo at the top of the atmosphere that is measured by satellite. A canopy radiative transfer model was developed to relate the fraction of the PAR absorbed by green canopy to the vegetation indices. Some parameterization schemes were obtained on the basis of canopy radiative transfer simulations. In addition, development of a method to retrieve surface PAR albedo is under way using the clear-sky composite data from visible channels. With the knowledge of the surface absorbed PAR and the PAR albedo, downwelling PAR can be derived which is then combined with APAR to derive FPAR. Therefore, the methodology we are developing is able to retrieve all components of PAR. These inversion algorithms will be tested using ground-truth observations collected during the BOREAS field campaigns. After validations, we will apply the algorithms to various satellite datasets including AVHRR, LANDSAT and SPOT for mapping the distributions of APAR and its components over Canada and the world.

[3cBO6] Investigation of snow cover variations in the boreal forest during the BOREAS 1994 winter campaign

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The winter field campaign of the Boreal Ecosystem-Atmosphere Study (BOREAS) was conducted during February 1994 north of Prince Albert, Saskatchewan and near Thompson, Manitoba focusing on snow processes in the boreal forest regime. Snow cover, a dominant feature of the boreal forest for six months of the year, is highly variable in space and time. Knowledge of the amount and distribution of snow is important to understand functioning of the ecosystem throughout the year and for applications such as assessing forest fire potential and soil moisture conditions.

Snow cover variations within the forest during the winter campaign were investigated using ground snow survey measurements, airborne and satellite passive microwave data, and airborne estimates of snow water equivalent (SWE). The development and validation of algorithms to derive snow extent and SWE information from passive microwave data are a major part of the investigation. Analysis of co-incident airborne passive microwave data and airborne gamma SWE is in progress, supported by special extensive ground surveys for validation. The resulting algorithms will be applied to satellite passive microwave data (Special Sensor Microwave Imager - SSM/I) to improve our ability to map regional snow water equivalent variations over the entire BOREAS study area. The relation between forest cover and forest species is also being investigated using the special ground survey data for incorporation in the algorithms.

These relationships will be applied to land cover classification data sets, for example those derived from Landsat TM, as a complementary approach to mapping regional variations in snow cover depth, water equivalent and extent. This paper will describe the data acquired during the winter experiment and present the initial results from the investigation.

Room/Salle: Arts 116 **[3cCI]** Wednesday/Mercredi

COASTAL OCEAN AND INLAND WATERS 4
OCÉAN CÔTIER ET EAUX INTÉRIEURES 4

Chair/Président: Rick Marsden

[3cCI1] Oceanic tides over the Newfoundland and Scotian Shelves

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A modified form of response analysis, which is essentially an orthotide formulation, is used to derive major semi-diurnal and diurnal tidal constituents over the Newfoundland and Scotian Shelves from Topex/Poseidon altimeter data. The modified orthotide formulation simultaneously solves for the semi-diurnal and diurnal constituents as well as the annual signal. Tidal elevations, derived from the Topex/Poseidon altimeter data, are interpolated to force a hydrodynamical model as open boundary conditions at every time step. The model is governed by 3-d primitive equations for homogeneous fluids with a free surface and uses a coordinate system which is orthogonally curvilinear in the horizontal and sigma in the vertical. The vertical eddy viscosity is estimated using a second-order turbulence scheme. The altimetric-tide-forced model is run to produce the M2, S2, N2, K1 and O1 constituents over the Newfoundland and Scotian Shelves. The model results are in good agreement with available tide-gauge data and current meter data, and consistent with the altimetric tides along the satellite ground tracks within the model domain.

[3cCI2] Improvement of tidal predictions using multiple years of tidal analyses

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It is a tradition in the prediction of tides to use one year of data from which to derive a set of harmonic tidal constants for use in future predictions. The software package presently used by the Canadian Hydrographic Service (Foreman 1977) was designed to operate optimally in this manner. This method assumes that interannual variations in these tidal constants are in eqiuilibrium with the tidal potential. This system has a few deficiencies: It is difficult to take advantage of many years of data. It offers little guidance on the noise levels in individual constituents. Any trends in the constituents must be evaluated separately. I describe here a software package which operates on the output of multiple years of harmonic analyses to determine optimal tidal constants, noise levels in constituents, interannual trends and quality control. When applied to Canadian west coast ports, it has improved predictions and identified problems in data quality. Although this method is simple, it has not previously been applied to tidal analysis.

[3cCI3] Near-shore characteristics of the Great Whale River under-ice plume

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Data were collected near the mouth of the Great Whale River, at the boundary between the fresh riverine waters and Hudson Bay from mid-April to early May 1990. Using moored current meter records, CTD profiles, echosounding and tide gauge measurements, the nearshore characteristics of the under-ice river plume are determined. Focus of the study was the shallow region within 2 km of the river mouth.

At certain phases of the tide, for lowest low tides, high amplitude rapid fluctuations in both the temperature and salinity fields were observed. During these periods, supercritical Froude numbers often occurred, indicating the possibility of an internal hydraulic jump. At semi-diurnal periods, a negative correlation between pycnocline depth and tidal height was observed in the near shore region.

[3cCI4] A sediment and carbon budget for the Mackenzie Shelf of the Beaufort Sea; what we know, what we don't know, and what the likely effect of change will be

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The Land-Ocean Interaction in the Coastal Zone (LOICZ) program focusses on material transports in the coastal zone and the likely effects of global change on those transports. The Arctic is thought to be both one of the most sensitive regions on the globe to climate change and an important feedback component in the climate system. Therefore, the large continental shelves of the Arctic Ocean may provide a key sentinel for such change. We here attempt to construct a sediment and carbon budget for the Canadian Beaufort Shelf. This region is of interest because it freely connects to the Arctic Ocean, it is impacted by a large, sediment laden river (the Mackenzie), and it is the best proxy on the North American side of the Arctic for the large Russian Shelves. Despite years of study under a variety of programs which arguably provide the best data set for any Arctic river/shelf system, we still cannot construct a complete carbon budget. We discuss here the components we know, those we don't know, and what we believe the major changes will be in the light of predictions of regional temperature rise.

Room/Salle: Multi-purpose Room [3cWO] Wednesday/Mercredi

WOCE 1
WOCE 1

Chair/Président: Howard Freeland

[3cWO1] Inferring meridional mass and heat transports of the Indian Ocean by combining a general circulation model with climatological data

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It is commonly perceived that the meridional overturning of the Indian Ocean is characterized by northward inflow at depth followed by strong upwelling and southward outflow at mid-depths. Such an overturn transports heat southward to balance the net surface heating. To examine whether this picture is consistent with a general circulation model (GCM) in near-steady state and climatological data, annual mean temperatures and salinities are assimilated into a GCM of the Indian Ocean north of 32S using the adjoint method. Results indicate that an optimal model state does not support strong upwelling, and that the conventional picture of overturning is not necessary to produce realistic meridional heat flux. These key findings are illustrated by three assimilation experiments:

(1) The best fit of the model to climatology while maintaining a steady state is achieved by relaxing temperatures near the southern and northern boundaries to optimized values. The meridional overturning, characterized by weak upwelling, only has a strength of 4.5 Sv. The heat flux is southward almost over the entire latitudinal domain with a maximum of 1.1 PW.

(2) When model temperatures near the boundaries are relaxed to climatological rather than optimized values, a steady state consistent with climatology is also found. The overturning is vigorous (16 Sv) but characterized by strong downwelling, which is in conflict with the conventional perception. Away from the boundaries, the heat transport is southward with a maximum of 0.5 PW.

(3) Adding a constraint that requires large northward flow at depth causes the model to produce strong upwelling. However, the model fails to achieve a steady state.

[3cWO2] JEBAR, Bottom Pressure Torque and Gulf Stream Separation

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A diagnostic finite element barotropic ocean model has been used to simulate the circulation in the North Atlantic. With the inclusion of the JEBAR term (the Joint Effect of Baroclinicity And Relief), the Gulf Stream is found to separate at the correct latitude, $\sim 35^0 N$, off Cape Hatteras. Results suggest that the JEBAR term in three key regions (offshore of the separation point in the path of the main jet, along the slope region of the North Atlantic Bight and in the central Irminger Sea) is crucial in determining the separation point. The transport driven by the bottom pressure torque component of JEBAR, Ψ_B, dominates the solution. Excluding high latitudes (in the deep water formation regions) density variations in the upper $1000m$ of the water column govern the generation of the JEBAR term in our model.

Examination of results from the WOCE-CME (World Ocean Circulation Experiment - Community Modelling Effort) indicates that the bottom pressure torque effects are underestimated in the CME by almost an order of magnitude. Removing the JEBAR term in each of the three key areas forces our modelled Gulf Stream to overshoot its observed separation point as in the Community Model. The reason for the behaviour of the CME is unclear, but may be associated with the diffuse nature of the modelled thermocline as suggested by our model's sensitivity to the density field above $1000m$.

[3cWO3] Sensitivity of an ocean model to sub-grid mixing schemes

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The sensitivity of an idealized, two-hemisphere, coarse resolution ocean general circulation model to sub-grid scale mixing parameterizations is examined. Three different mixing schemes are used: 1) lateral/vertical mixing; 2) Isopycnal/Diapycnal mixing; 3) Gent and McWilliams (1990) mixing. The comparison is also extended to a global ocean model and the results are compared to a simple scaling analysis of the thermocline equations.

[3cWO4] Model spin up and meridional overturning in OGCMs

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Sensitivity experiments with an isopycnal ocean general circulation model (OGCM) show how meridional overturning depends on model parameters and on surface buoyancy flux at high latitudes. The model spins up to its equilibrium overturning within several thousands of years. This time scale depends on supply of internal mixing energy that regulates advection/diffusion balance between interior layers. These results clearly demonstrate that (1) isopycnal models can have overturing circulation that is comparable to that in non- isopycnal OGCMs, and (2) no apriori estimates can be made of the strength of the overturning, or on deep penetration of tracers in an OGCM, if model spin-up is shorter than its overturning spin-up time scale.

[3cWO5] An Estimate of Advective Heat Flux in the Northeast Pacific Ocean From Satellite-Tracked Drifters

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As part of Canada's contribution to the WOCE Surface Velocity Program (SVP), 38 satellite-tracked surface drifters, drogued at 15 m depth, were deployed north of 30°N in the Northeast Pacific Ocean (180°-120°W) between 1990-1992. The mean and rms velocities derived from these drifter motions, combined with bi-weekly maps of XBT-derived sea surface temperatures (SST), were used to estimate the mean and eddy advective heat flux at 15 m between Autumn 1990 and Spring 1993, a period of transition from non-El Nino to El Nino conditions. The estimates, interpolated to a grid which encompasses the dominant spatial scales of upper ocean thermal structure variability in the region, were analyzed to extract the seasonal cycle of heat flux convergence and to elucidate the variability due to the developing El Nino. The XBT data were also used to determine mixed layer depth, and the contribution of the derived heat advection to the mixed layer heat budget was estimated.

Room/Salle: Auditorium [3dAM] Wednesday/Mercredi

ATMOSPHERIC MODELLING 3
MODÉLISATION DE L'ATMOSPHÈRE 3

Chair/Président: Norm McFarlane

[3dAM1] A Numerical Study of Mesoscale Flow over the Canadian Southern Atlantic Region During a Ground-Level Ozone Episode

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Some initial analyses of the meteorological measurements, obtained from the NARE-93 (Northern Atlantic Regional Experiment) summer intensive campaign, indicate that the lower atmosphere over some of the sites in the Canadian Southern Atlantic Region (SAR) is frequently under very stable conditions and characterized by complex layered structures. The details of the mesoscale flow and the structure of the lower atmosphere are of critical importance to the understanding of transport and oxidant problems in that region. A mesoscale, compressible (non-hydrostatic), community model (MC2) is used to simulate the flow over this region during the 1993 NARE summer campaign. The paper will be focused on the simulation between Aug. 26 and Aug. 29, 1993 which coincides with a ground level high ozone episode in the area. Model results, with a final horizontal resolution of 5 km, are compared with the aircraft measurements as well as some ground-based measurements. The low level jet, mechanisms of vertical mixing and their roles relating to the ground level high ozone in SAR are discussed.

[3dAM2] Tropospheric Distributions of NMHC in Winter Using a 3-D SL Chemical Transport Model and CMC objectively analysed meteorological data

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We are developing a 3-D global chemical transport model to study oxidation processes and possible effects of subsonic and supersonic aircraft in the troposphere and lower stratosphere. The model can be driven by climatological or objectively analysed wind fields. It contains a parameterized representation of the boundary layer and convection is currently modelled by a Prather-like scheme. Simple rainout is included. Both the latter processes are driven with statistical data from the AES GCM. The chemistry is oxidant chemistry and includes C2-C4 alkanes and C2-C3 alkenes (38 chemical species, 70 chemical reactions, 17 photolysis reactions). The semi-Lagrangian transport code was supplied by Phil Rasch (NCAR). The model uses sigma levels with the top currently at about 10 mb. We will present detailed distributions of NMHC, NOx, NOy species as well as Ozone and relate these to the emission fields and the dynamics. We will present estimates of ozone and CO transport from North America to Europe within the model for winter and possibly spring using Objectively Analysed winds from the Canadian Meteorological Centre degraded to T32 for the winter and spring of 1994/95.

[3dAM3] Numerical Modelling of Flow and Dispersion around a Building in neutral and non-neutral conditions

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Numerical simulation of atmospheric flows in presence of obstacles and terrain inhomogeneity is important for many purposes, in this number for risk assessment, pollution dispersion, air quality and town planning.

First part of this study addresses the interaction of a single building with the atmospheric flow. Second part is concerned with influence of the building on passive and non-passive pollutant dispersion, it includes also the case of heavy gas. The problem is treated numerically using finite volume method and turbulence modelling in 2D and 3D. Within this approach the influence of the atmospheric stratification has to be conveyed by the turbulence model and different variants of the k,n model have been applied and tested.

The undisturbed atmospheric boundary layer profile is used to prescribe the inlet boundary conditions and it is one of the principle mechanisms to include the influence of the atmospheric stratification in the numerical model. Naturally, the numerical results will depend on the inlet profiles and this point has to be treated carefully. The first possibility is to prescribe the inlet profile from some theory (e.g. Monin-Obukhov) or field measurements. This approach encounters a number of difficulties. The profiles of the turbulent quantities are not included in Monin-Obukhov theory; they are not covered by many experimental data sets. Next, the inlet profiles are not in agreement with the turbulence model inside the computational domain and this causes sometimes divergence of the numerical solution; so the numerical procedure becomes unreliable due to the deficiencies of the mathematical model. Further, this defect leads to an artificial evolution of the numerical profile over flat terrain and to a spurious dependence of the results in presence of obstacles from the position of the inlet. The second possibility is to construct an approximation of the initial profile, which is in agreement with the applied turbulence model. This approach permits to remove the convergence problems and gives clear idea and quantitative information about the discrepancies between the turbulence modelling and Monin-Obukhov theory.

Comparisons of the numerical results with existing experimental and numerical data are also included.

[3dAM4] Analytical solutions to Newtonian nudging model

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This study presents a linear analysis of solutions to a simplified mesoscale model with Newtonian nudging. The solution is given in an analytical form for each Fourier component of the time series of observed velocity. In response to the stationary part of the observed nudging velocity, solutions are on a semi-circle connecting observed velocity and the geostrophic velocity in u-v plane. For other Fourier components of observed velocity, the solution possesses the same frequency, but smaller amplitude and a phase lag. Attenuation in amplitude and lag in phase are expressed in analytical forms.

Target nudging schemes have been devised in order to ensure the model result is identical to observed velocities. We investigate this approach as well. An analytical form for this target velocity is derived, and is shown to result in a larger amplitude, and a phase lead compared with the observed velocity. The analysis shows that target velocity exists only for some observed velocities.

[3dAM5] A case study of mobilization and transport of the east asia dust

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A sanddust mobilization model and a sanddust transport model are coupled with Limited-Area Fine-Mesh Model of Peking University. Using the coupled model,the numerical simulation of an east-asia sandstorm occurring april 11-23, 1988, were run for 3 days.The region of simulation encompasses eight desert areas of east asia with a horizontal resolution of 200 km.The grid dimensions are 41x27. The simulation results show that the deposition of sanddust is always located at the northeast or southeast edge of a cold high pressure system,where the concentration of mid-size particles (about 4 -6 micron) three hours prior is located. There are two ways of transporting sanddust. One is that sanddust clouds are lifted upward over the desert areas into midlevels of the model atmosphere and advected pushed by a midlevel westerly jet. The other is that sanddust clouds are lifted by the upward motion only to low levels and transported by a shallow westerly jet. According to the 3-dimensional vedeo of the simulation,the largest concentration of sanddust, which originates above the area where the frictional velocity of the surface is much greater than 0.3 m/s,can be transported 1000 km away by this current synotic scale environment.

Room/Salle: Arts 108 [3dBM] Wednesday/Mercredi

BOUNDARY-LAYER METEOROLOGY 2
MÉTÉOROLOGIE AÉRONAUTIQUE 2

Chair/Président: Phil Austin

[3dBM1] A preliminary study of surface effects within Avalon Peninsula winter storms

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Five winter storms that affected the Avalon Peninsula of Newfoundland during the Canadian Atlantic Storms Program II (CASP II) field project are examined. Using the air mass transformation (AMT) model, we determined the low-level atmosphere impacts of 3 types of underlying surface: snow-covered land, open water at varying sea-surface temperature (SST) and sea ice at varying concentration. Land acted as a heat sink, open water as a heat source and sea ice acted as either a heat sink or a heat source. The presence of sea ice enhanced the possibility of freezing precipitation events at its edge.

[3dBM2] Incorporation of a simple land surface processes scheme into a mesoscale non-hydrostatic model

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This study reports the progress related to the incorporation of a simple parameterization of land surface processes (i.e., ISBA: Interactions Soil-Biosphere-Atmosphere) into a mesoscale non-hydrostatic (Meso-NH) Atmospheric Simulation System, jointly developed by the Centre national de recherches météorologiques (Météo-France) and the Laboratoire d'aéorologie (Université Paul Sabbatier). This model is based on a modified anelastic system and takes advantage of an interactive grid-nesting strategy; it thus represents a potentially powerful tool to investigate scales interactions and small-scale circulations. On the other hand, the ISBA scheme solves additional prognostic equations for the surface and mean surface temperature, the surface volumetric and mean volumetric water content, the interception water storage, the equivalent water content of the snow reservoir, and the snow albedo and density. This scheme, now including a more sophisticated treatment of snow and drainage, has been tested against several observational data sets (e.g., HAPEX-MOBILHY, EFEDA, FIFE). The structures of both the meso-NH model and the ISBA scheme, as well as some previous validations of the surface scheme, will be briefly presented. Then, preliminary results of the coupled system will be discussed, with special emphasis on the difficulties arising from the assimilation of the additional prognostic variables, and from the determination of the soil and vegetation parameters, kept to a minimum in the ISBA scheme. The soil composition, in terms of clay and sand fractions, is used to evaluate most of these parameters.

[3dBM3] A 2D finite difference numerical model on evaporation from lakes

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A two dimensional implicit finite difference, numerical model is developed to investigate evaporation from lakes due to local advection, modified by internal boundary layer growth. The model approach is similar to Taylor's models (1970 and 1971), using mixing length hypotheses. Model results include airflow over step changes in surface temperature and roughness under neutral and non-neutral thermal stratification. Because a constant surface flux layer is assumed, initial results are demonstrated for airflow below 50m of in the lowest part of the atmosphere under stable thermal stratification.

[3dBM4] Experiments with the land surface scheme CLASS in the MC2 model

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The land surface scheme CLASS developped for the Canadian GCM has been connected to the Mesoscale Compressible Community (MC2) model. CLASS has the potential of modelling with some realism the moisture and energy tranfers through the soil and the vegetative canopy, while the MC2 can simulate the atmospheric circulation at very high resolution. Initial experiments involve the definition of the roughness length based on high resolution topographical data (500 m) and vegetation classes. Different recipes for calculating the roughness lengths for momentum and for heat and moisture will be tested over a few areas including montains, forests and agricultural zones. The impact of the formulations on various quantities will be studied, such as near-surface wind, temperature, moisture, and their associated fluxes. Of particular interest is a formulation of surface drag using a roughness length with a dependence on wind direction.

[3dBM5] A Study of One Case of High Concentrations of Wood Smoke Particulates in the River Valley at Whitehorse.

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Strong wintertime inversions frequently combine with light winds to generate conditions with poor dispersion in the river valley at Whitehorse. Extensive use of wood burning for domestic heating causes high concentrations of suspended particulates during these periods. The primary control on wood smoke dispersion is small scale flow. A period of high pollutant levels is examined from February 1994. The influences of meteorology external to the valley, the meteorological structure of the valley, the topographic influences, the structure of the surface layer and the results from a mesoscale model (MC2) are considered. The goal of the study is to provide better understanding of conditions which lead to poor dispersion and improve prediction skill.

[3dBM6] Adaptation of a boundary layer column model for terminal area short term ceiling & visibility prediction

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Very short-term forecasting (0-60 minutes) of ceiling & visibility (C&V) at major terminals is a difficult task and an increased accuracy in C&V products made available to the aviation community could represent enormous benefits. In this presentation, the use of a high-resolution 1D column model for the improvement of short term forecasts of ceilings and visibilities will be presented.

For this work COBEL, a 1D nocturnal boundary layer model recently developed at the Laboratoire d'Aérologie (Université Paul Sabatier,Toulouse, France) for radiation fog forecasting purposes, is being modified for potential use within FAA's Integrated Terminal Weather System (ITWS). Work toward its adaptation to a wider range of applications has been undertaken at UQAM in collaboration with MIT Lincoln Laboratory.

Because it is a 1D model, COBEL must be coupled to either analyses or a 3D numerical model in order to incorporate mesoscale external forcings such as pressure gradients, horizontal advections of temperature and humidity, as well as cloud cover. COBEL can then be used to predict the local vertical structure of the lower atmosphere. COBEL's main features are a very high resolution near the surface, a 1.5 order turbulence closure scheme, a high spectral resolution infrared radiation scheme and an all or nothing condensation scheme.

Areas of recent model development are the adaptation of the model to daytime scenarios (addition of a solar radiation scheme) and the introduction of mesoscale vertical motion and local pressure tendencies as additional external forcings. The roles of such forcings in the production of fog or low clouds are then explored.

Room/Salle: Arts 118 **[3dFB]** Wednesday/Mercredi

FISHERIES AND BIOLOGICAL OCEANOGRAPHY
OCÉANOGRAPHIE BIOLOGIQUE ET DES PÊCHES

Chair/Président: Paul LeBlond

[3dFB1] Dissolved and particulate nucleic acid in the Okhotsk Sea during the Summer seasons, 1992-1994

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Research on biochemistry compounds of organic matter in the ecosystem of the Okhotsk Sea showed that, as a rule, the distribution of nucleic acid (NA) was conditioned by micro-organisms production (especially phytoplank- ton and bacterioplankton), associated with the non-living particulate orga- nic matter pool and sperm production during mass spawning events. The maximal concentrations of dissolved NA (up to 0.684 mg/l) over the whole period of study were observed on the Sakhalin and Kamchatka shelves and in the surface layers over the continental slope. With depth the con- centration of dissolved nucleic acid (DNA) decreased to the average values 200-500 mg/l, that constituted 2-5 % of dissolved organic matter. An increa- se in concentrations of dissolved and particulate proteins was also obser- ved there. Off the Kuril Islands the concentration of DNA was 2-3 times higher than that of protein which was characteristic for viruses, micoplazm and sexual products of hydrobionts. The value of this ratio was determined by species composition of picoplancton population. As a rule, the highest concentrations of particulate nucleic acid (PNA) were observed on shelf and in the 0-50 m layer. With depth their con- tent decreased by a factor of 2-3. Sometimes the surface concentrations of PNA were noted deeper (at depths of 100-200m). At these depths the ratio of PNA to protein increased by a factor of 2-3, that indicated the increa- sed content of POM of hydrobionts sexual products The content of PNA did not exceed 10-20 % of particulate protein. The uneven vertical distribution of PNA is determined by unsteadiness of micro- plankton distribution and, as a rule, maximums of PNA concentrations coin- cided with maximums and minimums of particulate protein concentrations. In the open Okhotsk Sea the maximal content of PNA in the photic layer (up to 37 mg/l) coincided with areas of the increased primary productivity. The content of PNA relatively to POM did not change essentially in the water column and was 3-8 %.

[3dFB2] The Distribution and Variability of Dissolved Oxygen in the Gulf of St. Lawrence

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in the gulf of St. Lawrence are analysed. The oxygen level measured in the Laurentian channel at depths greater than 200 m has been lower since 1981 than 1960's values. Because this water is advected toward the estuary from the shelf region under oxidative processes, present observed levels are below 3 ml l^{-1} near Anticosti Island. Such values are reported to cause undesirable physiological responses in cod which will in turn avoid these waters. We examine the relationship between the T, S and O_2 properties in the deep Laurentian channel. We discriminate the relative importance of the source waters: Labrador water (high in oxygen, in greater proportion in the 60's) and North Atlantic water (low in oxygen). Then we examine the possibility of hind-casting interdecadal variations in oxygen content using T–S characteristics observed in the gulf since the early 1950's and relate those results to fisheries.

[3dFB3] Acoustic Measurement of Net Avoidance

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During the summer of 1994, deep (to 2000m) net tows were conducted over the central hydrothermal vent site at Endeavor Ridge in the northeast Pacific. The zooplankton survey was conducted using a modified Tucker trawl with seven discrete .335mm nets and a one square metre frontal aperture. The gear was also equipped with

a forward facing 150 kHz acoustic Doppler current profiling transducer and a CTD transmissometer package. The ADCP measured volume flow incident to the net opening and mapped acoustic backscatter intensity from zooplankton in 70 4-metre bins anterior to the trawl. The backscatter data is analyzed to give indication to the to when (spatially), and to what degree, marine organisms in the path of the trawl evade the net.

[3dFB4] Effects of the Alaska Gyre Circulation on Fraser River Sockeye Salmon Return Times

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Fraser River sockeye salmon (Oncorhynchus nerka) are managed by escapement goals for each stock group (e.g. early Stuart, Chilko, Horsefly, and Adams). Achieving these escapement goals is complicated by interannual variations in the return times of each stock. Almost a decade ago, a simple temperature displacement model was used to develop predictive regressions of stock-specific return times using winter/spring sea surface temperatures in the northeast Pacific Ocean. In the last five years, however, these regressions have failed for most stocks - sockeye salmon returned later than predicted.

Computer simulations of the effects of ocean currents on sockeye salmon return migrations have shown that the interannual variability of northeast Pacific Ocean currents could account for year-to-year differences in return times as high as 2 wk, depending on the pre- migration distribution of a stock group. Stocks returning from the southern portion of the Alaska Gyre would receive a homeward assist by the eastward-flowing SubArctic Current; whereas, the northward-flowing Alaska Current would impede the homeward progress of stocks starting in the northern portion of the gyre. Thus, a stronger Alaska Gyre circulation would result in earlier return times for "southern" stocks and later return times for "northern" stocks.

We have hypothesized that sockeye salmon return migrations are affected by sea surface temperatures and ocean currents: surface temperatures delineate the southern boundary of pre-migration distributions and affect the ocean current regime from which sockeye salmon start their homeward migrations. We are using computer simulations to investigate the viability of this hypothesis. Our goal is to develop predictive models, using indices of ocean surface temperatures and currents, for forecasting stock-specific return times. This talk will discuss our methodology and present our predictions of Fraser River sockeye salmon return times for 1995 (unfortunately, it will not be possible to examine the accuracy of these predictions, because the fishery will not have started at the time of the conference).

[3dFB5] Those missing sockeye and the environment

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In late summer 1994 a crisis in the management of the Fraser River sockeye fishery occured following announcements of: 1- a discrepancy of nearly one million fish between estimates of early and mid-summer runs passing the Mission hydroacoustic counter and numbers of fish on spawning grounds; 2- an overestimation, by nearly 2 million fish, of the Adams River and other later runs before entering the river. This talk will present an overview of the findings of the Review Board appointed to examine the question and a discussion of the environmental questions (at sea and in the river) associated with the sockeye migration.

[3dFB6] The Effects of the Hudson Strait Outflow on the Biology of the Labrador Shelf

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Data collected on the Labrador Shelf are used to examine the hypothesis that a nutrient flux from Hudson Strait increases primary production on the northern Shelf and that this supports a developing food chain as the water is transported southward by the mean circulation. Our results confirm that the high nutrient levels on the northern Labrador Shelf in summer are due to advection from Hudson Strait. These nutrients enhance local plankton production but there is no biological evidence to support the idea of a developing food chain that is

advected southward along the Shelf.

Room/Salle: Arts 116 [3dLR] Wednesday/Mercredi

LONG RANGE FORECASTING 1
PRÉVISIONS À LONG TERME 1

Chair/Président: Madhav Khandekar

[3dLR1] Ensemble Forecasting at the Canadian Meteorological Centre

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The underlying idea of ensemble forecasting comes from the fact that operational analyses are not perfect for mainly two reasons: the unequal distribution of the observational network (few data over large bodies of the oceans) and variable quality of the observations (satellite data are not as reliable as radiosondes data). Thus the resulting analysis does not represent the "true" state of the atmosphere. Minor modifications to the analysis may in some cases improve the quality of the forecast. By integrating several "perturbed" analyses using low resolution model, more information can be obtained than from only one forecast done at high resolution. The reason for this is twofold: the mean of the forecasts can produce a better forecast (the averaging smooths out the unpredictable smaller scales) and the spread in the forecasts can give an idea of its uncertainty.

The way to modify the analysis is not obvious and was examined by Houtekamer and Derome (1994). The idea put forward in the present work is to perturb the observations themselves by adding to them random values of the order of magnitude of their observational errors. This set of perturbed observations is fed into a parallel assimilation cycle in order to produce a perturbed analysis. At the beginning, the operational analysis and the perturbed one are very similar. However, after a few days, because of the error growth caused by the 6-hour progs, differences become significant.

Independent parallel assimilation cycles (four were used during our experiments) can be generated by using different random values to perturb observations. It was found that in order to increase the differentiation between the perturbed analyses, different physics packages also had to be used by the model producing the trial fields. At the end of the spin up period (typically 4 days), it is possible to obtain 8 perturbed analyses (the doubling being obtained by substracting perturbations from the control).

Preliminary results of ensemble forecasts in the 10 to 15 day range will be shown and examples of the usefulness of the technique presented.

Reference: Houtekamer, P.L. and J. Derome, 1994, Prediction Experiments with Two-Member Ensembles, Mon. Wea. Rev., 122, No. 9, pp. 2179-2191.

[3dLR2] Long lead Seasonal Prediction of Canadian Surface Temperature by Canonical Correlation Analysis

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The predictive skill of surface temperature over Canada is investigated by the use of multivariate linear statistical methodology of Canonical Correlation Analysis (CCA). Using data over the 1955-92 period long lead time skill is evaluated by CCA in which predictor patterns in time and space are linearly related to subsequent predictand patterns. In this study, four consecutive 3-month predictor periods are used. Predictor fields are quasi-global sea surface temperature (SST) from 40S to 60N, Northern Hemisphere 500 mb heights and prior values of the predictand field. In order to capture low-frequency component in the data both predictor and predictand data are pre-filtered by the unrotated Emiprical Orthogonal Function (EOF) analysis and the amplitudes of the first six modes are then analyzed by CCA. The technique of cross- validation, where every year in turn is held out from the model development process and assigned as a forecast target, is used to assess skill. Correlation between forecast and observation defines the skill in our model. Results show useful predictive skill and for

some locations and for some seasons, CCA skill is far above those offered by chance or climatology.

[3dLR3] ENSO Prediction Using Neural Networks

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We have used neural networks to predict the equatorial sea surface temperatures (SST) from the tropical Pacific wind stress fields, in an attempt to nonlinearly model the relationship between the two. To predict the SST anomalies at time t + LT where t indicates a particular month and LT is the leadtime (in months), the network is trained with the first four dominant EOF modes of the wind stress field. For all modes, the amplitudes at times t-3, t-2, t-1 and t were included in the input to the neural network. The results show that the neural networks trained with data from 1952 to 1981 outperform persistence at all leadtimes in retroactive forecasts of SST anomalies in the central equatorial Pacific region (Nino 3.4) for the period 1982-1992. These skills are comparable to those of existing dynamical and linear statistical models. For leadtimes greater than 3 months, the neural networks forecast skills are superior to those of a multiple linear regression model. Thus for longer leadtimes, the introduction of nonlinearity in the model enhances the prediction skills. Results on predicting SST anomalies in other parts of the tropical Pacific, as well as evaluating the skill in the cross-validation mode, are also presented. Long-term goals include forecasting atmospheric teleconnections and coupling neural network models to GCMs.

[3dLR4] EOFS, Detection of Regional ENSO Signals, and Network Designs

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For nonhomogeneous fields of climate anomalies, emperical othorgonal functions (EOFs) form a natural reference frame for the optimal detection and forecasting of changes in regional anomalies. To determine the climate anomalies over Western Canada related to ENSO, we conducted EOF analyses of wintertime Northern Hemisphere 700mb and 500mb heights and of surface air temperature. The time series of the coefficients of the various modes were correlated with the time series of SST anomalies in the NINO3 region (5S-5N, 90-150W) of the equatorial Pacific in order to ascertain which modes of the variability are best correlated with the ENSO signal. We suggest that the modes which show the strongest significant correlations with ENSO may be used in a Canonical Correlation Analysis (CCA) prediction scheme for temperature and height anomalies over Western Canada related to ENSO. Finally we will briefly discuss how to use EOFs for the optimal designs of detection networks which yield minimal sampling errors and maximal signal-noise ratios.

[3dLR5] Variation in Predictability in Relation with the Pacific-North American Pattern

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Numerical experiments are performed to determine whether the forecast skill of a model is affected by the presence of a Pacific-North American (PNA) flow anomaly. The use of a three-level quasi-geostrophic model truncated at resolution T21 allows a large number of predictions to be made at low cost. A perfect-model approach is used, so that all forecast errors result from errors in the initial conditions. The relationship between the forecast behaviour and the year-to-year fluctuations of the PNA anomaly is investigated. Comparison of the forecasts errors made during the positive and negative PNA phases indicates that little difference in the error growth can be realized before about a week. After that period the forecast error grows faster during the negative PNA phase. The forecast skill for the medium-range predictions over the North Pacific, the North American and the North Atlantic regions is higher during the positive PNA phase than that during the negative PNA phase. A global signal of this relationship is also observed. The physical mechanism for the difference in the error growth between the two phases of the PNA is discussed.

[3dLR6] Climatic Teleconnections from the Pacific Ocean to the Canadian Prairies - Implications for long range forecasting of red spring wheat yields

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Large-scale atmospheric and oceanic circulation patterns and anomalies associated with El Niño/Southern Oscillation (ENSO) events have been shown to significantly impact on seasonal weather and grain yields over many parts of the world, including Canada. Previous research has indicated that the warming of the sea surface in the east equatorial Pacific (El Niño) tends to favor Canadian red spring wheat yields, while sea surface cooling in the same region (La Niña) mitigates against yields. In this study precipitation, temperature and wheat yield data for the Canadian prairies covering a 40 year period (1950-1989) are used to examine statistical relationships with ENSO parameters like SST (sea surface temperatures) and SOI (southern oscillation index).

Furthermore, the impact of the Pacific North American (PNA) atmospheric oscillation on temperatures and precipitation over the Canadian prairies is investigated by a statistical analysis. The correlation of the PNA index (which is defined in terms of mid-tropospheric geopotential height anomalies at selected locations over Hawaii, the Gulf of Alaska, Alberta and the Gulf of Mexico) with temperature, precipitation and yield values over the Canadian prairies is studied using data for the 31 year period (1964-1994).

In this study, regression methodology is applied to data for the 26 year period (1964-1989) to develop climate-based models for early prediction of red spring wheat yields for the Canadian prairies. Models utilizing monthly prairie precipitation and temperature data are compared to models supplemented with variables related to ENSO and PNA teleconnections. The predictive performance of these models is also assessed using independent data for the years 1990 through 1994. Models utilizing teleconnections appear to usefully enhance long-range forcasting of red spring wheat yields.

Room/Salle: Multi-purpose Room **[3dWO]** Wednesday/Mercredi

WOCE 2
WOCE 2

Chair/Président: Patrick Cummins

[3dWO1] Trends in Properties at Ocean Station Papa and B.C. Coastal Stations

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Sea surface temperatures in the N.E. Pacific Ocean show a warming trend, and salinities show a strong declining trend in data collected over the last 60 years. Both of these conspire to reduce the density of the surface layer over a large area of the N.E. Pacific. The declining surface density changes the energetic requirements for the formation of surface mixed layers and observations at Ocean Station Papa indicate that mid-winter mixed layers depths are showing a rapid decline. Other authors have reported an increase in productivity of the N.E. Pacific Ocean, and we suggest a mechanism that might explain this increase in productivity. Both the increase in productivity and the sharpening of the base of the mixed layer should tend to reduce winter nutrient levels, evidence is presented that nutrient levels in the N.E. Pacific are in fact declining.

[3dWO2] Mixing in the main thermocline of the North Atlantic

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The North Atlantic Tracer Release Experiment was designed to study diapycnal mixing in the main thermocline by the release and measurement over the following year of a small amount of Sulfur Hexafluoride, a man-made tracer detectable at extremely low levels. The tracer results tell us that the main thermocline diffusivity is very small. Is this consistent with our understanding of turbulent mixing generated by internal waves? We compare

the diffusivity measurements with observations of turbulent microstructure taken during the experiment, and with the models used to interpret them.We also comparethe results with measurements of internal wave shear and strain from moored current meters deployed during the experiment.

[3dWO3] Near-surface circulation in the Newfoundland Basin

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Altimetric measurements from the TOPEX/POSEIDON mission have been analyzed to produce maps of sea surface topography and associated geostrophic flow fields in the Newfoundland Basin. The results are compared with dynamic height fields based on hydrographic measurements obtained from C.S.S. Hudson in 1993 and 1994 as part of the Bedford Institute of Oceanography's contribution to WOCE Core Project 3.

[3dWO4] A new instrument for measuring temperature and salinity profiles from underway vessels.

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We have been developing a system capable of obtaining ocean profiles from vessel steaming at speeds up to 22 knots with the minimum operator interaction. A system that we consider as an operational prototype was used on Hudson during October/November 1994 to obtain temperature and salinity profiles to 600 metres at speeds up to 13 knots. The limitation to 600 metres was due to the limits of the pressure transducer of the CTD probe, not the mechanical capability of the system. The system uses a modern self recording CTD system that is housed in a heavy streamlined drop sonde which is deployed and recovered automatically using a computer controlled winch and handling system. The instrument will be used in June/July of 1995 to obtain a temperature/salinity section to 1500 metres as Hudson steams from the Irminger Sea to the Newfoundland Basin. It is hoped that this system will provide an alternative to expendable instrumentation when collecting routine upper ocean temperature, salinity or sound speed profiles.

[3dWO5] Dynamics of circulation in Okhotsk Sea using multiple chemical tracers of chlorofluocarbons and dissolved silicate along WOCE line P1W in 1993.

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The dynamics of circulation in Okhotsk Sea was studied along WOCE Line P1W from the Siberian shore to the Kuril Islands, during August-September, 1993 on the Russian RV Nesemeyanov.. Chemical measurements included chlorofluorocarbons CFC-11 and CFC-12, dissolved silicate and other nutrients, oxygen and physical oceanographic properties of T,S. A subsurface layer of maximum CFC's at about 100 m. depth extended from the Siberian shelf water to near Kuril Islands. The CFC's penetrated to about 1,000 m., the sill depth of the Deryugina Basin. The deeper Kuril Basin was free of freons in waters deeper than 800-1,000 m. Anthropogenic CO2 also penetrated to about the same depths. The dynamic features of the circulation in Okhotsk Sea is discussed based on features of the water masses as revealed by the chemical measurements, particularly on the formation of the North Pacific Intermediate Water (NPIW) and the inflow of the Pacific Warm Deep Water into Okhotsk Sea.

Room/Salle: Auditorium [3ePB] Wednesday/Mercredi

PUBLIC
PUBLIQUE

Chair/Président: Paul LeBlond

[3ePB1] The Little Ice Age in Canada

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The Little Ice Age (AD 1450 - 1850) was a period of cooler and moister climate around the world. In Europe, it affected harvests and caused advances of alpine glaciers. Because it started before recorded history in Canada, we have little information on its effects here. Archaeology, fossil pollen analysis, studies of glaciers and old tree-stumps give us some clues. Irish and Norse exploration of the New World, which flourished during the preceding Medieval Warm Period, was cut short by the Little Ice Age. In southern Ontario, the cooling may have killed beech forests, allowing the southwards expansion of the boreal forest. The aboriginals of the region, who were dependant on maize, beans, and squash, suffered from the reduced growing season. In the western cordillera, mountain glaciers advanced down-valley to their greatest extents in 10,000 years. At the same time, the tree-line receded downhill. In the prairies, where drought is a greater stress than the cold, previously dry lakes filled and streams ran faster. Further north, permafrost formed in peatlands, creating raised islands which were colonized by trees; these are now melting and the trees are dying.

Room/Salle: Multi-purpose Room [4aPL] Thursday/Jeudi

PLENARY
ASSEMBLÉE PLÉNIÈRE

Chair/Président: Phil Austin

[4aPL1] Effects of Climatic Warming on the Physics, Chemistry and Biology of Freshwater Lakes

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Lakes and streams in the Experimental Lakes Area, northwestern Ontario, were monitored for a broad suite of physical,chemical, hydrological and biological properties during the 1970's and 1980's, a period when climate in the area warmed by 2 degrees C. and precipitation declined to half of long-term averages.

Small lakes became clearer and thermoclines became deeper, due to a number of factors, including: (1) increased wind exposure caused by increasing forest fires in the lake basins; (2) decreased inputs of dissolved organic matter (DOM) from terrestrial catchments, caused by decreased soil moisture and increased oxidation of organic matter in soils, and (3) greater in-lake removal of DOM by microbial, chemical and photochemical processes.

Geochemical weathering of mineral soils and bedrock declined, but yields of base cations from burned vegetation and sulfate from drying organic soils caused major shifts in ionic ratios of lakes and streams. The combination of climatic effects on physical, chemical and biological processes in lakes and their catchments caused some streams to become more acidic, while lakes became more alkaline, and lakes to become increasingly phosphorus-limited.

The combination of physical and chemical changes caused declining summer habitats for cold stenothermic and UV-sensitive organisms.

[4aPL2] Low Frequency Variability in the Arctic Atmosphere/Sea Ice/Ocean Climate System

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The low frequency natural variability of the arctic climate system is modeled using a single-column, energy balance model of the atmosphere/sea ice/ocean system. Variability in the system is induced by forcing with realistic, random perturbations in the atmospheric energy flux convergence and cloudiness. The model predicts that the volume of perennial sea ice varies predominantly on multi-decadal time scales while other arctic climate variables vary mostly on intraannual and interannual time scales. The total simulated sea ice volume variance is most sensitive to perturbations of the atmospheric forcing in late spring, at the onset of melt. The variance in sea ice volume increases as the mean sea ice thickness increases and as the number of layers resolved in the sea ice model increases. This suggests that much of the simulated variance develops when the surface temperature is able to decouple from the sea ice interior during the late spring, when melting snow abruptly exposes the sea ice surface and changes the surface albedo. The minimum model requirements to accurately simulate the natural variability in the arctic climate are identified. The implications of the low frequency, natural variability in sea ice volume for detecting a climate change are discussed. Finally, calculations suggest that the variability in the thermodynamic forcing of the polar cap could lead to a freshening in the North Atlantic that is comparable to the freshening associated with the Great Salinity Anomaly.

Room/Salle: Arts 116 **[4bAR]** Thursday/Jeudi

SEA ICE AND ARCTIC STUDIES 1
GLACES DE MER ET ÉTUDES DE L'ARCTIQUE 1

Chair/Président: Paul LeBlond

[4bAR1] The Sea-ice Budget of the Arctic: Models and Observations

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Variability in the Arctic sea-ice budget (ice volume, growth/melt, and outflow) are studied using a multi-category dynamic-thermodynamic sea ice model forced with observed wind and air temperature fields over the period 1951-1990. After a very brief description of the model and forcing data, time series of various ice budget quantities will be examined and compared to observations where available. Emphasis will be placed on variability at interannual and longer time scales and on the supply of fresh water, via ice transport, from the Arctic into the Greenland Sea. Since the model simulates the evolution of the entire thickness distribution, we can also compare the behaviour of thick and thin ice. We find that time scales associated with ice less than 1m thick are short (on the order of a month or two), owing to open water formation and ridging destruction during synoptic storm events. On the other hand, the several year time scales associated with thick ice (> 5m), which accounts for nearly half of the ice volume in the central Arctic, result from slow net melt over each annual cycle and export through Fram Strait.

[4bAR2] Observed and Modelled Interannual Variability in Landfast Sea-ice

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A one-dimensional thermodynamic sea-ice model is developed and used to perform multi-year simulations of land-fast sea-ice and its snow cover. The model solves the transient heat conduction equation using a finite difference method, an arbitrary number of horizontal ice layers and one snow layer. Parameterizations of conductivity and surface albedo are based on observations. Bulk boundary layer formulae are used to convert standard meteorological observations into surface fluxes, and an oceanic mixed layer is included to allow heat storage during ice-free summer months. The model is applied to two locations in the Canadian high Arctic:

Resolute, NWT and Alert, NWT. The sites were chosen because of the available meteorological observations and ice and snow depth measurements spanning the period 1955-1990. With specified snowfall, the model is quite successful at reproducing seasonal and interannual variability in maximum ice thickness, snow depth, freeze-up and break-up dates. Sensitivity studies demonstrate the relative importance of variables such as air temperature, snow depth and snow cover properties (e.g. density) on interannual variability of maximum ice thickness and the duration of the ice-free season.

[4bAR3] Sea ice response to wind forcing on the Labrador shelf

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In the spring of 1994, two beacons with anemometers were deployed on pack ice off Cartwright, Labrabor. These instruments provided hourly 2 metre winds as well as beacon position. An RDI acoustic doppler current profiler (ADCP) was moored on the ocean bottom in this area to provide ice velocities and ocean currents. The response of the pack ice to the forcings by wind and ocean currents will be presented. The data from the beacons on the pack ice will be compared with hourly observations at Cartwright airport and with another beacon deployed on Grady Island just off the coast. CMC regional finite element model forecasts of the 10 metre boundary layer winds are also compared with beacon obsevrvations to determine the feasibilty of using these forecast winds in operational ice models.

[4bAR4] A Dynamical Model of Sea-Ice Based on Quasi-Static Granular Flow Theory

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The ocean circulation in the Arctic is strongly influenced by the nature of its ice cover. Ice formation in the Arctic region along with ice melt in the Norwegian and Greenland seas and North Atlantic Ocean create a net southward flux of fresh water and northward flux of heat which strongly influence the rate of deep water formation in the North Atlantic and hence the ocean thermohaline circulation. Moreover, interactions between ice floes influence the sea-ice motion and therefore must be taken into account to obtain a realistic simulation of the ice velocity field. In previous climate studies, sea-ice has been considered as an inviscid fluid or a non-linear viscous fluid with no resistance in tension. Since sea-ice in the Arctic is made up of many floes, it can be considered as a granular material of relatively large scale. Moreover, photograph of the sea-ice cover taken at high altitudes show a distinct lead pattern which is typical for that type of material. In this study, a sea-ice rheology applicable to quasi-static granular flow and based on a double sliding model is presented. The ice is considered to have a constant internal angle of friction and no cohesion (no resistance in tension). Results are presented and compared with other sea-ice model.

Room/Salle: Multi-purpose Room [4bCL] Thursday/Jeudi

CLIMATE AND PALEOCLIMATE 2
CLIMAT ET PALÉOCLIMAT 2

Chair/Président: Ian McKendry

[4bCL1] Measurements of the Forcing Radiation of Global Warming

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Global warming is driven by increases in the greenhouse effect of the atmosphere. Atmospheric spectra of greenhouse radiation from the atmosphere have been measured at ground level from Peterborough at a resolution of 0.2 wavenumbers. This long wave radiation consists of thermal emission from CO2 and H2O as well as many trace gases such as CH4, CFC11, CFC12, CFC22 and HNO3. The forcing radiative fluxes from CFC11, CFC12 and CH4 have been quantitatively measured. The implications for global warming potentials are discussed. It is planned to compare these measurements with the radiation code from the Canadian GCM. The thermal emission spectra of several gases such as methane, CFC11 and CFC12 have also been measured in the laboratory.

[4bCL2] Parameterizations of the Microphysical and Thermodynamical Characteristics of Clouds from In-situ Observations: Effects of Cloud on Climate Change

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Clouds play an important role for climate change which is dependent on their different internal physical and dynamical structures within various environmental conditions. In general, climate and forecasting models use simple relationships among cloud physical, thermodynamical, and dynamical parameters. In-situ observations collected over North-Eastern Canada are used to understand the effect of cloud on climate. The observations include particle and aerosol size and number concentration, temperature (T), liquid water content (LWC), and vertical air velocity (w). Individual case studies suggest that there are strong relationships among the above observations, but variability is also large from one case to other case. Observations are averaged along 200 s legs to represent cloud scales within the models. LWC versus T profile show that cloud water content decreases with increasing temperature within marine stratus clouds. Increasing aerosol concentration results in increasing droplet concentration which indicates the importance of aerosol loading into the atmosphere. In-cloud w oscillations are found to be larger than in the cloud-free environment. This study suggests that understanding climate change strongly depends on cloud physical, dynamical, and thermodynamical characteristics.

[4bCL3] Current developments in land surface modelling within the Canadian Climate Research Network

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The Canadian Climate Research Network was established in 1993 under funding from Canada's Green Plan. The objective of the Network is to foster research aimed at improving the ability of the Canadian GCM to simulate current and possible future climates. To achieve this goal, collaborative research projects have been solicited in various aspects of climate modelling. Several research "nodes" have been set up to date, addressing such areas as middle atmosphere modelling; regional climate modelling; land surface modelling; palaeoclimate studies; and climate variability.

This presentation will focus on research which is being undertaken within the land surface modelling "node" of the Network. This work is directed at the validation and improvement of CLASS ("Canadian Land Surface Scheme"), the land surface model which forms part of the Canadian GCM. The work of the "node" falls into two categories. In the first, CLASS is being tested and refined against field measurements from a wide range of Canadian ecosystems. This component involves ten co-investigators from Canadian universities across the country along with their student assistants. Under the second, the regional-scale performance of CLASS is being evaluated in coupled-mode studies with the RCM (Regional Climate Model) and with the MC2 (Mesoscale Compressible Community) model. This effort involves six co-investigators and their research assistants from different universities and government laboratories. Preliminary results for the first six months of the project will be presented.

[4bCL4] Multidecadal climate variability in the Indian Ocean/Australasian region during the austral summer

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Analysis of COADS and UKMO GISST data for the 1900-1983 period in terms of 21 year epochs has shown that during the austral summer (January - March) the Indian Ocean/Australasian region is characterised by substantial multidecadal variability in parameters like SST, wind stress, mean sea level pressure, atmospheric vertical motion and cloudiness. The most pronounced changes appear to be a coherent waxing and waning of the semipermanent southern Indian Ocean anticyclone and SST in the midlatitudes of the southern Indian Ocean.

An ocean general circulation model has been used to investigate possible links between the observed SST

variability and epoch wind anomalies over the Indian Ocean region. Modulations to the southern Indian Ocean gyre in the model and associated vertical motions largely control the SST response when the epoch winds are imposed and lead to greatest SST anomalies in the Agulhas retroflection and outflow zones. The relatively weak epoch wind anomalies over the northern Indian Ocean produce no significant SST response in the model there. Additional experiments indicate that the model SST in the southern Indian Ocean is also sensitive to changes in the magnitude of the climatological winds over the tropical Pacific Ocean on these time scales. The mechanism involves a modulation of the Indonesian throughflow which in turn influences the magnitude of the southern Indian Ocean gyre and hence the SST in the Agulhas outflow zone.

[4bCL5] Cyclic Spectral Analysis of Fluctuations in A GCM Simulation

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Due to the variety of periodic or quasi-periodic deterministic forcing (e.g., diurnal cycle, seasonal cycle, Milankovitch cycles, etc.), most climate fluctuations are cyclostationary process since they are modulated by these cycle. Difficulties in using conventional spectral analysis to explore seasonal variation of climate fluctuations have indicated the need for some new statistical technique. It is suggested here that the cyclic spectral analysis be used for interpreting such fluctuations. The technique is adapted from cyclostationarity theory in signal processing. To demonstrate the usefulness of this technique, a cyclostationary stochastic climate model are constructed. Our results shows that the seasonal cycle is strong modulation in the amplitude of the covariance and spectrum. It is clear that the "seasonal cycle" cannot be "removed" by simply filtering it at the annual cycle and its harmonics. The seasonal variation of intraseasonal oscillation in tropics have also been studied on a zonally symmetric all-land planet in the absence of external forcing. The idealized planet has no ocean, no topography. Fifteen year seasonal runs of the atmosphere are analyzed with the NCAR Community Climate Model (CCM2, R15). Analysis of the simulation data indicates the presence of intraseasonal oscillation in tropics which are also localized in the time of year.

Room/Salle: Arts 108 [4bCO] Thursday/Jeudi

CHEMICAL OCEANOGRAPHY AND LIMNOLOGY 1
OCÉANOGRAPHIE CHIMIQUE ET LIMNOLOGIE 1

Chair/Président: Tom Pederson

[4bCO1] The Seasonality of Diagenetic Trace Metal Profiles in a Seasonally Anoxic Lake

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High-resolution pore water profiles of dissolved Mn, Fe, Ni, Cu, Zn, As, Pb, nitrate, phosphate, sulphate and ammonium and associated solid phase distributions were collected from Balmer Lake, Ontario, over the course of full four-season cycle to assess the diagenetic cycling of metals in the sediments and their exchange with the overlying water column. The waterbody has served as a tertiary polishing pond for two adjacent mining operations, and as a result, hosts high metal inventories.

Basic physical profiling during the spring, summer and fall indicates well- mixed and fully oxygenated conditions of the shallow water column (approx. 4 m). Interstitial Fe and metabolite profiles during these periods are indicative of anoxic conditions in close proximity to the sediment- water interface. Sharp decreases in the concentrations of Zn, Cu, Ni and sulphate at shallow sediment depths suggest metal removal as sulphide precipitates. Arsenic distributions appear to be largely controlled by the behaviour of the oxyhydroxides of Fe and Mn. As a result of ice cover, anoxic conditions develop above the sediment-water interface in the late winter months. The seasonal changes in pore water metal profiles over the fall-winter-spring transition will be discussed with respect to the extent and direction of benthic metal fluxes.

[4bCO2] Cadmium in shelf and slope sediments from the Canada Basin (Arctic Ocean)

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The depth distribution of cadmium in twelve box cores from the continental shelf and slope in the Beaufort and East Siberian Seas follows the same pattern: From surface values of 0.15–0.80 $\mu g\ g^{-1}$ to 2.5 $\mu g\ g^{-1}$, the cadmium content of the sediment always decreases with depth, reaches a minimum, and then increases sharply with further depth. Below the sharp increase, the cadmium content is relatively constant and, in several cores, higher than in the surface sediment. In one core the increase in cadmium is from 0.10 $\mu g\ g^{-1}$ to 2.5 $\mu g\ g^{1-}$. The depth where the sharp increase takes place is always immediately below the bottom of a manganese-enriched surface layer, whose thickness ranges between 1 and 25 cm.

The depth variation of the cadmium content is not caused by changes in lithology since aluminium is virtually invariant within each core, nor can it be ascribed to the presence of carbonate-rich or organic-rich layers. Anthropogenic causes can also be ruled out because of the consistent appearance of cadmium enrichment below the manganese-enriched layer and the great variation in the thickness of this layer. The data are consistent with a mechanism wherby dissolved cadmium diffuses downward into the sediment and is precipitated, possibly as a sulfide, immediately below the manganese enrichment which corresponds to the oxygen-containing layer. The dissolved cadmium may diffuse directly into the sediments from the overlying water column, or it may be produced by dissolving particulate cadmium deposited at the sediment–water interface.

[4bCO3] Silver geochemistry and the potential of silver as an indicator of sewage in the Strait of Georgia

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Silver concentrations in sediments from the Point Grey Dumpsite and offshore from the Iona Sewage Treatment Plant, both in the Strait of Georgia, were determined. Silver concentrations in sewage sludge, municipal wastewater and sewage contaminated sediments are commonly greater than those naturally present in sediments. Silver data on sediments are relatively sparse because natural concentrations are difficult to detect. In this study, sediment digests were preconcentrated and analyzed by ICP-MS in order to detect low levels of Ag. The ability to detect low Ag levels in sediments is critical in tracking sewage effluent that originates from a deep sea outfall equipped with diffuser ports, like that at Iona.

Previous studies have shown that Ag is taken up in the water column by organic matter and Fe-Mn oxides. Upon degradation of the organic matter or reduction of the oxides, Ag is released. Silver is enriched in anoxic sediments likely from the precipitation of the sulphide or from the association of Ag with organic matter and/or pyrite. This spectrum of controls on Ag geochemistry in Strait of Georgia sediments will be assessed by comparing the distribution of Ag to the distributions of a suite of other trace or major elements.

[4bCO4] Seasonality of Trace Metal Reactivity in an Estuary

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Howe Sound, a fjord near Vancouver, Canada, is impacted by acid mine drainage from an abandoned copper mine. Natural leaching processes in the mine workings produce metal-rich runoff which enters Howe Sound by way of Britannia Creek and a submerged outfall. Submerged mine tailings may also release metals into the environment.

The dispersion of mine-derived copper, cadmium, zinc and iron in the estuary is monitored on a monthly basis. Britannia Creek waters seem to be confined to the surface as a result of the density stratification of the estuary, which acts as a barrier for vertical mixing. As a result, highest dissolved metal concentrations are usually found at the surface. They decrease to background over a distance of a few hundred meters off the creek mouth. The submerged tailings do not seem to be a significant source of dissolved metals.

Seasonal variability is observed in both trace metal concentration and reactivity. In winter, metal concentrations are higher in the creek and in the estuary due to increased leaching and flushing of the residual ore within the mine. The extent to which metals are removed from solution in the estuarine mixing zone by adsorption, flocculation and precipitation also varies seasonally, particularly with cadmium, but in general there is extensive removal of copper and iron and less pronounced removal of cadmium and zinc.The seasonality is likely a result of changes in river runoff, biological activity, particle concentration and composition, DOC content, estuarine circulation patterns and acid mine drainage (AMD) generation rates.

Room/Salle: Auditorium [4bPE] Thursday/Jeudi

PERD 1
GRDE 1

Chair/Président: David Lynch

[4bPE1] Shelf Circulation Models and the Real World

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Assessment of predictive skill is an essential part of shelf circulation modelling. In this talk I will review our attempts to address this problem through (i) cross validation, whereby some data are withheld at the model-fitting stage and used subsequently to test the model's predictive power, and (ii) the use of statistical models to obtain an upper bound on how well any linear circulation model can be expected to perform. I will illustrate the talk with examples based on our models of the Scotian Shelf, including a new 3D model that can assimilate data such as coastal sea level in real-time and is suitable for operational applications.

[4bPE2] A Model Comparison of Baroclinic Instability in the Presence of Topography

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As an initial step toward simulation of baroclinic eddies and associated cross-shelf fluxes in the Labrador Current, the stability characteristics of three eddy-resolving primitive equation models (Bryan-Cox level model, Blumberg-Mellor sigma coordinate model, Bleck-Boudra isopycnal model) are examined in the quasi-geostrophic limit and for more realistic representations of topography and current structure. The calculations show significant differences between the models in terms of growth rate for baroclinic waves and the influence of bottom topography. The differences in model solutions are discussed in terms of physical parameters (eg. viscosity) and numerical errors associated with the various discretization processes used.

[4bPE3] A 3D coupled ice-ocean model applied to Hudson Bay, Canada: The seasonal cycle and time-dependent climate response to atmospheric forcing and runoff

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Physics of the Marine Environment Division Maurice Lamontagne Institute, Department of Fisheries and Oceans, 850 Route de la Mer, Mont-Joli, Qc Canada G5H 3Z4

A coupled ice-ocean model is developed and applied to reproduce the basin-scale ice and ocean physical properties of Hudson Bay (HB). The thermodynamic ice model is based on Mellor and Kantha [1989] and is coupled to the Blumberg and Mellor [1987] ocean model. Models for albedo, evaporation, storms, frazil ice production and radiation are included. Gridded monthly means of winds, temperature, precipitation, runoff and cloudiness force the model. The seasonal changes in sea ice thickness and concentration, temperature and salinity fields are reproduced. Ocean circulation and ice dynamics take simple forms to reproduce the large scale cyclonic ocean circulation and southward ice drift. Salt and heat fluxes are analysed. We examine the model response to the following changes: (1) a negative winter SAT anomaly associated with a strong westerly event from the NAO, (2) a high runoff year, (3) regulated runoff for hydro-power, (4) increased fall storm intensity, (5) constantly warmer conditions. We find that pre-conditioning of the ocean for winter, controlled by the heat transfer to the atmosphere and freshwater input rates, and associated mixed layer depth attained before freezing occurs,

has a strong control over the following ice season. The results suggest that varying runoff has more effects on sea-ice production in southeastern HB than NAO-associated temperature changes, but that both have small effects on the ice cover compared to the observed interannual variability. Regulated runoff produces a positive sea-ice anomaly during the winter months, significant (>10 cm) in the southeastern part of the Bay but less than 1 cm on the average. We conclude that ~ 90 % of the excess winter runoff remains liquid. No significant delay is computed for breakup dates (<3 days in southeastern HB and <1 day over all). Other controls from the atmosphere are required to explain the natural interannual variability of the ice cover. Summer and fall winds and air temperature, controlling water column winter pre-conditioning, spring cloud cover, controlling heat gain, and snow cover, controlling the winter insulation, can explain relatively large changes in the system.

[4bPE4] Simulation of the climatological seasonal cycle of northern B.C. coastal waters with the Princeton Ocean Model

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Preliminary results from an application of the Princeton Ocean Model (POM) to the coastal waters off northern British Columbia are discussed. The initial objective of the study is simulation of the climatological seasonal cycle of the region including Dixon Entrance, Hecate Strait and Queen Charlotte Sound. A numerical experiment with wind and buoyancy forcing derived from standard climatological atlases shows reasonable agreement with observations on several points. This includes the occurence of a cyclonic eddy in Dixon Entrance, seasonally varying flow in Hecate Strait and a surface outflow at Cape St. James. The results show considerable differences with previous shallow water modelling of the region, although significant topographic control of the flow is still evident.

[4bPE5] Three-dimensional prognostic modelling of the Georgia-Fuca basin using GF8

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GF8 is a three-dimensional baroclinic model using fixed horizontal levels in the vertical and a uniform rectangular grid in the horizontal. Time-stepping is implemented by means of a semi-implicit algorithm, so that mode-splitting is not required. Turbulence closure is implemented using a modified form of the Mellor-Yamada level-2 formulation. Time-varying forcing by winds, river flow and coastal processes at the boundaries is included in the model, in addition to tidal forcing. The model was originally developed using a 2-km grid for the Georgia-Fuca basin, and has been used extensively for water quality and other applications with grid sizes ranging between 9 m and 5 km. Its rapid execution speeds allow extensive simulations on workstation computers, and its accuracy is equivalent to other models presently available. A recent implementation using a 1-km grid for the Georgia-Fuca basin will be presented and comparison made with the original 2-km grid model and with observational data. The data selected for validation consists of current meter and water level measurements, and also surface currents obtained from HF-radar studies conducted in 1992 and 1993.

Room/Salle: Arts 118 **[4bWF]** Thursday/Jeudi

WEATHER FORECASTING
PRÉVISIONS MÉTÉOROLOGIQUE

Chair/Président: Al Wallace

[4bWF1] Composite Analyses of Large-Scale Circulation Fields Associated with Weakly and Rapidly Intensifying Cyclones in Atlantic Canada

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We study the phenomenon of explosive cyclogenesis from the perspective of the 36-h time evolution of the large-scale ciculation fields within which weakly and explosively intensifying cyclones occur. This is accomplished by a construction of two composite groups of cyclones that have experienced similar maximum deepening rates within

a five degree latitude- longitude geographical domain in the western North Atlantic Ocean near Newfoundland. A comparison is made between the stronger and weaker cases of one set of 14 cyclones compiled over ten cold seasons. Synoptic-scale features for the stronger cases, distinct from those of the weaker cases, are detected throughout the 36-h period prior to the time of most rapid intensification. The explosive cyclones generally formed when downstream conditions over the North Atlantic were colder than average, with an anomalously strong Icelandic Low and zonal thermal jet. The physical implications of these results will be discussed in terms of the possible role of downstream heat fluxes and deep baroclinity on explosive cyclogenesis.

[4bWF2] Coupling of a Synoptic-Dynamic Diagnostic Package (DIONYSOS) with a Regional Climate Model (RCM)

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A Synoptic-Dynamic diagnostic package (DIONYSOS) is used to evaluate the impact of thermodynamic and dynamic atmospheric forcings on the development of an Arctic low pressure system as simulated by UQAM's Regional Climate Model. DIONYSOS calculates contributions from atmospheric forcings to vertical motion, divergence as well as to vorticity, potential vorticity, and geopotential height tendencies. Atmospheric forcings taken into account are vorticity advection, laplacian of temperature advection, laplacian of latent heat release, laplacian of sensible heat release, friction and orography. DIONYSOS has been tested with equally good results using output from three different models: the Regional Finite Element Canadian operational model (RFE), the ARPEGE French operational model and UQAM's RCM (Regional Climate Model). DIONYSOS is running daily at the Maritimes Weather Center, the Service Central d'Exploitation Météorologique (the CMC of France) and University of Quebec in Montreal. This presentation will discuss the forcings responsible for the development of an Arctic low pressure system as simulated by the RCM. Emphasis will be placed on better understanding the role of the ice distribution and its direct and indirect impact on the cyclone development.

[4bWF3] On the application of climatic data to estimate on-ground icing at selected airports in Canada, the United States and Europe

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Hourly climate archives for 28 airports in Canada, the United States and Europe have been analyzed to estimate the frequency of occurrence of on-ground icing events and their potential for hazard to aircraft operations. Ten hazard types, including frost, rime from fog, blowing snow and seven different types of precipitation were defined and all observations of each hazard type were stratified by season, time of day, wind speed and direction and surface temperature. Canadian stations were found to have similar rates of occurrence of hazardous conditions as were observed in Scandinavia and Germany, but Canadian stations have higher precipitation amounts associated with these conditions. Stations in western Europe and the United States had lower occurrence frequencies by comparison and lower precipitation amounts. Hazardous conditions in Canada were most often attributed to snow, while frost was the cause of more hazardous hours in Europe.

[4bWF4] Diagnostic Analysis on Forecast Skill

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On the basis of the diagnostic analysis of 500 hPa height's initial analysis field and forecast field data, 790 cases' forecast skill of T42L9 model of National Meteorology Center at Beijing have been carefully surveyed at five forecast time levels (24h,48h,72h,96h,120h) using statistic method. Two basic results have been obtained in the following: a)The forecast skill of T42L9 model below three day time level is very good, however, it is not desirable above three day time level. therefore, forecasting forecast skill should be done together with the forecast products. b)There are some significant periods of dayly forecast skill at fifth time level of T42L9 model according to the power spectrum analysis of dayly forecast skill of north hemesphere,Asia,north America and Europe areas. An Error Contamination Mechanism hypothesis is put forward to explain why and how dayly forecast skill remarkably changes . A simple barotropic quasi-geostrophic spectrum model is used to examine two typical cases' barotropic instability. The fifth-day forecast skill of one of the typical cases of T42L9 model

is extremly low(ACC<0.3) and the other case's forecast skill of T42L9 model is extremly high(ACC>0.8). The results show that whether the forecast skill at the fifth time level is high or low deponds on the instability of initial field of the model and the allocation of error with background field of the cases.

Room/Salle: Multi-purpose Room [4cPD] Thursday/Jeudi

CONGRESS THEME PANEL DISCUSSION
THÈME DISCUSSION

Chair/Président: Nancy Cutler

[4cPD1] Environmental Services: Clients, Innovation and Commercialization

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National Weather Service, Directorate, Environment Canada.

Environmental Services is taken to be a broad range of knowledge, information and technology services related to the environment.

Panel Objective: To discuss the risks and benefits of current trends in the focus on clients, innovation and commercialization in atmospheric and oceanic science and services in Canada and abroad.

The panelists outline their points of view during 10 minutes each of opening remarks. The chair may also wish to make some opening remarks. This will be followed by a proposed 1 hour panel discussion with audience interaction.

Panelists:

Ms. Gail Gabel, President of G S Gabel Corporation.

Dr. David Schindler, Killam Professor of Ecology, University of Alberta.

Mr. Gary Wells, Director of Environmental Services for Pacific and Yukon Region of Environment Canada.

Mr. R. Woodward, President, B.C. Science Council.

Chair: Ms. N. Cutler, Director General, National Weather Service Directorate, Environment Canada.

Room/Salle: Arts 118 [4cPE] Thursday/Jeudi

PERD DISCUSSION
GRDE DISCUSSION

Chair/Président: Oleh Mycyk

[4cPE1] Panel Discussion of Coastal Ocean Models and Applications.

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The chair will begin the discussion with a brief review of the future needs of the offshore oil industry for coastal ocean models. Participation in the following discussion will be opened to all attending. A few topics which may be addressed are: 1) The need to integrate current and wave models? 2) Is a local meteorological model needed for wave or current forecasts? 3) What engineering problems can coastal ocean models address? 4) What is the application of such models outside Canadian waters? 5) What is the application of current models to a community ice model? 6) Who are the end users of oil spill and wave models?

Room/Salle Main Foyer, Student Services Bldg [4cPO] Thursday/Jeudi

POSTER
AFFICHE

No Chair/ Pas de Président

[4cPO1] Microclimate of A Prairie Aspen Grove

Bretell DL[1], Archibold OW[2], and Ripley EA[3] <eripley@marathon.usask.ca>
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Two automatic weather stations were set up at the Kernen Crop Research Farm near Saskatoon in December 1993. One station was placed at the centre of an aspen grove 0.25 ha in size; the other to the west of the grove in undisturbed mixed prairie. Daily measurements included air temperature, relative humidity, solar radiation, wind speed, and soil temperatures at 3 depths. A snow course was set up over the winter period.

Analysis of a full year's data shows that the greatest differences between the aspen grove and the prairie coincide with the 'leafing-out' period in the spring and may be attributed to the presence of a full leaf canopy. Air temperatures differed less than 1 °C between inside and outside over the entire period. Solar radiation showed greater variation with an average 51 % penetration without canopy to an average 25 % under full canopy. Wind speed ratios varied from an average 41 % with no canopy to 6 % with full canopy. While air temperatures remained similar over the winter months, the diminished wind speeds suppressed windchill values inside the grove an average 260 W m-2. At the time of the maximum air temperature, the minimum relative humidity inside the grove was 14 % higher than outside. This difference can be attributed to increased evapotranspiration rates from the vegetation during the summer months. Soil temperatures, though most variable at the 10 cm depth, reacted slowly to air temperature changes, particularly under the snow pack.

[4cPO2] UQAM Regional Climate Model: Diagnostics of 2 two-month simulations

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

Results from simulations obtained with two different configurations of the model are presented. The two configurations share the same 45-km horizontal resolution grid of 120 by 120 points. This polar-stereographic grid covers a (5400 km by 5400 km) area centred over the state of Vermont. Differences in the two configurations appear in the number of vertical levels, where 10 and 30 levels are used respectively. Lateral boundary conditions for this integration were taken from GCMII archived data. Diagnostics of primary meteorological fields from the 10 level RCM integration are compared with those from the GCM to analyse the impacts of the increased horizontal resolution on the atmospheric flow. The comparison between the 10 and the 30 level versions is made to analyse the influence of increasing the vertical resolution on the simulated atmosphere.

[4cPO3] Spatial and Temporal Characteristics of Precipitation during the BOREAS Summer 1994 Field Campaigns

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[2]University of Washington, Seattle, Washington
[3]University of Waterloo, Waterloo, Ontario

A C-band weather radar system was operated at the Boreal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area in Saskatchewan during the summer Intensive Field Campaigns, mid May to mid September 1994. Major science issues associated with a better understanding of the cloud, land-surface, and biophysical feedbacks in the physical climate system require detailed knowledge of the spatial and temporal variation of precipitation. Moreover, upscaling of detailed local-scale energy and mass balances using remote sensing and modelling is an essential component of climate studies like GEWEX and BOREAS. The need for upscaling arises from the fact that important transport mechanisms occur at the scale of hundreds of km, but important hydrological processes (e.g., infiltration, plant water uptake) are difficult to measure except at the field scale. This upscaling requires knowledge of the spatial distribution of precipitation at temporal scales of 10 min and spatial scales of 1 to 10 sq. km. The best tool at present for measuring precipitation distributions in time over minutes to hours and spatial scales of kilometres to hundreds of kilometres is weather radar.

This paper presents preliminary results from the analysis of BOREAS weather radar data in terms of hydrologic inputs. Analysis will show the temporal and spatial means and variability for significant precipitation events. The paper will highlight examples from the field season that demonstrate the special capability of weather radar as a complement to ground-based observations.

[4cPO4] Distribution of Solar Ultraviolet-B Radiation in Canada.

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An introductory study leading to an evaluation of a UVB radiation climatology is presented. Qualitative and quantitative characteristics of surface biologically effective UV radiation over Canada are based on analysis of data from three different sources. UVB data have been obtained from MeteoMedia/The Weather Network which operates a network of 24 UV-Biometer 501 instruments across Canada. The UV-Biometer 501 is the latest model of the Robertson-Berger (RB) broad band UVB pyranometer. Ozone data have been acquired from the Total Ozone Mapping Spectrometer on the Nimbus-7 and Meteor-3 satellites and weather data comes from the Atmospheric Environment Service (AES). All data embrace the 18 month period from July 1992 to December 1993.

Comparison of the quality of UVB data sets from the RB and the Brewer spectrophotometer (both from AES, Toronto, from January - December 1993) provides good evidence of high RB performance quality.

The limited number of sites and short history of observations allow for analysis of short term patterns and irregularities. Thus, analysis is provided for daily and monthly courses of the surface UVB. The relationships between UVB amount and: clouds, visibility, humidity, pressure, and ozone is shown for the stations in the RB network.

[4cPO5] The influence of atmospheric conditions on the scaling properties of radar echoes in central Saskatchewan.

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The scaling properties of ensembles of precipitation echoes observed by radar have been analyzed and related to synoptic scale atmospheric conditions. Precipitation echo ensembles observed at 6.5 minute intervals for a 240 km by 240 km area by a C-band weather radar located at Elbow, Saskatchewan during four days in July 1991 are analyzed. The scaling properties of these ensembles are represented by the perimeter/ area (D_p) and Korchak (D_k) parameters and by several multifractal measures. The paper describes the variability of these

scaling properties for different synoptic conditions and compares them to other indicators of precipitation extent and intensity such as fractional areal coverage and precipitation mass. Variations in these scaling properties associated with reflectivity threshold, altitude, precipitation type, atmospheric stability, and large scale moisture convergence are also described.

[4cPO6] A Simple Adaptive Threshold Image Segmentation Algorithm for Weather Satellite Imagery

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This paper describes a simple adaptive threshold image segmentation algorithm for use with weather satellite imagery. The algorithm could be used as the first processing step in an automated interpretation system, which would also involve additional steps such as segment identification, analysis and interpretation of meteorological features of interest, using intelligent computation methods.

The algorithm developed computes different threshold values for different regions of the image and has the advantage that it is easy to implement, executes quickly and provides good results in preliminary tests. For the type of system envisioned, the approach taken assumes that 1) the segmentation method need not be optimal and 2) that simple thresholding can be an effective method of segmentation, at least over a portion of the image. The resulting segments reduce the complexity from thousands of pixels to a small number of objects which can be more easily handled by an interpreter.

The algorithm was tested on a series of APT images obtained from a site in Rhode Island (Summer/94) and selected images acquired onboard the NRC Convair 580 aircraft during measurement flights in the Beaufort Sea and Arctic Storms Experiment (BASE) during Sept-Oct, 1994 near Inuvik, NWT. Results from this work are presented.

[4cPO7] Preliminary Study of Tracer Transport in MAM

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A preliminary study has been carried out to characterize the 3-D global scale structure of transport patterns of the results obtained from the MAM (Middle Atmosphere Model) by a domain-filling trajectory calculation in which very large numbers of particle trajectories are used to visualize the evolution of a flow at high spatial resolution. This method is computationally cheap and is very powerful in depicting the more detailed tracer transport structure for the wind with a relatively coarse resolution. The results present some examples of the evolution of the 3D structure of the polar vortex and of the vortex roll-up along a long, narrow streamer of air in the stratosphere. Also the diabatic circulation will be introduced to illustrate the mean tracer transport in the meridional plane.

[4cPO8] Numerical experiments with finite-element model of the Okhotsk sea general circulation

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The response of the Okhotsk Sea general circulation to different wind situations is examined. The finite element model of the Novosibirsk Computing Center adapted for the Okhotsk Sea is used for this purpose. The model has 0.25 deg. x 0.25 deg. horisontal resolution and all main features of the bottom topography deeper than 30 m are depicted. The wind stresses of Hellerman & Rosenstein (1983) and Wright(1988) are imposed at the sea surface. To simulate the ice cover during the period from December to May the wind forcing is supposed to be zero above the ice covered regions. Numerical experiments are carried out with flat bottom and with the real bottom topography both for seasons/Winter, Spring, Summer and Autumn/ and for all 12 months separately in attempt to study the transition from one wind stress situation to another. The model is responded sensitively to remarcable wind stress changes from Winter to Summer monsoon. Some characteristic features of the Okhotsk sea general circulation are shown during barotropic study: large-scale cyclonic circulation is formed during the period of especially strong northerly winds (Autumn). Some quasi-stationary eddies are obtained north of

Hokkaido coast, above the Kuril Basin and west of Kamchatka Peninsular.

[4cPO9] Seasonality of Atmosphere-Ocean Coupling in ENSO

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JISAO, GJ-40, University of Washington, Seattle, WA 98195, USA

A 13-year record (1979-1992) of monthly-mean Microwave Sounding Unit oceanic precipitation and mean-tropospheric temperature anomalies are regressed onto an index of eastern equatorial Pacific sea surface temperature (SST) anomalies. This analysis revisits the composite study of ENSO variability by Rasmusson and Carpenter (1982), but emphasizes simultaneous relationships with the eastern equatorial Pacific cold tongue, instead of lagged relationships with conditions along the Peru coast. Regression statistics are binned for the months January through May and July through November, the climatological warm and cold seasons in the eastern Pacific, respectively.

Typical ENSO warm event anomalies during the warm season are characterized by enhanced equatorial precipitation and a significant increase in mean-tropospheric temperatures centered about 15 degrees latitude in each hemisphere. Anticyclonic upper tropospheric wind anomalies are associated with this pattern of mean-tropospheric temperature anomalies. The ENSO-related precipitation fluctuations are located within the core of the equatorial dry zone, and act to produce a strong anomalous tropospheric response. Typical ENSO warm event anomalies during the cold season are characterized by enhanced precipitation along the outer margins of the equatorial dry zone, but the core of it is unaffected. The corresponding positive anomaly in the mean-tropospheric temperature field is much weaker than that observed in the warm season.

[4cPOa] Seasonal Patterns of the Heat Island in Saskatoon

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Spatial temperature patterns are investigated using data from climatological stations, a supplementary network of eight short-term stations, and automobile transects. Preliminary analysis is revealing some interesting relationships.

Comparison of five climate stations with records for the period 1985-1988 revealed distinct seasonal temperature regimes in different areas of the city. At the airport, minima were about 1 ° C higher than elsewhere, especially during the winter months; maxima near the city centre averaged 1 ° C higher than elsewhere during the summers.

The 8-station network gave a more-detailed picture. Minima were 2-3 ° C above average downtown, compared to 1 ° C below average in the southeastern part of the city. Maxima differences were smaller (1-2 ° C), and appeared to be due mainly to shade and shelter effects.

Temperatures were measured at 110 locations using automobile-mounted sensors. On a summer afternoon, the downtown area was 8 ° C warmer than the eastern side of the city; at night, the city centre was 3-4 ° C warmer than the suburbs. Autumn data showed an early-morning gradient from 0 ° C in the northwest to over 4 ° C in the southeast under clear skies and a light westerly wind. By evening, the gradient had diminished to 2 ° C. A few hours later, as the wind veered to southerly and cloud moved in, an urban heat island became apparent with temperatures ranging from 12 ° C in the city centre to less than 8 ° C in the southeastern suburbs.

[4cPOb] Microclimate of an aboriginal winter camp site at Wanuskewin

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Wanuskewin, located approximately 10 km north of Saskatoon, has functioned as a winter campsite for Plains Indians for centuries. The campsite is situated in a lightly- wooded tributary valley of the South Saskatchewan River, where an amphitheatre-like depression enjoys a south facing aspect. The site appears to be ideally located to maximize solar radiation input as well as benefit from reduced wind. The degree to which these benefits occur is the subject of this research.

The microclimate of the valley site was compared with that of the surrounding uplands during the period 1 November 1994 - 30 April 1995. Parameters measured included maximum and minimum air temperatures, relative humidity, snow depth and windspeed. In addition, temperatures recorded from a thermocouple placed one meter above ground within an unoccupied tipi. Windchill values were calculated as an indicator of the benefit of the valley location for human winter habitation.

Preliminary analysis of the data shows only slight differences in average maximum and minimum temperatures, with the valley site being about a half degree more extreme than the upland. Relative humidities, also, are more extreme by 2 - 3 %. The temperatures in the uninhabited canvas tipi are about the same as outside, on average, although they differ by as much as several degrees on individual days.

Windspeed exhibits the main difference, being reduced to 50 % in the valley, on average. This has the effect of diminishing the windchill by about 200 W m-2 (from 1250 to 1050).

[4cPOc] Partitioning of pollutant metals in suspended particulates of Sudbury area lakes, Ontario.

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The behavior and fate of heavy metals in lakes in the Sudbury basin are still not well understood. This report focuses on particle size distribution of trace metals in five lakes near Sudbury. The particulate matter was sequencially separated into 0.4, 0.2 and 0.1 μM fractions with polycarbonate filters. This work was carried out using teflon-lined Go-flow bottles and on-site laboratory with "class-100" clean facilities. Suspended particulates were simultaneously recovered by the continuous flow centrifuging of 600-1500 litres of lake waters. Results indicate 2-10 times less particulate metals were recovered during winter ice cover. Filtered particulates were well distributed among all four size fractions. Higher concentrations of Fe, Mn, Ni, Pb, Se were more frequently found in the 0.2->0.4 μM range while As, Cd, Tl and Zn were associated with the colloidal <0.1-0.2 μM fractions. Decreasing efficiency of particulate metal recovery from the Westfalia centrifuging system were found to be Pb>Zn>Fe >Mn>Tl>Cd>Ni>Cu. Geochemical implications of metal distribution in the various size fractions will be discussed.

[4cPOd] Lagrangian modelling of diffusion transport in the upper layer of the sea under influence of wind and wind waves.

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A turbulent diffusion in the upper ocean layer defines a process of vertical exchange of heat, gases, nutrients, pollutants. The intensity and the anisotropy of turbulence depends on vertical current shear, wind waves, and ocean swells. Often a turbulent diffusion process cannot be described in terms of local isotropic turbulence theory. Therefore, preliminary experimental investigation of diffusion process is needed for estimation of mixing intensity. Usually, this is a full-scale experiment on fluorescent dye diffusion recorded by aero- photography. In practice, the actual dye distributions differ from the theoretical under the unfluence of wind, waves, and swell. Elongation of dye spots, shape deformation, rotation, and comet-like distortions are observed. In order to evaluate the influence of wind, waves and swell on the diffusion process a three-dimensional Lagrangian model of diffusion transport in the upper ocean layer was developed. It is assumed that the injecting of substance is instantaneous and localized at the point. The equations of motion in Lagrangian coordinates could be written: $dX/dt = Ud(z) + Uz(z) + Uw(z) + U'(z)$ $dY/dt = Vd(z) + Vz(z) + V'(z)$ $dZ/dt = Wp + W'$ where: Ud(z), Vd(z) - components of wind-driven currents; Uz(z), Vz(z) - components of wave transfer by the swell; U'(z), V'(z) - horizontal turbulent components; Uw(z) - wave transfer by wind waves; Wp(z) - vertical velocity of settling particles; W' - vertical turbulent component. The vertical profile of wind-driven current is calculated using Ekman's theory. The model takes into account a wave transfer by waves (Stokes's transfer) and a nonconservative feature of diffused matter.

[4cPOe] An experimental investigation of convective heat transfer from conical ice particles

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Observations show that most of cloud and precipitation particles such as graupel and hailstones are conical (List, 1959; Barge and Isaac, 1970; Locatelli and Hobbs, 1976). The drag and mass transfer coefficients for conical hailstones were found to be higher than spherical models (List, 1961; Schemenauer and List, 1972). Although the parameters driving the heat and mass transfer of conical graupel were examined (Cober and List, 1993), a more detailed investigation is necessary to improve the understanding of heat transfer processes of conical ice particles. The experiments were carried out in the Cloud Physics Icing Tunnel at the University of Toronto. The test particles were smooth ice conical with cone base diameters of 2.0 cm, cone angles of 60, 70 and 90o, and four kinds of base segment. The experiments were stared by exposing the "warmed" ice particles ($\sim$ -6 ° C) into a cold airflow (-21 ° C) with no supercooled water droplets. The air speed varied from 1.7 to 4.5 m/s, corresponding to Reynolds numbers of $2800 < Re < 7400$. The particles were rigidly suspended in the measuring section of the tunnel. The surface temperatures of the particles were remotely measured using an "AGEMA Infrared 800" thermal imaging system. The experimental results indicated that the convective heat transfer of conical ice particles is non-homogeneous, and varies significantly with the position from the front point to the airflow. The variation of the local transfer is also dependent on the cone angle and the degree of sphericity of the cone base. The overall heat transfer coefficient of a conical particle is larger than that of a sphere with the same size. These results can be used to better understand growth and melting of natural and artificial ice particles, and to interpret their structure.

Room/Salle: Multi-purpose Room [4dAQ] Thursday/Jeudi

AIR QUALITY
QUALITÉ DE L'AIR

Chair/Président: Sara Pryor

[4dAQ1] An Updated Gas-Phase Chemistry Mechanism for Regional Pollution Modelling.

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One of the most important components of a model of tropospheric chemical processes is the mechanism used to describe the gas-phase reactions. Due to constraints on computer processing time and memory space, these mechanisms are usually condensed versions of more complicated reaction sets. A new tropospheric reaction mechanism for regional air quality modelling is described. The mechanism is an updated version of that used in the Acid Deposition and Oxidant Model (ADOM) (Venkatram et al., 1988). Mojor differences from the previous (ADOM-II) mechanism include: (1) An improved method of condensing hydrocarbon reactions, providing more accurate simulations on time scales of importance for pollution episodes (Makar, Li and Stockwell, 1995), (2) Updated rate constants for all reactions. Many of these have changed by a large amount since the previous chemistry update. (3) A new lookup table/parameterization for the photolysis reactions, with rates being calculated as functions of temperature, pressure, solar zenith angle, total number column and ozone column densities. The new mechanism has been evaluated against smog chamber data from several sources, and against a detailed mechanism based on the best currently available data for tropospheric chemistry. Comparisons will be made between the previous mechanism (ADOM-II) and the improved version (ADOM-III) for several tests cases ranging from "background" air chemistry to highly polluted smog episodes.

[4dAQ2] Measurement of Ozone Dry Deposition in the Lower Fraser Valley

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Dry deposition of ozone is one of the important sinks for ozone in the atmospheric boundary layer. During the

summer of 1994 eddy correlation and gradient measurements of surface layer ozone fluxes were taken at a site near Pitt Meadows in the Lower Fraser Valley of B.C. Surface cover around the field site is a mix of cultivated and pasture areas fairly representative of the rural areas of the valley. Ozone measurements for eddy correlation were taken with a fast response chemiluminescent sensor. Vertical gradients of ozone concentration were measured with a UV absorption monitor sampling alternately at two levels. The measurements are used to calculate values of surface resistance to ozone deposition. The 10 Hz ozone time series from the chemiluminescent sensor are also used to test the use of using the variance and dissipation methods for ozone flux measurements. The dissipation method seems to be limited in its usefulness because of the difficulty of making sufficiently accurate measurements of the vertical gradient of ozone concentration. Finally the use of cospectral similarity between ozone and temperature fluctuations for calculating ozone fluxes using slower response sensors is investigated.

[4dAQ3] Investigating a Multi-Layer dry deposition Model Against Single Layer Models and O_3 Measurements from Four Land-Use Types

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A multi-layer dry deposition model is compared with three single-layer models and with observed data available for a fully leafed and leafless deciduous forest, a cotton field and a vineyard. Although the multi-layer model was originally developed for tall canopies, its application to the lower canopies of the present study appears suitable. The estimated dry deposition velocity from the multi-layer model appears to perform better than the single-layer models when compared against the observations over cotton and the vineyard, and less favourably when compared against the forest observations. Sensitivity tests with the multi-layer model for the fully leafed forest indicate that modifications to the formulations of the stomatal, cuticle and soil resistances, and to the radiation formulation can lead to improvements.

[4dAQ4] A Clean Air Day in the Lower Fraser Valley of British Columbia

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The characteristics of a recent clean air day in the Lower Fraser Valley of British Columbia are presented. The meteorology is described, and ambient air concentrations of criteria pollutants detailed. The representativeness of this day as a typical clean air day, and its potential use as an air quality benchmark are discussed.

[4dAQ5] Visual Air Quality in Waterton and Glacier Parks

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Anthropogenic emissions of sulphur dioxide (SO2) have been related to a decrease in visual range through the growth of hygroscopic ammonium sulphate particles. Problems with quantifying the role of SO2 on visibility impairment include a large uncertainty in the long-range transport, chemistry and deposition; poor quantification of the role of other particles; and a scarcity of field data.

The Canada-U.S. Air Quality Accord commits both countries to making progress in the prevention of significant deterioration of visibility with respect to transboundary air pollution. Oil and gas development in Alberta has been identified by U.S. researchers as a primary source of SO2 leading to poor visibility in the mountain parks. In response to this concern, AES installed a nephelometer in Waterton Park in May, 1993 to monitor the visibility. The monitor is providing data which can be compared with information from a similar station in Glacier Park. The information from thse monitors can be used to determine a baseline value for visibility in order to assess change in the mountain parks.

The first year's data from the nephelometer has been analyzed and compared with values obtained from the U.S. station. Back trajectories have been used in an attempt to determine gross source regions for air entering the park areas. A comparison of events with low visual air quality in each park will be compared to determine whether the same or different air masses are impacting the two sites.

[4dAQ6] The Effects of Stable Stratification on the Flow and Dispersion Within Idealized Urban Street Canyons

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This paper presents the results of a study about the effects of stable stratification in the atmosphere on the wind pattern and pollutant concentrations within two-dimensional urban street canyons. The numerical simulations were accomplished using the TEMPEST Code which are based on the k-epsilon turbulence closure approach. A 30 m wide line pollutant-source was placed at ground level centered within each street canyon. The influences of two incident stable stratified sheared turbulent inflows are calculated and compared with those of an incident neutral stratified sheared and turbulent atmospheric boundary layer profile. Two-dimensional buildings were arranged to provide cases having 1, 2, or 4 street canyons. The influences of the two-dimensional building heights are examined by altering between a 60 m building height and a 90 m building height. In all cases, the building width is constant at 120 m and the urban street canyon width is 60 m.

The numerical simulation results demonstrate significant influences on the wind structure and pollutant concentrations within the street canyons due to different building configurations as well as incident boundary conditions. In particular, changes in the recirculating flow pattern above the street and on top of the canyon buildings affects the pollutant transport within and out of the street canyon. The influences are much weaker after the second or third downstream street canyon. The results are displayed using scientific visualization techniques. This study is important for assessing the potential for human exposures to pollutants that may be released within an urban street canyon.

Room/Salle: Arts 108 [4dCO] Thursday/Jeudi

CHEMICAL OCEANOGRAPHY AND LIMNOLOGY 2
OCÉANOGRAPHIE CHIMIQUE ET LIMNOLOGIE 2

Chair/Président: R.W. MacDonald

[4dCO1] Redox behaviour and speciation of chromium in Saanich Inlet, B.C., Canada.

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We present some preliminary results from our seasonal study of Cr cycling and speciation with changing water column redox conditions in Saanich Inlet, Vancouver Island, B.C.. Saanich Inlet has a fjord-like structure with a maximum depth of 240 m and a sill depth of 70 m. Deep water anoxic conditions are established in late winter or early spring as oxygen consumption exceeds renewal by mixing. Flushing takes place in late summer and early fall when upwelled water in the Pacific off the coast of the island spills over the sill.

Oxygen values from May to August 1994 averaged 5-8 ml/L at the surface, dropping off to zero below 130 m. Starting in early fall, the interface is displaced upwards and oxygen is detectable in the previously anoxic waters as basin flushing starts.

Total Cr and Cr(VI) values decreased from approx. 3-5 nM at the surface to as low as 0.2 nM in the deep anoxic waters. Cr(VI) values show a general decrease from the interface towards the bottom in May, June and July. In early fall, the values start to rise in the anoxic region as a result of basin flushing. Cr(III) values are in the 0.2-1.0 nM range. In May, June and July, Cr(III) is the dominant Cr form in the anoxic waters in agreement with thermodynamic calculations. This trend changes in late summer and early fall as oxygen is now detectable in the deep water. Results from laboratory studies to simulate conditions in the basin will be presented.

[4dCO2] Interannual climate variability reflected in laminated sediments of an anoxic basin, saanich inlet, b.c.

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Finely laminated sediments preserved in the virtually anoxic basin of Saanich Inlet provide a record of local

climatological conditions. The correlation of sediment lamina characteristics and climatological instrumental data may disclose evidence of pre-anthropogenic local climate. A continuous record of seasonal laminae variability has been documented from 1993 as far back as the mid 1800's. Sediments which accumulate on the floor of Saanich Inlet are from seasonally alternating sources. The winter terrigenous sediment is supplied by runoff from the nearby Cowichan River. The spring sediment is produced by diatom blooms. Freeze coring techniques provide technological advances to separate and analyse each of the spring and winter couplets. High resolution X-radiographs disclose fine-scale records of alternating terrestrial and marine sediment input, both inter and intra-annually. Core chronology was determined using œsuperscript 210 Pb and œsuperscript 137 Cs techniques, laminae counting, and anthropogenic evidence. Correlation of core replicates were determined with the aid of a tree-ring correlation program. Analysis of inorganic and organic carbon, nitrogen, bulk densities, œdeltaœsuperscript13C, œdeltaœsuperscript 15N, and laminae thicknesses have been undertaken to accomplish the sediment/ climate correlation.

[4dCO3] Estimating particle decay in the water column from sediment trap data

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A model equation is developed for determining depth-dependent rates of decay of particulate material settling through the water column. It is designed for use with sediment trap data where an increase in flux with depth is measured, but can be used where increases in flux with depth are not recorded. The equation relies on the premise that the flux of material to a lower sediment trap is equal to the flux at an upper trap times a decay function (the 'accountable' flux) plus an amount of material for which the source is not readily known (the 'unaccountable' flux). Besides determining the decay rate of the accountable flux, the equation estimates the material composition of the unaccountable flux and therefore provides information on the cause of measured increases in flux with depth. The equation is applied to data collected from southern British Columbia fjords where, in general, increases in flux with depth have been recorded. Solutions for the decay of particulate organic carbon agree with estimates of decay using oceanic sediment trap data. In Sechelt Inlet, the compositional signitures of the accountable and unaccountable fluxes, combined with hydrographic data, suggest that trapping efficiency caused the increases in flux with depth during that experiment.

[4dCO4] Annual Variations of d13C and d15N of particulate organic matter in La Perouse Bank off Vancouver Island

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An intensive investigation of the stable carbon and nitrogen isotopic composition of settling particulate organic matter (POM) was conducted at Station L (48=B039'N,126=B040'W) on La Perouse Bank off Vancouver Island, Canada. Annual variations of d13C and d15N of particulate samples collected by sediment traps occur at two different frequencies. The annual low frequency variation is probably governed by a relatively short trophic transfer of the isotope signals, accompanying the increase in primary production from winter to summer. High frequency variations in spring, summer and early autumn are due to the periodic injection of subsurface nitrate from wind-driven upwelling and resulting diatom blooms, leading to a negative correlation between the two isotope ratios in sinking POM. The vertical profiles of d15N of nitrate and suspended POM in the spring are highly corrected, suggesting that suspended POM is one of the sources of subsurface nitrate. The fact that the d15N of the nitrate reservoir was lighter than that of sinking POM in the subsurface layer suggests that lateral nitrate input from the open ocean may be significant.

[4dCO5] Methane, Molecular Nitrogen and Production-destruction Processes in Ecosystem of the Okhotsk and the Bering Seas

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Based on data obtained during Summer, 1993 in the Bering, Okhotsk Seas and of the Kuril Islands correlation analysis of methane (CH4) and free molecular nitrogen (N2) with dissolved oxygen, nutrients,organic carbon,

organic nitrogen, organic phosphorus was conducted. In same areas the dependence of CH4 and N2 contents on some hydrochemical characteristics of production-destruction processes. CH4 maximum in the photic layer allows to suppose its biological origin. The strong correlations were obtained between methane and chlorophyll "a" in the Bering Sea (r=0.74, n=19), between CH4 and organic phosphorus (r=0.35, n=121) and chlorophyll "a" (r=0.34, n=121) in the Okhotsk Sea, with ammonia (r=0.33, n=96), off the Kuril Islands, with nitrites and nitrates(r=0.76, n=0.31, r=0.57, n=31, respectively) and apparent oxygen utilization the Sakhalin shelf were obtained. Over the whole aquatory of the Okhotsk sea there was a strong correla- tion relationship between N2 and other nitrogen compounds (ammonium, nitri- te, nitrate, organic nitrogen), and dissolved oxygen and apparent oxygen utilization. On the basis of the correlation analysis it may be supposed that the Sakhalin Shelf and waters of the Kuril Islands are characterized by predominance of processes of denitrification and ecosystem loses the or- ganic and mineral forms of nitrogen. The open Okhotsk Sea is characterized by processes of nitrification and molecular nitrogen may be involved in the functioning of the Okhotsk Sea ecosystem.

[4dCO6] Modelling of barium - barite cycling in the oceanic water column - a step towards understanding the fertility of the Ocean and the use of barium as a paleoproductivity tracer

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Barium as a bio-intermediate element is thought to be a good tracer of the oceanic fertility and paleoproductivity. The exact mechanism of Ba uptake in the euphotic zone, barite formation within biogenic detritus, its subsequent release in deep waters and the dissolution of barite crystals is still under research. Within this framework we present a mathematical model for barium - barite cycling in the water column. The basic assumption is that the dissolved Ba is taken up (passively or actively) by POM in the euphotic zone and exported through the aggregates in the deep waters. There, the already formed barite crystals, are released due to disaggregation and remineralization. The subsequent dissolution of barite could occur under certain thermodynamic conditions. The model outcomes are presented for the Southern Ocean situation. They agree with the measured profiles.

Room/Salle: Auditorium [4dFD] Thursday/Jeudi

GEOPHYSICAL FLUID DYNAMICS 1
DYNAMIQUE GÉOPHYSIQUE DES FLUIDES 1

Chair/Président: Gordon Swaters

[4dFD1] On the baroclinic stability of ocean surface fronts

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A new model is developed to study how the relationship between the Rossby number, the ratio of the layer depths, and the beta plane effect changes the stability of geostrophic fronts. The model is a two layer, shallow water approximation where the dynamics of the thin frontal layer are to leading order geostrophic but not quasigeostrophic as changes in the frontal height are of the same order as the scale frontal height. The model is also developed so that it can be put into non-canonical Hamiltonian form.

A comprehensive linear and nonlinear stability analysis of the model is presented. It is shown that, in the absence of shear in the lower layer velocity, that linear stability can be established only for fronts whose heights are decreasing monotonically. The Hamiltonian structure is exploited to derive variational principles for both an appropriately constrained energy functional and an appropriately constrained linear momentum functional. Based on these principles, conditions are found that rigorously establish the linear and nonlinear stability of steady and parallel shear flow solutions, respectively.

In addition, a numerical analysis of the problem is presented. Numerical methods are used to examine both the linear eigenvalue problem resulting from the normal mode analysis and the full nonlinear system. The numerical simulations allow for a wide range of parameter values to be studied and show that flows which do not satisfy the linear stability conditions tend to become unstable and break up into large scale eddies. The results from these studies are compared to each other and the theoretical findings.

[4dFD2] On the Finite Amplitude Instability of Geostrophic Fronts

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A reduced gravity model with an outcropping interface developed by Cushman-Roisin (1986, JPO) is presented to describe the evolution of geostrophic fronts. The model describes a two layer shallow water system where only the uppermost layer is active and each outcrop line describes a front. The frontal dynamics described are geostrophic but not quasigeostrophic since the depth variation of the front is on the order of the depth of the front itself. The finite evolution of the neutrally stable modes found by Cushman-Roisin (1986, JPO) is described. A weakly nonlinear wave packet theory is developed describing the evolution of these modes for a geostrophic wedge-like front. It is shown that the evolution of the wave packets is governed by the Nonlinear Schroedinger Equation and that the Stokes wave solution is stable. The implications of this for the two layer stability problem are discussed.

[4dFD3] On the Weakly Nonlinear Baroclinic Instablility of a Mesoscale Gravity Current in a Channel

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A weakly nonlinear theory for a baroclinic gravity current in a channel is developed based on Swaters (1991, JFM) model of cold core eddies on a sloping continental shelf. In this model, the frontal dynamics evolve geostrophically but not quasigeostrophically because deflections in the front are not small in comparison to the scale height of the front itself. Since the channel water dynamics are quasigeostrophic, the model equations represent an 'intermediate lengthscale' balance.

In the linear stability theory it is found that a parameter which measures the rate of change of the thickness of the gravity current is important in determining if a disturbance applied to the mean flow is unstable. A marginal stability curve can be calculated such that this parameter is the dependent variable against the perturbation wavenumber. In the weakly nonlinear theory, the thickness is made slightly supercritical for a certain mode, and equations for the resulting disturbance are derived using asymptotic analysis with a slow time variable. This method allows the retention of the nonlinear terms in the perturbation equations which otherwise make the problem intractable.

It is found that for modes other than the most unstable mode, the disturbance evolves like a dnoidal wave, similar to that found by Pedlosky (1970, JAS) for a basic two-layer model of baroclinic instability. If the supercriticality is centred about the most unstable mode, then a slow space variable may be introduced, and the resulting equations represent the evolution of a baroclinic wavepacket. The hyperbolic nature of the gravity current equation means that an infinite set of nonlinear PDEs results because of interactions between integral multiples of both the cross and along channel modes. Truncation after two equations gives a solitary wave solution (see Pedlosky (1972, JAS)). Including more equations appears to give periodic solutions in slow time if the cutoff occurs directly after a mean flow mode.

[4dFD4] Strongly Curved Flow Profiles In Quasigeostrophic Stability Theory

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Piecewise linear flow profiles are formally disallowed in quasigeostrophic stability theory because they have unbounded curvature. This fact is well known but evidently little discussed, and studies which make use of such profiles appear from time to time in the literature. A scaling analysis suggests that the maximum vertical curvature in the zonal wind consistent with quasigeostrophic theory is $O(\frac{N^2 U}{f^2 L^2})$ where N^2 and U are the tropospheric scales of static stability and zonal wind, f is the coriolis parameter, and L is the horizontal length scale. Comparisons are made between the stability characteristics of some piecewise linear flows and similar flows that satisfy this curvature constraint. Minor differences were found for the semi-bounded shear layer, but significant discrepancies were found for the symmetric jet, particularly in the short wave region. We conclude that extreme caution must be exercised when using piecewise linear flow profiles in Q.G. stability theory.

[4dFD5] Nonlinear Stability of Generalized Phillips Model

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This paper investigates the nonlinear stability in the two-layer and three-layer generalized Phillips' models, for which the velocities are constants in each layer, and the upper and lower boundaries are either rigid or free.

By employing Arnold's method and an a priori estimate method, we establish the nonlinear stability criteria of the two-layer generalized Phillips' model. We also obtain linear stability criteria of this model by using a normal mode method. It is shown that the nonlinear criteria are the same as the linear ones, but the nonlinear ones are applicable to finite-amplitude disturbances. The influence of the free surface on nonlinear stability is discussed. The results indicate that the influence of the free surface on stability can be ignored in oceans, but not in the atmosphere. Linear and nonlinear stability criteria in three-layer generalized Phillips' model are also obtained by the above method, which exactly coincide in form, but the physical meanings are essentially different. We also discuss the influence of the curvature of the velocity on stability. It is found that it is favourable to the instability when the velocity shear is concentrated at lower levels.

[4dFD6] Linear Stability Analysis of a Frontal Oceanic System over a Submarine Ridge

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The stability of frontally-trapped baroclinic waves along the crest of an oceanic ridge on an f-plane is examined to determine under which conditions two neighboring, inviscid water layers, each of uniform density and momentum, can coexist without eddies mixing associated to the instabilities. A linear stability analysis for a weak disturbance is performed over a steady laminar state. This study has been motivated by sparse observations of a front under the Arctic icepack in the region of the Lomonosov ridge. The study follows that of Gawarkiewicz (1991) for a frontal system over a shelf-break, but deviates by building an implicit dispersion relation to solve, by finite difference, a 4^{th} order ordinary differential equation. The implicit dispersion relation for a submarine ridge, with straight slopes that extend to infinity, depends on four parameters that characterise the physical system: the nondimensional wave number, the nondimensionalised slopes of the ridge, and a physical quantity, analogous to the Froude number, that characterises the shearing force against the buoyancy at the pycnocline. The model is applied to various cases: First, the ridge is symmetric. In the second case, one slope is made small in order to simulate a shelf-break and to allow comparison with Gawarkiewicz's (1991) model. The imposition of a false bottom seaward from the front, by a change of boundary conditions, allows comparison with Flagg and Beardsley (1978).

Room/Salle: Arts 116 [4dIV] Thursday/Jeudi

INTERANNUAL VARIABILITY 1
VARIABILITÉ INTERANNUELLE 1

Chair/Président: Madhav Khandekar

[4dIV1] Interannual variability of SST and the overlying atmospheric circulation in the western South Atlantic.

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The interannual variabilty of the sea surface temperature, atmospheric sea level pressure and winds in the South Atlantic Ocean is studied using a 40-year period of annual COADS Data (1953-1992). Two time series are constructed by averaging SST data over the Brazil and Malvinas Currents regions. A composite analysis is performed by selecting warmer- and colder-than-normal years from these series and averaging them to obtain the structure of the warm and cold episodes for each region. The spatial pattern of interannual variability is then constructed by subtracting the cold from the warm composite in both regions. Using the cold and warm years taken from the SST series, the composite analysis is also performed for the SLP and wind fields, to represent the variability of the overlying atmospheric circulation. The resulting SST pattern exhibits bands of

zonally elongated centers of action with alternating signs. Similar bands are also found in the SLP and wind difference fields. A close relationship between SST and surface atmospheric circulation is evident, suggesting a local thermodynamic interaction which involves changes in the ocean-atmosphere heat exchange. These results resemble those of Kushnir (1994) who performed a similar analysis in the North Atlantic Ocean.

[4dIV2] Intense Extra-Tropical Northern Hemisphere Winter Cyclone Events: 1899-1991

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The climatology of intense winter cyclone events is extracted from a 90-year set of daily mean sea level analyses. Changes in the geographical distribution and changes in the temporal distribution are presented and discussed.

[4dIV3] Interannual Atmosphere-Ocean Coupled Variability in the North Atlantic: Observations and Modelling

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Recently Peng and Fyfe (1994) applied a singular value decomposition analysis to several decades of observed monthly-mean sea-surface temperature and sea-level pressure anomalies and found that the dominant mode operates on a quasi-biennial time-scale with wind fluctuations overlying regions of large SST anomalies (as in Deser and Blackmon, 1993). It has been suggested that the wind anomalies contribute to the formation of the SST anomalies by altering the fluxes of sensible and latent heat at the ocean surface, with the so-formed SST anomalies then tending to reinforce the wind anomalies (i.e., a positive feedback mechanism). Here we explore this in more detail, both observationally and with long integations (60 year) with an atmospheric GCM which is 1) forced with fixed SST boundary conditions or 2) coupled to an interactive oceanic mixed layer model.

[4dIV4] An ecologically-based regionalization framework for regional and national climate data analysis in Canada

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In a joint effort, State of Enivronment Reporting and the Atmospheric Environment Service are investigating Canadian climate variability and change within the Environment Canada ecological land classification (eco-zone) framework. Previous efforts along these lines involved analysis of the Historical Canadian Climate Database (HCCD) over 11 large climatic regions. A more detailed understanding of changes in temperatures and precipitation across Canada is possible through the finer spatial resolution of 21 eco-system-based eco-zones. In the present work, the best available historical climate data is fit into the pre-defined eco-zone structure - the structure itself is not re-defined on the basis of climate alone.

The Historical Canadian Eco-climatic Database (HCECD) was created for this study, and holds homogeneous temperature records and preliminary precipitation data for 137 sites. The elements included in the HCECD are monthly, seasonal and annual values of maximum, minimum and mean temperatures and total precipitation. The HCCD was the source for much of the data but additional datasets were required, particularly in the North. Methods used in the preparation of these are presented, along with examples. A selection of the analyses available from the HCECD are presented, with particular attention to annual mean temperatures and precipitation, over the period with the most complete data coverage nationally, 1948-present.

Room/Salle: Arts 116 **[4dLR]** Thursday/Jeudi

LONG RANGE FORECASTING 2
PRÉVISIONS À LONG TERME 2

Chair/Président: Madhav Khandekar

[4dLR1] Past Practice and Prospects for Climate forecasting in Canada

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Monthly to seasonal outlooks are examined from their historic development within Environment Canada. Current operational practices are reviewed against a study of potential users' needs and the results of a survey of Climatic Perspectives readers. The accuracy requirements in user surveys have utility thresholds for accuracy that can not be met with current methods. Not surprisingly, results from CP readers indicate less interest in the climate outlooks than other climate information based on past data. The results of the surveys are inconsistent with public, media and institutional interest in long-range outlooks. The possibility for improved climate outlooks based on the results of computer simulations is examined. An update on what may be possible within a framework of government cutbacks and a devolution of responsibilities to the private sector will be presented.

[4dLR2] Teleconnections between ENSO events and growing season extended dry spells on the Canadian Prairies

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This paper analyzes possible teleconnections between ENSO events (both El Nino and La Nina) and growing season (May to August) extended dry spells on the Canadian Prairies during the period 1948-1991. Results show that El Nino events are associated with more positive 50 kPa anomalies and more extended dry spells while La Nina events are associated with more negative 50 kPa anomalies and fewer extended dry spells over the Prairie region during the growing season. Both relationships occur during the second growing season following the maturity of an ENSO event (i.e. approximately a 17 to 20 month lag). It is suggested that these relationships occur due to a series of atmosphere - ocean teleconnections in the Pacific Ocean. These include ENSO events, the Pacific North America (PNA) teleconnection pattern, North Pacific sea surface temperature anomalies, 50 kPa anomalies over the Canadian Prairies and growing season extended dry spells over the Prairie region. The results are incorporated into a conceptual model which may form the basis of long-range forecasting of extended dry spells on the Canadian Prairies.

Room/Salle: Arts 118 **[4dPE]** Thursday/Jeudi

PERD 2
GRDE 2

Chair/Président: Mike Foreman

[4dPE1] Turbulent dissipation measurements applied to models of shelf seas

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In this contribution we report on the first set of observations of turbulent dissipation in the water column in the European shelf seas using the FLY profiler, which allows measurements to be made to within a few centimetres

of the bottom. Observations over full tidal cycles were obtained in March and July 1993 in conditions of (i) near vertical homogeneity with and without surface heating, and (ii) strong thermal stratification. The observations were made in parallel with measurements from conventional moored current meters and a profiling CTD/transmissometer system with calibration of the latter by gravimetric samples to provide estimates of seston distributions.

The flow properties, both mean and turbulent, are compared with hindcasts of the flow made using models of the dynamics and vertical diffusion with different closure schemes. We use the 1-d dynamics model (Simpson and Sharples 192) with a Mellor-Yamada level 2 closure scheme to represent the interaction of flow and stratification. In the simplest version of this model (MY level 2), we neglect the time derivative and vertical diffusion terms and assume a local equilibrium between shear and buoyancy production of the turbulent K.E. and dissipation. In the second (MY 2.1) we allow for the influence of turbulence diffusing upwards into the flow from the main generation zones near the bottom boundary.

[4dPE2] Oil Spills in Open and Ice-Infested Waters: A Comparative Need for Data on Water Currents

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In an uncontained oil spill in open waters the oil spreads to a thin film covering a rather large area. Depending on this areal extent different portions of the slick will be subject to different meteorological and oceanographic influences. The spatial distribution of water currents, in particular, can have a significant impact on the drift of the oil slick. In ice-infested waters, where the water temperatures are near freezing, the oil film thickness is found to be greater than that on warm waters and the extent of spread of the oil is dependent on the ice concentration. As the ice concentration increases the oil contaminated area also increases. But beyond a certain ice concentration, around 80 %, the ice floes are nearly touching each other and any newly spilled oil is likely to be trapped between floes reducing the oil contaminated area.

In this paper, some recent oil spill cases in open warm water will be discussed in terms of the impact of water currents on spill motion. Oil spill behaviour in ice-infested waters will be illustrated with examples and the conditions under which a detailed knowledge of water currents may be required will be discussed.

[4dPE3] Tidally forced under-ice Ekman Layers observed by an acoustic Doppler current profiler

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A simple, tidally forced Ekman model is fit to acoustic Doppler current profiler observations of the horizontal velocity field sampled during the SARES experiment. An assimilation inversion technique is demonstrated that does not require the use of Lagrange multipliers and an adjoint equation. The gradient of the cost function is obtained through direct differentiation of the equations of motion and associated boundary conditions. The method proved to be very robust and provided a good fit to the data for the K_1 component of the tide. A maximum value of 4.75×10^{-3} m^2 s^{-1} was obtained for the vertical eddy viscosity which implied a nutrient transport 50 times less than that required to meet ice-algae demand. It is proposed that turbulence associated with the passage of high frequency internal waves, rather than the background tide, is responsible for mixing nutrients to the ice-water interface.

[4dPE4] Vertical structure of the currents off Newfoundland

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Vessel-mounted acoustic doppler current profilers (ADCP) were used to collect velocity profiles along transects off Newfoundland and southern Labrador since 1991, as part of the physical oceanographic components of cod

ecosystem research under the northern cod science program (NCSP). Concurrent with the ADCP surveys several cross-shelf CTD transects were also occupied. The NCSP also supported an extensive mooring program which provided velocity time series from a number of locations and depths over the same time period, as well as a drifter program to provide near surface currents on the shelf. Earlier studies using a sub-set of this data have shown that the ADCP data can be quite useful to describe aspects of the mean circulation on the shelf. Consequently, we are implementing an ADCP archival and processing system for a UNIX SUN workstation based on the CODAS 3 software package from University of Hawaii. Work is underway to examine this extensive data set to delineate the vertical structure of the circulation on the continental shelf along the east coast of Newfoundland at different time scales. In addition, the near-surface circulation deduced from this analysis will be compared with the current map for the same area compiled by the International Ice Patrol, and with the surface currents deduced from the drifter tracks collected under NCSP.

[4dPE5] Internal wave directional spectra using an acoustic Doppler current profiler

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An acoustic Doppler current profiler was deployed through land-fast ice near Resolute, North-West Territories. It recorded a distinct train of high frequency (periods < 20.0 min) internal waves lasting 10 hours. Assuming linear dynamics, a modal decomposition of the three velocity channels led to the modal pressure anomaly taking a role analogous to that of the surface displacement sensed by a surface following heave, pitch, and roll buoy. Partitioning the data into frequency dependent cross-spectral matrices of the modal horizontal pressure anomaly enabled the computation of high resolution, data-adaptive directional spectra, recently presented for use with surface gravity waves. The mode 1 directional spectra were particularly sharp, and indicated a cross-channel point of origin of the waves to the north-east of the study site. The lowest two frequency bands contained considerable spectral power density that could not be accurately described by the modal decomposition. A direct examination of the cross-channel velocity time series indicated substantial low frequency (periods > 30.0 min) horizontal flow without a corresponding coherent vertical velocity component, attributed to a density driven along-isopycnal flow created by salt rejection emanating from a broad shelf to the north-east.

[4dPE6] Intercomparison of surface wind data off the BC Coast

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We compare surface winds and wind stress that are available to force ocean circulation models along the B.C. Coast. Data from three sources are examined: (a) moored buoys, (b) COADS ship data, and (c) automated CMC forecasts. Several AES/DFO buoys were moored along the B.C. coast starting in the fall of 1987, with their number gradually increasing in early 1990s to a total of 9 offshore and 6 inshore buoys (4 in Queen Charlotte Sound, Hecate Strait and Dixon Entrance and 2 in Georgia Strait). Hourly observations from these buoys give good temporal coverage, despite gaps in data due to instrument failure and short observing periods in some of the buoys. The COADS release 1a monthly trimmed standard data set was binned into 2x2 degrees grids and covers the period 1980-1992. We compare monthly mean statistics of wind and pseudo-stress in 1991-92, as calculated from buoy data and from overlaping COADS grids. Automated forecast products were supplied by CMC beginning in March 1994 in support of ocean current modelling at IOS. These data are on a 50-km AES forecast model grid and include u and v components of wind at the model lowest sigma level. We make a comparison between 12-hour forecast winds and 12-hour averages of surface winds from adjoint AES/DFO buoys.

Room/Salle: Arts 116 [5aAR] Friday/Vendredi

SEA ICE AND ARCTIC STUDIES 2
GLACES DE MER ET ÉTUDES DE L'ARCTIQUE 2

Chair/Président: Greg Flato

[5aAR1] Sea-Ice, Polar Amplification and Arctic Climate Warming

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From increasing greenhouse gases, all global climate models (GCM) predict warming of the Earths surface and of the lower atmosphere. In polar regions and particularly in the Arctic, sea-ice cover is a major factor for regional warming. As an example, in a double CO2 scenario, the Canadian model (CCC/GCMii) calculates a reduction of about 66 % of the total mass of sea-ice. A reduction of sea-ice cover and thickness implies a surplus of solar energy storage into the ocean during late spring and summer. Consequently a warmer sea-surface temperature (SST) anomaly is formed and the energy returned to the atmosphere during the cold season. For a double CO2 scenario, the CCC/GCMii produces a 12 to 15K warming over the Arctic ocean during January, while the global mean warming is only 3.5K. During the last 15 years, a global warming trend seems to be emerging. Although the amplitude is not yet statistically significant, the pattern is in general agreement with the CO2 warming pattern. The main exception being the Arctic ocean where no amplification is yet apparent.

The response to a transient increase of greenhouse gases may explain in part the substantial difference between observations and models in the high Arctic. A series of diagnostics and simulations is carried out to determine the sensitivity of Arctic sea-ice to warm anomaly from external forcing like that of greenhouse gases. The hypothesis is that an onset threshold of radiative forcing is required to activate the multi-annual sea-ice-temperature feedback. A weak forcing results in a small temperature anomaly where the heat storage is exhausted during the current year and does not compound into the following years. On the other hand, a double CO2 forcing is sufficiently strong to activate the retreat of multi-annual sea-ice and allow the winter climate to drift to a much warmer condition by compound effect. This study uses the new Local Climate Model LCM/FIZ-C, a 1D column version of the CCC/GCMii physics, to investigate the ice sensitivity and pave the way to a future major experiment of transient CO2 climate simulation.

[5aAR2] Arctic Climate Sensibility to the Alteration of CCN/ICN and the Water Vapor Cycle

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Recent simulations show that acid aerosols produce larger but less numerous water droplet. Droplet volume is increased by 2 orders of magnitude whereas vertical water flux is enhanced by 3 orders of magnitude in the high H2SO4 concentration case. This result is due to lowering critical supersaturation and increasing coagulation rate of subsaturated particles in the accumulation mode of haze. These results generally agree with observations showing 10 to 1000 time lower fraction of ice nucleating particles in anthropogenic influenced Arctic haze period.

From the climate point of view, the acidification of Arctic aerosols may provide part of the explanation for the observed cooling trend in high Arctic during the cold season. When coupled to the strong water vapor greenhouse effect, the air mass dehydration rate produces a positive feedback resulting in a cooler surface temperature. Further investigations are necessary to draw firm conclusion on the magnitude of this process. A project underway at UQAM uses a nested regional climate model (MC2/RCM) within the CCC/GCM to assess the role of anthropogenic and biogenic aerosols on the Arctic surface energy balance.

[5aAR3] BASE special model performances and analysis of mesoscale weather with MC2 model advanced output

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The Beaufort and Arctic Storms Experiment (BASE) was conducted over the southern Beaufort Sea and Mackenzie River Delta from September 1 1994 to October 14 1994. BASE provided a unique source of information on Arctic weather systems with the availability of two X-band Doppler radars, a research aircraft, enhanced rawinsondes and satellite images.

A special operational forecasting guidance was prepared for the field experiment with the mesoscale compressible community model (MC2). The special model was run with a horizontal resolution of 15 km to 30 hours once per day, at night, using the lateral boundary conditions from the operational RFE model. The initialisation included parts of the BASE special observations (extra radio-sondes and surface stations) and 25 km resolution analysis for ice based on SSM/I data. After a brief description of the model, its performance during BASE will be compared to observations. The in-house numerical database assembled at RPN especially for BASE will be described shortly. Based on the September 26 1994 precipitation bands event at Tuktoyaktuk, a case study will show the model sensitivity to the Beaufort Sea ice extent. Comparisons between Doppler radar data and MC2 model output will be shown for this actual BASE event. MC2 forecast of outgoing flux of infra-red energy at the top of the atmosphere as well as infra-red flux to the ground will be compared with observations and with IR and VIS satellite pictures.

[5aAR4] An oil spill tracking component for the Multi-category Particle-In-Cell (McPIC) sea-ice model.

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In this extension of the Multi-category Particle-In-Cell (McPIC) sea ice model, the interaction between ice and oil is treated by splitting the spilled oil into discrete parcels which are either free-floating or associated with nearby ice 'particles' according to a weighting scheme based on the ice concentration, the ice particle areas and the distance of these ice particles from the spill location. Oil particles are then advected either by an empirical formulation of wind-induced surface currents or by the computed motion of the ice particles, following the methodology described by Neralla and Venkatesh et al.

[5aAR5] Contaminant study in the Arctic Ocean

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A high resolution coupled ice-ocean model of the Arctic is run as part of a contaminant study. A passive tracer is introduced in order to assess the potential transport of pollutants. Results will be discussed within the context of the general circulation.

Room/Salle: Multi-purpose Room [5aCL] Friday/Vendredi

CLIMATE AND PALEOCLIMATE 3
CLIMAT ET PALÉOCLIMAT 3

Chair/Président: Ian McKendry

[5aCL1] Climate Variability in a Low-Order Coupled Atmosphere-Ocean Model

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The behavior of the climate system is investigated through the use of a low-order coupled atmosphere-ocean general circulation model. Both the atmosphere and ocean models are fully dynamic: the former is defined

by three ordinary differential equations derived from a truncated Fourier series expansion of the mean and perturbation components of the quasi-geostrophic potential vorticity equation, while the latter is specified by six ordinary differential equations representing the time-dependent variations of ocean temperature and salinity in a 3-box model of the North Atlantic.

Equilibrium states are never attained in the coupled system within 10000 years of integration; the deep ocean flow continually adjusts to the atmospheric regime changes associated with particular ocean circulations, which leads to new circulations and new atmospheric regimes. Low-frequency quasi-periodic oscillations about a single state of the thermohaline circulation result from an advective-diffusive process, modulated by the correlation of the atmospheric behavior with the phase of the ocean cycle. The climate is strongly effected by interactions with the ocean, leading to distinct atmospheric patterns for different phases in the oscillations, and a conversion of some of the high-frequency atmospheric signal to lower frequencies. Furthermore, owing to the richness of the atmospheric response to small modifications in the meridional and zonal gradients in diabatic heating, even modest adjustments in the ocean circulation resulting from interactions with the high-frequency atmospheric component also leads to climate change over relatively short time periods.

[5aCL2] On The Importance of the Sea Surface Temperature – Evaporation Feedback for the Ocean's Thermohaline Circulation

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A simple new parameterization is presented which allows the dependence of evaporation on sea surface temperature (SST) to be included in uncoupled ocean models under traditional mixed boundary conditions. In two preliminary experiments, a positive feedback is produced between high latitude convection and evaporation. A positive perturbation to the overturning circulation warms the sea surface at high latitudes, enhancing evaporation and hence the sea surface salinity, which then feeds back onto the overturning. A negative perturbation allows the reinforcement of a fresh pool at high latitudes through cooling SSTs and the consequent reduction in evaporation.

Two case studies featuring internal variability of the ocean's thermohaline circulation on decadal and millennial timescales are then considered. The mechansim for both types of variability appears essentially unchanged under the evaporative feedback, but the period and/or the duration of the oscillations can be shortened. Overall, the small magnitude of the time-dependent component of the evaporation tends to support the accepted use of fixed freshwater fluxes as a good first approximation.

[5aCL3] A discussion of mode transitions in a simple global ocean model

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The existence of multiple equilibria in models of the climate system is now well established and leads to the possibility that a transient change in forcing could cause a much longer lasting change in the earth's climate. Such changes may be large and important, as evidenced by the so-called "climate drift" problem which often occurs when ocean and atmosphere models are coupled.

Unfortunately, most studies of the multiple equilibria of the climate system have dealt primarily with the existence and description of these equilibrium states, and we know relatively little about the transitions between them or the location of the present climate state relative to these transition points. Exceptions to this statement generally involve either box models or single ocean basin models: the gap between these models and the real world remains very large. To reduce this gap, I will use the more realistic (but still idealized) climate model developed in Stocker, Wright and Mysak (1992) [updated to include the ocean model formulation of Wright, Vreugdenhil and Hughes (1995)] to further investigate the nature and the importance of these transitions.

In particular, I will discuss the following questions: (1) how does the model climate state depend on both interbasin and intrabasin exchanges of water via the atmosphere; (2) where do transitions between the various equilibrium states occur and where is the models "present climate state" located relative to these transition points; (3) what is the sensitivity of model results to model idealizations; and (4) what has all this got to do with the climate drift problem?

[5aCL4] The stability of a zonally-averaged thermohaline circulation model

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A combination of analytical and numerical techniques are used to efficiently determine the qualitative and quantitative behaviour of a one-basin zonally averaged thermohaline circulation ocean model. In contrast to earlier studies which use time stepping to find the steady solutions, the steady state equations are first solved directly to obtain the multiple equilibria under identical mixed boundary conditions. This approach is based on the differentiability of the governing equations and especially the convection scheme. A linear stability analysis is then performed, in which the normal modes and corresponding eigenvalues are found for the various equilibrium states. Resonant periodic solutions superimposed on these states are predicted for various types of forcing.

The results are used to gain insight into the solutions obtained by Mysak, Stocker and Huang in a previous numerical study in which the eddy diffusivities were varied in a randomly forced one-basin zonally averaged model. It is shown that the new methodology can effeciently predict the stability of the various steady states and provide good estimates of the period and structure of the resonant stable oscillations found in the previous study.

[5aCL5] Flux corrections in coupled ocean-atmosphere models

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Most coupled models have to use flux corrections to avoid climate drift. This arises from the incompatibility of the mean oceanic and atmospheric states. Historically, atmospheric models were developed with bottom boundary conditions that were only prescribed SSTs or mixed layer oceans using heat flux adjustments. In validating a particular atmospheric model against observations of the present climate, constraints were not placed on the ocean heat and freshwater transports implied by the surface heat and freshwater fluxes. For example, a small error of say 5 Wm^{-2} extra heat into the southern half of the Pacific Ocean and a small excess heat loss of $5Wm^{-2}$ all over the northern half of the Pacific Ocean would imply a 0.4×10^{15} W transport of heat from the South to North Pacific. Such a systematic error of 5 Wm^{-2} could easily be overlooked unless the implied ocean heat transport was considered. Indeed, 5 Wm^{-2} is smaller than the local errors in the observed heat flux field. When an atmospheric model is coupled to an ocean model with implied heat and salt transports incompatible with each other, a drift in the climate system must occur. This drift adversely affects both the atmosphere and the ocean. The use of flux corrections/adjustments may stabilize this drift, but they have the undesirable effect of being physically unfounded and often of larger magnitude (in places) than the climatological mean fluxes. As shown by ocean modelling studies, ocean models are capable of sustaining internal modes of oscillation under a specified freshwater flux boundary condition with thermal damping. In coupled atmosphere-ocean simulations, any variability found when flux corrections are used is difficult to interpret. In this talk ways are considered of obtaining the minimum possible flux correction. A discussion and intercomparison with existing techniques of determining these flux corrections is also presented.

Room/Salle: Auditorium [5aFD] Thursday/Jeudi

GEOPHYSICAL FLUID DYNAMICS 2
DYNAMIQUE GÉOPHYSIQUE DES FLUIDES 2

Chair/Président: Paul LeBlond

[5aFD1] Does the two constituent nature of seawater affect its potential vorticity dynamics?

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It is now well established that the two constituent nature of seawater (i.e., the fact that density at a given

pressure depends on both temperature and salinity) plays an important role in determining ocean circulation, both through double diffusive processes and because surface buoyancy fluxes are essentially independent of salinity. Here we ask to what extent the potential vorticity dynamics of the ocean might also be affected by the "spiciness" of seawater. It is well known that one cannot, even in the absence of irreversible mixing and friction, define an oceanic Ertel's potential vorticity which is conserved. Similarly, the approximate potential vorticities typically used to study large scale flow are not conserved unless simplifications are made to the equation of state. Here we present analogs to both the standard quasigeostrophic and planetary geostrophic balance equations for a two constituent ocean. The "forcing" terms in the potential vorticity equations become important where variance in the buoyancy frequency associated with its dependency on the speed of sound becomes large. Possible implications, both to ocean dynamics and to data analysis (e.g., inverse methods such as the beta spiral) are discussed.

[5aFD2] A Semi-Geostrophic Model of the Leeuwin Current off West Australia

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An outcropping reduced gravity semi-geostrophic model for the Leeuwin current is developed. The system is described by geostrophy in the alongshore direction and is fully non-linear in the offshore direction. Flow is driven by a specified Indonesian throughflow at the Northern end of the domain.

Non-dissipative steady state analytical solutions are obtained for vanishing and constant potential vorticity of the source waters. The solutions describe a poleward flowing Eastern boundary current with a trapping scale on the order of the internal Rossby radius. This scale magnifies poleward as the solution becomes increasingly dominated by curvature of the interface field. Alongshore current speeds at the Northern end of the domain are about 1.5 m/s and decrease southward.

In order to obtain more realistic flow variables and structure numerical methods are used to introduce topography and diapycnal mixing into the model. The addition of diapycnal mixing results in an overall broader current which focuses and deepens poleward and yields more reasonable current speeds. Topography further reduces the magnitude of the current necessary to obtain solutions which are trapped along the eastern boundary. Solutions for various choices of parameter values, as well as different assumptions regarding the potential vorticity structure of the source waters are also presented and compared with the analytic results.

[5aFD3] Variability in forced/dissipative barotropic flow over topography

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Barotropic, quasigeostrophic flow over topography serves as a useful model for studying the effects of eddy/topography interactions in driving large-scale mean flows. In the inviscid case, statistical mechanics provides a means for deducing the mean and fluctuating spectra. However, no predictive theory is available when forcing and dissipation are present. Numerical simulations have been used here to examine the properties of such flows under conditions where the energy residence time is much greater than the eddy turnover time, as in the oceans. A principal result is that flow energy and variability are strongly dependent upon whether applied torques locally reinforce or oppose the tendency for eddys to drive mean flow. Negative correlations between torque and topography reinforce the tendency, and give rise regions of high energy and low variability. Positive correlations oppose the tendency, and are associated with regions of high variability but relatively low energy.

[5aFD4] Asymmetric geopotential height fluctuations from symmetric winds

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At mid-latitudes, geopotential height fluctuations, Φ, are asymmetric in the sense that large-amplitude excursions (several standard deviations) below the mean are much more likely than fluctuations of the same size above the mean. This asymmetry is a basic characteristic of the variability of Φ which we quantify by extracting from observations the probability density function (PDF) of Φ and its skewness (third moment of the PDF

nondimensionalized by its variance) in the global domain for winter and summer.

From a diagnostic study based on computing Φ from the observed winds through the balance equation, the nonzero skewness of Φ can clearly be attributed to the rectification of near-symmetric velocity fluctuations by the advective nonlinearity.

The subtle dependence of the skewness on key flow parameters is illustrated through an analytic model for idealized wind fluctuations on a beta-plane. General expressions for the PDF, its asymptotic form, criteria for the presence of exponential tails, and the generic dependence of the skewness on a generalized Rossby number are derived. For the case of a δ-function velocity spectrum, closed-form expressions for the PDF and skewness are obtained and compared to observations.

[5aFD5] Relative angular momentum balances of quasi-geostrophic circulation models

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Calculations of the local vertical component of relative angular momentum are considered for quasi-geostrophic circulation models. The angular momentum diagnostic measures the net horizontal spin of the flow within an ocean basin and complements traditional budgets of energy, vorticity and linear momentum. In particular, the diagnostic can help identify the role of bottom topographic stresses in driving ocean circulation. Calculations of torque balances are presented for several numerical experiments with single-layer and multi-layer models. In experiments with an idealized continental slope topography, a cyclonic circulation, which is driven by a significant topographic form torque, develops in the abyssal layer.

Room/Salle: Arts 108 **[5aMA]** Friday/Vendredi

MIDDLE ATMOSPHERE 1
ATMOSPHÈRE MOYENNE 1

Chair/Président: John Fyfe

[5aMA1] The Canadian Middle Atmosphere Model :Some Results from Multi-Year Simulations.

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The Canadian Middle atmosphere Model (MAM) is being constructed as a collaborative project between several Canadian University groups and the AES. The goal of the project is to develop a comprehensive 3-D model of the atmosphere that extends from the surface to the mesopause. Ultimately the model will include interactive chemistry, semi-lagrangian transport, an up to date stratospheric/mesospheric radiative code and modern gravity wave parameterizations. Considerable progress on this development work has been made within the past year and multi-year simulations have been made with the two master versions of the model together with other shorter experimental simulations. The first of these, (MAM1), is an upward extended version of the third generation GCM of the Canadian Centre for Climate Modelling and Analysis (CCCMA). The second version (MAM1B) includes a number of additional features, the major component of which is a new IR radiation package suitable for the stratosphere and mesosphere. Further radiative components and the semi-lagrangian transport code developments will be added in the near future to MAM2. Chemistry has been added but has not yet been made interactive. We will present a description of the model together with results from the first two 3-year simulations and compare these with middle atmosphere climate data (CIRA).

[5aMA2] The Canadian Middle Atmosphere Model: Sensitivity of the SH General Circulation to Mesospheric Drag Processes

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Results from the first generation Canadian Middle Atmosphere Model are examined for the June-July-August season. Compared to observations, the model produces anomalously warm temperatures in much of the southern hemisphere polar stratosphere. Preliminary investigations suggest that this feature results from an inaccurate representation of mechanical drag processes in the model, and not from possible shortcomings in the radiation schemes.

The downward control principle is used to quantify the direct effects of both resolved (planetary wave) and unresolved (parameterized) mechanical forcing in the vicinity of the warm anomaly. This principle relates the mean meridional diabatic circulation at a given level to the vertically integrated mechanical forcing above that level. In particular, it allows the effects of planetary wave forcing, parameterized gravity-wave drag and numerical dissipation to each be considered separately. Results of simulations using varying strengths of the parameterized gravity-wave drag and numerical dissipation are presented in order to assess their influence on planetary wave activity and on the thermal structure of the southern hemisphere polar stratosphere.

[5aMA3] Towards Dynamic Stratospheric Ozone Analyses and Forecasts for Canada

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In the long term, the AES should have a data assimilation and prediction system that is capable of treating variables, including chemical constituents such as ozone, in the middle atmosphere. Until recently the Canadian Global Spectral Forecast Model used in the global data assimilation and medium-range forecast system at CMC has concentrated on the troposphere. However, research and development is in progress to improve its treatment of the stratosphere in support of dynamic ozone analyses and forecasts in support of the UV index program. Ozone has been incorporated as a passive tracer in the model: initially no sources or sinks of ozone are considered; the ozone is simply advected in the model. For this, a three-dimensional initial ozone field is required, and in the first version was produced by carrying out a horizontal analysis of total column ozone, then distributing the ozone in the vertical using a fit to climatological profiles with a tropospheric ozone mixing ratio of .4 ppmv. This was found to give unrealistic detail and low ozone values in mountainous regions. Significant improvements were obtained by zeroing the tropospheric ozone (so all the ozone is in the stratosphere), increasing the stratospheric vertical resolution, and raising the model top to near 1 mb. In trying to further improve the initial ozone distribution, we are testing other tropospheric ozone profiles and coupling the model with a 3-D variational ozone analysis technique. In the near future we should be in a position to substitute dynamical forecast trial fields for the perfect prog fields in the current operational system, thus producing a fully dynamic stratospheric ozone analysis and forecast system.

[5aMA4] The Upward Propagation of Planetary Waves Forced by Tropospheric Baroclinic Eddies

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The generation of planetary-scale disturbances in the troposphere by baroclinic eddies has been much studied (Gall, et. al. 1979; MacVean 1985; Young and Villere 1985). The nonlinear wave-wave coupling mechanism identified in these studies is very efficient and typically results in an initial growth rate of planetary-scale waves that can exceed the initial growth rate of the unstable baroclinic eddies. Far less consideration has be given to the upward propagation of the planetary-scale disturbances from the troposphere into the stratosphere. The issue of upward propagation is crucial to determining the role of this mechanism as a component of the

tropospheric forcing of the stratosphere.

In the present study we employ a simple dry general circulation model to simulate the upward propagation of planetary waves that are nonlinearly forced by unstable baroclinic eddies in the troposphere. The simulations are performed at T42 truncation with 30 vertical levels extending from the surface to 95km elevation. Rayleigh friction and Newtonian cooling are employed with a 25 day time scale to continually relax the flow back to zonally symmetric initial conditions which reflect winter climatology. Long integrations show the continual growth and decay of baroclinic eddies in the troposphere, with intermittent events in which there is significant propagation of long waves, sometimes wave-1, sometimes wave-2, up into the stratosphere. In this experiment all long-wave variability in the stratosphere is a direct consequence of tropospheric forcing events associated with baroclinic eddies. However, even in this case it is not straightforward to relate specific forcing events in the troposphere with episodic bursts of upwardly propagating planetary waves in the stratosphere, as is often attempted from atmospheric observations. We use various approaches, including time-lag correlations (Randel 1987), to try and gain better insight into what measure of the tropospheric circulation best describes the tropospheric forcing of the stratosphere.

[5aMA5] Comparisons of Gravity Wave Drag Parameterization Schemes in a Simplified Model of the Middle Atmosphere

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Two gravity wave drag (GWD) parameterization schemes based on a broad spectrum of vertically propagating gravity waves have recently been advanced. Hines (1995) has developed a scheme based on his Doppler spread theory. Fritts and Lu's (1993) parameterization is derived from the spectral characteristics of observed gravity waves in the middle atmosphere. These GWD schemes differ fundamentally from previous ones, notably that of Lindzen (1981), which are based on the saturation of a single monochromatic gravity wave. In this presentation the schemes of Hines, Fritts and Lindzen are compared, first using climatological mean wind profiles and then by employing them in a time-dependent model of the middle atmosphere. In order to examine the sensitivity of the schemes to the various tunable parameters, the quasi-geostrophic model of McLandress and McFarlane (1993) which employs a sophisticated radiation scheme is used.

Room/Salle: Arts 118 **[5aPE]** Friday/Vendredi

PERD 3
GRDE 3

Chair/Président: William Crawford

[5aPE1] Model Simulations for Dixon Entrance and the North Coast of British Columbia

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The development and validation and two three-dimensional models are described. The first is a tidal model that assumes a homogeneous density, while the second is a diagnostic baroclinic model whose forcing is derived from CTD observations. Whereas the tidal model is validated against historical tide gauge and current meter data, the baroclinic model currents are compared with current meter observations during the CTD cruises. In particular, CTD data from all four seasons provide snapshots of seasonal changes in the Rose Spit Eddy and the tidal model demonstrates that the eddy does not arise solely due to tidal rectification.

[5aPE2] Study of Mean Water Circulation in Dixon Entrance Region (British Columbia)

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Dixon Entrance Region is a coastal area with a complicated topography in which the second and third most important B.C. rivers (Skeena and Nass) flow. The waters are stratified all year round and the salinity of surface

waters reaches a minimum in early summer, when snow on top of the mountains melts. The surface water circulation is characterized by a pair of eddies: the cyclonic Rose Spit Eddy and the anticyclonic Learmonth Bank Eddy.

The mean water circulation is studied numerically with a finite element model. The model is three-dimensional, diagnostic, and nonlinear. The model grid is composed of horizontal triangular elements and a vertical sigma-coordinate system. Extensive salinity and temperature measurements are used to calculate the tridimensional density field. Density, wind, and river runoff data are then used to determine the mean forcings which drive the model. Model results are compared with Eulerian and Lagrangian current measurements.

An investigation on the role that freshwater runoff from the two rivers, wind, and baroclinic pressure gradient play on the mean circulation is carried out. The contribution of those three forcings to the formation of the two eddies is examined. Results obtained using data from different seasons and also different years are compared.

[5aPE3] Numerical Modeling and a Comparison to Observations of Flow around Canyons

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Canyons have recently attracted the attention of the numerical modeling community as a test site for an intercomparison of models (Haidvogel, 1995). However, as flow around and within canyons is not yet dynamically understood, we will consider the comparison between a simple, layered, numerical model and a set of observations. The most comprehensive set of observations with regards to low frequency phenomena are the 1984 observations over Astoria Canyon. (Hickey, 1995).

In order to simulate the observations the timing of the forcing must be correctly incorporated. In contrast, sensitivity studies show that the flow is insensitive to changes in the geometry of the canyon, the density steps between the layers and the depths of the layers. Three layers are, however, incapable of reproducing the full variation in the vertical observed at Astoria.

[5aPE4] A Model for Suspended Sediment Transport in the Benthic Boundary Layer

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A sediment transport model is being developed for the dispersion and transport of suspended particles in the benthic boundary layer on the continental shelf. The model is one component of an impacts zone assessment model for drilling discharges on benthic organisms such as the sea scallop on Georges Bank. A key feature of the model is the simplified representation of vertical mixing through the random exchange of blocks of material and the use of observational suspended sediment profiles as probability density functions for the overall vertical distribution. Horizontal transport is then represented through advection of the blocks in vertically- and time-varying flow fields taken from observations or a numerical circulation model. This separation of the vertical and horizontal transport components substantially reduces the model's computational requirements, while allowing focus on the dominant boundary-layer process of shear dispersion - horizontal dispersion due the interaction of vertical mixing and vertical shear in the horizontal currents. The effective horizontal dispersion rates in the model are consistent with the fundamental idea that shear dispersion is linearly proportional to the product of the vertical mixing time scale and the mean square velocity deviations experienced by the particles. This simple relationship, developed for massless tracers, is extended to include particles with a finite settling velocity for both steady and periodic (e.g. tidal) flow. The effects of different tidal and mean current profiles and of different vertical distribution parameterizations are illustrated using observational information from a drilling site on Sable Island Bank and the scallop grounds on Georges Bank.

[5aPE5] A case study of wave-current interaction in a strong tidal current

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During August 1991, a field program was carried out in the vicinity of Cape St. James, off the British Columbia

Coast, where a strong tidally driven flow interacts with an active wave climate. Surface current maps were obtained from a CODAR type HF radar (Seasonde) over an area of about 350 km^2 around the Cape. A series of Loran-C drifters were also deployed during the experiment, and used as ground truthing for the radar. A comparison between the drifter and the radar surface currents indicates a reasonable agreement.

Wave information was acquired with three Waverider buoys deployed around the Cape. A significant modulation of the wave properties at the tidal period was observed for the buoy located in the area where the currents are maximum. The tidally induced changes in the wave field are modelled with a local wave-current interaction model based on wave action conservation and on a high frequency limiting spectral shape. The model is applied on a period of 11 days for which the wind was relatively steady. The magnitude of the modeled tidal modulation of the wave field is in fairly good agreement with the measurements. However, during the first half of the period, the modulation of the total wave energy is significantly out of phase with the buoy data. The effect of refraction by the current on the waves is assessed using a backward ray tracing method and two-dimensional surface current maps. It is proposed that refraction effects are important during the first part of the study period, and are a plausible cause for the phase discrepancy between the measurements and the results of the local model.

Room/Salle: Multi-purpose Room **[5bCL]** Friday/Vendredi

CLIMATE AND PALEOCLIMATE 4
CLIMAT ET PALÉOCLIMAT 4

Chair/Président: Andrew Weaver

[5bCL1] A Coupled Ocean-Atmosphere Model for Climate Studies

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An atmospheric model for use in process-oriented coupled ocean-atmosphere studies of the ocean's role in climate change/variability is described. Since time scales of variability associated with atmospheric processes are short compared to the oceanic time scales of interest (decadal to century) we appeal to a simple eddy-diffusive energy-moisture balance model (EMBM) for our atmospheric processes.

Physically, the thermodynamic branch of our model is similar to classical energy balance models to which we have added forcing terms arising from air-sea interaction. The hydrological cycle is modelled by employing an eddy diffusive approximation to the atmospheric moisture balance equation. The moisture source term arising from evaporation is modelled by the traditional bulk formula approach, while the precipitation is parameterized in terms of the atmospheric specific humidity.

The EMBM has been coupled to an ocean general circulation model (OGCM), and results from recent idealized coupled EMBM-OGCM model experiments will also be presented.

[5bCL2] Late Quaternary Geochemical and Stable Isotopic Records from the Gulf of Alaska

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Palaeoceanographic work in the subarctic northeast Pacific has so far been limited by the common presence of turbidites and by the relatively shallow CCD. ODP Site 887 is on the Patton Murray Rise, an elevated plateau which is isolated from these effects. This area is centered under the Alaska Gyre, an area characterized by the domal upwelling of nutrient-rich waters. The controls on productivity in this region remain unclear since the mere presence of nitrate does not ensure enhanced nitrate uptake and productivity. However, past increases in productivity are suggested by the accumulation of diatomaceous oozes, defined by high Si/Al values and by concomitant increases in normalized Ba content.

High-resolution vertical profiles (10 cm, 14 kyr) of %CaCO3, Si, Ba, %organic carbon, Corg/N, and Mn provide a preliminary chemical stratigraphy at Site 887B. Sections from 887A and 887C were spliced into the 887B profile to obtain a continuous composite record, and although calcite is not continuously distributed throughout the core, a preliminary age model is presented based on radiocarbon, d18O, and biostratigraphic data from 887A

and 887B. This information will be used to determine the nature of temporal variations in the deposition of biogenic phases and the associated geochemical response of the sediments.

[5bCL3] Dendroclimatic Records of Climate Change Over the Last Millennium at High-Elevation Sites in Strathcona Provincial Park, Vancouver Island

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Dendroclimatological analysis begins with the understanding that tree rings provide a signal of the annual environmental limitations to tree growth. Consequently, growth suppression events can frequently be calibrated with historical station records to illustrate climatic fluctuations for the extent of a tree-ring chronology. The discovery of ancient trees at timberline on Vancouver Island provides an opportunity to develop millennium-long proxy climatic records. This paper describes research undertaken at five sites in the Forbidden Plateau/Comox Glacier Nature Conservancy Areas of Strathcona Provincial Park. Ring-width indices were developed from living Mountain Hemlock/Yellow-cedar trees. The site chronologies are of variable length, with the oldest dating back to between 800 to 1200 A.D. Notable periods of suppressed or augmented tree growth characterize the chronologies of both species. In the case of hemlock, the suppression intervals appear to reflect seasons characterized by soil moisture stress/reduced winter snowfalls. The growth response of Yellow-cedar is similar, although perhaps more closely related to growing season moisture variations. These analyses show that both species display considerable climatic sensitivity and suggest a potential for developing proxy climatic records spanning the last millennium.

[5bCL4] The effects of duration of record and of method of analysis on climate change conclusions derivable from historical temperature data

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Earlier discussions of the global warming hypothesis have used linear regression of temperature versus year over the period 1880-1990 in support of the argument that the globe is warming. In this study, historical temperature data have been analyzed from a group of stations having long records (much greater than 110 years). The linear trends in temperature at each of these stations were determined for the period 1880-1990 and for other periods of varying lengths, all ending in 1990. At each station, the calculated trends were highly dependant on the time periods selected for analysis.

An attempt was then made to filter the original data using filters of different lengths in order to distinguish between short-term and long-term components in the trends.

[5bCL5] A technique for the identification of inhomogeneities in annual temperature series.

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Reliable climate datasets are essential for climate change studies. Unfortunately, most long term climatological time series have been affected by a number of non-climatic factors, such as relocation of the observing site, changes in instrumentation, or by some alterations in the observing procedures, and frequently these datasets do not represent only real climate variation occurring over time.

A new technique has been developed for the identification of inhomogeneities in annual temperature time series. A principal objective is to identify artificial step changes and trends in the series of a candidate station in the absence of prior knowledge of time of site changes and other factors, and therefore decreasing the dependency on the station history files which are often incomplete. This new technique is based on linear regression models in which the dependent variable is the series of the candidate station and the independent variables are the series of some neighbouring stations. Additional independent variables are systematically introduced in the model in an attempt to describe and measure steps and trends occurring in the tested series and not in the neighbouring series. A model is finally accepted when the residuals are considered to be random variables.

The description of the technique is presented along with its application to simulated and archived data through the provision of selected examples.

Room/Salle: Auditorium **[5bFD]** Thursday/Jeudi

GEOPHYSICAL FLUID DYNAMICS 3
DYNAMIQUE GÉOPHYSIQUE DES FLUIDES 3

Chair/Président: Paul LeBlond

[5bFD1] The slow manifold and initialization for the shallow water equations on f-plane

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Functional equations of the slow manifold are obtained for the shallow water equations on f-plane. These equations are solved by iteration method on powers of nonlinearties. Lying on the slow manifold initial data evolve on this manifold during all time and will not generate solutions with frequency of inertial-gravity waves. The evolution equation on the slow manifold is obtained. The slow manifold and the motion equation on it are constructed for the shallow water equations with discrete time. Knowledge of exact differential equations for the slow manifold allows to solve the problem of initialization in a new way and to take into account property of the difference scheme for the time.

[5bFD2] Beyond $(g'h)^{\frac{1}{2}}$, the speed of gravity currents in a rotating frame

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The velocity of the head of a buoyancy driven gravity current has been measured in the laboratory by previous researchers and found to depend linearly on the baroclinic wave speed. This relationship has been re-investigated in the laboratory by measuring the velocity of the head of a surface gravity current for a wide range of initial parameters. The velocity, u_N, was found to depend on the ratio between the Coriolis parameter, f, and the stratification, N, as well as the baroclinic wave speed, c:

$$u_N = c\left(1 - b\frac{f}{N}\right)$$

where b is a non-dimensional coefficient.

This relationship can be predicted by scaling the shallow water equations. The theoretical technique allows the laboratory results to be scaled to field situations to give

$$u_N = c\left(1 - b\frac{f}{N}\alpha\right)$$

where α is the flow aspect ratio.

[5bFD3] In search of Holmboe's instability

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Holmboe (Geofys. Publ., 24, 1962) investigated the stability of stratified shear flows with a density interface that is much thinner than the velocity interface. For a range of Richardson numbers he predicted the existence of two trains of internal waves of equal strength that travel at the same speed, but in opposite directions with respect to the mean flow. Unfortunately, there have been few experimental observations of the Holmboe instability. We hypothesize that this is because in experiments performed in mixing layer channels the effect of unequal boundary layers on either side of the splitter plate is to generate a flow in which the centers of the velocity and density profiles are displaced vertically from each other. It is shown theoretically that this lack of symmetry inhibits the formation of the Holmboe instability. The results of recent experiments in a facility that eliminates this profile asymmetry will be presented. These experiments provide the best realisations of the Holmboe instability to date. We have also examined the non-linear evolution of both symmetric and non-symmetric

Holmboe instabilities numerically and have compared the results with those of the laboratory experiments.

[5bFD4] Large amplitude internal gravity waves: comparison between weakly nonlinear theory and a primitive equation model

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Large amplitude, vertically trapped internal waves are commonly found in coastal regions where they are generated when tidal currents flow over topographic features. These waves are important for a number of reasons. For example, the strong currents associated with them can transport particles great distances and effect sound transmission. These waves are commonly modeled with weakly-nonlinear theories. A primitive equation numerical model has been used to accurately simulate the time evolution of internal waves as described by the fully nonlinear, inviscid Boussinesq equations. High spatial and temporal resolutions are used to get accurate solutions which are then compared with the weakly-nonlinear theoretical predictions. A hierarchy of evolution equations are considered. The simplest includes first-order nonlinear and dispersive terms (yielding the KdV equation). The most complex includes second-order nonlinear and dispersive effects along with nonlinear-dispersive terms.

Room/Salle: Arts 116 [5bIV] Friday/Vendredi

INTERANNUAL VARIABILITY 2
VARIABILITÉ INTERANNUELLE 2

Chair/Président: William Hsieh

[5bIV1] A 3-D empirical normal mode comparative study of a numerical AMIP integration with the NMC analysis.

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Empirical normal modes (ENM) analyses, see (Brunet, 1994, JAS), of a 10 year AMIP integration of the Canadian Semi-lagrangian global spectral forecast model (T63 with 23 vertical levels and prescribed SST and sea ice) and of NMC analyses covering the same period (1978- 1988) are compared. An ENM analysis permits the empirical reconstruction of the excited normal modes in a time series, as well as their respective variances and phase speed relationship. This approach enables quantitative and qualitative discussions of the wave mechanisms present in real or numerically simulated sheared flows. The present analysis will focus on the winter polar vortex wave dynamics of the Northern hemisphere from 1000mb to 100mb. Special attention is given to the time scales of few days, i.e., baroclinic wave- activity, to several weeks, i.e., the slow variability. We discuss how well the numerical model captures the observed wave-activity at different time and spatial scales.

[5bIV2] Progress on AMIP-like integrations with the RPN Spectral Forecast Model

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A follow-up to the first RPN AMIP integration is reported upon. The new simulations utilise higher spatial resolutions both in the vertical and in the horizontal. Furthermore, several modifications the physical parametrizations have been implemented in order to correct for deficiencies identified in the first run. We will compare a control (using a repeating but specified seasonal cycle of sea surface temperature and sea ice coverage) with the standard AMIP-type simulation (i.e. which use varying monthly mean values of these fields for the 1979- 1988 decade). We will also compare our results with NMC-supplied analyses with our the simulated decade.

The RPN AMIP integrations are done with a version of the Canadian global spectral forecast model. It should then come as no surprise that the work reported here also profited from the modifications to the operational version of the model, as discussed by Ritchie, Beaudoin and Leduc in another paper.

[5bIV3] A study of the interannual variability (1948-1994) of the CIL core temperature in the Gulf of St. Lawrence, with special emphasis on the very cold early 1990's.

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The interannual variability of the mean core temperature of the cold intermediate layer (CIL) is investigated for six sub-areas of the Gulf of St. Lawrence: the Estuary, the NorthWest, NorthEast, Central and Southern Gulf, and Cabot Strait. Only data from continuous profilers such as bathythermographs and CTDs were considered in our analyses. Our most important result is that from 1986 to 1994, the CIL core temperature was below normal over most of the Gulf, this cold period being most intense from 1990 to 1994. In carrying out our analyses, we found that the definition of the CIL commonly used for Labrador and Newfoundland shelf waters ($T < 0$ C) is not adequate for a long-term study of the CIL in the Gulf of St. Lawrence, as there are many years for which no such waters could be found in the Gulf by late summer for instance. We performed several tests to determine what definition of the CIL would best characterize the full range of interannual variability of the CIL as well as its annual cycle, and finally picked a working definition of $T < 3.0$ C. A mean annual cycle of the CIL's properties was calculated for each of the six subareas of the Gulf. The mid-summer warming rates thus obtained were used to construct time series of the CIL core temperature extrapolated to July 15, using all available data from May 01 to September 30 of each year. Those time series of CIL core temperatures were then compared to average winter air temperatures at a few weather stations inside and outside the Gulf to try to distinguish between local and remote atmospheric forcing.

[5bIV4] Explosive cyclogenesis over the North Atlantic: Some results based on a new long term climatology

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In the past 15 years there has been a dramatic increase in our knowledge of the physical processes that govern the development of explosively developing cyclones. Most climatologies of these events are based on relatively short time periods and as a result questions as to the inter-annual variability in their frequency and location of occurrence have been left unanswered. In this paper, some initial results will be presented that are based on a new climatology of explosively developing cyclones over the North Atlantic that is based on a 40 year time series of objectively analysed sea-level pressure fields. As will be shown, the approximate order of magnitude increase in the length of the underlying time series, as compared to previous climatologies, allows one to establish that there are indeed two locations within the basin in which the probability of the occurrence of an explosively developing cyclone is high. In addition to the location within the region of the Gulf Stream, which has been the focus of most work on explosive cyclones, there is also a location to the East of Newfoundland where these events are not uncommon. Evidence will also be presented that suggests that the processes responsible for the events that occur in these two locations are dramatically different. In particular, it will be shown that the events that occur to the East of Newfoundland appear to be the result of an interaction between two cyclones.

[5bIV5] Effects of Circulation Anomalies on the Hydrology of the Mackenzie River Basin

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The Mackenzie River drains an area of approximately 1.6 million km^2 and produces an average annual outflow of more than 333 km^2 into the Arctic Ocean. Although some characteristics of this flow are very regular (e.g., the timing of the spring peak flow at the mouth of the Mackenzie), many other flow characteristics, particularly in the upstream portion of the basin, undergo significant variations from year to year. This variability suggests that individual subbasins respond differently to the dominant synoptic regimes occurring in a particular year.

This presentation discusses the possible causes of the variability in the outflow of the Mackenzie River into the Arctic Ocean during the spring. Monthly 50 kPa geopotential height anomalies associated with anomalies in monthly precipitation and temperature patterns for different parts of the basin have been analyzed. This analysis suggests that monthly circulation anomalies have a stronger relationship to monthly temperature anomalies than to monthly precipitation anomalies. Furthermore, the conditions leading to monthly precipitation anomalies in the mountains appear to be different from those associated with similar precipitation anomalies over the

flatter terrain. The relationship between anomalies in the climatological patterns and variations in hydrologic parameters such as the timing and magnitude of the spring peak flow were also examined. However, simple linkages between the climatological anomalies and river hydrology are difficult to isolate because the behaviour of the river at a particular location is dependent on many upstream hydrologic processes. Implications of these findings for predicting the hydrology of the Mackenzie River are discussed.

Room/Salle: Arts 108 [5bMA] Friday/Vendredi

MIDDLE ATMOSPHERE 2
ATMOSPHÈRE MOYENNE 2

Chair/Président: John Fyfe

[5bMA1] A Comparison of Middle Atmosphere Model Fields with TOMS Ozone

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The meterological total ozone algorithm, METOZ, employs tropopause height and stratospheric temperature to predict column total ozone. METOZ is currently being used to model total ozone fields for an existing ten-year climate simulation from the Canadian Climate Centre second generation general circulation model called MAM. Monthly and seasonal total ozone results from the model are presented: these are compared with 10 year average observed values from the Total Ozone Mapping Spectrometer instrument on the NIMBUS7 satellite.

[5bMA2] The Observation of Polar Stratospheric Clouds with the WINDII Instrument on UARS

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A search for polar stratospheric clouds in the Antarctic has been conducted with the WINDII instrument on UARS. The illumination source employed was scattered moonlight since WINDII has a very sensitive CCD camera. The measurements were taken in two channels, one through the interference filter at 730 nm with a bandpass of 16 nm and a second without any optical filter so that the bandpass was over 1000 nm. The clouds were observed on a number of days in August, 1994. Images of the clouds were obtained with a vertical resolution of 1 km. A characteristic spatial signature for PSCs was found. A comparison of the altitude profile of scattered light from measured ice particles with the observed profiles of scattered light from WINDII images was conducted.

[5bMA3] The Canadian Middle Atmosphere Model: The Chemistry Module.

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One of the goals of the Middle Atmosphere Model (MAM) project is to be able to predict the response of the middle atmosphere to natural or anthropogenic perturbations. To this end one of the features of the model is a comprehensive chemical modelling package to solve gas phase and heterogeneous chemistry and which will ultimately be coupled to the radiation code as well as to the transport code. In order to perform climate studies the chemistry solver must be efficient and certainly competitive with the radiation and dynamics. The current chemical set includes thirteen species and families as prognostic variables, viz., O_x, NO_x, HNO_3, HNO_4, ClO_x, HCl, Cl_2O_2, BrO_x, HBr, H_2O_2, H_2O, CH_4, and N_2O, with 20 other species (H, OH, HO_2, O_3, O, O^1D, Cl, ClO, HOCl, OClO, $ClONO_2$, Br, BrO, HOBr, $BrONO_2$, BrCl, NO, NO_2, NO_3, N_2O_5) treated time-dependently but without transport and H_2 which is kept constant. The number of transported species will be increased when semi-Lagrangian transport is included. Heterogeneous reactions on aerosols are currently not included but the current chemical solver is sufficiently robust to handle parameterized heterogeneous chemistry. The current scheme being tested is a mass conserving fully implicit backward difference scheme. We are investigating two

solvers, one is a full Newton's method (being tested in a chemical transport model). The other scheme is a variant which uses a reduced version of the Jacobian. We will report on the results for the latter method with some discussion (a) of the solver, (b) of timings as compared to dynamics and radiation, and (c) outline future plans for climate runs for both preindustrial conditions and also current and future conditions. We will also present some results of a 3 month chemical scenario run using this technique.

[5bMA4] Thermal and Chemical Impacts of Large Volcanic Eruptions

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The eruption of Mount Pinatubo on June 15, 1991 has provided a wealth of information on the impact of heterogeneous chemical reactions on the chemical composition of the stratosphere. The changes to the stratospheric chemistry induced by the sudden input of large quantities of stratospheric aerosol are expected to be influenced by the radiative effects of these aerosol particles through temperature feedback loops. Heating by the aerosol particles can change the chemical rate constants of reactions that are significant in determining the ozone concentration in the 10 to 30 km layer.

We present a numerical study of the changes in the chemistry and in the thermal structure of the stratosphere induced by the sudden input of stratospheric aerosol by Mount Pinatubo. We use a one-dimensional diurnally average photochemical model with 60 atmospheric constituents, 148 chemical reactions and 38 photochemical reactions (Blanchette and McConnell, 1992). Aerosol content is taken from observations made at Laramie, Wyoming (Hofmann, 1990; Deshler, 1992). Halocarbon emissions are estimated from production rates (OECD, 1981; McCulloch, 1992) and projected from the Montréal Protocol and the London and Copenhagen Amendments. The photochemical model has been coupled with a column radiation model developped by the Canadian Climate Center (and currently used in the GCM Version 3) which evaluates solar and terrestrial heating by aerosols, O_3, N_2O, CH_4, CO_2, H_2O, CFC-11 and CFC-12.

In this study, the evolution of the impact of heating by aerosol on ozone concentration is assessed and is compared to the changes in ozone that follows directly from enhanced efficiency of heterogeneous chemical reactions. The changes in the thermal structure of the atmosphere that follow the combined heating of volcanic aerosols and ozone are determined. These results will be used to discuss the potential of some volcanic eruptions to disrupt the climate and chemistry of the stratosphere. This study focuses on the effects from 1990 to 1996 of Mount Pinatubo eruptions.

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[5bMA5] Matrix Parameterization of the 15 Micron CO_2 and Cooling in the Middle Atmosphere (15-150 km) for Arbitrary CO_2 Concentration

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[3]UQAM, Montreal, Canada

A matrix parameterization of the 15 micron CO2 band radiative cooling in the middle Earth atmosphere for both LTE (local thermodynamic equilibrium) and non-LTE layers is proposed. For the atmospheric region between 15 and 80 km matrix coefficients for CO2 concentrations of 150, 360, 540 and 720 ppm have been pre-calculated using a line-by-line technique. A method for interpolation of the matrix coefficients for arbitrary CO2 concentration is suggested. In the layer between 80 and 110 km, where non-LTE effects start to occur, a recurrence relation between the cooling rates for two neighboring altitude levels is used. To calculate the cooling rate above 110 km, a simple approach accounting for both an absorption of the radiative flux formed below 110 km and cool-to-space terms is suggested. An accuracy of the parameterization is examined for different temperature profiles as well as for different atomic oxygen concentrations in the non-LTE layer.

Room/Salle: Arts 118 **[5bPE]** Friday/Vendredi

PERD 4
GRDE 4

Chair/Président: Keith Thompson

[5bPE1] Comprehensive Finite Element Model for Continental Shelf Circulation

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Design and application of a full-featured 3-D finite element shelf model will be described. The model is fully nonlinear and baroclinic, with prognostic evolution of temperature and salt fields. Vertical mixing is represented by the Mellor-Yamada level 2.5 turbulence closure, with the Galperin adjustments. Horizontal exchanges utilize Smagorinsky closure. Time-domain integration incorporates all nonlinearities.

A case study in the Gulf of Maine illustrates model performance. The geographic coverage includes the Gulf, the Bay of Fundy, Georges and Browns Banks, and the Scotian Shelf. Several important nonlinear shelf processes are demonstrated including tidal rectification, frontal circulation, wind-induced mixing and circulation, and the generation of a coastal current. The adaptation and testing of radiation boundary conditions for finite element models will also be addressed.

Particular emphasis is placed on the circulation on and around Georges Bank, which separates the Gulf from the Northwest Atlantic at the shelf break. The role of seasonal baroclinicity in modulating the large-scale (order 100 km) circulation around the bank will be presented in relation to transport and retention of larval fish. Several interesting mechanisms of shear dispersion will be shown to account for bank-wide dispersal of nutrients and zooplankton. Finally, the role of small-scale (order 10 km) topography in generating important tidally-rectified currents on the bank top will be discussed.

[5bPE2] Weakly Nonlinear Oscillatory Flow Over An Isolated Seamount

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Cobb Seamount is a roughly axisymmetric seamount 500 km west of the Washington State coast. It has an approximate radius of 24 km and rises to within 25 m of the sea surface. Freeland (1994) found that the recirculation around this seamount did not appear to be linked to the presence of a stratified Taylor column. However, residual velocities can be generated by tidal rectification over topography and these should strengthen recirculation. Recirculations and Taylor columns have biological significance in that they may enhance potential fish residency in the region (Lough and Bolz, 1989; Freeland, 1988).

As a preliminary look at residual velocities over axisymmetric topography, barotropic oscillatory flow over a

generalized seamount is formulated with a weakly nonlinear solution, the results of which are compared to those of a finite element numerical model. The weakly nonlinear formulation gives an upper limit for residual velocities and indicates that these velocities are proportional to the aspect ratio of the seamount. Furthermore, the approach shows that the presence of bottom friction is necessary for significant residual velocities to occur.

[5bPE3] A 3-D diagnostic model of the Labrador and Newfoundland and shelves

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A diagnostic model has been developed to study the mean circulation and wind driven currents in the Labrador Sea and the Labrador and Newfoundland shelves. The model domain is a rectangle encompasssing the Labrador Sea and the Grand Bank. The grid size is 20 km. Seasonal mean density density with a resolution of 1/6 degree compiled by DeYoung et al. (1994) are used to compute the pressure gradient terms in the momentum equations. The currents are forced by wind, atmospheric pressure and sea surface elevation at the northern boundary. For the mean circulation, the northern sea level is tuned to produce a 35 Sv transport across the Hamilton Bank section. Superimposed on the mean circulation are wind driven currents, which consist of a gradient current and an Ekman flow. Different types of wind forcing including storms are used to run the model. The results are analyzed to study various aspects of sea surface elevation, coastal currents, continental shelf waves, and baroclinc effects.

[5bPE4] Seasonal Baroclinic Circulation in the Scotia-Maine and Grand Banks Regions

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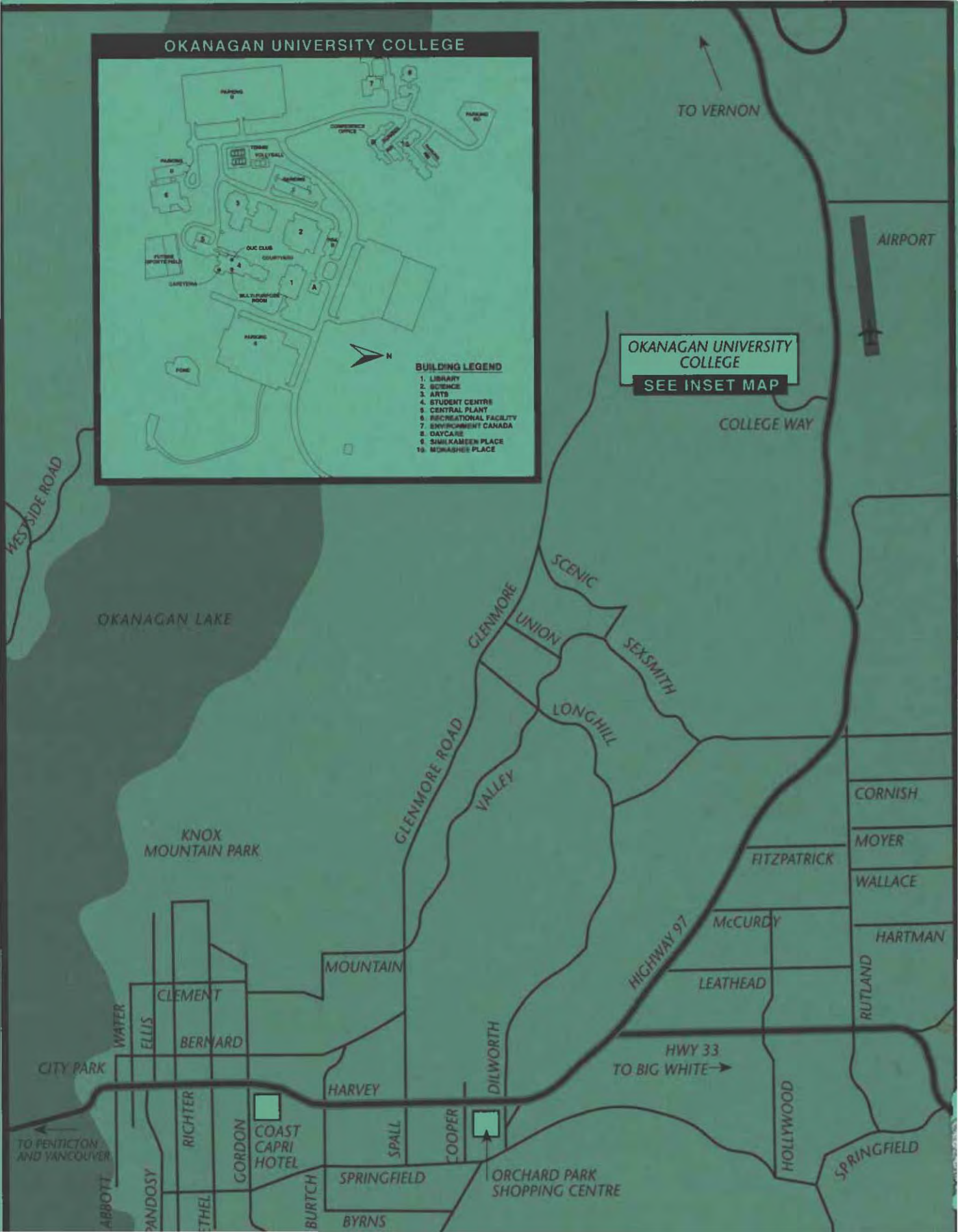
As part of a collaborative effort with scientists at Dartmouth College (Hanover, N.H.) and the University of North Carolina (Chapel Hill, N.C.), three-dimensional numerical circulation models are being developed for application to various fisheries and environmental impacts questions on the northwestern Atlantic shelf. The models use a triangular finite-element mesh which allows a high-resolution representation of the coastline and topography, and include forcing by tides, wind, density gradients and boundary inflows. An important component of the model flow fields is the seasonal baroclinic circulation which we examine here using climatological density fields obtained from a historical database, the FUNDY5 diagnostic circulation model (Naimie and Lynch 1993), and other diagnostic analyses. The major features of the baroclinic circulation in the Scotian Shelf, Gulf of Maine and Grand Banks regions are described using density fields for selected seasons, together with observational current information. These features include large-scale throughflows, strong topographic steering with anticyclonic (cyclonic) flow around banks (basins), year-round persistence, and a seasonal variation in intensity. The importance of the density field estimation procedure, model boundary conditions, friction and other factors to the model flow fields is discussed.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