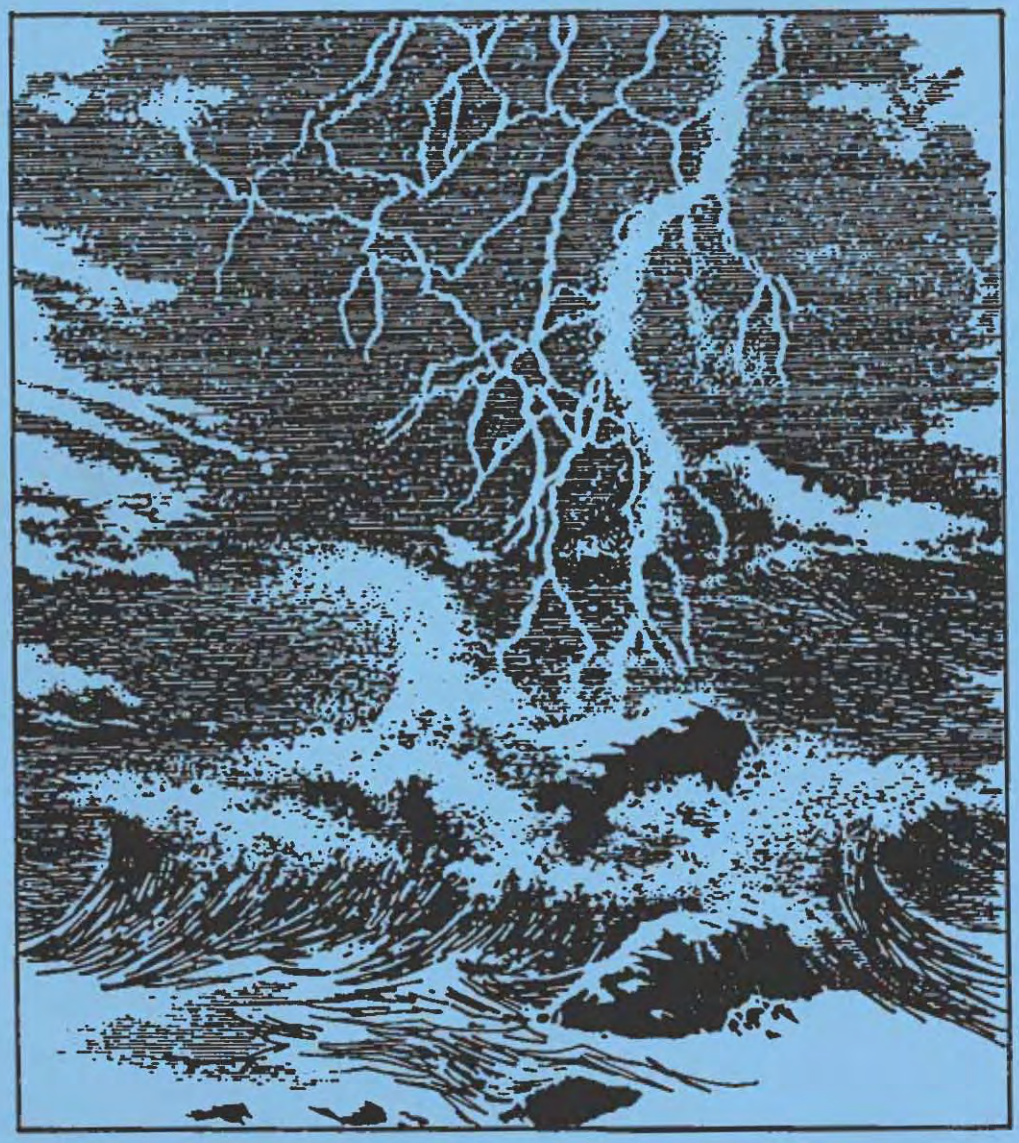
22nd Annual Congress / 22^{e} Congrès annuel

Canadian Meteorological and Oceanographic Society

La Société Canadienne de Météorologie et d'Océanographie

Program and Abstracts / Programme et résumés



Hamilton, Ontario - June 7-10 juin 1988

PROGRAM AND ABSTRACTS / PROGRAMME ET RÉSUMÉS

22nd Annual CMOS Congress / 22^{e} Congrès annuel de la SCMO

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Twenty-second Annual Congress

Canadian Meteorological and Oceanographic Society

The Toronto Centre of the Canadian Meteorological and Oceanographic Society (CMOS) will host the Twenty-second Annual CMOS Congress and Annual General Meeting in Hamilton from June 7 to 10, 1988. The Theme is "Severe Weather and Its Impact". In addition to invited and contributed papers relating to the general theme, sessions will be held on other aspects of meteorology and oceanography.

For the CMOS Congress, the scientific program and the local arrangements were organized by:

SCIENTIFIC PROGRAM COMMITTEE

R.E. Stewart, Chairman
C. Anderson
M.A. Donelan
W.D. Hogg
P.I. Joe
M.J. Leduc
G.W.K. Moore
P.A. Taylor

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P.F. Hamblin, Publicity-Promotions Convenor
J.R. Salmon, Social Convenor
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INVITED SPEAKERS

W.R. Cotton, Colorado State University
C.L. Crozier, Atmospheric Environment Service
A.G. Davenport, University of Western Ontario
L.R. Lemon, Unisys Corporation
T.S. Murty, Institute of Ocean Sciences
M.J. Newark, Atmospheric Environment Service
L.W. Uccellini, National Aeronautics and Space Administration
A.F. Wallace, Atmospheric Environment Service

Vingt-deuxième congrès annuel

Société canadienne de météorologie et d'océanographie

Le Centre de Toronto de la Société canadienne de météorologie et d'océanographie (SCMO) sera l'hôte du 22e Congrès annuel et de l'Assemblée générale annuelle à Hamilton du 7 au 10 juin 1988. Le Congrès a pour thème "Le temps violent et ses répercussions". Outre les communications présentées par les conférenciers invités et les autres participants sur le thème général, il y aura des séances sur d'autres aspects de la météorologie et de l'océanographie.

Pour ce congrès, l'organisation et le programme scientifique dépendaient de:

COMITÉ DU PROGRAMME SCIENTIFIQUE

R.E. Stewart, Président
C. Anderson
M.A. Donelan
W.D. Hogg
P.I. Joe
M.J. Leduc
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CONFÉRENCIERS INVITÉS

W.R. Cotton, Colorado State University
C.L. Crozier, Service de l'environnement atmosphérique
A.G. Davenport, University of Western Ontario
L.R. Lemon, Unisys Corporation
T.S. Murty, Institut des sciences de la mer
M.J. Newark, Service de l'environnement atmosphérique
L.W. Uccellini, National Aeronautics and Space Administration
A.F. Wallace, Service de l'environnement atmosphérique

The Canadian Meteorological and Oceanographic Society is very grateful to the following organizations for sponsorships or grants:

La Société canadienne de météorologie et d'océanographie tient à remercier les organismes suivants de leur assistance:

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Summary of Meetings

All meetings will be held in the Royal Connaught Hotel.

GROUP	TIME	ROOM
Monday, June 6		
Scientific Committee	0900-1200	Aberdeen
Climatological Bulletin Editorial Board	0900-1200	Boardroom 1
Operational Meteorology SIG	0900-1200	Boardroom 2
Education Committee for Oceanography	0900-1200	Boardroom 5
Floating Ice SIG	0900-1200	Boardroom 6
Education Committee for Meteorology	0900-1200	WentWorth
Accreditation Committee	0900-1600	Boardroom 3
LIMEX / LEWEX	0900-1600	Boardroom 7
SCOR	0900-1700	Hamilton
Air Pollution SIG	1300-1500	Boardroom 2
ATMOSPHERE-OCEAN Editorial Board	1300-1600	Aberdeen
CMOS Centre Chairpersons	1300-1600	Boardroom 1
Chinook Editorial Board	1300-1600	Boardroom 6
Mesoscale Subcommittee	1300-1600	Boardroom 5
Professionalism Committee	1600-1800	Boardroom 5
CMOS National Council	1600-2400	Aberdeen
Tuesday, June 7		
Agricultural and Forest Meteorology SIG	1600-1800	Boardroom 1
Publications Committee	1600-1800	Boardroom 2
Annual General Meeting	1900-2400	Ontario

Summary of Sessions

TIME	SESSION	TITLE	ROOM
Monday, June 6			
1900-2200	Ice Breaker Reception		Ballroom
Tuesday, June 7			
0820-0850		Opening	Ballroom
0850-1010	1	Plenary I	Ballroom
1010-1040	Coffee		
1040-1200	2A	Severe Weather I	Ballroom
	2B	Ocean Circulations	Ontario
	2C	Climate I	Connaught
1200-1320	Lunch		
1320-1500	3A	WOCE / JGOFS	Ballroom
	3B	Waves I	Ontario
	3C	Mesoscale	Aberdeen
1500-1530	Coffee		
1530-1710	4A	Cloud Physics	Ballroom
	4B	Waves II	Ontario
	4C	Pollution	Aberdeen
1730-1900	5	Posters I	Connaught
1730-1900	Wine and Cheese		
Wednesday, June 8			
0830-0950	6	Plenary II	Ballroom
0950-1020	Coffee		
1020-1200	7A	CASP	Ballroom
	7B	Coastal Oceanography I	Ontario
	7C	Climate II	Aberdeen
1200-1320	Lunch		
1320-1440	8	Posters II	Connaught
1500-2300	Evening in Niagara		
Thursday, June 9			
0830-0950	9	Plenary III	Ballroom
0950-1020	Coffee		
1020-1200	10A	Severe Weather II	Ballroom
	10B	Coastal Oceanography II	Ontario
	10C	LIMEX	Connaught
1200-1320	Lunch		
1320-1500	11A	NWP / GCM	Ballroom
	11B	Forecast Operations I	Ontario
	11C	LIMEX / LEWEX	Connaught
1500-1530	Coffee		
1530-1710	12A	Remote Sensing	Ballroom
1530-1650	12B	Forecast Operations II	Ontario
1530-1700	12C	Ocean-Climate Interaction	Connaught
1830-2200	Cocktails and Annual Banquet		
Friday, June 10			
0830-0950	13	Plenary IV	Ballroom
0950-1020	Coffee		
1020-1200	14A	Impact and Response	Ballroom
	14B	Coastal Oceanography III	Ontario
	14C	Geophysical Fluid Dynamics	Connaught

Résumé des réunions

Toutes les réunions seront tenues à l'hôtel Royal Connaught.

COMITÉ	HEURE	SALLE
Lundi le 6 juin		
Comité scientifique	0900-1200	Aberdeen
Conseil de rédaction du Bulletin climatologique	0900-1200	Boardroom 1
GIS : météorologie d'exploitation	0900-1200	Boardroom 2
Comité d'éducation en météorologie	0900-1200	Boardroom 5
GIS : glaces flottantes	0900-1200	Boardroom 6
Comité d'éducation en océanographie	0900-1200	Wentworth
Comité d'accréditation	0900-1600	Boardroom 3
LIMEX / LEWEX	0900-1600	Boardroom 7
SCOR	0900-1700	Hamilton
GIS : météorologie de la pollution de l'air	1300-1500	Boardroom 2
Conseil de rédaction d'ATMOSPHERE-OCEAN	1300-1600	Aberdeen
Comité des présidents des centres	1300-1600	Boardroom 1
Conseil de rédaction du Chinook	1300-1600	Boardroom 6
Sous-comité sur l'échelle moyenne	1300-1600	Boardroom 5
Comité sur le professionnalisme	1600-1800	Boardroom 5
Conseil de la SCMO	1600-2400	Aberdeen
Mardi le 7 juin		
GIS : météorologie agricole et forestière	1600-1800	Boardroom 1
Comité des publications	1600-1800	Boardroom 2
Assemblée générale annuelle	1900-2400	Ontario

Résumé des sessions

TIME	SESSION	TITLE	ROOM
Lundi le 6 juin			
1930-2200	Réception d'accueil		Ballroom
Mardi le 7 juin			
0820-0850		Ouverture	Ballroom
0850-1010	1	Plénière I	Ballroom
1010-1040	Café		
1040-1200	2A	Temps violent I	Ballroom
	2B	Circulations océaniques	Ontario
	2C	Climat I	Connaught
1200-1320	Repas		
1320-1500	3A	WOCE / JGOFS	Ballroom
	3B	Vagues I	Ontario
	3C	Échelle moyenne	Aberdeen
1500-1530	Café		
1530-1710	4A	Physique des nuages	Ballroom
	4B	Vagues II	Ontario
	4C	Pollution	Aberdeen
1730-1900	5	Affichages I	Connaught
1730-1900	Vins et fromages		
Mercredi le 8 juin			
0830-0950	6	Plénière II	Ballroom
0950-1020	Café		
1020-1200	7A	PCETA	Ballroom
	7B	Océanographie côtière I	Ontario
	7C	Climat II	Aberdeen
1200-1320	Repas		
1320-1440	8	Affichages II	Connaught
1500-2300	Soirée Niagara		
Jeudi le 9 juin			
0830-0950	9	Plénière III	Ballroom
0950-1020	Café		
1020-1200	10A	Temps violent II	Ballroom
	10B	Océanographie côtière II	Ontario
	10C	LIMEX	Connaught
1200-1320	Repas		
1320-1500	11A	NWP / GCM	Ballroom
	11B	Prévision opérationnelle I	Ontario
	11C	LIMEX / LEWEX	Connaught
1500-1530	Café		
1530-1710	12A	Télédétection	Ballroom
1530-1650	12B	Prévision opérationnelle II	Ontario
1530-1700	12C	Interaction océan-climat	Connaught
1830-2200	Cocktail et banquet annuel		
Vendredi le 10 juin			
0830-0950	13	Plénière IV	Ballroom
0950-1020	Café		
1020-1200	14A	Répercussions et intervention	Ballroom
	14B	Océanographie côtière III	Ontario
	14C	Dynamique géophysique des fluides	Connaught

Program / Programme

Tuesday 7 June
Mardi le 7 juin

0820-0850: OPENING REMARKS / SÉANCE D'OUVERTURE **(Ballroom)**

0850-1010: (Ballroom) **Tuesday / Mardi**
SESSION 1: THEME PLENARY I
Chairperson / Président : A.J. Chisholm
SESSION 1 : THÈME PLÉNIÈRE I

0850: THE EDMONTON TORNADO
Alton F. Wallace, Atmospheric Environment Service, Edmonton, Alta.

0930: MESOSCALE CONVECTIVE SYSTEMS TO THE LEE OF THE ROCKY MOUNTAINS
William R. Cotton, Colorado State University, Dept. of Atmospheric Science, Fort Collins, Colo.

1010-1040: Coffee / Café

1040-1200: (Ballroom) **Tuesday / Mardi**
SESSION 2A: SEVERE WEATHER I
Chairperson / Président : M. Leduc
SESSION 2A : TEMPS VIOLENT I

1040: SEVERE WEATHER DISCRIMINATION TECHNIQUE BASED UPON DERIVED PARAMETERS OBTAINED FROM STANDARD RADIOSONDE DATA
D. Vigneux and V. Turcotte, Atmospheric Environment Service, Montréal, Qué.

1100: PROPAGATION OF SEVERE THUNDERSTORMS: A PROGNOSTIC TOOL FOR THE OPERATIONAL SEVERE WEATHER FORECASTER
D. Vigneux, Atmospheric Environment Service, Montréal, Qué.

1120: WIND SHEAR AS A PREDICTOR OF SEVERE WEATHER FOR THE EASTERN UNITED STATES
Hugh M. Stone, National Weather Service, Garden City, N.Y.

1140: INTENSE RADAR ECHOES IN TROPICAL RAIN EVENTS
Mauricio de Agostinho Antonio, Universidade de Bauru and Instituto de Pesquisas Espaciais, Bauru, Brazil

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1040-1200: (Ontario) **Tuesday / Mardi**
SESSION 2B: OCEAN CIRCULATIONS
Chairperson / Président : F. Boyce
SESSION 2B : CIRCULATIONS OCÉANIQUES

1040: A NUMERICAL MODEL OF THE INTERANNUAL VARIABILITY IN THE NORTHEAST PACIFIC OCEAN
William W. Hsieh and Warren G. Lee, Dept. of Oceanography, University of British Columbia, Vancouver, B.C.

1100: SEASONAL TRANSPORT VARIATIONS IN THE NORTH ATLANTIC - A MODEL STUDY
Richard J. Greatbatch and Allan Goulding, Dept. of Physics and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Nfld.

1120: A THERMOCLINE MODEL FOR THE NORTH PACIFIC
M.G.G. Foreman, Institute of Ocean Sciences, Sidney, B.C.
A.F. Bennett, Oregon State University, Corvallis, Ore.

1140: RESPONSE OF THE INDIAN OCEAN TO 50-DAY ATMOSPHERIC OSCILLATIONS
G. Mertz, Y. Gratton and M. Couture, Dép. d'Océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1040-1200: (Connaught) **Tuesday / Mardi**
SESSION 2C: CLIMATE I
Chairperson / Président : B.W. Boville
SESSION 2C : CLIMAT I

1040: METEOROLOGICAL DROUGHT IN THE SOUTH SASKATCHEWAN RIVER BASIN WITHIN SASKATCHEWAN
D.J. Bauer and L.E. Welsh, Hydrometeorology Research Division, Atmospheric Environment Service, Saskatoon, Sask.

1100: RELATIONSHIP BETWEEN PRAIRIE DRY AND WET SPELLS AND ATMOSPHERIC FLOW PATTERNS IN THE MID-TROPOSPHERE
J.L. Knox, Atmospheric Environment Service, Downsview, Ont.
R. Lawford, National Hydrology Research Centre, Saskatoon, Sask.

1120: A METHOD FOR THE ESTIMATION OF ERRORS IN THE SPATIAL INTERPOLATION OF RAINGAUGE DATA
Norman Bussières and Bill Hogg, Atmospheric Environment Service, Downsview, Ont.

1140: EXTENSION OF TORONTO TEMPERATURES TIME SERIES FROM 1840 BACK TO 1778 USING VARIOUS UNITED STATES AND OTHER DATA
R.B. Crowe, Atmospheric Environment Service, Downsview, Ont.

1200-1320: Lunch / Repas

1320-1500 (Ballroom) **Tuesday / Mardi**
SESSION 3A: WOCE / JGOFS
Chairperson / Président : P. LeBlond
SESSION 3A : WOCE / JGOFS

1320: WOCE AS A COMPONENT OF THE WORLD CLIMATE RESEARCH PROGRAM
Gordon A. McBean, Canadian Climate Centre, Institute of Ocean Sciences, Sidney, B.C.

1335: THE WOCE GYRE PROGRAM IN THE NORTH ATLANTIC
R. Allyn Clarke, Bedford Institute of Oceanography, Dartmouth, N.S.

1350: NUMERICAL MODELLING PROBLEMS IN WOCE
Greg Holloway, Institute of Ocean Sciences, Sidney, B.C.

1405: WOCE RELATED STUDIES AT MEMORIAL
Richard Greatbatch, Memorial University of Newfoundland, St. John's, Nfld.

1420: AN OVERVIEW OF MODELLING STUDIES OF OCEAN-CLIMATE INTERACTION AT MCGILL
Charles A. Lin and Lawrence A. Mysak, Dept. of Meteorology, McGill University, Montréal, Qué.

1435: WHAT IN THE WORLD IS JGOFS?
Kenneth L. Denman, Institute of Ocean Sciences, Sidney, B.C.

1450: BENTHIC FLUXES IN JGOFS: CLOSING THE CHEMICAL MASS BALANCES
S.E. Calvert, Dept. of Oceanography, The University of British Columbia, Vancouver, B.C.

1320-1500: (Ontario) **Tuesday / Mardi**
SESSION 3B: WAVES I
Chairperson / Président : B. Eid
SESSION 3B : VAGUES I

1320: OBSERVATIONS OF THE STRUCTURE OF NEAR-SURFACE TURBULENCE IN THE PRESENCE OF WIND WAVES
N. Merzi, I.K. Tsanis and M.A. Donelan, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

1340: SMALL-SCALE WAVE BREAKING AND CONSEQUENCES FOR GAS TRANSFER
N. Merzi and M.A. Donelan, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

1400: DIRECTIONAL SPECTRA OF WAVES IN CHANGING WIND CONDITIONS
I.K. Tsanis and M.A. Donelan, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

1420: WAVE-INDUCED PRESSURE MEASUREMENTS IN FAVOURABLE AND ADVERSE WINDS
M.A. Donelan, I.K. Tsanis, K.K. Kahma and N. Madsen, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

1440: A COMPARISON OF NEAR-SURFACE TURBULENCE CHARACTERISTICS OBSERVED USING BACKSCATTER FROM BUBBLES AND DIRECT WATER-VELOCITY MEASUREMENTS
Eugene A. Terray and Blair H. Brumley, Dept. of Ocean Engineering, Woods Hole Oceanographic Institution, Woods Hole, Mass.

1320-1500: (Aberdeen) **Tuesday / Mardi**
SESSION 3C: MESOSCALE
Chairperson / Président : D. Steyn
SESSION 3C : ÉCHELLE MOYENNE

1320: A MESOSCALE CLIMATOLOGY FOR EASTERN NORTH AMERICA
Douglas A. Wesley, Michael D. Moran and Roger A. Pielke, Dept. of Atmospheric Science, Colorado State University, Fort Collins, Colo.

1340: USING KING CITY DOPPLER RADAR TO FORECAST THE MOTION OF THE RAIN-SNOW LINE IN PRE-WARM-FRONTAL PRECIPITATION CASE STUDY, NOVEMBER 25, 1987
Michael Leduc, Ontario Weather Centre, Toronto, Ont.

1400: THE LAKE-EFFECT SNOWSTORM OF 5-6 JANUARY 1988 IN SOUTHERN ONTARIO
Brian P. Murphy, Ontario Weather Centre, Toronto, Ont.

1420: MOMENTUM TRANSFER IN SEVERE DOWNSLOPE WINDSTORMS
R. Laprise, Canadian Climate Centre, Downsview, Ont.
W.R. Peltier, University of Toronto, Toronto, Ont.

1440: SIMPLE GUIDELINES FOR ESTIMATING WIND SPEED AND TURBULENCE VARIATIONS DUE TO SMALL-SCALE TOPOGRAPHIC FEATURES
J.L. Walmsley and P.A. Taylor, Boundary-Layer Research Division, Atmospheric Environment Service, Downsview, Ont.
J.R. Salmon, Contractor, 24 Heslop Drive, Toronto, Ont.

1500-1530: Coffee / Café

1530-1710: (Ballroom) **Tuesday / Mardi**
SESSION 4A: CLOUD PHYSICS
Chairperson / Président : E. Lozowski
SESSION 4A : PHYSIQUE DES NUAGES

1530: THE WARM RAIN REVOLUTION
Roland List, Dept. of Physics, University of Toronto, Toronto, Ont.

1550: GROWTH OF LOW-DENSITY GRAUPEL IN AN ICING TUNNEL
Roland List and Stewart Cober, Dept. of Physics, University of Toronto, Toronto, Ont.

1610: A 1-D MICROPHYSICAL MODEL DRIVEN BY RADAR DATA
Luc Ostiguy and Isztar Zawadzki, Université du Québec à Montréal, Montréal, Qué.

1630: COMPARISON BETWEEN CIRCULARLY POLARIZED S-BAND RADAR FIELDS AND GROUND PRECIPITATION PATTERNS
Jean St-Pierre and Enrico Torlaschi, Université du Québec à Montréal, Montréal, Qué.

1650: THE VERTICAL PROFILE OF SEA SPRAY CONCENTRATION OVER THE OCEAN SURFACE: A NUMERICAL SIMULATION
Y. Zhuang, E.P. Lozowski and J.D. Wilson, Dept. of Geography, University of Alberta, Edmonton, Alta.

1530-1710: (Ontario) **Tuesday / Mardi**
SESSION 4B: WAVES II
Chairperson / Président : A.J. Bowen
SESSION 4B : VAGUES II

1530: OBSERVATIONS OF SPECTRAL CHANGES OF WAVES IN SHOALING WATER
M. Skafel and M. Donelan, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.
H. Graber, Woods Hole Oceanographic Institution, Woods Hole, Mass.
P. Liu and D. Schwab, Great Lakes Environmental Research Laboratory, Ann Arbor, Mich.
S. Venkatesh, Atmospheric Environment Service, Downsview, Ont.

1550: OBSERVATIONS AND MODELS OF WAVE-INDUCED SEDIMENT RESUSPENSION IN LAKE ST. CLAIR
T.J. Simons, W.M. Schertzer, M.G. Skafel and M.A. Donelan, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

1610: THE IMPACT OF SEASAT-A SCATTEROMETER WINDS ON OCEAN-WAVE ANALYSIS AND MODELLING
R. Lalbeharry, M.L. Khandekar and S. Peteherych, Atmospheric Environment Service, Downsview, Ont.

1630: BED SHEAR STRESS ESTIMATES IN A SHALLOW LAKE
P.F. Hamblin and F.M. Boyce, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario

1650: ON THE DEEP-WATER FETCH LAWS FOR WIND-GENERATED SURFACE GRAVITY WAVES
F. Dobson, W. Perrie and B. Toulany, Physical and Chemical Sciences, Bedford Institute of Oceanography, Dartmouth, N.S.

1530-1710: (Aberdeen) **Tuesday / Mardi**
SESSION 4C: POLLUTION
Chairperson / Président : L. Barrie
SESSION 4C : POLLUTION

1530: STATISTICAL FORECAST MODELS FOR TROPOSPHERIC OZONE POLLUTANTS IN THE LOWER FRASER VALLEY, B.C.
D.G. Steyn and S.M. Robeson, Dept. of Geography, The University of British Columbia, Vancouver, B.C.

1550: MESOSCALE ATMOSPHERIC DISPERSION: A COMPARISON OF TRACER OBSERVATIONS AND NUMERICAL PREDICTIONS
Michael D. Moran and Roger A. Pielke, Dept. of Atmospheric Science, Colorado State University, Fort Collins, Colo.
Richard T. McNider, Dept. of Mathematics and Statistics, University of Alabama at Huntsville, Ala.

1610: ARCTIC AIR POLLUTION: A CASE OF HEMISPHERIC TRANSPORT
L.A. Barrie, Atmospheric Environment Service, Downsview, Ont.

1630: TOWARD ESTIMATION OF CLIMATIC EFFECTS DUE TO ARCTIC AEROSOLS
Jean-Pierre Blanchet, Canadian Climate Centre, Downsview, Ont.

1730-1900: (Connaught) **Tuesday / Mardi**
SESSION 5: POSTERS I (on display)
Chairperson / Président : W.D. Hogg
SESSION 5 : AFFICHAGES I

Category 1: OCEAN AND LAKE CIRCULATIONS
Sujet 1 : CIRCULATION : LACS ET OCÉANS

P1: A MODEL OF RELEVANCE TO GULF STREAM RECIRCULATION
Richard J. Greatbatch, Dept. of Physics and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Nfld.

P2: CIRCULATION IN A LARGE SHALLOW NORTHERN ESTUARY
L. Veilleux and R.G. Ingram, Dept. of Meteorology, McGill University, Montréal, Qué.

P3: HORIZONTAL MIXING IN THE ATLANTIC EQUATORIAL UNDERCURRENT ESTIMATED FROM DRIFTING BUOY CLUSTERS
B.K. Pal and B.G. Sanderson, Dept. of Physics, Memorial University of Newfoundland, St. John's, Nfld.

Category 2: OCEAN-ATMOSPHERE-ICE
Sujet 2 : OCÉAN-ATMOSPHÈRE-GLACE

P4: SEA-ICE MOTION OFF LABRADOR AND EASTERN NEWFOUNDLAND
Ingrid Peterson and Graham Symonds, Bedford Institute of Oceanography, Dartmouth, N.S.

P5: SEA-ICE PROGRAM OFF LABRADOR AND NEWFOUNDLAND SHELVES
S. Prinsenberg, Bedford Institute of Oceanography, Dartmouth, N.S.

P6: THE ROLE OF REMOTELY SENSED IMAGERY IN ICE FEATURE AND PROCESS DETECTION IN EAST COAST PACK-ICE DURING A SEVERE ICE EVENT
Scott Paterson and S. Digby Argus, Canada Centre for Remote Sensing, Ottawa, Ont.

P7: SOME SAR RESULTS OF THE LABRADOR EXTREME WAVES EXPERIMENT (LEWEX)
A.S. Bhogal, INTERA Technologies Ltd., RADARSAT Project Office, Ottawa, Ont.

P8: COMPARISON OF AIRBORNE MICROWAVE DIGITAL IMAGERY FROM LIMEX'87
Michael John Collins, York University, North York, Ont.

P9: SEA-ICE EXTENT AND ANOMALIES IN THE GREENLAND AND LABRADOR SEAS
L.A. Mysak and D.K. Manak, Dept. of Meteorology, McGill University, Montréal, Qué.

P10: TURBIDITY AND TEMPERATURE GRADIENTS OBSERVED IN THE GREAT LAKES USING NOAA / AVHRR DATA
A. Touré and A.R. Condal, Dép. des Sciences géodesiques et Télédétection, Université Laval, Québec, Qué.
G.J. Irbe, Atmospheric Environment Service, Downsview, Ont.

Category 3: WAVES
Sujet 3 : VAGUES

P11: DESCRIPTION OF THE "WAVES" PLATFORM AND RELATED EQUIPMENT
J. Valdmanis, I.K. Tsanis and M.A. Donelan, Canada Centre for Inland Waters, Burlington, Ont.

P12: GENERAL STRATEGY AND RESULTS FOR A GREAT LAKES WIND-WAVE RESEARCH PROGRAM AT THE ATMOSPHERIC ENVIRONMENT SERVICE
Stephen Clodman, Atmospheric Environment Service, Downsview, Ont.

P13: WIND STRESS OVER WIND WAVES: EXPERIMENTS ON LAKE GENEVA
N. Merzi, Canada Centre for Inland Waters, Burlington, Ont.

P14: ALGEBRAIC AND NUMERICAL TURBULENCE MODELS OF WIND-DRIVEN WATER CURRENTS
I.K. Tsanis, Canada Centre for Inland Waters, Burlington, Ont.

P15: COMPARISONS OF SOME WAVE PREDICTION MODELS
C.T. Bishop, M.G. Skafel and M.A. Donelan, Canada Centre for Inland Waters, Burlington, Ont.
K.K. Kahma. Finnish Institute of Marine Research, Helsinki, Finland

P16: INTRODUCTION OF AN ICE FACTOR IN A THIRD-GENERATION WAVE MODEL
D. Masson and W. Perrie, Bedford Institute of Oceanography, Dartmouth, N.S.

Category 4: BIOCHEMISTRY AND OCEANOGRAPHY
Sujet 4 : BIOCHIMIE ET OCÉANOGRAPHIE

P17: VOLUME-FREQUENCY DISTRIBUTIONS OF MARINE PHYTOPLANKTON IN A TEMPERATE NERITIC ENVIRONMENT
Louis A. Hobson, Dept. of Biology, University of Victoria, Victoria, B.C.

P18: GEOCHEMICAL AND STABLE ISOTOPE STUDIES OF MEDITERRANEAN SEA SAPROPELS
S.E. Calvert, Dept. of Oceanography, The University of British Columbia, Vancouver, B.C.
M.R. Fontugne, Centre des faibles radioactivités, Gif-sur-Yvette, France

P19: ORGANIC MATTER ENRICHMENTS, CARBON ISOTOPES AND OXYGEN DEPLETION IN THE GLACIAL EASTERN PACIFIC: ARE THEY LINKED?
Thomas F. Pedersen, Dept. of Oceanography, The University of British Columbia, Vancouver, B.C.

P20: A MULTIVARIATE ANALYSIS OF ENZYMATIC ACTIVITIES AND BIOCHEMICAL CHARACTERISTICS OF IN SITU MARINE PLANKTON
Jean-Pierre Chanut and Patrick Mayzaud, Dép. d'Océanographie, Université du Québec à Rimouski, Rimouski, Qué.

P21: AN OXYGEN MODEL FOR ICE-FREE AND ICE-COVERED RESERVOIRS
R.C. McCrimmon, 341 Galena Cres., Mississauga, Ont.
P.F. Hamblin, W.J. Snodgrass and A.A. Smith, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.

P22: THE ESTIMATION OF CRUDE OIL EVAPORATION IN THE AES OIL SLICK PREDICTION MODEL
A. Bishnoi and V.R. Neralla, Atmospheric Environment Service, Downsview, Ont.
J.D. Covill and A.Y. McLean, Martec Limited, Halifax, N.S.

Category 5: ATMOSPHERIC DYNAMICS
Sujet 5 : DYNAMIQUE ATMOSPHÉRIQUE

P23: LOW-PASS FILTERED PERSISTENCE OF 50-KPA HEIGHT ANOMALY
Amir Shabbar, Canadian Climate Centre, Downsview, Ont.

P24: COMPUTER ENTRAILS AND THE CLIMATE BUSINESS
E.P. Lozowski and C. Nguyen, Division of Meteorology, Dept. of Geography, University of Alberta, Edmonton, Alta.

Category 6: OPERATIONAL WORKSTATIONS
Sujet 6 : SYSTÈMES OPERATIONNELS

P25: ISIS: INTEGRATED SYSTEM FOR ICE SENSING
A. Fraser and R.A. Gorski, Ontario Hydro, Toronto, Ont.

P26: SWORD: A SEVERE WEATHER FORECAST AND DETECTION SYSTEM
Richard W. Miller and Klaus H. Schaedlich, Ontario Hydro, Toronto, Ont.

P27: RADAR DATA PROCESSING SYSTEM: ON THE USE OF FULL-SCAN RADAR DATA IN SEVERE WEATHER FORECASTING
H.P. Biron, Centre Metéorologique du Québec, Atmospheric Environment Service, Montréal, Qué.

P28: A CODED MARINE FORECAST PREPARATION SYSTEM
Allan W. MacAfee, Maritimes Weather Centre, Atmospheric Environment Service, Bedford, N.S.

Category 7: MESOSCALE AND BOUNDARY LAYER
Sujet 7 : ÉCHELLE MOYENNE ET COUCHE LIMITE

P29: STRUCTURE OF A NORTH PACIFIC FRONTAL SYSTEM
G.A. McBean, Canadian Climate Centre, Atmospheric Environment Service, Sidney, B.C.
R.E. Stewart, Atmospheric Environment Service, Downsview, Ont.

P30: SECONDARY FRONTAL DEVELOPMENT OBSERVED DURING CASP - COMPARISONS WITH THEORY
R. Paul Ford and G.W. Kent Moore, Dept. of Physics, University of Toronto, Toronto, Ontario

P31: OBSERVATIONS OF THE THERMODYNAMIC ENVIRONMENTS ASSOCIATED WITH LAKE-EFFECT SNOWBANDS USING PORTABLE RADIOSONDE EQUIPMENT
Gregory P. Byrd, Dept. of the Earth Sciences, SUNY College, Brockport, N.Y.
Tom Niziol, National Weather Service Forecast Office, Buffalo, N.Y.

P32: A COMPARISON OF THE WIND OVER THE ICE-PACK TO THAT OF A COASTAL STATION IN HUDSON BAY
Pierre Larouche, Maurice-Lamontagne Institute, Dept. of Fisheries and Oceans, Mont-Joli, Qué.

P33: SIMPLE MODELS OF DIABATICALLY FORCED MESOSCALE CIRCULATIONS AND THE ROLE OF RESONANCE
Alain Robichaud and Charles A. Lin, Dept. of Meteorology, McGill University, Montréal, Qué.

Category 8: CLOUD PHYSICS
Sujet 8 : PHYSIQUE DES NUAGES

P34: RAIN SPECTRA AND EQUILIBRIUM PEAKS MEASURED IN TORONTO IN 1987
Roland List and Robert Nissen, Dept. of Physics, University of Toronto, Toronto, Ont.

P35: MÉTHODE DE CORRECTION DES EFFETS DE PROPAGATION SUR LES MESURES DE RADAR À POLARISATION CIRCULAIRE À 3 GHZ
Bernard Pettigrew and Enrico Torlaschi, Université du Quebéc à Montréal, Montréal, Qué.

Category 9: IMPACT AND RESPONSE
Sujet 9 : RÉPERCUSSIONS ET INTERVENTION

P36: ENVIRONMENTAL EMERGENCIES· AN AES RESPONSE SYSTEM
Evelyn E. Wilson, Atmospheric Environment Service, Downsview, Ont.
James Salmon, Contractor, 24 Heslop Drive, Toronto, Ont.

P37: A DEMONSTRATION METEOROLOGICAL MONITORING NETWORK IN THE VICINITY OF PICKERING NUCLEAR GENERATING STATION
Peter Taylor, Atmospheric Environment Service, Downsview, Ont.
James Salmon, Contractor, 24 Heslop Drive, Toronto, Ont.
Lily Truong, Atomic Energy Control Board, Ottawa, Ont.

Wednesday, 8 June
Mercredi le 8 juin

0830-0950: (Ballroom) **Wednesday / Mercredi**
SESSION 6: THEME PLENARY II
Chairperson / Président : M. Donelan
SESSION 6 : PLÉNIÈRE II

0830: THE APPLICATION OF REGIONAL-SCALE NUMERICAL MODELS TO THE STUDY OF EXTRATROPICAL CYCLONES THAT PRODUCE SEVERE WINTER WEATHER
L.W. Uccellini, NASA Goddard, Greenbelt, Md.

0910: IMPACT OF SEVERE WEATHER PHENOMENA OVER WATER
T.S. Murty, Institute of Ocean Sciences, Sidney, B.C.

0950-1020: Coffee / Café

1020-1200: (Ballroom) **Wednesday / Mercredi**
SESSION 7A: CASP
Chairperson / Président : G.A. Isaac
SESSION 7A : PCETA

1020: A NEW DEVELOPMENT EQUATION AS AN AIDE FOR UNDERSTANDING EXPLOSIVE DEVELOPMENT IN CASP / GALE STORMS
Peter Zwack, Dép. de physique, Université du Québec à Montréal, Montréal, Qué.

1040: MICROSCALE. MESOSCALE. AND STORMSCALE FEATURES IN WINTER STORMS
Ronald E. Stewart, Atmospheric Environment Service. Downsview. Ont.

1100: STORM FRONT MOTION ESTIMATED FROM MESONET WIND OBSERVATIONS IN CASP
Carl Anderson. Physical and Chemical Sciences, Bedford Institute of Oceanography. Dartmouth. N.S.

1120: ESTIMATES AND OBSERVATIONS OF THE CROSS-SHORE VARIATIONS OF NEAR-SURFACE WINDS AT THE LAND-SEA BOUNDARY DURING CASP
Peter A. Taylor. Boundary-Layer Research Division. Atmospheric Environment Service. Downsview, Ont.
James R. Salmon, Contractor, 24 Heslop Dr., Toronto, Ont.
Fred W. Dobson, Will Perrie, Peter C. Smith and Bechara Toulany, Bedford Institute of Oceanography, Dartmouth, N.S.

1140: INERTIAL RESPONSE TO CASP IOP 14, 6-7 MARCH 1986
Peter C. Smith, Dept. of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth. N.S.

1020-1200: (Ontario) **Wednesday / Mercredi**
SESSION 7B: COASTAL OCEANOGRAPHY I
Chairperson / Président : D. Wright
SESSION 7B : OCÉANOGRAPHIE CÔTIÈRE I

1020: FORTNIGHTLY PULSING OF SURFACE FRESHWATER OUTFLOW FROM JUAN DE FUCA STRAIT
D.A. Griffin, P.H. LeBlond, R.E. Thomson and B.M. Hickey, Dept. of Oceanography, The University of British Columbia, Vancouver, B.C.

1040: PREDICTING THE RETURN ROUTES OF THE FRASER RIVER SOCKEY SALMON WITH MULTIPLE REGRESSION TECHNIQUES
Liusen Xie and William W. Hsieh, Dept. of Oceanography, The University of British Columbia, Vancouver, B.C.

1100: MIXING AND TRANSPORT ON THE VANCOUVER ISLAND CONTINENTAL SHELF
William R. Crawford, Richard K. Dewey and Paul H. LeBlond, Institute of Ocean Sciences, Sidney, B.C.

1120: INFLUENCE OF FRESHWATER RUNOFF ON UNDER-ICE MIXING IN SOUTHEAST HUDSON BAY
R. Grant Ingram and S. LePage, Dept. of Meteorology, McGill University, Montréal, Qué.

1140: CIRCULATION AND MIXING PROCESSES IN THE MIDDLE ST. LAWRENCE ESTUARY
C. Bélanger, Y. Gratton and J.A. Gagné, Dép. d'Océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1020-1200: (Aberdeen) **Wednesday / Mercredi**
SESSION 7C: CLIMATE II
Chairperson / Président : J.A. Davies
SESSION 7C : CLIMAT II

1020: AN APPRAISAL OF PHYTOPLANKTON-CLOUD ALBEDO-CLIMATE FEEDBACK USING A MEAN ANNUAL GLOBAL ENERGY BALANCE MODEL
Howard W. Barker and John A. Davies, Dept. of Geography, McMaster University, Hamilton, Ont.

1040: SURFACE ALBEDO ESTIMATES FROM NIMBUS-7 ERB DATA AND A TWO-STREAM APPROXIMATION OF THE RADIATIVE TRANSFER EQUATION
Howard W. Barker and John A. Davies, Dept. of Geography, McMaster University, Hamilton, Ont.

1100: A STUDY OF THE EFFECTS OF VERTICAL MOTION ON OZONE OVER THE NORTH POLAR VORTEX
Lewis L. Poulin and W.F.J. Evans, Atmospheric Environment Service, Downsview, Ont.

1120: A COMPARISON OF INCOMING SOLAR RADIATION AT MARINE AND CONTINENTAL STATIONS
F.W. Dobson and S.D. Smith, Bedford Institute of Oceanography, Dartmouth, N.S.

1140: BULK MODELS OF SOLAR RADIATION AT SEA
F.W. Dobson and S.D. Smith, Bedford Institute of Oceanography, Dartmouth, N.S.

1200–1320: Lunch / Repas

1320–1440: (Connaught) **Wednesday / Mercredi**
SESSION 8: POSTERS II
Chairperson / Président : C. Anderson
SESSION 8 : AFFICHAGES II

The listing of posters is found on pages 13–17.
La liste des affiches est aux pages 13–17.

Thursday 9 June 1988
Jeudi le 9 juin

0830–0950: (Ballroom) **Thursday / Jeudi**
SESSION 9: THEME PLENARY III
Chairperson / Président : R.G. Humphries
SESSION 9 : PLÉNIÈRE III

0830: DOPPLER WEATHER RADAR AND THE CANADIAN SCENE
C.L. Crozier, Atmospheric Environment Service, Downsview, Ont.

0910: MESOCYCLONE AND RELATED SEVERE THUNDERSTORM DETECTION BY CONVENTIONAL AND DOPPLER WEATHER RADAR
Leslie R. Lemon, UNISYS Corporation, Great Neck, N.Y.

0950–1020: Coffee / Café

1020–1200: (Ballroom) **Thursday / Jeudi**
SESSION 10A: SEVERE WEATHER II
Chairperson / Président : M. English
SESSION 10A : TEMPS VIOLENT II

1020: OBSERVABLE CHARACTERISTICS OF THE SEVERE STORM ENVIRONMENT
Arjen Verkaik, Beamsville, Ont.

1040: A SURVEY OF SEVERE SUMMER STORMS OBSERVED BY KING WEATHER RADAR
T.R. Nichols, P.I. Joe and C.L. Crozier, Atmospheric Environment Service, Downsview, Ont.

1100: THE DETECTION OF MESOCYCLONES WITH THE KING CITY DOPPLER RADAR
P.I. Joe, C.L. Crozier and T.R. Nichols, Atmospheric Environment Service, Downsview, Ont.

1120: EVALUATION OF THE IMPACT OF DOPPLER RADAR ON SEVERE THUNDERSTORM FORECASTING, 1985-1987
Michael Leduc, Ontario Weather Centre, Toronto, Ont.

1140: OPERATIONAL PRODUCT USAGE PATTERNS ON THE DAR^{3}E WORKSTATION ASSOCIATED WITH SEVERE CONVECTIVE OUTLOOKS IN NORTHEAST COLORADO
Kenneth F. Heideman, NOAA/ERL/ESG/PROFS, Boulder, Colo.

1020-1200: (Ontario) **Thursday / Jeudi**
SESSION 10B: COASTAL OCEANOGRAPHY II
Chairperson / Président : Y. Gratton
SESSION 10B : OCÉANOGRAPHIE CÔTIÈRE II

1020: MODELLING THE CIRCULATION IN NEWFOUNDLAND'S OFFSHORE
Hisashi Hukuda and Richard J. Greatbatch, Dept. of Physics and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Nfld.

1040: THE BAROTROPIC TIDE IN FJORDS: WHERE DOES ALL THE ENERGY GO?
Brad de Young and Steve Pond, Physical and Chemical Sciences, Bedford Institute of Oceanography, Dartmouth, N.S.

1100: NUMERICAL SIMULATION OF CSWs ON THE LABRADOR SHELF
Savithri Narayanan, Memorial University of Newfoundland, St. John's, Nfld.

1120: DESCRIPTION AND DYNAMICAL INTERPRETATION OF LOW-FREQUENCY MOTION OVER THE LABRADOR / NEWFOUNDLAND SHELF
D. Wright, B. de Young and D. Greenberg, Ocean Circulation Division, Bedford Institute of Oceanography, Dartmouth, N.S.

1140: WIND-DRIVEN UPWELLING IN THE NORTHWEST GULF OF ST. LAWRENCE
M. Couture and Y. Gratton, Dép. d'Océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1020-1200: (Connaught) **Thursday / Jeudi**
SESSION 10C: LIMEX
Chairperson / Président : C.L. Tang
SESSION 10C : LIMEX

1020: LIMEX'87 THE PILOT LABRADOR ICE MARGIN EXPERIMENT
L. McNutt, C.L. Tang, S. Digby Argus, C.E. Livingstone, F. Carsey and W. Winsor, RADARSAT Project Office, Canada Centre for Remote Sensing. Ottawa, Ont.

1040: THE USE OF SAR FOR ICE FEATURE AND PROCESS DETECTION IN EAST COAST PACK-ICE
S. Digby Argus and C. Livingstone, RADARSAT Project Office, Canada Centre for Remote Sensing, Ottawa. Ont.

1100: UPWELLING AT THE ICE EDGE OFF THE NEWFOUNDLAND COAST
C.L. Tang, Physical and Chemical Sciences, Bedford Institute of Oceanography, Dartmouth, N.S.

1120: AN ICE MOTION ALGORITHM: A CASE STUDY OF ITS APPLICATION TO THE EAST COAST DURING LIMEX
T.K. Hirose, J.S. Paterson, L. McNutt and S. Argus, RADARSAT Project Office, Canada Centre for Remote Sensing, Ottawa, Ont.

1200-1320: Lunch / Repas

1320-1500: (Ballroom) **Thursday / Jeudi**
SESSION 11A: NWP / GCM
Chairperson / Président : C. Lin
SESSION 11A : NWP / GCM

1320: APPLICATION OF THE SEMI-LAGRANGIAN METHOD TO A MULTILEVEL SPECTRAL PRIMITIVE EQUATIONS MODEL
Harold Ritchie, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

1340: A BAROCLINIC TWO-TIME-LEVEL SEMI-LAGRANGIAN MODEL
Jean Côté and Andrew Staniforth, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

1400: MODÉLISATION DE LA VAPEUR D'EAU DANS UN MODÈLE SPECTRAL DE L'ATMOSPHÈRE
René Laprise, Centre Climatologique Canadien, Downsview, Ont.

1420: GEOSTROPHIC ADJUSTMENT AND WIND-DRIVEN SPIN-UP IN COARSE RESOLUTION UPPER-OCEAN MODELS
J.Y. Cherniawsky and L.A. Mysak, Dept. of Meteorology, McGill University, Montréal, Qué.

1440: PARAMETERIZATION OF MOIST CONVECTION IN THE CCC ATMOSPHERIC GENERAL CIRCULATION MODEL
N.A. McFarlane, Canadian Climate Centre, Downsview, Ont.

1320-1500: (Ontario) **Thursday / Jeudi**
SESSION 11B: FORECAST OPERATIONS I
Chairperson / Président : J.H. Alexander
SESSION 11B : PRÉVISION OPÉRATIONNELLE I

1320: AN EVALUATION OF EXPERIMENTAL PROBABILISTIC RADAR REFLECTIVITY FORECASTS ISSUED DURING THE PROFS 1987 REAL-TIME FORECAST EXERCISE
Herb A. Winston, NOAA/ERL/ESG/PROFS, Boulder, Colo.

1340: SWIFT - A PRELIMINARY EVALUATION
John M. Bullas and J. Carr McLeod, Atmospheric Environment Service, Downsview, Ont.

1400: A LOW CLOUD EXPERT ADVISORY TERMINAL FORECASTER
Peter Zwack, Dép. de physique, Universite du Québec à Montréal et Centre de recherche informatique de Montréal
Yves Chartier, Dép. d'informatique et de recherche opérationnelle, Université de Montréal et Atmospheric Environment Service
André Cotnoir, Dép. de physique, Université du Québec à Montréal et Atmospheric Environment Service
Jean Goulet, Dép. d'informatique et de mathématique, Université de Sherbrooke et Centre de recherche informatique de Montréal
Evelyne Haussen-Tropper, Dép. de mathématique et d'informatique, Université du Québec à Montreal et Centre de recherche informatique de Montréal
Monroe Newborn, School for Computer Sciences, McGill University et Centre de recherche informatique de Montréal

1420: FULL RESOLUTION METEOROLOGICAL SATELLITE DATA RECEPTION FOR CANADA
B. Bar-Haim, Array Systems Computing, Downsview, Ont.
B. Wannamaker, R.R. 3, Caledon East, Ont.

1440 A REAL-TIME SYSTEM FOR OPERATIONAL RECEPTION AND PROCESSING OF METEOROLOGICAL SATELLITE DATA
R.G. Humphries, L.W. Diehl, L. Laba and P.D. Erickson, MacDonald Dettwiler and Associates Ltd., Richmond, B.C.

1320-1500: (Connaught) **Thursday / Jeudi**
SESSION 11C: LIMEX / LEWEX
Chairperson / Président : S. Venkatesh
SESSION 11C : LIMEX / LEWEX

1320: A TWO-DIMENSIONAL COUPLED ICE-OCEAN TURBULENT CLOSURE MODEL IN THE MARGINAL ICE ZONE
M. Ikeda, Physical and Chemical Sciences, Bedford Institute of Oceanography, Dartmouth, N.S.

1340: WAVE-ICE INTERACTION STUDY DURING LIMEX / LEWEX '87
B.M. Eid and C.M. Morton. MacLaren Plansearch Limited, Halifax, N.S.
W.D. Winsor and J.H. Lever. C-CORE, Memorial University of Newfoundland, St. John's, Nfld.
V.J. Cardone, Oceanweather Inc., Cos Cob, Conn.

1400: LOAD COMBINATIONS AND RISK ASSESSMENT FOR ICE STRUCTURE INTERACTIONS IN THE MARGINAL ICE ZONE
Ian J. Jordaan, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Nfld.
William D. Winsor, C-CORE, Memorial University of Newfoundland, St. John's, Nfld.

1420: THE LABRADOR EXTREME WAVES EXPERIMENT (LEWEX) DATA REPORT
A.S. Bhogal, INTERA Technologies Ltd., RADARSAT Project Office, Ottawa, Ont.

1500-1530: Coffee / Café

1530-1710: (Ballroom) **Thursday / Jeudi**
SESSION 12A: REMOTE SENSING
Chairperson / Président · G.A. McBean
SESSION 12A : TÉLÉDÉTECTION

1530: AN ELECTRONICALLY SCANNED MICROWAVE IMAGING RADIOMETER
Cameron Grant, Centre for Research In Experimental Space Science, York University, North York, Ont.
Greg Healy, COM DEV, Cambridge, Ont.

1550: MULTIFREQUENCY SPACEBORNE PASSIVE MICROWAVE OBSERVATIONS OF THE OCEAN AND ATMOSPHERE
I.G. Rubinstein and R.O. Ramseier, CRESS, York University, North York, Ont.

1610: USE OF CLOUD INFORMATION TO IMPROVE TOVS RETRIEVALS
J.D. Steenbergen, T.-C. Yip and B.T. Greaves, Atmospheric Environment Service, Downsview, Ont.

1630: TIME SERIES AVHRR AND SHIP TEMPERATURE DATA FOR THE JACQUES-CARTIER PASSAGE
A.R. Condal and Y. Carbonneau, Dép. des Sciences géodesiques et Télédétection, Université Laval, Québec, Qué.
D. Lefaivre, Institut Maurice-Lamontage, Pêches et Océans, Mont-Joli, Qué.
V.G. Koutitonski, INRS-Océanologie, Rimouski, Qué.

1650: PASSIVE MICROWAVE SNOW AND ICE SIGNATURES FROM THE ST. LAWRENCE RIVER
Caren Garrity, Microwave Group, CRESS, York University, North York, Ont.

1530-1650: (Ontario) **Thursday / Jeudi**
SESSION 12B: FORECAST OPERATIONS II
Chairperson / Président : P. Zwack
SESSION 12B : PRÉVISION OPÉRATIONNELLE II

1530: IMPROVEMENT OF NUMERICAL WEATHER ELEMENT FORECASTS
N. Brunet, D. Soucy, R. Verret and N. Yacowar, Canadian Meteorological Centre, Montréal, Qué.

1550: AN ANALYSIS OF THE IMPACT OF DIFFERING CLIMATOLOGICAL REGIMES ON PROBABILISTIC PRECIPITATION FORECASTS
Denice C. Walker, NOAA/ERL/ESG/PROFS, Boulder, Colo.

1610: DETERMINATION OF MOST PROBABLE PREDICTED 50-KPA PATTERN BY EMPIRICAL ORTHOGONAL FUNCTIONS
Amir Shabbar, Canadian Climate Centre, Downsview, Ont.

1630: INTERACTIVE, MACHINE-ASSISTED DVORAK TYPHOON CLASSIFICATION
B.W. Wannamaker, Sea Scan, R.R. 3, Caledon East, Ont.

1530-1700: (Connaught) **Thursday / Jeudi**
SESSION 12C: OCEAN-CLIMATE INTERACTION
Chairperson / Président : G. Boer
SESSION 12C : INTERACTION OCÉAN-CLIMAT

1530: A SIMPLE COUPLED STEADY-STATE ARCTIC ICE-OCEAN MODEL
A.J. Willmott, Exeter University, United Kingdom
L.A. Mysak, Dept. of Meteorology, McGill University, Montréal, Qué.

1545: A QUASI-GEOSTROPHIC CIRCULATION MODEL OF THE NORTHEAST PACIFIC OCEAN
P.F. Cummins, Institute of Ocean Sciences, Sidney, B.C.
L.A. Mysak, Dept. of Meteorology, McGill University, Montréal, Qué.

1600: A MECHANISTIC MODEL OF ISOPYCNAL DIFFUSION IN THE OCEAN
Charles Lin, Dept. of Meteorology, McGill University, Montréal, Qué.

1615: ISOPYCNAL AND LATERAL DIFFUSION IN A BOX OCEAN CIRCULATION MODEL
William Gough and Charles A. Lin, Dept. of Meteorology, McGill University, Montréal, Qué.

1630: NUMERICAL EXPERIMENTS WITH A TWO-LAYER UPPER-OCEAN BOX MODEL: WIND-DRIVEN SPIN-UP AND MIXING OF INITIAL TEMPERATURE GRADIENTS
J. Cherniawsky, L.A. Mysak, C.A. Lin and C.W. Yuen, Dept. of Meteorology, McGill University, Montréal, Qué.

1645: RESULTS OF A TWO-LAYER UPPER-OCEAN CLOBAL GENERAL CIRCULATION MODEL FORCED AT THE SURFACE
C.W. Yuen, C.A. Lin, L.A. Mysak and J.Y. Cherniawsky, Dept. of Meteorology, McGill University, Montréal, Qué.

Friday, 10 June
Vendredi le 10 juin

0830-0950: (Ballroom) **Friday / Vendredi**
SESSION 13: THEME PLENARY IV
Chairperson / Président : S.D. Smith
SESSION 13 : PLÉNIÈRE IV

0830: UNDERSTANDING THE SEVERE STORM HAZARD: WHERE DO WE GO FROM HERE?
Michael J. Newark, Atmospheric Environment Service, Downsview, Ont.

0910: THE DESTRUCTIVE EFFECTS OF WINDS
A.G. Davenport, University of Western Ontario, London, Ont.

0950-1020: Coffee / Café

1020-1200: (Ballroom) **Friday / Vendredi**
SESSION 14A: IMPACT AND RESPONSE
Chairperson / Président : J.W.S. Young
SESSION 14A : RÉPERCUSSIONS ET INTERVENTION

1020: WEATHER AWARENESS AND EMERGENCY RESPONSE
Jerrine Verkaik, R.R. 1, Beamsville, Ont.

1040: PROJECT TORNADO - A COOPERATIVE EFFORT TO INCREASE TORNADO PREPAREDNESS IN ONTARIO
Barry Greer and Michael Leduc, Ontario Weather Centre, Toronto, Ont.
James Ellard, Emergency Planning Ontario, Ministry of the Solicitor General, Toronto, Ont.

1100: CONDUCTING FIELD SURVEYS OF STORM DAMAGE CAUSED BY SEVERE THUNDERSTORMS AND TORNADOES
Richard Hogue and Jasmin Kern, Ontario Weather Centre, Toronto, Ont.

1120: THE WEATHER AS A FACTOR IN CANADIAN DISASTERS
Bob Jones, Atmospheric Environment Service, Ottawa, Ont.

1140: A 3-D HEMISPHERIC TRACER MODEL AND ITS APPLICATIONS
J. Pudykiewicz, Atmospheric Environment Service, Dorval, Qué.

1020-1200: (Ontario) **Friday / Vendredi**
SESSION 14B: COASTAL OCEANOGRAPHIE III
Chairperson / Président : R. Greatbatch
SESSION 14B : OCÉANOGRAPHIE CÔTIÈRE III

1020: INTERPRETING SATELLITE SEA-SURFACE TEMPERATURE IMAGES WITH WIND AND CURRENT DATA IN JACQUES CARTIER PASSAGE
D. Lefaivre, A. Condal, V.G. Koutitonsky, P. Ouellet and D. Hains
Physical Oceanography Division, Maurice Lamontagne Institute, Dept. of Fisheries and Oceans, Mont-Joli, Qué.

1040: THE VORTICITY BALANCE ON THE B.C. CONTINENTAL SHELF
H.J. Freeland, Institute of Ocean Sciences, Sidney, B.C.

1100: SATELLITE OBSERVATIONS OF A BASIN EDDY IN THE LOWER ST. LAWRENCE ESTUARY
G. Mertz, Y. Gratton and J.A. Gagné, Dép. d'Océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1120: A FINITE-ELEMENT TIDAL MODEL FOR THE SOUTHWEST COAST OF VANCOUVER ISLAND
M.G.G. Foreman, Institute of Ocean Sciences, Sidney. B.C.

1020-1200: (Connaught) **Friday / Vendredi**
SESSION 14C: GEOPHYSICAL FLUID DYNAMICS
Chairperson / Président : H-R. Cho
SESSION 14C : DYNAMIQUE GÉOPHYSIQUE DES FLUIDES

1020: NON-LINEAR BALANCE AND GRAVITY-INERTIAL WAVE SATURATION IN A SIMPLE ATMOSPHERIC MODEL
Richard Menard, Canadian Climate Centre, Downsview, Ont.

1040: DEVELOPMENT OF MARGINALLY UNSTABLE BAROCLINIC VORTICES
P. Gauthier and T. Warn, Dept. of Meteorology, McGill University, Montréal, Qué.

1100: NON-SEPARABLE QUASI-GEOSTROPHIC BAROCLINIC INSTABILITY
G.W. Kent Moore and W.R. Peltier, Dept. of Physics, University of Toronto, Toronto, Ont.

1120: ROSSBY WAVE GENERATION BY MOVING CURRENTS
Rose G. Wood, Dept. of Meteorology, McGill University, Montréal, Qué.

1140: THE APPLICABILITY OF GRADIENT TRANSPORT MODELS TO HORIZONTAL DIFFUSION IN THE OCEAN
Brian G. Sanderson and B.K. Pal, Dept. of Physics and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Nfld.

Abstracts / Résumés

0850-1010: (Ballroom) **Tuesday / Mardi**
SESSION 1: THEME PLENARY I
SESSION 1 : THÉME PLÉNIÈRE I

THE EDMONTON TORNADO
Alton F. Wallace

During the afternoon of July 31, 1987 the city of Edmonton, Alberta was struck by a devastating tornado. Classified as F4 on the Fujita tornado intensity scale, this severe tornado caused 27 deaths, injured hundreds and produced more than $300 million dollars in property damage.

Information on the physical dimensions of this violent tornado and its associated damage path will be presented. Details on the gradient of tornado intensity, its visible forms, and the life-cycle will be provided. A video tape that was synthesized from a number of home videos of the tornado will be shown.

The meteorological conditions associated with the severe weather outbreak of July 31 will be discussed. The dynamic and thermodynamic environment will be examined using the traditional (after Miller) approach. The effects of buoyancy and wind shear in determining storm severity will also be considered. Using available radar and satellite imagery, storm evolution will be discussed, with the primary focus on the explosive development of the supercell tornadic thunderstorm. In conjunction, the weather forecasts and warnings issued on July 31 will be outlined.

After the events of July 31, the Minister of Environment commissioned an independent review of the weather warning system. This review was chaired by Dr. Keith Hage, Professor Emeritus, University of Alberta. The study concluded that the weather service reacted swiftly and earlier warning of the tornado was not possible given the technology available. A number of weaknesses were uncovered, however, and a series of recommendations were made to address these. A brief presentation will highlight the more important conclusions, deficiencies and recommendations.

MESOSCALE CONVECTIVE SYSTEMS TO THE LEE OF THE ROCKY MOUNTAINS
William R. Cotton

It is well known that the Rocky Mountains and the High Plains play an important role in the genesis of summertime convective storms. Not well understood, however, is the actual physical processes responsible for the genesis of such convective storms. Even less understood is the role that mountain convection plays in the genesis of what I shall call *orogenic mesoscale convective systems.*

Several examples of orogenic mesoscale convective systems will be presented. The results of two-dimensional numerical simulations of the genesis of mesoscale convective systems (MCSs) will be described. A conceptual model of MCS genesis will be given which is based on the results of the numerical experiments and case study analyses.

The conceptual model describes six stages of orogenic MCS development: 1) Stage 1 in which convergence is developed as a result of the interaction between the mountain/plains thermally-driven upslope circulation and the ambient flow over the mountains; 2) Stage 2 is earmarked by the formation of deep convection over the mountains; 3) Stage 3 is associated with the formation of a 12-km deep solenoidal circulation with anticyclonic shear of the meridional flow aloft and cyclonic shear at low levels; 4) Stage 4 begins when the embryonic MCS moves from the mountains over the eastern plains where greater subsidence is encountered and upward motion within the MCS core collapses; 5) Upon entering Stage 5 the MCS enters a more generic phase of its lifecycle in which it undergoes repeated cycles of growth, overdevelopment, and weakening. After sunset further destabilization by longwave radiative cooling results in the MCS achieving peak vertical velocity; and 6) During Stage 6 the MCS transforms from an unsteady MCS having a scale less than the Rossby radius (λ_R) into a more geostrophically-balanced mesoscale convective complex (MCC) having a scale greater than λ_R.

Implications of the presented conceptual model to the general problem of MCC genesis and to the genesis of MCCs over the higher-latitude Canadian prairie will be given.

1040-1200: (Ballroom) **Tuesday / Mardi**
SESSION 2A: SEVERE WEATHER I
SESSION 2A: TEMPS VIOLENT I

SEVERE WEATHER DISCRIMINATION TECHNIQUE BASED UPON DERIVED PARAMETERS OBTAINED FROM STANDARD RADIOSONDE DATA

D. Vigneux and V. Turcotte

Two of the difficulties that have to be overcome by the severe weather forecaster are the assessment of the severity of thunderstorms likely to develop in a given synoptic situation, and the precise location as to where these storms are likely to occur. This paper describes a technique currently used operationally at the Centre Météorologique du Québec to infer "a priori" the severe convection potential in a real-time forecasting environment. Buoyant energy obtained by the parcel method and mean low-level windshear obtained from regular UA soundings are used to calculate an index related to the severe weather potential. Assuming convection occurs, this index is used to discriminate severe from non-severe thunderstorm environments prior to the onset of convection

The operational application of this technique requires a sounding typical of the convective environment in which thunderstorms will develop, and forecasts of surface temperatures and dew points. This technique, as will be shown, provides a very good indication as to

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whether or not the current situation is conducive to the formation and development of severe thunderstorms. A case study illustrating the operational application of the technique will also be presented.

PROPAGATION OF SEVERE THUNDERSTORMS· A PROGNOSTIC TOOL FOR THE OPERATIONAL SEVERE WEATHER FORECASTER
D. Vigneux

Storm characteristics are highly sensitive to the environmental wind profile. The organization of storms within a convective environment exhibits strong dependence upon the vertical wind structure, and propagation characteristics of individual cells could be significantly different from tropospheric large-scale winds. Temporal evolution of thunderstorms obtained from 3-D numerical cloud models reproduce this dependence between storm characteristics and wind profiles.

Since these models are unavailable in real-time operations, results from numerical simulations from the Klemp-Wilhelmson cloud model for six typical wind profiles are used to infer storm evolution characteristics once thunderstorms have started to develop. The model wind profile that most closely matches the current wind profile for the region of interest is first identified, and the modelled storm behaviour (type of convection and propagation parameters) is then used as guidance for the "real" situation.

A dozen cases have been looked at, of which four have been studied in detail; for the latter, storm evolution inferred from the cloud model is in remarkable agreement with the storm evolution as observed on radars. Results obtained so far seem promising for cases of storm splitting and deviation of supercellular storms. A case study for the May 29, 1987 Montreal hailstorm will be presented.

WIND SHEAR AS A PREDICTOR OF SEVERE WEATHER FOR THE EASTERN UNITED STATES
Hugh M. Stone

Various numerical and observational studies have indicated that wind shear may be useful in explaining and possibly forecasting the type of convective storms that develop under unstable atmospheric conditions. In this study we examine the relationship between the occurrence of severe weather and various measures of wind shear and buoyant energy. The various shear and stability parameters are computed from 1200 GMT raob data for fifteen locations over the eastern United States during the spring and summer of 1987. Afternoon (1800 to 2400 GMT) severe weather occurrences within a 125-mile radius of these raob stations are also tabulated. The relationship of each parameter to the occurrence or non-occurrence of severe weather in the vicinity of the station is examined through point biserial correlation, then multiple correlation with screening regression is done for the entire group of parameters.

Our data set is divided into two parts: stable and unstable days. We find a significant correlation between wind shear and the occurrence of severe weather

In the unstable data. A new measure of wind shear is introduced, the vector product shear (VPS), which combines the direction shear and speed shear into a single quantity. The VPS is found to have substantially better correlation than the more traditional measures of shear that do not account for the turning of the wind with height. Our unstable subset is further stratified into spring and summer subsets. We find that shear, in particular VPS, is a fairly good predictor of severe weather in the springtime but almost worthless in the summer. In summer, severe weather is better correlated to buoyant energy.

INTENSE RADAR ECHOES IN TROPICAL RAIN EVENTS
Mauricio de Agostinho Antonio

During the months of spring and autumn. tropical Brazil in the Southern Hemisphere is reached by instability lines and rainbands associated with cold fronts that present intense precipitation cores. A meteorological C-Band radar operating in Bauru, Brazil (22°35'S and 49°00'W) has been monitoring rain events with digital data logging since 1981. Some of the precipitating bands have speeds faster than 40 km/h. reflectivity values greater than 50 dBZ, tops exceeding 12 km and hail. in some cases, which is unusual in the region, but which affects the local agriculture.

Four intense rain events were selected for analysis· 18 and 30 October 1982, 10 April 1987 and 14 June 1987.

In the cases of 18 and 30 October 1982. the rains occurred early in the morning and were preceded by strong gusts that produced some material damage in the area; each case was associated with a strong cold front in the area. On the first day, 18 October, one radar echo with reflectivities greater than 50 dBZ was monitored for 82 min for an area southwest/south of the radar. The echoes verified in this event had individual movements of about 100 km/h while the rainband, composed of these echoes, was moving with a speed of about 45 km/h. On the second ay, 30 October, a precipitation echo was observed to have reflectivities greater than 50 dBZ and hail larger than 2 cm during a 5-min period when it reached the radar site.

In the 10 April 1987 event the Bauru radar detected intense rain echoes in an organized band 100 km long that was moving southeast at about 54 km/h. The echoes were analysed for about 140 min and gave reflectivities greater than 50 dBZ and maximum tops of 13.2 km during this period. For 14 June 1987, two distinct sequences were selected. The first, during during the morning, corresponded to a precipitating band 100 km long moving to the east at 71 km/h. Reflectivities exceeded 60 dBZ and tops were 13 km. In the second sequence, in the afternoon, the reflectivities of the echoes were greater than 55 dBZ and tops were higher than 16 km. A rain echo under analysis had a speed of about 60 km/h and hail that caused heavy damage in a coffee plantation.

This study presents the temporal and spatial evolution of radar echoes for the events mentioned and the predominant synoptic situation in the area.

A NUMERICAL MODEL OF THE INTERANNUAL VARIABILITY IN THE NORTHEAST PACIFIC OCEAN
William W. Hsieh and Warren G. Lee

A 3-dimensional finite-difference model of the North Pacific Ocean from 16°N to 60°N has been used to study the interannual variability in the northeast Pacific. A hindcast was performed with the observed windstress and surface air temperature from 1955 to 1979 driving the model. The subarctic gyre showed large seasonal variation in the barotropic transport. Empirical orthogonal functions were used to identify the dominant modes in the interannual variability of the currents, water temperature and volume transport as computed by the model.

SEASONAL TRANSPORT VARIATIONS IN THE NORTH ATLANTIC - A MODEL STUDY
Richard J. Greatbatch and Allan Goulding

Results from a linear barotropic model calculation for the North Atlantic will be described. The model is forced by the climatological monthly mean surface wind stress of Helleman and Rosenstein and includes real bathymetry. The model solves the equations in frequency space rather than using a time-stepping procedure. Particular attention will be focussed on the Labrador Sea area.

A THERMOCLINE MODEL FOR THE NORTH PACIFIC
M.G.G. Foreman and A.F. Bennett

In an effort to better understand the circulation of heat and salt in the North Pacific Ocean, a three-dimensional model is presently under development at the Institute of Ocean Sciences. Although this model incorporates real bathymetry, real coastlines, and has a high resolution in the vertical, the model physics have been simplified in order to facilitate data assimilation. A discussion of the model development, preliminary testing, and future directions will be presented.

RESPONSE OF THE INDIAN OCEAN TO 50-DAY ATMOSPHERIC OSCILLATIONS
G. Mertz, Y. Gratton and M. Couture

It is well known by meteorologists that zonal winds in the tropics fluctuate at 40- to 50-days' period. This oscillation is strongest in the Indian and western Pacific Oceans. We force a numerical reduced gravity model of the Indian Ocean with a 50-day oscillation of the zonal wind stress, trapped within 10° of the equator and uniform with longitude. The response includes an oscillating western boundary current which separates from the African. Coast and forms an eddy of alternating

cyclonic, anticyclonic circulation. A system of oscillating equatorial jets develops. We compare the response off the coast of Kenya with current measurements from this area to show that the calculated response corresponds well with the observed 50-day oceanic signal.

1040-1200: (Connaught) **Tuesday / Mardi**
SESSION 2C: CLIMATE I
SESSION 2C : CLIMAT I

METEOROLOGICAL DROUGHT IN THE SOUTH SASKATCHEWAN RIVER BASIN WITHIN SASKATCHEWAN
D.J. Bauer and L.E. Welsh

Streamflow in the South Saskatchewan River Basin is primarily a function of snowpack accumulation and snowmelt on the eastern slopes of the Rockies. However, precipitation, and in particular the lack thereof, can have significant impacts on the demands for water from the system. A better understanding of the frequency, severity and duration of droughts would benefit water use planners and government agencies involved in mitigating the effects of drought. With this in mind a study of dry and wet periods in the South Saskatchewan River Basin was undertaken.

The study was designed to:

(a) provide an analysis of past meteorological droughts in the basin
(b) provide a statistical base on the frequency of meteorological droughts of varying duration and severity.

Monthly precipitation data for 12 long-term climate stations in and adjacent to the basin were used to prepare a time series of monthly deficits and surpluses of "effective precipitation" for six sub-regions in the basin. Criteria for specifying drought were developed and applied to these time series to identify droughts within the period of record. Frequency analysis was used to estimate the mean recurrence interval for droughts of various intensities.

RELATIONSHIP BETWEEN PRAIRIE DRY AND WET SPELLS AND ATMOSPHERIC FLOW PATTERNS IN THE MID-TROPOSPHERE
J.L. Knox and R. Lawford

We identify dry and wet spells over the Canadian Prairies during the 40-year period 1946-1985 and investigate their relationship with the circulation at the 50-kPa level. The target area is first subdivided into five regions on the basis of characteristic differences in precipitation climatology, and for each region in turn, the occurrences of dry and wet months are determined. These events are then grouped according to five "seasons" and much of the analysis focuses on the three growing seasons: SPRING defined as April and May; EARLY SUMMER, June and July; and LATE SUMMER, August and September. The 50-kPa anomaly fields for the Northern Hemisphere are composited for the DRY and WET groupings respectively, and the composites are then differenced to determine the main distinguishing features. For each region-season combination the WET and DRY composites are clearly distinguishable, not only over North America

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but also upstream and downstream of the continent. Each field is usually characterized by an amplified North Atlantic Oscillation but with opposite N-S polarity. In the case of the southwestern Prairie region, a notable distinguishing feature of the two composites is the reversal in E-W polarity of the Northeast Pacific-North America oscillation. The extent to which these teleconnections might be used for monthly prediction of dry or wet spells over Prairie regions will also be discussed.

A METHOD FOR THE ESTIMATION OF ERRORS IN THE SPATIAL INTERPOLATION OF RAINGAUGE DATA

Norman Bussières and Bill Hogg

The authors describe a method to estimate errors in spatial interpolation of daily raingauge data. The method relies on rainfall patterns generated from processed radar data. Variability in these patterns is assumed to represent variability in actual surface precipitation. These patterns served as reference values gridded at intervals of .05 degrees of latitude and longitude. From the reference arrays, samples were extracted at the geographical coordinates of climatological stations. Coordinates of all stations from 84°W to 71°W and from 47°N to 40°N were used. The reference samples were interpolated using objective analysis (OA) techniques. The new patterns generated by spatial OA were compared to the reference patterns. The authors present the resulting error maps. Error sources are: 1) the choice of the weighting function, and 2) the inhomogeneities of physiography. This method isolated the first type of error, since physiographic effects were not included during reference pattern generation. The authors present and discuss the results of intercomparisons and evaluations of four OA techniques. They also discuss the application of interpolation errors to network analysis and to the integration of raingauge data with arrays of precipitation estimates from remote sensing.

EXTENSION OF TORONTO TEMPERATURES TIME SERIES FROM 1840 BACK TO 1778 USING VARIOUS UNITED STATES AND OTHER DATA

R.B. Crowe

Daily maximum and minimum temperatures for Toronto City exist and are archived from March 1, 1840 to the present day. This lengthly time series can be extended considerably by using standard differences in mean monthly temperatures between Toronto and a number of United States stations, the earliest of which dates from July 1778. In addition, there are considerable temperature data taken three times a day from another station in Toronto in the 1830s' decade. These data were adjusted and monthly mean temperatures calculated.

SESSION 3A : WOCE / JGOFS

WOCE AS A COMPONENT OF THE WORLD CLIMATE RESEARCH PROGRAM
Gordon A. McBean

It is clear that the oceans play a major role in the evolution of the earth's climate. For short time-scales the main impact is in the direct coupling through air-sea fluxes, but for longer time scales (decades to centuries) it is necessary to include the full ocean as a component of global climate models. The World Ocean Circulation Experiment is designed to develop the understanding necessary to model the ocean (on climate time-and space scales) and to provide a reference data set for model validation. WOCE will be possible because of the development of new technologies to observe the global ocean, new computers to handle the data and run the models, and theoretical advances in both data assimilation and modelling.

THE WOCE GYRE PROGRAM IN THE NORTH ATLANTIC
R. Allyn Clarke

A review of WOCE-related studies in the North Atlantic, with emphasis on BIO's contributions.

NUMERICAL MODELLING PROBLEMS IN WOCE
Greg Holloway

The problem of modelling the world ocean circulations will be discussed within the conceptual framework of WOCE.

WOCE-RELATED STUDIES AT MEMORIAL
Richard Greatbatch

The following projects are currently underway or being planned: (I) Circulation and variability in the N. Atlantic with particular interest in the Labrador Sea (Greatbatch, Lazier (BIO), Narayanan, Thompson (Dalhousie), Wright (BIO), (II) Dynamics of the Labrador current and the coastal waters off eastern Canada (Greatbatch, Hay, Narayanan, Sanderson). Both these projects involve modelling studies and the collection and analysis of data.

AN OVERVIEW OF MODELLING STUDIES OF OCEAN-CLIMATE INTERACTION AT MCGILL
Charles A. Lin and Lawrence A. Mysak

An overview will be given of the ongoing research studies on ocean and climate dynamics carried out by members of the Climate Research Group at McGill University. A major initiative of this Group is to develop and implement a global ocean circulation model for coupling to the Canadian Climate Centre atmospheric general circulation model for climate studies. The ocean model is a two-layer primitive equation global upper ocean model with a thermodynamic sea-ice model. The model has been run in the uncoupled mode using climatological seasonally varying wind stress and heat fluxes. The results show that the mixed layer temperature and depth are well simulated; the currents are found to be too weak. Further experiments and diagnostic heat budget studies are being carried out. A box version of this model corresponding to the North Atlantic has also been formulated. The wind-driven spin-up of this model has been examined; these results show a well developed double gyre circulation with realistic volume transports. Other limited area model studies consist of a quasi-geostrophic eddy resolving circulation model of the northeast Pacific ocean with realistic coastline and bottom topography, and the comparison of isopycnal and lateral diffusive parameterizations using both purely diffusive models, as well as a multi-level primitive equation circulation model of the Atlantic.

A high-latitude Arctic ice-ocean model has also been developed; it is a thermodynamic, reduced-gravity model forced by steady wind stress and air temperature. The model is applied to the Greenland and Norwegian Seas; the simulated ice-edge position compares favorably with the observed climatological sea-ice distribution.

WHAT IN THE WORLD IS JGOFS?
Kenneth L. Denman

JGOFS, the Joint Global Ocean Fluxes Study, is an international study of the global ocean planned for the 1990s, in conjunction with WOCE, the World Ocean Circulation Experiment. The goals of JGOFS are to understand, on ocean basin scales, the sources, sinks and pathways in the ocean of biologically active elements - carbon, nitrogen, sulphur and oxygen. In particular, the role of the ocean in the global carbon cycle must be determined. Possibly as much as half of the carbon that is released into the atmosphere from fossil fuels and deforestation does not stay there. If the deep ocean is the recipient of this carbon, there is doubt that physical means alone can remove it fast enough from contact with the atmosphere. Phytoplankton in the world ocean removes more than enough carbon through photosynthesis to account for the loss, but we are uncertain as to how much ends up in the deep ocean and how much is recycled in the surface waters. Resolving these fluxes in order to close the global carbon budget is the goal of JGOFS. It is not clear that we can achieve that goal by the year 2000.

BENTHIC FLUXES IN JGOFS: CLOSING THE CHEMICAL MASS BALANCES
S.E. Calvert

The program of benthic flux studies in JGOFS aims to quantify the fluxes of carbon and associated elements in the benthic boundary layer and in the sediment column and to decipher the sedimentary record of changing oceanographic and climatic conditions at any given site in the ocean. These studies will be carried out in close collaboration with programs for the measurement of particle fluxes through the water column and studies of benthic biological processes.

In spite of considerable recent progress in understanding the general processes of particle accumulation and remineralization at the benthic boundary, there is a continuing need to determine the relationship between the settling and burial fluxes of carbon and associated biogenic elements in a range of environments in the ocean, and how these fluxes are related to upper water column processes. The program will eventually require that a suite of standard benthic measurements are made on a basin-wide scale, probably involving measurements of benthic solute fluxes, particle settling and reworking, and the establishment of high-resolution sediment records. The planning is centred on a series of latitudinal and margin-open ocean transects; this will permit a) comparison of processes at oligotrophic, mesotrophic and eutrophic sites, b) evaluation of the importance of boundary fluxes, and c) examination of changing benthic fluxes during glacial and interglacial episodes.

The program will require considerable investment in the development of new instrumentation for benthic flux studies in parallel with the development of new analytical capabilities.

1320-1500: (Ontario) **Tuesday / Mardi**
SESSION 3B: WAVES I
SESSION 3B : VAGUES I

OBSERVATIONS OF THE STRUCTURE OF NEAR-SURFACE TURBULENCE IN THE PRESENCE OF WIND WAVES
N. Merzi, I.K. Tsanis and M.A. Donelan

Basic characteristics of winds, wind-generated waves and water velocities were measured in a 10 m long, 30 cm wide, 60 cm high wind-wave flume at the Canada Centre for Inland Waters. The behaviour of the turbulent dissipation, ε obtained from the decay of the turbulence, was examined as a function of depth. Turbulent dissipation was calculated as the rate of decay of the horizontal turbulent energy, $\varepsilon \simeq d(\overline{u'^2})/dt$.

Turbulent dissipation was calculated also according to the logarithmic velocity distribution, $\varepsilon = u_{*w}^3/kz$, where u_{*w} is the friction velocity in

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the water. Differences between the two methods were attributed to the additional turbulence causing mechanisms such as wave breaking and wave-turbulence interaction. Wave heights and slopes were measured in the time domain in connection with the turbulence measurements to examine qualitatively the influence of the wind-generated waves on the near-surface turbulence.

To clarify the mechanisms for generation of near-surface turbulence a flow visualization study was conducted as well. Warm water was introduced to the water surface through a weir-type arrangement forming a thermal wedge. When the wind was applied it generated a drift current and waves that caused mixing of the cold water with the overlying warm water. The consequent refractive index variations were detected with a shadowgraph system. A camera and a video system were used to obtain pictorial representations of the mixing phenomena.

SMALL-SCALE WAVE BREAKING AND CONSEQUENCES FOR GAS TRANSFER

N. Merzi and M.A. Donelan

A laboratory study has been made to determine the different sources of near-surface water turbulence in a 10 m long, 30 cm wide, 60 cm high wind-wave flume at the Canada Centre for Inland Waters. Wind and water velocities were measured in connection with wave height and slope measurements using tap water and also water containing dissolved surfactants to suppress wave generation.

The commercial surfactant, sodium lauryl sulphate ($NaC_{12}H_{25}SO_4$) was used at different concentrations to suppress wind waves to varying degrees. At the same wind speed, turbulent intensities in the water were measured with different surfactant concentrations. The turbulence velocity spectra were normalized alternately with wind parameters and with wave parameters in order to obtain a reliable parameterization. The normalization operation with wave parameters was conducted using the entire spectrum and also with respect to only the quasi-saturated part of the spectrum limited by breaking rather than fetch.

Besides the wind shear applied at the air-water interface, wave breaking at different scales and wave-turbulence interaction may contribute to the generation of near-subsurface turbulence. The rate of transfer of water phase controlled gases is believed to depend on the turbulent intensity in water, in which case an increase of turbulence by an additional mechanism would be expected to enhance gas transfer.

DIRECTIONAL SPECTRA OF WAVES IN CHANGING WIND CONDITIONS

I.K. Tsanis and M.A. Donelan

An array of six capacitance wave staffs of 4.8-mm diameter, which are arranged in a pentagon with one at the centre, is used for determination of directional spectra of waves. This array was installed on the NWRI research platform that is positioned in 12 m of water, 1.1 km off the beach at the west end of Lake Ontario near Hamilton, Ontario.

The design of the array, its size and geometry were based on the range of wavelengths of interest. The wave periods of interest are between 0.6 and 8.0 seconds, which according to linear theory correspond to wavelengths of 0.5 to

76 metres. In order to avoid spatial aliasing the distance between the wave staff at the centre and the others is 0.25 m. The array is symmetrical in order to reduce differences in directional sensitivity.

The data are analyzed using the Maximum Likelihood Method (MLM) and for comparison, the conventional Fourier component analysis is also shown both using slopes and elevation (pitch-roll buoy equivalent) and including curvatures (cloverleaf buoy equivalent). Several cases, including rapidly turning winds and east swell advancing against strong west winds, are provided for illustration. The transition between sea and swell in changing winds is explored in some detail.

WAVE-INDUCED PRESSURE MEASUREMENTS IN FAVOURABLE AND ADVERSE WINDS

M.A. Donelan, I.K. Tsanis, K.K. Kahma and N. Madsen

The rate of exchange of energy and momentum between wind and waves is perhaps the most crucial parameter in the development and prediction of waves on lakes and oceans. Little is known about the rate of wind-induced growth in strong favourable winds and less about the rate of attenuation of swell advancing against the wind.

A vertical array of three pairs of static and dynamic pressure probes were installed on the National Water Research Institute's platform in Lake Ontario to examine the structure of wave-induced pressure and wind fluctuations. The pressure probes were installed on a large damped vane so that they always faced the wind and this "wind follower" could be moved vertically so that pressure measurements could be made between 1 m and 5 m from the surface. Beneath this elevator was a single wave staff for assessing phase differences between waves and induced pressure and 5 m away was an array of six wave staffs to estimate the wave directional spectrum.

Over the three periods of our experimental phase (October-December 1985, 1986, and 1987) we have collected several hundred hours of data with this apparatus including cases of high winds gusting to 27 m/s generating very rapidly growing wind waves, and cases of strong west winds propagating against swell from the east. The rates of growth and attenuation in these and other cases are analyzed and discussed in terms of current theoretical ideas on wind-wave coupling.

A COMPARISON OF NEAR-SURFACE TURBULENCE CHARACTERISTICS OBSERVED USING BACKSCATTER FROM BUBBLES AND DIRECT WATER-VELOCITY MEASUREMENTS

Eugene A. Terray and Blair H. Brumley

A comprehensive suite of meteorological and hydrodynamic measurements were made from a fixed platform in Lake Ontario during the WAVES experiment. This paper focuses on data from two instruments, a string of BASS acoustic travel time current meters distributed throughout the top 5 m of the water column, and a nearby 200 kHz/1 MHz inverted echosounder mounted about 7 m below the surface. The wave-velocity component (the portion coherent with surface elevation) was removed from the current records, giving profiles of mean current, turbulent kinetic energy, and shear stress. For high wind conditions, these profiles show a deviation from wall layer scaling close to the surface. Acoustic backscatter profiles show bubble clouds in this same

region, suggesting that intermittant wave breaking maintains a well-mixed layer near the surface. Eddy diffusivity estimates from backscatter profiles using Thorpe's method are higher than expected from wall layer scaling.

1320-1500: (Aberdeen) **Tuesday / Mardi**
SESSION 3C: MESOSCALE
SESSION 3C : ÉCHELLE MOYENNE

A MESOSCALE CLIMATOLOGY FOR EASTERN NORTH AMERICA
Douglas A. Wesley, Michael D. Moran and Roger A. Pielke

A subjective synoptic classification scheme has been used to categorize the dominant daily synoptic weather pattern for the five-year period from 1975 to 1979 for each grid square in a 5 × 7 grid placed over eastern North America. Seven synoptic categories were used in the classification: warm sector of an extratropical cyclone; region of cyclonic surface isobar curvature ahead of a warm front; region of cyclonic isobar curvature behind a cold front; region beneath a polar anticyclone; region beneath a subtropical anticyclone or ridge; tropical cyclone; and unclassifiable pattern. The grid extends from 36°N to 48.5°N and from 68°W to 89°W ; this area includes much of the Great Lakes region, Ohio Valley, St. Lawrence Valley, northern Appalachians, and U.S. northeastern seaboard. One of four surface synoptic pressure gradient classes was also assigned each day to each grid cell.

A variety of statistics have been calculated for this climatological data set, including joint frequency tables, category persistence probabilities, category transition probabilities, and time series analyses. A comparison of statistics for different grid squares, rows, or columns reveals mesoscale variations in the synoptic climatology with latitude, longitude, and season. For instance, the seasonal movement of the polar front and its mean position over this region can be seen as can the northward and westward extent of the Bermuda High. Climatic modifications due to the presence of the Great Lakes and the Appalachians are also evident in the statistics. This mesoscale climatology was prepared in order to determine the frequency of occurrence of synoptic conditions which favour the generation of terrain-forced mesoscale circulations such as lake-land breezes and mountain-valley winds, part of a larger investigation into the impact of mesoscale atmospheric circulations on the long-range transport of air pollutants. However, this climatology can also be applied to such areas as air pollution potential climatology, evaluations of wind energy potential, and environmental impact assessments.

USING KING CITY DOPPLER RADAR TO FORECAST THE MOTION OF THE RAIN-SNOW LINE IN PRE-WARM-FRONTAL PRECIPITATION CASE STUDY, NOVEMBER 25, 1987
Michael Leduc

On November 25, 1987 a major precipitation event occurred across Southern Ontario. Precipitation amounts of 30 to 50 mm water equivalent were common across much of the south with this storm. These amounts were well predicted by

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the numerical models and by the Ontario Weather Centre forecasts. The phase of the precipitation was however very poorly handled especially in areas just to the north of Metro Toronto. Forecasts indicated that mostly rain would fall but instead, these areas received 20 to 30 cm of heavy wet snow and a significant period of freezing rain.

One of the main inputs which led to forecasts of mostly rain was that the rain/ snow line was initially north of Toronto and with warm advection forecast by the numerical progs, it was expected that the line would move slowly northward during the day.

This paper will show how wind profiles from King City Doppler indicated that the easterly cold outflow from a Quebec high was quite deep (6 thsd feet) and how winds in this outflow were actually backing with height indicating that cold air advection was continuing through the layer. The recognition that this cold air advection was going on might have provided the forecaster the evidence he needed to confirm that the rain/snow line would not move northward and might even have shown a slight southward motion. especially combined with some evaporative cooling as the precipitation began.

Doppler radar data will be examined through the day of November 25 to see how it related to the changes in precipitation phase reported across Southern Ontario.

THE LAKE-EFFECT SNOWSTORM OF 5-6 JANUARY 1988 IN SOUTHERN ONTARIO

Brian P. Murphy

Conventional surface and upper-air aeorological data are combined with satellite, conventional, and doppler radar data to give a description of a major lake-effect snow storm which dumped in excess of 50 cm of snow across Southern Ontario between the morning of January 5 and the morning of January 6, 1988.

Three-hourly surface analyses will be used to show that a thermally induced surface mesolow and trough line remained nearly stationary for about 12 hours. Conventional and doppler radar data will be used to show that the band of heaviest snow was associated with the surface mesosystem which was the result of the passage of a very cold air mass across the open waters of Lake Huron and Georgian Bay. The combination of convergence, extreme low-level instability, and a significant fetch across the open waters of Lake Huron and Georgian Bay created conditions conducive for the generation of locally very heavy flurries and snowqualls along the trough line. Snowfall rates of up to 9 cm per hour were reported in the heaviest snowqualls.

MOMENTUM TRANSFER IN SEVERE DOWNSLOPE WINDSTORMS

R. Laprise and W.R. Peltier

The analysis of the dynamical stability properties of finite-amplitude internal gravity waves launched by the flow of a stratified unbounded fluid over an obstacle reveals that Long's solution to the nonlinear steady-state equations for the mountain wave problem is not physically realizable from the initial value problem when a critical wave steepness is exceeded. This critical wave steepness is characterized

by the simultaneous appearance of overturning streamlines (rotors), a neutralization of the ambient stratification by the internal wave, and a local Richardson number less than one quarter. It is found that the dominant unstable mode takes the form of a deep resonant disturbance which derives its growth by conversion of the kinetic energy associated with the shear in the basic state nonlinear wave through the action of the Reynolds stress. A detailed diagnostic momentum budget calculation performed on the data produced by a numerical simulation of breaking mountain waves resulting in a severe downslope windstorm reveals the interplay between the divergence of vertical flux of horizontal momentum transported by the mountain wave, the acceleration of the flow, and the pressure difference across the obstacle.

SIMPLE GUIDELINES FOR ESTIMATING WIND SPEED AND TURBULENCE VARIATIONS DUE TO SMALL-SCALE TOPOGRAPHIC FEATURES

J.L. Walmsley, P.A. Taylor and J.R. Salmon

The paper by Taylor and Lee (1984), describing simple guidelines for estimating wind speeds on hilltops and at similar complex terrain locations, has attracted considerable attention and is being widely applied. In our use of these guidelines we have found it desirable to make several improvements and additions to the procedures. Specifically, we have added an option which makes appropriate adjustments to the wind data from a nearby reference site if there is none available just upwind of the topographic feature or roughness change under consideration and we have included an option for rolling terrain (i.e., a situation in which the upstream terrain is not flat). The calculation of internal boundary layer (IBL) heights generated by changes in surface roughness has been modified and a calculation of turbulence intensity has been incorporated. These changes will be described and results of sample applications will be presented.

We have found it useful to code the guidelines as an interactive program for use on IBM compatible microcomputers. A copy of the software may be obtained on request by sending the first author a floppy disk, either 5.25 inch (13.3 cm) double-sided double-density or 3.5 inch (8.9 cm). The files to be provided include a source program in Microsoft QuickBASIC Version 3.0, stand-alone executable files (for use on microcomputers with or without a math coprocessor), a documentation file and a sample output file.

THE WARM RAIN REVOLUTION
Roland List

The combination of laboratory experiments on the collision and breakup of drops, numerical modelling of rainshafts and rain measurements in Malaysia have given new exciting insights into warm rain. In particular: 1) Warm rain in 1-dimensional shafts has size distributions of invariant shape, independent of rainfall rate. 2) All relationships between any rain parameters are linear, in particular the Z/R relationship. Thus, the radar reflectivity is proportional to the rainfall rate. 3) Experimental data on steady warm rain taken in Penang confirm these findings. This means that radar has much improved and simplified applications in the tropics.

GROWTH OF LOW-DENSITY GRAUPEL IN AN ICING TUNNEL
Roland List and Stewart Cober

The growth of graupel was simulated in a closed circuit wind tunnel. Twenty-seven sets of growth conditions were produced at laboratory pressure (100 kPa) by varying temperature from -10 to -20°C, updraft velocity from 1.5 to 2.5 m/s and liquid water content from 1.0 to 3.0 g/m^3. The final mass and density were parameterized in terms of the cloud characteristics and the growth time, and comparisons were made with natural graupel and other laboratory investigations. The density was found to decrease with growth time until it reached an equilibrium value (between 0.14 and 0.41 g/cm^3) which was dependent on the temperature and updraft velocity. Mass growth rate was dependent on all the stated cloud parameters. This investigation is the first to successfully grow and study conical graupel.

A 1-D MICROPHYSICAL MODEL DRIVEN BY RADAR DATA
Luc Ostiguy and Isztar Zawadzki

The evolution of precipitation in a CASP storm was studied using radar data and a model of the growth of precipitation in which microphysical processes are parametrized. The model is driven by vertical velocities obtained from radar data under the assumption of equilibrium between the rate of precipitation growth and the rate of generation of supersaturation.
The model indicates that the equilibrium is indeed established by the time the precipitation reaches the ground. The model results are used in turn to improve the estimate of vertical velocity from radar data. Thus, an interactive and convergent method is developed by which microphysical information can be inferred from radar observations.

COMPARISON BETWEEN CIRCULARLY POLARIZED S-BAND RADAR FIELDS AND GROUND PRECIPITATION PATTERNS
Jean St-Pierre and Enrico Torlaschi

Data from the four channels of circularly polarized S-band radar together with precipitation measurements from a volunteer-operated network and from three instrumented vehicles directed underneath the high reflectivity zones of hailstorms are analysed and compared. The data were collected during the 1983 summer season as part of the field research activities of the Alberta Research Council's Atmospheric Sciences Research Program. Because the radar returns from the farther sections of storms could be affected by passage through the precipitation close to the radar, a correction procedure on the data of individual range gates is applied. The ability of this radar to distinguish between rain and hail is being evaluated from the data and will be presented.

THE VERTICAL PROFILE OF SEA SPRAY CONCENTRATION OVER THE OCEAN SURFACE· A NUMERICAL SIMULATION
Y. Zhuang, E.P. Lozowski and J.D. Wilson

The primary objective of this study is to calculate the vertical profile of the concentration of spray drops above the ocean surface, relating these to the controlling parameters (drop size and emission velocity, friction velocity, $u*$, and surface roughness, z_o). The profiles are calculated using the trajectory simulation approach. By numerically simulating the stochastic turbulent trajectories of a very large number of ejected spray droplets (with a range of sizes and ejection velocities), the average liquid water content has been deduced as a function of height from the average residence time of the droplets in each of a set of horizontal layers above the ocean surface.

1530-1710: (Ontario) **Tuesday / Mardi**
SESSION 4B: WAVES II
SESSION 4B : VAGUES II

OBSERVATIONS OF SPECTRAL CHANGES OF WAVES IN SHOALING WATER
M. Skafel, M. Donelan, H. Graber, P. Liu, D. Schwab and S. Venkatesh

In the fall of 1985 the Canadian National Water Research Institute (NWRI) and the U.S. Great Lakes Environmental Research Laboratory (GLERL) conducted a field measurement program in Lake St. Clair to assess the effect of shallow water on wave characteristics and predictability. Six towers were installed over a distance of twenty kilometres and a range of water depths from 3.7 m to 7.0 m. Each tower was equipped with wave staffs and alternate towers also measured wave directional properties. Four meteorological buoys provided representative estimates of over-lake winds and stability. The highest waves observed had characteristic heights of 1.8 m and peak periods of 5.3 seconds or wavelengths of 36.6 m in water depth of 7.0 m. The spectra of these waves

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are compared to equivalent deep water spectra and the differences in, particularly peak spectral density and equilibrium range slope, are noted and related to wavelength-to-depth ratios. A useful prognostic variable in many parametric wave models - the ratio of wave energy to phase speed of the spectral peak - was found to be unaffected by water depth. This result has significant consequences for parametric wave modelling in shallow water.

OBSERVATIONS AND MODELS OF WAVE-INDUCED SEDIMENT RESUSPENSION IN LAKE ST. CLAIR
T.J. Simons, W.M. Schertzer, M.G. Skafel and M.A. Donelan

Measurements of currents, waves, suspended solids and sedimentation were conducted on Lake St. Clair in 1985. These data are described and are used to calibrate models of the water circulation and to develop a sediment resuspension model. A dynamic relationship between suspended matter and wave orbital velocity is derived at a tower site based on simultaneous measurements of waves and suspended solids. The model is extended to other locations in the lake by deriving bottom orbital velocities based on wave parameters computed from a conventional steady-state wave model. The resulting sediment resuspension model is used to compute net sedimentation values, which are compared with sediment trap data. The analysis suggests that an accurate wave model is a pre-requisite for modelling sediment resuspension in shallow lakes.

THE IMPACT OF SEASAT-A SCATTEROMETER WINDS ON OCEAN-WAVE ANALYSIS AND MODELLING
R. Lalbeharry, M.L. Khandekar and S. Peteherych

The short-lived satellite SEASAT(28 June-10 October 1978) provided valuable wind/wave data for approximately 100 days over the North Atlantic ocean. On board the satellite an oblique-viewing microwave radar, known as SEASAT-A Satellite Scatterometer (SASS), was used to sense high resolution over-water winds in approximately 1400-km swaths extending across the sub-satellite tracks. In this study the dealiased SASS winds have been objectively blended with the conventional ship winds to produce a suitable wind field for driving a spectral ocean wave model. The objective analysis scheme used here is the method of successive correction, modified to account for the variable data density, data quality, and the application of an elliptical weighting function. The analysed winds are produced initially on a rectangular grid over the North Atlantic and are then transformed onto a spherical orthogonal grid for input to a spectral ocean wave model. The model products are examined and validated against the observed in-situ and remotely-sensed wave data to provide an assessment of the impact of SASS winds on ocean wave analysis and modelling. Examination of the results indicate that SASS winds can provide a useful input for validating wave models in a hindcast mode. An analysis of wave height errors suggests that integration of SASS winds into the wind analyses generate wave height fields more accurately than those generated by using only the ship winds.

The goal of this study is to develop suitable algorithms for incorporating satellite-sensed wind and wave data into an AES spectral ocean wave model.

BED SHEAR STRESS ESTIMATES IN A SHALLOW LAKE
P.F. Hamblin and F.M. Boyce

Knowledge of sediment resuspension processes is vital to the understanding of the fate of contaminants in lakes. Theories accounting for the effect of wind-wave related orbital motions near the bed in enhancing the current boundary-layer shear stress, such as Grant and Masden (1979) and Christofferson and Johnsson (1985), require input of the bed roughness besides the wave orbital motion, wave frequency, mean current and angle between the waves and current. The effective bed roughness was estimated for an experimental site in Lake St. Clair by comparing the theoretical estimates of boundary-layer dissipation to observations of dissipation in the bottom boundary layer from a current profiler. Dissipation estimates were obtained by means of spectra of 0.5-s sampled currents by the method of Stewart and Grant (1962) except that wave influences are treated by linear filtration of the spectra and by the theory of Lumley and Terray (1983).

ON THE DEEP-WATER FETCH LAWS FOR WIND-GENERATED SURFACE GRAVITY WAVES
F. Dobson, W. Perrie and B. Toulany

During CASP an array of 9 wave buoys (3 directional, 6 not) was deployed along a 25-km line offshore from Martinique Beach, NS. A large set of high-quality wave spectra was collected in conjunction with extensive meteorological information. The data set is unique in the sense that a large onshore swell component was normally present.

Offshore-wind cases for three windows: ±5°, ±15°and ±30° with respect to the shore normal, have been considered. Wind speed was found to be a strong function of fetch, and this was allowed for in the analysis. Power-law regressions have been produced of dimensionless sea energy, peak frequency and high-frequency spectral level (the Kitaigorodskii "alpha" parameter) vs. dimensionless fetch and wind speed (inverse "wave age"). The regressions are compared with earlier work (the Joint North Sea Waves Project and the CCIW Lake Ontario data).

The comparisons indicate that the CASP wave energies were larger and peak frequencies lower than for earlier experiments at large dimensionless fetch, but about the same for small fetches. We attribute the differences to differences in fetch-averaged winds, and to the presence of shoreward-travelling swell.

SESSION 4C : POLLUTION

STATISTICAL FORECAST MODELS FOR TROPOSPHERIC OZONE POLLUTANTS IN THE LOWER FRASER VALLEY, B.C.
D.G. Steyn and S.M. Robeson

Statistical models for the temporal variation of daily maximum and hourly average ozone concentrations at two monitoring stations in the lower Fraser Valley, B.C., are developed in order to aid forecasting of adverse air quality. The models are developed using data from the years 1978 to 1985, and tested using data from 1986.

For the daily maximum concentration, three models are presented. They are a deterministic-stochastic model, an autoregressive, integrated, moving-average model, and a temperature-persistence model. The most successful of these is the temperature-persistence model, which performs significantly better than pure persistence, while the other two models are no better than pure persistence. These conclusions hold at both sites tested.

For the summertime hourly average concentrations, an exponentially-weighted persistence model and a lagged multivarigate regression model are presented. The regression model uses lagged values of ozone and nitrogen dioxide as forecast parameters. Both models have considerable forecast capability as shown by comparison with data for 1986.

MESOSCALE ATMOSPHERIC DISPERSION: A COMPARISON OF TRACER OBSERVATIONS AND NUMERICAL PREDICTIONS
Michael D. Moran, Roger A. Pielke and Richard T. McNider

Mesoscale atmospheric dispersion may be defined as the transport and diffusion of an air pollutant or other atmospheric constituent over horizontal distances of between 20 and 1000 km and time periods ranging from several hours to several days. The multi-country contamination experienced during the 1986 Chernobyl disaster is one recent example of mesoscale dispersion. A mesoscale tracer experiment was carried out in the central United States in July, 1980 to study this phenomenon. Two perfluorocarbon tracers were released from a single site in Oklahoma during a three-hour period into a northerly flow. Tracer concentrations were monitored along two sequential sampler arcs, one located 100 km north and one located 600 km north of the release site. Tracer concentrations up to three orders of magnitude above background levels were detected along both arcs.

A mesoscale atmospheric dispersion modelling system has been used to simulate this tracer experiment. The dispersion modelling system consists of two coupled numerical models, one a prognostic three-dimensional mesoscale meteorological model and the other a Lagrangian particle dispersion model. Model predictions were compared to observations with respect to plume arrival time, intensity, width and duration. A number of sensitivity experiments were also carried out to examine the influence of terrain slope and synoptic-scale environment on the plume dispersion predictions. The nocturnal low-level jet usually present over this region in the sum-

mer was found to play an important role in the transport and diffusion of the perfluorocarbon plume, suggesting the need for a realistic treatment of the planetary boundary layer in modelling mesoscale atmospheric dispersion. A comparison of the performance of this mesoscale dispersion modelling system with other long-range, short-term dispersion models which have been applied to the same data set supports this view.

ARCTIC AIR POLLUTION: A CASE OF HEMISPHERIC TRANSPORT
L.A. Barrie

From December to April the Arctic air mass is polluted by man-made mid-latitudinal emissions from fossil fuel combustion, smelting and industrial processes. For the rest of the year pollution levels are much lower. This is due to less efficient processes of pollutant removal and better south-to-north transport during winter. In winter the Arctic air mass covers much of Eurasia and North America. Meteorological flow fields and the distribution of anthropogenic SO_2 emissions in the Northern Hemisphere favour northern Eurasia as the main source of visibility-reducing haze. This has recently been assessed quantitatively using a Lagrangian chemical transport model. A Canadian Arctic air pollution research program supported by the Atmospheric Environment Service has been in effect since 1979. It involves long-term baseline measurements in the High Arctic, chemical-transport modelling and studies of the chemical/physical processes unique to the northern polar region.

In this paper the nature of Arctic air pollution is briefly reviewed with an emphasis on knowledge gaps. A significant recent discovery is that over the Arctic ice-cap at polar sunrise the destruction of lower tropospheric ozone is occurring. This is linked photochemically with a bromine compound, bromoform, that is most probably of natural origin from marine biota under the ice-cap. This phenomena helps explain the large springtime variability persistently observed in surface ozone concentration in Alaska and on Northern Ellesmere Island.

TOWARD ESTIMATION OF CLIMATIC EFFECTS DUE TO ARCTIC AEROSOLS
Jean-Pierre Blanchet

During the last decade, the estimation of the climatic implications of principal anthropogenic aerosols (soot and sulphates) has been investigated by observation and modelling efforts at three scales of dimension: 1) the aerosol scale where the optical properties are determined, 2) the kilometre scale where the radiative fluxes and diabatic heating are felt, and finally 3) the regional and hemispheric scales where the climate question pertains. This paper summarizes the current results on these three scales, with an emphasize on the comparisons between observations and model results.

Category 1: OCEAN AND LAKE CIRCULATIONS
Sujet 1 : CIRCULATION : LACS ET OCÉANS

A MODEL OF RELEVANCE TO GULF STREAM RECIRCULATION
Richard J. Greatbatch

Potential vorticity conserving solutions have been found numerically for an eight-level quasi-geostrophic ocean. The solutions have features in common with observations of the Gulf Stream and its recirculation.

CIRCULATION IN A LARGE SHALLOW NORTHERN ESTUARY
L. Veilleux and R.G. Ingram

Measurements of current velocity , temperature , salinity and water level were made over a period of 2 months in Rupert Bay , a large (875 km^2) and shallow estuary located on the southeastern corner of James Bay . From the analysis of time series , the main features of the circulation and mixing patterns were evaluated . The tidal amplitude is large and mixing is sufficiently intense to create vertically homogeneous conditions in many areas . Secondary flows are important . Fronts and lateral gradients of temperature and salinity were also observed . The effects of wind stress on the dynamic balance of the estuary will be discussed

HORIZONTAL MIXING IN THE ATLANTIC EQUATORIAL UNDERCURRENT ESTIMATED FROM DRIFTING BUOY CLUSTERS
B.K. Pal and B.G. Sanderson

We reanalysed the relative dispersion of four clusters of drifters in the Atlantic Equatorial Undercurrent. Drogue depths were 70 to 90 m and the cluster dimensions were 3 to 10 km. The analysis was carried out for three different cases of advection: (i) extracting the mean cluster motion, (ii) extracting the mean cluster motion and displacements due to linear deformations from the initial position and (iii) extracting the mean cluster motion and displacements due to instantaneous deformations. The residual tracks are then used to calculate the mean eddy kinetic energy, space-time correlation of the Lagrangian velocity, integral time-scale, mixing length and eddy-diffusivities. The ratio of the mixing length to standard deviation of position is found to lie between 0.1 and 0.2.

SEA-ICE MOTION OFF LABRADOR AND EASTERN NEWFOUNDLAND
Ingrid Peterson and Graham Symonds

Sea-ice motion off Labrador and eastern Newfoundland was monitored in the early months of 1985 to 1987, using 28 satellite-tracked beacons deployed on ice floes. Six of the beacons were equipped with anemometers positioned at 2 metres above the ice surface. About 40 - 60% of the variance of daily ice velocity on the shelf could be explained by the geostrophic wind, while up to 70% could be explained by using anemometer winds instead.

Daily ice movement was also estimated by tracking ice features in sequential visible AVHRR satellite imagery. The resulting velocity fields agreed well with the ice beacon velocities, and revealed the influence of spatially-varying currents in the vicinity of the various banks and saddles on the shelf.

SEA-ICE PROGRAM OFF LABRADOR AND NEWFOUNDLAND SHELVES
S. Prinsenberg

A 5-year sea-ice program (1985-1990) at B.I.O. is determining by observation and modelling, the motion and southern extent of the sea-ice pack off Labrador and Newfoundland Shelves. Satellite-tracked beacons are being developed and provide along with sequential satellite images ice drift data. The first three years of data show that the wind stress dominates the ice drift forces. Model results have provided insight to several physical processes along the ice-edge but are hampered in their effort to determine the southern sea-ice extent due to the lack of the ice volume flux entering the area from the north. Although the sea-ice program can provide LIMEX with estimates of ice drift data along the Labrador coast, it is just starting to develop ice-thickness satellite tracked beacons which are required to provide the ice volume flux not just the ice areal flux. Data show that the seasonal variability of ice thicknesses along the eastern Canadian coast depends on the persistence of northwesterly cold air flow in winter, which also encourages the southern transport of ice from Davis and Hudson Straits into the Labrador Sea.

THE ROLE OF REMOTELY SENSED IMAGERY IN ICE FEATURE AND PROCESS DETECTION IN EAST COAST PACK-ICE DURING A SEVERE ICE EVENT
Scott Paterson and S. Digby Argus

During March 1987 a joint remote sensing and oceanographic experiment took place over the northern Grand Banks. The experiment, the Labrador Ice Margin Experiment (LIMEX), coincided with an unusual severe ice event which resulted in a hazardous ice situation along the eastern coast of Newfoundland and the closure of St John's port. This paper presents remotely

sensed imagery of this situation from NOAA and LANDSAT satellites, Atmospheric Environment Service (AES) side-looking airborne radar (SLAR) and the newly commissioned Canada Centre for Remote Sensing (CCRS) C-Band Synthetic Aperture Radar (SAR) system.

The imagery illustrates the dramatic changes in the pack-ice extent and composition that occurred between 13-26 March. Initially, between 4-11 March, winds were predominantly westerly and then northerly. During this period, the pack extended to its maximum southern and eastern extent, a situation illustrated by imagery taken 11-13 March. On March 15, the wind became north-easterly, then south-easterly, a change which caused the ice to be compacted in a 20-km band against the shore during a period of poor visibility, and a number of ships were beset. This is illustrated by imagery from 14-20 March. On 20 March, winds changed to bear from the north-east and with temperatures above 0°C., swell penetrated into the ice from the open ocean. The situation is demonstrated by imagery taken from 23-26 March.

Imagery shown here demonstrates the use of remotely sensed imagery for monitoring ice events on the East Coast. It also demonstrates the complementary nature of the data from different instruments and platforms, and the value of radar data for identifying features of importance within the pack.

SOME SAR RESULTS OF THE LABRADOR EXTREME WAVES EXPERIMENT (LEWEX)

A.S. Bhogal

The LEWEX experiment which took place off the east coast of Newfoundland in March 1987, provided an opportunity to observe ocean waves with a number of remote and in-situ instruments. As one of several major aircraft instruments taking part in this experiment, the C-band synthetic aperture radar (SAR) aboard the CCRS CONVAIR 580 aircraft acquired ice imagery in transit and ocean imagery over the LEWEX site.

The SAR data acquired during LEWEX show a number of interesting features which include open ocean waves and waves and eddy signatures in ice.

In this paper, some results from LEWEX will be presented which centre around the computation of directional spectral estimates from SAR imagery of waves in the ocean and ice. In particular, trends in the data, the dependence of SAR spectral estimates on the range-to-velocity ratio (for both ocean and ice imagery) and aircraft velocity corrections to the spectral estimates will be addressed. Future directions in pursuit of methods for estimating calibrated directional wave height spectra from SAR imagery of ocean waves will also be presented.

COMPARISON OF AIRBORNE MICROWAVE DIGITAL IMAGERY FROM LIMEX'87

Michael John Collins

The Labrador Ice Margin Experiment (LIMEX) was conducted off the eastern coast of Newfoundland. The study period (March) was to have coincided with the period of maximum ice extent and the onset of its retreat. While meteorological conditions conspired against

this goal, a great deal of useful surface, airborne and satellite measurements were collected. The image data used in this study are from the CCRS C-band SAR and the NORDA K_a band radiometer. The presentation of the data involves pertinent instrument specifications and imaging geometries of the two sensors, detailed flight lines, photographs of the digital imagery as well as strategies for the intercomparison study.

SEA-ICE EXTENT AND ANOMALIES IN THE GREENLAND AND LABRADOR SEAS

L.A. Mysak and D.K. Manak

Ice extent and anomalies in the Greenland and Labrador Seas were studied using monthly Arctic sea-ice concentration data for the 32-year period 1953-1984. (Sea-ice concentration is defined as the fraction of a $1^{\circ} \times 1^{\circ}$ grid area covered by ice and is given in tenths.) Data from both of these seas reveal smooth annual cycles in the ice extent. However, while the Labrador Sea is nearly ice-free during summer, the Greenland Sea remains about 50% ice-covered during this season.

A large positive ice anomaly of up to 25% of the seasonal cycle was observed in the Greenland Sea for the 1962-1972 period, with the peak occurring in 1968. In the Labrador Sea, on the other hand, there was a large positive anomaly which extended over the years 1970-1974, with the maximum occuring in 1972. To study in more detail these and other ice anomalies during the whole 1953-1984 period, the Greenland-Labrador Sea region was divided into 5 subregions and time series of monthly anomalies were obtained for each subregion. A cross-correlation analysis of the anomalies from these smaller regions revealed a consistent pattern of lags, which implies the continuous movement of both positive and negative ice anomalies southward along the east coast of Greenland and into the Labrador Sea, and then southward along the coast of Labrador and northeast coast of Newfoundland. The average "speed of travel" of these ice anomalies is 2.7 cm s^{-1}, which is roughly the same as the average current speed (2-3 cm s^{-1}) of the subpolar gyral circulation and also the advection speed of "The Great Salinity" anomaly in the northern North Atlantic (Dickson et al., 1988).

TURBIDITY AND TEMPERATURE GRADIENTS OBSERVED IN THE GREAT LAKES USING NOAA/AVHRR DATA

A. Touré, A.R. Condal and G.J. Irbe

The temporal, spatial and spectral resolution of the AVHRR combine to form an excellent tool for monitoring changes in water quality, temperature patterns and coastal upwelling. AVHRR is especially useful in monitoring surface water temperature patterns over time, both because of the spectral bands of the instrument and the high resolution of the temporal coverage. This capability applied to the Great Lakes and nearshore areas permits to detect periodic changes in water quality and temperature throughout the year. This will in turn allow us to better understand the influences of weather changes in

the Great Lakes region. Ratio near IR/visible and temperature maps for lakes Ontario, Erie, Huron and Superior have been produced. Their values have been correlated for different surface types: water, clouds, lands surfaces, snow and ice-covered surfaces. These correlations and periodicities in time will be presented and discussed.

All of our AVHRR data (1982 → 1985) have been acquired from the archives of the Aerospace Meteorology Division of the Atmospheric Environment Service in Downsview, Ontario. The AVHRR data are geometrically and radiometrically corrected, then an optional correction is applied to compensate for atmospheric effects. Cloud/water and ice/water discriminators have also been applied to the data.

A temporal analysis of time series of AVHRR near-IR/visible and temperature maps have been performed and analysed as a function of several meteorological parameters.

Category 3: WAVES
Sujet 3 : VAGUES

DESCRIPTION OF THE "WAVES" PLATFORM AND RELATED EQUIPMENT

J. Valdmanis, I.K. Tsanis and M.A. Donelan

The WAVES experiment took place in 1985-86-87 on specially built towers and platforms at the west end of Lake Ontario, near Hamilton. Extensive wind and wave related experiments were conducted by the National Water Research Institute, the Woods Hole Institution of Oceanography, the Naval Research Laboratory and other institutes. This poster and the associated video film introduces the studies, emphasizes the hardware constructed, and indicates the scale of operation.

The main platform stood in 12 metres of water, 1.1 km offshore. Three supplementary towers were placed nearer to shore. Two waverider buoys were at 4 and 11 km offshore. An onshore trailer collected data via underwater cable links. The main sensed parameters were water (wave) levels, water currents, air speed, pressure and backscattered microwave energy. Several of these high-speed sensors were mounted on special positioning devices, including a new hydraulic-powered wave follower. The total number of sensors exceeded 60 and the total amount of data collected during the three years was about 5 billion measurements.

The experiments are expected to yield results that will permit more accurate calculations of the mixing of pollutants spilled on the surface of lakes and oceans; will extend knowledge of the interchange of energy, heat and gaseous pollutants between the atmosphere and the lakes and oceans; will improve our understanding of how winds generate waves and ocean currents; and

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will improve the accuracy of engineering design of offshore structures.

High-speed computers will be used to reduce this enormous data set to a much smaller set of statistics that will then be used to describe the physics of the air-water interface in ways that will be meaningful to environmental scientists and modellers. In the final step of the basic research-to-practical applications route, modellers will then use the statistical information to produce improved models (pollution dispersal, wave forecasting, weather forecasting, etc.) that are the tools for the appropriate management of natural resources or that contribute to public safety.

GENERAL STRATEGY AND RESULTS FOR A GREAT LAKES WIND-WAVE RESEARCH PROGRAM AT THE ATMOSPHERIC ENVIRONMENT SERVICE

Stephen Clodman

A systematic research program in large-lake wind-wave modelling is under way at the Forecast Research Division of the Atmospheric Environment Service. Scale analysis is used to define the conditions for a simplified yet accurate wind-wave model for large lakes. The Donelan-Schwab non-spectral model is found suitable. Some improvements to this model were found to give highly refined results when used with NDBC buoy case studies on Lake Michigan. The new version of this model will be implemented operationally.

The work can be extended in several useful ways. Test runs at different buoy locations would obtain comparative climatology for the different Great Lakes. A simple correction to the wave height might give a reasonably accurate model for moderately shallow water such as most of Lake Erie. Another version would be used for smaller (and possibly shallow) lakes such as Lake St Clair. The model can also be usefully applied to enclosed seas and bays of the ocean - a study has been made on the Beaufort Sea. Provision can be made for varying ice boundary (e.g. Beaufort Sea). More generally, large lakes make a very good location for the study of young wind-driven waves.

WIND STRESS OVER WIND WAVES: EXPERIMENTS ON LAKE GENEVA

N. Merzi

A fixed platform, installed 100 m from the shoreline in a 3 m water depth on Lake Geneva, Switzerland, was instrumented with velocity, temperature and wave-height sensors including cup anemometer profiles up to 13 m. One hundred and thirty-two data sets were analyzed to calculate the wind stress in the constant stress layer. The variation of the wind stress has been examined as a function of the wind speed, U_{10} and the roughness Reynolds number, $R_{e*} = u_* z_o/\nu_a$, where u_* is the friction velocity, z_o is the roughness length, and ν is the kinematic viscosity. In addition, dimensionless parameters characterising wind and wave fields, such as inverse wave age U_{10}/C_p and wave steepness, H_s/λ, have been found to stratify the data; where C_p is the celerity of the dominant waves, H_s is the significant wave height and λ is the wavelength.

Additional measurements were conducted close to the interface with

special Pitot-static tubes between 0.50 m and 2.23 m to examine the variation of the wind stress as a function of height. As a rule, the logarithmic distribution of the wind speed holds at levels higher than 2.0 m. On the other hand, there is a tendency for the wind stress to be slightly less towards the interface (around 80%) where the data were quite scattered. The ratio of the wind stress measured close to the air-water interface to the wind stress in the constant stress layer is plotted as a function of dimensionless height, z/λ. A clear height dependency is not evident.

ALGEBRAIC AND NUMERICAL TURBULENCE MODELS OF WIND-DRIVEN WATER CURRENTS

I.K. Tsanis

The equation of motion in the x-flow direction, see Figure 1, for a steady two-dimensional, wind-driven nearly horizontal flow (boundary-layer assumptions are applied) in homogeneous media (no-stratification) in the x-z plane, and neglecting the acceleration terms, is in nondimensional quantities

$$0 = \bar{P}_h + \frac{d^2\bar{u}_h}{dz_h^2} - \frac{h}{\nu u_s}\frac{d\,\overline{u'w'}}{dz_h} \qquad (1)$$

$$z_h = \frac{z}{h}\,,\ \bar{u}_h = \frac{\bar{u}}{u_s}\ :\ \bar{P}_h = \frac{h^2}{\mu u_s}\frac{dp}{dx}$$

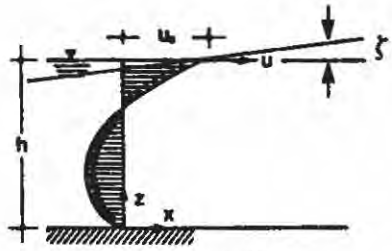

Figure 1

with the boundary conditions $\bar{u}_h\,(z_h = 0)$ and $\bar{u}_h\,(z_h = 1) = 1$. In the above $p = \rho g(h + \zeta - z) + p_a$, p_a = atmospheric pressure, ρ = density, g = acceleration due to gravity, ν = kinematic viscosity, ζ = surface elevation, u and w = velocity components in x and z directions, the bar denotes temporal mean values while the prime denotes fluctuating quantities.

Solution of Eq. (1) with an appropriate "turbulence closure" hypothesis yields the velocity distribution $\bar{u}_h = \bar{u}_h\,(z_h)$. Zero to two-equation algebraic and numerical models of steady two-dimensional wind-induced water currents are reviewed in this paper. In particular, the existing mean velocity profiles and the assumed or calculated eddy viscosities based on the above turbulence models are compared.

A review and sensitivity analysis of distributions of mixing lengths on the mean velocity current distribution are presented and conclusions are drawn.

The finite-element approach is used to obtain solutions of Eq. (1) based on an arbitrary variation of the eddy viscosity distribution. Linear shape functions are introduced into Eq. (1) and the optimization is carried out by differentiating the functional with respect to nodal values and setting the derivatives to zero. The element influence matrix yielded relates the $\bar{P}_h$ and $\bar{u}_h$. Examples for a parabolic eddy viscosity distribution are presented.

The calculated velocity profiles based on the above models are compared with existing laboratory and field results and conclusions are drawn.

COMPARISONS OF SOME WAVE PREDICTION MODELS

C.T. Bishop, M.G. Skafel, M.A. Donelan and K.K. Kahma

Comparisons of some wave prediction models are made using data from several sources. Results from three different one-dimensional wave climate models are intercompared for a deepwater site near Stoney Creek on Lake Ontario. One of the wave climate models, the PHEW model, is used for detailed comparisons against measured wave data at sites in Lakes Ontario, Erie and St. Clair. The wave prediction formulas of JONSWAP, SMB and Donelan are all used with the PHEW model. Modifications to the JONSWAP formulas, proposed in the 1984 edition of the U.S. Army Corps of Engineers Shore Protection Manual, are evaluated in a steady-state comparison against 1972 Lake Ontario data.

Results show that these empirical formulas can be used to give acceptable estimates of wave height and period in both steady-state and one-dimensional wave climate models. The older SMB formulas appear to give the best overall results. Predictions of dominant wave direction show poorer correlation with measurement. The Donelan algorithm to estimate wave direction improves the prediction of directions slightly.

The Donelan two-dimensional wave model has been developed from its original single storm version to run as a wave-climate model over time periods of years. Comparisons with measured data show good agreement and marked improvement with respect to the prediction of wave directions.

INTRODUCTION OF AN ICE FACTOR IN A THIRD-GENERATION WAVE MODEL

Diane Masson and Will Perrie

Wave modelling in regions partially covered by ice should include the effect of the ice cover on the development of the wave spectrum. To this end, a new energy term is included in the energy balance equation, which is integrated here with the help of a third-generation wave model, the so-called WAM model. The latter is based on an explicit representation of the input, non-linear and dissipation source functions. The wind input follows the Bight of Abaco experiment of Snyder et al. and the dissipation, the general form suggested by Hasselmann for the dissipation due to small-scale white-capping processes. The non-linear transfer due to wave-wave interactions is obtained from a discrete interaction parameterization of the Boltzmann integral without a priori assumptions on the shape of the spectrum. The effect of ice cover, which strongly depends on the ratio of the ice floe diameter to the wavelength, is introduced in the propagation scheme to account for the extra dissipation and the increase of the directional spread about the mean wave direction. These two processes affect the ice cover in accordance with the estimated values of the attenuation and scattering cross-sections of the floes. The integration is performed for the case of a simple rectangular ocean and for the more complex situation of the LIMEX/LEWEX experiment, and preliminary results are presented.

Category 4: BIOCHEMISTRY AND OCEANOGRAPHY
Sujet 4 : BIOCHIMIE ET OCÉANOGRAPHIE

VOLUME-FREQUENCY DISTRIBUTIONS OF MARINE PHYTOPLANKTON IN A TEMPERATE NERITIC ENVIRONMENT

Louis A. Hobson

A seasonal study was carried out to determine whether or not volume-frequency distributions of near surface nano- and microplankton were approximated by a power function model in temperate neritic waters. Measurements of buoyancy frequency, the nutrients, NO_3-N, $Si(OH)_4$-Si, and PO_4-P, phytoplankton photosynthetic pigments, and cell concentrations and volumes were made around a frontal zone in the Strait of Georgia, Canada, at approximate triweekly intervals from April 1983 to September 1984, excluding the months from October to February. The model accounted for a large percentage of the variance in spectra when nano-flagellates and dinoflagellates dominated phytoplankton crops in pre-diatom bloom and nutrient depleted waters. When diatoms dominated crops, the fit was better in summer than in spring months and often was positively correlated to temperature. The possible covariance of temperature and grazing by large omnivorous zooplankters on diatoms was considered.
Most of the values for the exponent of the power function varied around a value of -0.92, which was derived from linear regression analysis of a logarithmically (to the base e) transformed allometric equation. A geometric mean or functional regression slope was used because the slope varied with the correlation coefficient and because the relationship describes an allometric dependence (Ricker, 1973).
Results support the use of a power function model to predict volume-frequency spectra of temperate neritic phytoplankton whenever diatoms are not abundant or from the time of the demise of the spring diatom bloom until at least the early fall season when diatoms are abundant. The presence of diatoms, such as Lauderia borealis, Skeletonema costatum, and Thalassiosira nordenskioldii in larger numbers than predicted by their cell volumes invalidates use of the model during spring months.

GEOCHEMICAL AND STABLE ISOTOPE STUDIES OF MEDITERRANEAN SEA SAPROPELS

S.E. Calvert and M.R. Fontugne

The origin of organic-rich horizons (sapropels) in sequences of normal sediments from the eastern basin of the Mediterranean Sea is poorly understood. Two hypotheses currently debated involve the preferential preservation of deposited organic matter under anoxic conditions and an increased supply of carbon to the sediments during periods of increased primary production. Studies of the major and minor element geochemistry of the bulk sediments and the stable isotopic composition of the organic fraction place some constraints on these two explanations.

In a single piston core from the continental slope off the Nile, the del 13C value of the carbon in the sapropels lies between -21 and -22‰

whereas the normal marls have values around -17‰. This contrast shows that the organic material in the sapropels and the marls has different sources, and this signifies that the oceanographic conditions have varied during the accumulation of these two facies. This in turn indicates that the formation of the sapropels simply by the preservation of the carbon is unlikely. The sapropels are also enriched in Ba relative to the aluminosilicate contribution; this strongly supports an increase in primary production during the sapropel events. The combined information is consistent with an increased carbon flux as the most likely mechanism for the formation of the sapropels.

ORGANIC MATTER ENRICHMENTS, CARBON ISOTOPES AND OXYGEN DEPLETION IN THE GLACIAL EASTERN PACIFIC: ARE THEY LINKED?
Thomas F. Pedersen

A series of recently published models suggest that a vertical restructuring of the oceanic distribution of nutrients could be responsible for the decrease in atmospheric CO_2 observed during glacial periods. Such models require as a corollary that the concentration of O_2 in deep water must have decreased concurrently, and it has been suggested that such a depletion may have been responsible for the ubiquitous enrichment of organic matter found in glacial-age sediments in the eastern equatorial Pacific. However, detailed comparison of carbon isotope measurements made on planktonic and benthic foraminifera, with the profile of the sedimentary organic carbon distribution in a core from the central Panama Basin, demonstrate that the peak period of organic carbon accumulation (in late Glacial Stage 2) is independent of the somewhat earlier increased gradient in ^{13}C between surface and bottom waters. Because the gradient can be related to the difference in oxygen concentration between the surface and the deep ocean, these data suggest that the enrichment of sedimentary organic matter which characterizes the last glacial maximum in the east Pacific did not result from accumulation under oxygen-deplete conditions.

A MULTIVARIATE ANALYSIS OF ENZYMATIC ACTIVITIES AND BIOCHEMICAL CHARACTERISTICS OF IN SITU MARINE PLANKTON
Jean-Pierre Chanut and Mayzaud Patrick

The activity levels of digestive enzymes and the abundance of marine zooplankton species measured during a spring bloom were studied in order to identify d the relationship between enzymatic activities and biochemical or spectral characteristics of in situ marine plankton.
A principal component analysis of instrumental variables originally introduced by Rao as an extension of the PCA and multiple regression methods is presented in terms of Escoufier's RV coefficient between two sets of variables and applied to these data.
Some close associations between the laminarinase and the very small particles appear at the beginning of the spring bloom in conjunction with a high abundance of phytoplankton feeders (as barnacle nauplii) at 5-m depth. Similarly, a clear association between trypsin and the larger size particles appears during the second part of the spring bloom in conjunction with the abundance of different species of copepods. This succession could bring some new in-

sight in the question of the definition of ecological compartments, or in the question of surveying the temporal successions of zooplankton in terms of biochemical measurements in situ.

AN OXYGEN MODEL FOR ICE-FREE AND ICE-COVERED RESERVOIRS

R.C. McCrimmon, P.F. Hamblin, W.J. Snodgrass and A.A. Smith

Modelling of dissolved oxygen in ice-free lakes and reservoirs has received considerably more attention than for ice-covered water bodies. Undesirably low dissolved oxygen concentrations usually occur during warmer ice-free periods but can also occur during ice-covered periods due to the absence of dissolved oxygen sources such as reaeration and primary productivity. The one-dimensional dynamic reservoir simulation model, DYRESM, which is well tested for temperature and salinity in ice-free and ice-covered lakes and reservoirs, has been extended in this study to include dissolved oxygen and particulate and soluble phosphorus. The cycling of phosphorus between particulate and soluble forms is used to simulate biomass formation and decomposition. Redfield stoichiometry is applied to determine the corresponding release and consumption of dissolved oxygen. Phosphorus return from the sediments and particulate phosphorus settling are also included. The model requires daily meteorological input as well as inflows, outflows and inflow parameter concentrations to simulate vertical profiles of the water quality constituents on a daily basis.

Applications to two reservoirs in Southern Ontario and a lake in Northern Ontario are shown to result in reasonable agreement with field observations. The hypolimnetic anoxia that both reservoirs experience was successfully simulated. Sediment oxygen demand accounted for 80% of this oxygen loss. At the surface of the reservoirs production rates fluctuated widely but the effects were generally counterbalanced by reaeration. Simulation of the Northern Ontario lake showed production and decomposition to be neglible during ice-cover. However, lack of data did not allow for rigorous calibration for this lake. The model also predicts that the quality of the bottom water in the northern lake is improved by the proposed construction of a reservoir engulfing the lake site.

THE ESTIMATION OF CRUDE OIL EVAPORATION IN THE AES OIL SLICK PREDICTION MODEL

A. Bishnoi, J.D. Covill, A.Y. McLean and V.R. Nerella

Under the conditions of a typical oilspill, information on the composition of the spilled oil is usually unknown within the time limits required to prepare a usable, real-time forecast (or NOWCAST) of slick behaviour.

For example, the composition of crude oil likely to be encountered during exploratory or development drilling is almost inevitably unknown and drilling engineers and petroleum geologists can only make estimates of oil type such as heavy crude, light crude, or condensate.

Since immediate real-time forecasts are essential for the on-scene commander at a spill, he cannot make effective use of oil slick trajectory models which require knowledge of the composition of the spilled oil to calculate evaporative losses.

This paper describes work to develop a method of estimating evaporative losses of crude oils using compositions inferred from an initial assumption about specific gravity, which, of all the oil property parameters, is the one which is most readily available or estimated.

The relationship between specific gravity and composition was established by examining a data base of 626 crude oils. Correlations were established between specific gravity of each crude and the proportion of the following fractions, C_1-C_7, C_8-C_{12}, C_{13}-C_{18}, and the residuum. Thus the specific gravity could be used to develop a low component composition which could then be used to estimate rates of evaporation using the Rasult's low-type approach.

The paper demonstrates the use of the technique within the framework of the new microcomputer version of the AES real-time oilslick prediction model EORS (Emergency Oil Spill Response Software). EORS is also discussed.

Category 5: ATMOSPHERIC DYNAMICS
Sujet 5 : DYNAMIQUE ATMOSPHÉRIQUE

LOW-PASS FILTERED PERSISTENCE OF 50-KPA HEIGHT ANOMALIES

Amir Shabbar

The persistence of the planetary-scale 50-kPa height anomalies for 1946-66 is documented. Persistence is expressed in terms of the degree to which a height value north of 30°N remains constant during the next several pentads. The purpose of this study is to examine the skill of persisting antecedent and/or perfect prognosis pentads that have been subjected to the first five monthly empirical orthogonal function (eof) of the following month. The results are stratified by climatological seasons.

Since we are interested in examining the persistence skill of the planetary-scale features, only the low-order eofs containing information about large-scale features are used. These eofs will filter out small-scale atmospheric circulation features. The starting sequence consists of antecedent and/or perfect prognosis pentads that have been combined using both exponential and linear weights.

A number of verification statistics, including per cent correct sign, pattern correlation and root-mean-square error of the height anomalies are calculated. The verification is performed on raw observed data as well as eof filtered data and the results are compared with the simple persistence of the unfiltered data.

COMPUTER ENTRAILS AND THE CLIMATE BUSINESS
E.P. Lozowski and C. Nguyen

A thermal index, derived from the monthly mean temperature time series for Edmonton Municipal Airport, exhibits a recent interesting temporal structure, with possible implications for climate dynamics and extended range forecasting. What this has to do with computer entrails and the climate business will be revealed.

Category 6: OPERATIONAL WORKSTATIONS
Sujet 6 : SYSTÈMES OPERATIONNELS

ISIS: INTEGRATED SYSTEM FOR ICE SENSING
A. Fraser and R.A. Gorski

Weather conditions can be significant factors in the operation of Ontario Hydro's power system. There are occasions when preventative action, limits on the flow of electricity, and reconfiguration of the power system are required due to adverse weather conditions. Adverse weather conditions such as freezing precipitation and saturated atmospheric conditions near freezing may result in sustained outages on the Ontario Hydro bulk power system due to the formation of various ice phenomena.

The Ontario Hydro Integrated System for Ice Sensing (ISIS) consists of a network of passive ice monitors and active ice detectors. Passive ice monitors are used to measure ice accretion amounts on horizontal and vertical surfaces and around cylinders which simulate conductors. This quantitative data is used in the testing and verification of ice accretion models for simulating design values of ice loads.

Active ice detectors provide real-time monitoring on the presence of ice accretion, dry bulb temperature and humidity conditions. The system is designed to alert power system operators to the presence of icing conditions and to provide the Ontario Hydro Meteorology Centre with real-time data on icing conditions at major nodes on the transmission network.

The active ice detector system consists of:

- A Rosemount ice detector mounted on the station microwave tower.

- A Campbell Scientific Model 201 temperature/relative humidity probe.

- A Campbell Scientific CR21 data logger and modem.

Icing signals are annunciated in the control room of the transformer station and are accessed hourly by a Hewlett-Packard HP 1000 minicomputer which handles all real-time data processing for the Ontario Hydro Meteorology Centre.

Meteorological operations staff utilize this information in conjunction with other data sources in locating, tracking, and forecasting the duration of icing events which may pose a risk to bulk transmission of electricity in Ontario.

The ISIS network consists of eight passive ice monitors (in operation since 1982) and seven active ice detector systems (in operation since October 1987) located at major transformer stations in southern Ontario.

SWORD: A SEVERE WEATHER FORECAST AND DETECTION SYSTEM

Richard W. Miller and Klaus H. Schaedlich

Ontario Hydro provides electric power to the province of Ontario from 68 hydroelectric stations, seven fossil-fueled stations, and four nuclear stations. Some 26,500 kilometres of transmission line make up the Bulk Electrical System which delivers power to customers across the province. The Ontario Hydro Meteorology Section developed the Severe Weather Forecast and Detection System (SWORD) to provide power system control centre operators with information regarding severe weather which might jeopardize the security of the power supply.

SWORD is a real-time operational tool designed to:

1) Process and analyse large amounts of weather data (surface observations, upper-air data, digital radar data, and lightning locator data).
2) Provide a simplified user-oriented evaluation of severe weather which could adversely affect the power system.

The SWORD system processes 16 weather parameters through 18 criteria (conditions) to provide detection and short-range (half-hour) forecasts of tornados, lightning, high winds, freezing precipitation, and fog. Output is provided for each of 402 grid squares measuring 64 km x 64 km. The SWORD output software consists of a package of five programs.

1) Current SWORD Output - a graphics map display of the current severe weather status of each grid square.
2) System Severe Weather - a tabular output of power system facilities in each grid square in which severe weather is occurring and the nature of the weather.
3) SWORD Display and Edit - an interactive graphics map display which allows the forecaster to preview and edit input data fields.
4) Severe Weather Review - a diagnostic program which allows the forecaster to view input data values, condition status, and output for a selected grid square.
5) SWORD Review - a graphics display of the total number of severe weather occurrences in each grid square which have been detected in the last six hours.

The SWORD Programs run on a Hewlett-Packard HP 1000 minicomputer, which handles all of the real-time data processing for the Ontario Hydro Meteorology Centre. Input data consists of surface and upper-air observations obtained from Environment Canada and the US National Weather Service, digital radar data from Environment Canada weather radars, and lightning data from an LLP lightning detector network. The SWORD system is automatically scheduled every half hour and the status of each grid square - detection, high potential for occurrence, low potential for occurrence, not detected or data missing is evaluated for the

highest priority weather element occurring. Weather elements are scanned in priority order: 1) tornado, 2) lightning, 3) high winds, 4) freezing precipitation and 5) fog.

This information is passed via data link to the power system control centre's Data Acquisition and Computer System (DACS) for the use of system control operators. To our knowledge this is the only such facility in use for power system operations in Canada.

RADAR DATA PROCESSING SYSTEM: ON THE USE OF FULL-SCAN RADAR DATA IN SEVERE WEATHER FORECASTING

H.P. Biron

A prototype Radar Data Processing System (RDPS) has been in use at the Centre Météorologique du Québec since October 1987. This system allows real-time reception and processing of full volumetric data from the McGill radar for use by operational forecasters. RDPS provides meteorologists with a powerful tool to display and analyze radar data in multiple ways and to produce short-term forecasts of precipitation; the capabilities of the system allows an in-depth determination of thunderstorm structure and evolution as well as a better diagnosis of thunderstorm severity in an operational environment. RDPS is thus an invaluable tool to monitor severe storms, leading eventually to the issuance of weather warnings whenever the situation warrants.

This poster session will illustrate briefly the RDPS structure, functionality and components; several types of outputs from RDPS will be displayed, with strong emphasis on the interpretation of these outputs and their use in an operational severe weather forecast desk environment.

A CODED MARINE FORECAST PREPARATION SYSTEM

Allan W. MacAffee

A software package has been developed to assist meteorologists at the Maritimes Weather Centre (MWC) in composing the marine forecast. This package, referred to as the "COded MARine Program" or COMAR, allows the forecaster to enter meteorological data into a computer-generated form using an aviation style format. The coded message is converted into marine forecast bulletins, in both English and French, which are similar in both content and tone to that manually prepared by forecasters.

There are several advantages to COMAR: the amount of time devoted to typing the forecast is dramatically reduced which, in turn, allows the forecaster more time to assess meteorological elements; a more standardized bulletin is produced with emphasis on the more important elements; the quality of the final product is meteorologically dependent, not language dependent; internal consistency is better maintained; changes can be incorporated to within minutes of deadline. Furthermore, COMAR automatically copies the coded data to an archive file. By storing the coded data, the entire forecast is available for subsequent verification.

Category 7: MESOSCALE AND BOUNDARY LAYER
Sujet 7 : ÉCHELLE MOYENNE ET COUCHE LIMITE

STRUCTURE OF A NORTH PACIFIC FRONTAL SYSTEM
G.A. McBean and R.E. Stewart

During the Storm Transfer and Response Experiment, 3-hourly profiles of wind, temperature and humidity were made during the passage of an occluded frontal system. Further, a weather radar was used to map the distribution of rain elements in the clouds. The basic structure of the front will be described. Analysis of the radiosonde and surface data allow for the computation of the main terms in the equations for rate of change of horizontal temperature gradient, transverse wind shear and static stability. It was found that low-level convergence, which is a major factor on frontogenesis over land, has little impact on frontogenesis over the oceans due to the smoothing of near-surface temperature gradients by thermal exchange with the ocean. The frontolysis due to the tilting of isotherms by the differential vertical motion and frontogenesis ahead of the existing front by diabatic heating are the main effects. In the shear budget, the tilting term and convergence terms are both important. This analysis demonstrates the importance of various physical processes to the decay of a front over the ocean.

SECONDARY FRONTAL DEVELOPMENT OBSERVED DURING CASP - COMPARISONS WITH THEORY
R. Paul Ford and G.W. Kent Moore

A two dimensional Hoskins-Bretherton type frontal zone has been shown by Moore and Peltier (1987) to be unstable to perturbations with along-front wavelengths of approximately 1000 km. This model assumes a front which is much longer than it is wide with velocities along the front greater than those across the front, as is generally observed in synoptic-scale situations. The mode of instability which exhibits the largest growth rate is still essentially a baroclinic phenomenon, though the length scale of the resulting disturbance is around 1000 km and the vertical depth is less than 4 km. Storms with such dimensions have been observed in nature, examples of which are polar-front lows, polar lows and comma clouds.

An examination of CASP data indicated that several of the cases of significant cyclogenesis off the east coast possessed some of the features described above. In particular, IOP's 3,4,6 and 11 were chosen for more detailed study on the following basis. Firstly, they formed along an existing frontal zone which may have at least partly been due to the passage of a previous storm. These zones were quite long in extent and therefore satisfy one of the assumptions of the theory. Next, they showed little structure at 500 mb through much of their lives and so must have been relatively shallow. Lastly, their trajectories take them through the heart of the CASP upper-air network, thereby making study of their vertical structure possible.

Sounding data are interpolated to a 3-D Cartesian reference grid. Vertical and horizontal cross-sections of the wind and temperature fields are compared to those derived by the theory of Moore and Peltier. The embedded mesoscale structure as seen in the CASP radar data is displayed and preliminary comparisons with regions of convective instability predicted by Moore and Peltier are made. Future work will involve the use of GALE data to study these systems in their genesis stages.

OBSERVATIONS OF THE THERMODYNAMIC ENVIRONMENTS ASSOCIATED WITH LAKE-EFFECT SNOWBANDS USING PORTABLE RADIOSONDE EQUIPMENT

Gregory P. Byrd and Tom Niziol

The forecasting of lake-effect snow events to the lee of Lake Erie and Lake Ontario has proven to be a difficult problem. The only regular sounding location to the lee of these lakes is at Buffalo. Unfortunately, only a few of the Buffalo soundings are launched within heavy lake-effect snowbands. Many more soundings within and adjacent to these features are needed if we are to adequately understand their environments and bring about forecasting improvements.

A current observational effort eliminates the problem of a fixed sounding location through the use of a portable radiosonde unit. The equipment can easily be transported to the vicinity of a lake-effect snowband using a standard passenger vehicle. The radiosonde can be readied and launched within 10 minutes. During the winter season of 1987-88, approximately 20 of these soundings were launched in various locations throughout western New York. Soundings were launched prior to squall development as well as within well-developed lake effect squall bands. In addition, soundings were launched in clear regions adjacent to the snowbands and were compared to the innerband soundings.

Preliminary results show that prior to band development, the boundary layer is well mixed and achieves a mixing condensation level, with a capping inversion some distance above. Soundings within the band show moist adiabatic lapse rates and saturated conditions, with a capping inversion and drying immediately above the band. When compared to soundings taken outside of the band, the innerband soundings show a higher inversion level. This indicates penetration of updrafts above the synoptic inversion for distances of one-half kilometre or more in some instances. This would appear to be in agreement with observed radar echo top and sounding comparisons in many lake-effect events.

A COMPARISON OF THE WIND OVER THE ICE-PACK TO THAT OF A COASTAL STATION IN HUNDSON BAY

Pierre Larouche

A comparison is made between two weather stations separated by 25 km. One is situated in Great Whale River (Hudson Bay) and the other is on the fast ice cover 12 km from shore. The first is a permanent installation of the Canadian Atmospheric Environment Service and the second is an Aanderaa automatic weather station operated for a period of 32 days. The two records are examined for possible differences that could result from local orographic effects.

SIMPLE MODELS OF DIABATICALLY FORCED MESOSCALE CIRCULATIONS AND THE ROLE OF RESONANCE

Alain Robichaud and Charles A. Lin

Analytical solutions for a 2-dimensional airflow over diabatic sources are derived using a 2-dimensional, linear, Boussinesq, inviscid, hydrostatic model. Flows over an elevated diabatic source, a surface diabatic source and also over a combination of both sources are considered. The elevated source is identified as due to cooling by melting while the surface source is associated with land/sea temperature differences. Melting frequently produces near $0^{o}C$ isothermal layers. The atmosphere in this case tends to have strong static stability in the melting layer, capped by a much less stable layer aloft. This creates a strong change in the vertical wavenumber, which might lead to resonant amplification of mesoscale perturbations. A piecewise uniform model for the vertical wavenumber is used to demonstrate this resonant response. Resonance conditions for both types of diabatic sources are derived and compared. Comparison with sounding data obtained from CASP suggests that the resonance mechanism is potentially important for precipitation enhancement due to melting.

Category 8: CLOUD PHYSICS
Sujet 8 : PHYSIQUE DES NUAGES

RAIN SPECTRA AND EQUILIBRIUM PEAKS MEASURED IN TORONTO IN 1987

Roland List and Robert Nissen

With rain spectra from Malaysia taken for warm rain and serving as a baseline other spectra have been measured in Toronto with the same equipment, namely a Joss-Waldvogel Disdrometer and a PMS 2-DC Grey Scale Spectrometer Probe. Peaks in the drop size distributions emerged at similar equilibrium values as predicted by Valdez and Young (1975) and List, Donaldson and Stewart (1987). The results show a "streaky" pattern of rain packages arriving at the ground, similar to those for convective precipitation in Malaysia, but shorter in duration and with smaller horizontal dimensions. Many raindrop packages, however, do not show the evolution with time as those from Malaysia do. Instead of a time delayed arrival of subsequently smaller drops - leading also to an overlap of packages and associated transient peaks - the new data often (but not always) show simultaneous arrival of drops of the whole spectrum. This new pattern is associated with the high wind to which the sampling station was exposed during rainfall on top of a 16-story building. This strongly suggests that the sorting mechanism observed in Malaysia during convective precipitation is associated with shear in the boundary layer rather than with pulsating rain clouds.

MÉTHODE DE CORRECTION DES EFFETS DE PROPAGATION SUR LES MESURES DE RADAR À POLARISATION CIRCULAIRE À 3 GHz
Bernard Pettigrew and Enrico Torlaschi

Lorsque l'onde émise par un radar est polarisée circulairement, il est utile d'interpréter le signal reçu, polarisé elliptiquement, comme étant le résultat de la superposition de deux ondes circulaires orthogonales. Ce changement de l'état de polarisation est causé par la non-sphéricité des hydrométéores en tant que cible et en tant que milieu de propagation. Si on veut éviter des interprétations hasardeuses des mesures de radar, les effets introduits par la précipitation, comme milieu anisotropique de propagation, doivent être attentivement considérés.
Les composantes circulaires de l'onde reçue peuvent être décrites par le biais des paramètres de polarisation: le facteur de réflectivité équivalent, Z_e, le rapport de dépolarisation circulaire, CDR, et la covariance complexe des deux composantes, $\rho \exp(j \phi)$. Ces derniers sont reliés à leurs homonymes propres à la cible via le terme de propagation $p \exp(j \chi)$. Ces relations s'expriment à travers un système de quatre équations, six inconnues, à savoir: Z_{ei}, CDR_i, ρ_i, ϕ_i, p et χ (l'indice i indique les paramètres intrinsèques de la cible). Toutefois, à 3 GHz il a été montré que pour la pluie $\phi_i \simeq 0$ et $\chi \simeq \pi/2$. Ces hypothèses permettent de fermer le système d'équations et d'estimer les valeurs des paramètres de polarisation Z_{ei}, ρ_i, CDR_i et de p. Dans le but de valider cette méthode, des observations de radar à polarisation circulaire provenant d'un modèle simple de précipitation sont simulées numériquement à l'aide des principes de fonctionnement de ces radars. Par la suite, les valeurs intrinsèques des paramètres de polarisation sont estimées. Finalement, on trouve que ces derniers sont voisins des valeurs propres à la cible.
En conclusion, l'application de la méthode qu'on propose permet de mieux interpréter les mesures de ce type de radar.

Category 9: IMPACT AND RESPONSE
Sujet 9 : RÉPERCUSSIONS ET INTERVENTION

ENVIRONMENTAL EMERGENCIES: AN AES RESPONSE SYSTEM
Evelyn E. Wilson and James. Salmon

Accurate and timely information on present and forecast weather conditions are vital when responses are made to the accidental release of hazardous substances into the atmosphere. During these emergency events, quick decisions must be made by lead agencies and first responders on evacuation, containment and clean-up actions based on readily available atmospheric data and guidance materials. Support services and technical expertise on atmospheric phenomena are also needed in real-time.

The AES Environmental Emergency Response (EER) Program and Emergency Weather Station (EWS) system are presented and discussed. Real-time response services provided by AES and activities to ensure an ongoing state of preparedness are briefly described. The recently developed EWS prototype 1 system for deployment by regional offices during emergencies will be introduced.

A DEMONSTRATION METEOROLOGICAL MONITORING NETWORK IN THE VICINITY OF PICKERING NUCLEAR GENERATING STATION

Peter Taylor, James Salmon and Lily Truong

The possibility of accidental releases of toxic material from a nuclear generating station(NGS) in Canada is minimal, but still needs to be considered in safety analyses and in the preparation of emergency response plans. In the event of such a release, wind speed and direction, together with other meteorological parameters, are among the important data which would be needed by emergency response teams attempting to deal with the situation. In complex terrain or coastal areas, near-surface winds and diffusion characteristics can exhibit substantial spatial variation which should be recognised and taken into consideration. This is not possible with the present Pickering NGS meteorological instrumentation and, as a consequence, very conservative meteorological assumptions had to be made in safety analyses. More detailed measurements of low-level surface wind and the vertical profiles of wind and temperature would allow better determination of diffusion characteristics and could be of considerable help in an emergency situation.

In order to demonstrate the type of network of surface meteorological stations which could be installed, and to collect one year's data for safety analysis and model validation purposes, the Atmospheric Environment Service (AES) of Environment Canada, in collaboration with the Atomic Energy Control Board (AECB) and the Ontario Ministry of the Solicitor General, have deployed one primary station, comprising a 26 m profile tower and a PAQMOS (Portable Air Quality and Meteorological Observing System) 10 m post, and eight secondary stations with 10-m PAQMOS posts in a temporary network around the Pickering NGS. This network will be described and preliminary data will be presented to illustrate the type of spatial variations that can occur.

0830-0950: (Ballroom) **Wednesday / Marcredi**
SESSION 6: THEME PLENARY II
SESSION 6 : PLÉNIÈRE II

THE APPLICATION OF REGIONAL-SCALE NUMERICAL MODELS TO THE STUDY OF EXTRATROPICAL CYCLONES THAT PRODUCE SEVERE WINTER WEATHER

Louis W. Uccellini

Since the late 1800s, meteorologists have debated the role and relative importance of various physical and dynamical processes in the development of extratropical cyclones. The debate continues today, especially with respect to studies of rapid cyclogenesis along the East Coast of the North American

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continent and over the North Atlantic Ocean that produces severe winter storms in the United States and Canada.

In this presentation, a review is offered that shows that the theoretical basis for cyclogenesis has displayed a remarkable circular evolution. In the late 1800s, latent heat release was considered the important driving mechanism for cyclones. By 1950, the dynamical processes associated with amplifying waves were thought to provide the energy exchange required for cyclogenesis. By 1980, physical processes associated with oceanic boundary-layer and latent heat release were again emphasized as primary forcing mechanisms in rapidly developing storms. The review also illustrates how numerical models have played a critical role in the most recent transition, where model sensitivity studies have been used to demonstrate the important contribution of latent heat release and boundary-layer exchange processes. Nevertheless, the overabundance of model sensitivity studies has perhaps put too much emphasis on the "either-or" approach to describing the relative importance of one process (latent heat) over others (boundary-layer, upper-tropospheric dynamic processes) and vice versa. Evidence is presented from observation- and model-based diagnostic studies that indicate that the rapid cyclogenesis associated with severe winter weather represents a situation in which all of the physical processes must interact in a way that induces a "self development" in which all of the processes feed back upon another in a positive manner. The model-based studies indicate that the individual physical and dynamical processes may represent necessary conditions for rapid cyclogenesis, but are not sufficient to produce the major storms. It is only through a synergistic interaction between dynamical features associated with trough-ridge patterns and jet streaks and physical processes associated with latent heat release and boundary-layer physics that the rapid cyclogenesis will proceed.

The review will also include an illustration of how the voluminous information associated with a model simulation of an East Coast storm can be displayed with a four-dimensional graphics device to better illustrate (1) the interaction of various diagnostic fields associated with cyclogenesis and (2) the airflow through the cyclone before and during the rapidly developing phase of the storm.

IMPACT OF SEVERE WEATHER PHENOMENA OVER WATER

T.S. Murty

The impact of severe weather phenomena over water could be seen and felt in diverse forms, such as: storm surges, seiches, wind waves and swell including giant waves, icing on marine structures, marine fog, oil tanker accidents leading to oil spills, early closing and late opening of seaways (e.g. St Lawrence Sea way) due to heavy ice flows, water spouts due to meso-scale atmospheric phenomena, flash floods in rivers and lakes, flash floods due to sudden lifting of ice jams in rivers due to sudden and unusual warming and ice push and ice ride up on shores causing damage to coastal structures. After an initial brief discussion of water spouts with a few examples over Lake Winnipeg and elsewhere and examples of ice push and ride up on Lake St Clair and James Bay, most of the talk will be confined to a discussion of storm surges, due to the limited time available.

Starting in about the mid-1960's storm surges have become the world's foremost natural hazard, surpassing even earthquakes in terms of deaths and destruction. This problem is getting steadily worse due to coastal erosion and more and more people living near the coastlines (about one third of the world's population). The storm-surge problems are discussed as a global problem and not just in Canadian waters. One has to distinguish between the generally west-to-east travelling extra-tropical cyclones at higher latitudes and the east-to-west travelling tropical cyclones at lower latitudes. Embedded in these synoptic scale systems are meso-scale systems such as squall lines.

The tangential wind stresses and sea-level atmospheric pressure gradients associated with these travelling weather systems cause storm surges in shallow coastal waters. After a discussion of the relevant equations including the influence of an ice layer, storm surges in various water bodies on the globe will be critically examined and compared. Specifically storm surges in the Great Lakes, Eastern Canadian Waters, Gulf of Mexico, Bay of Bengal and the north Sea will be considered. The very imporotant role of tides in storm surge-prediction will be discussed.

1020-1200: (Ballroom) **Wednesday / Mercredi**
SESSION 7A: CASP
SESSION 7A : PCETA

A NEW DEVELOPMENT EQUATION AS AN AIDE FOR UNDERSTANDING EXPLOSIVE DEVELOPMENT IN CASP/GALE STORMS

Peter Zwack

Recently, a number of studies have emphasized the existence of a special type of extra-tropical cyclonic storm that undergoes explosive cyclogenesis, i.e., its development phase, although rather short (< 24 h), produces pressure falls of the central storm pressure of more than 24 mb in 24 hours. This type of system occurs mainly over the oceans and is extremely dangerous as it produces extreme winds and waves. It has been named a "bomb" by Sanders and Gyakum (1980) and extensive recent studies have pointed out a number of the atmospheric characteristics associated with such rapid development. Up to now, however, there seems to be a lack of a relatively simple theoretical framework which could be used to understand how the various factors operate together to produce the explosive cyclogenesis. One of the goals of the CASP/GALE and especially ERICA programs is to try to understand the genesis and development of these intense weather systems.

Zwack and Okossi (1986) have recently presented the derivation of a new development equation that improves considerably on the classical Petterssen-Sutcliffe development equation by explicitly adding orographic, boundary layer, upper atmospheric (above the level of non-divergence) forcing as well as the effects of deep convection. In this paper, the development equation will be generalized so that it can be applied at any level in the atmosphere. In

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addition, in an attempt to understand the explosive development of the storm in CASP IOP 14 (March 6-8, 1986), results will be presented of an application of the development equation to an analytical storm, adjusted as much as possible to represent the structure of the atmosphere during IOP 14.

MICROSCALE, MESOSCALE AND STORMSCALE FEATURES IN WINTER STORMS

Ronald E. Stewart

Based mainly upon work conducted in association with the Canadian Atlantic Storms Program (CASP), increased understanding of winter storms has been gained at scales ranging from individual particles to fronts and to entire storms. Precipitation is often in the form of a mixture of types, although the heaviest precipitation amounts are often in the form of snow. At the surface, both warm and cold fronts are typically tied to transitions between precipitation types owing to the horizontal variation in diabatic forcing and the dynamic consequence of this. Storms themselves illustrate evolution and organization also linked to diabatically-forced circulations in conjunction with Coriolis effects.

It is anticipated that substantial improvements in forecasting at all scales will follow as the crucial role of microscale processes is incorporated into forecasting procedures and numerical simulations.

STORM FRONT MOTION ESTIMATED FROM MESONET WIND OBSERVATIONS IN CASP

Carl Anderson

Frontal passages associated with extratropical storms are typically marked by rapid veering of the surface wind. In a simple model in which the mesoscale structure of the storm is subject only to translation at the storm velocity, a front appears to propagate with a local velocity equal to the projection of the storm velocity on the local normal to the front. Thus when the fronts are oriented at small angles to the storm track, their apparent local velocities differ significantly from that of the storm itself.

The oceanic response to surface wind stress forcing, through the generation of anti-cyclonic rotating inertial currents, is dependent upon the mesoscale features of the forcing wind stress field, and may be significantly enhanced if the wind vector rotates in step with the resulting current. Thus, to fully account for the inertial response of the ocean to storm forcing, a description is required of the mesoscale forcing, including the apparent movement of storm fronts.

Surface (10 m) winds were recorded during winter storms in CASP by a triangular mesoscale network (mesonet) of seventeen

anemometer towers on the Nova Scotia mainland. The observed winds were highly coherent over distances of up to 100 km (the maximum tower spacing) over a frequency range of from 0.05 to 3 cph (half the sampling frequency). Rapid veering of the wind (180° in as little as 4 hours in some cases) marked the passages of fronts through the array.

The wind direction cross-correlations among the mesonet anemometers were used to estimate the local frontal propagation velocity through the mesonet in a case-by-case analysis. It was found that the propagation of fronts, as signalled by the observed wind shifts, was often at large angles to the storm track, resulting in frontal velocities of only a fraction of the associated storm velocities. The estimated frontal motion appears to account for features of the oceanic inertial response found in case studies of CASP storms.

ESTIMATES AND OBSERVATIONS OF THE CROSS-SHORE VARIATIONS OF NEAR-SURFACE WINDS AT THE LAND-SEA BOUNDARY DURING CASP

Peter A. Taylor, James R. Salmon, Fred W. Dobson, Will Perrie, Peter C. Smith and Bechara Toulany

The CASP 1986 field data include measurements of inland, coastal and marine near-surface winds from stations in the Halifax mesonet and from a Minimet buoy, 30 km offshore from Martinique Beach. They provide some interesting comparisons. Selected measurements will be used to provide wind input to the BIO studies of fetch-limited wave growth based on data from a line of wave buoys extending offshore from Martinique. In addition the data set contains some aircraft-based measurements of wind speed at approximately 50 m elevation along the buoy line.

The present paper will use 'Guidelines' estimates of local flow perturbations due to topography and surface roughness changes to 'correct' the data from the coastal mesonet sites. The guidelines will also be used to model the offshore wind and turbulence variations and to connect the aircraft and surface based measurements. Different empirical forms of offshore, near-surface wind variation on scales up to about 30 km, associated with roughness change effects, will be compared for use with fetch-limited wave-growth models.

INERTIAL RESPONSE TO CASP IOP 14, 6-7 MARCH 1986

Peter C. Smith

A case study of the response to the CASP IOP 14 storm indicates that the inertial wave field may be generated by a strong wind shift propagating onshore at a speed of 10 m s^{-1}. On the eastern side of the CASP mooring array, clockwise current oscillations propagate onshore in the surface layer (8.1 ± 0.9 m s^{-1}) while baroclinic waves in the pycnocline move offshore at roughly internal wave speed (1.8 m s^{-1}). Furthermore, the temperature and salinity fluctuations are in (out of) phase with longshore current in the deep (surface)

layer. These properties are consistent with two-dimensional models of Kundu (1986) and Millot and Crepon (1981). However, on the western side of the array, the inertial oscilltions are more complex; the clockwise current phase speed is considerably reduced by sharp steepening of the phase lines at the coast and evidence for offshore propagation of internal waves is less clear.

The implications of these observations for modelling the full three-dimensional inertial wave field will be discussed.

1020-1200: (Ontario) **Wednesday / Mercredi**
SESSION 7B: COASTAL OCEANOGRAPHIE I
SESSION 7B : OCÉANOGRAPHIE CÔTIÉRE I

FORTNIGHTLY PULSING OF SURFACE FRESHWATER OUTFLOW FROM JUAN DE FUCA STRAIT

D.A. Griffin, P.H. LeBlond, R.E. Thomson and B.M. Hickey

A 19-year time series of surface salinity data from lighthouses has been examined jointly with river discharge, tidal current and wind data to try to understand the relation between freshwater runoff into the Strait of Georgia and surface salinity fluctuations at the mouth of Juan de Fuca Strait. Strong tidal periodicities in salinity variations at MM (27.55 days) and MSf (14.76 days) at Race Rocks are related to fluctuations in tidal mixing in Haro Strait and other narrow and shallow passages connecting Georgia Strait to Juan de Fuca. The turbulent bottom boundary layer usually extends to the surface in these passages, preventing classical baroclinic estuarine flow by vertically mixing salt and momentum. For a few days during neap tides, however, a pulse of fresh water may escape from the Strait of Georgia; should the wind be from the northwest at that time, the resulting pulse is greatly enhanced. Current measurements from moorings at the mouth of Juan de Fuca Strait in 1984 and satellite imagery of surface temperature in the area confirm the correlation with tides and winds for that year.

PREDICTING THE RETURN ROUTES OF THE FRASER RIVER SOCKEYE SALMON WITH MULTIPLE REGRESSION TECHNIQUES

Liusen Xie and William W. Hsieh

The Fraser River sockeye salmon (*Oncorhynchus nerka*) returns via either the northern route of Johnstone Strait or the southern route of Juan de Fuca Strait. The percentage of salmon diverting via the northern route shows interesting interannual variability. Prior to 1977, the diversion rate was highly correlated with river runoff, whereas after 1977, the diversion was

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highly correlated with the coastal sea surface temperature instead. To resolve this strange phenomenon, stepwise multiple regression was used to identify the relevant physical variables that influence the diversion rate. Nonlinear effects and the presence of threshold levels were also incorporated.

MIXING AND TRANSPORT ON THE VANCOUVER ISLAND CONTINENTAL SHELF
William R. Crawford, Richard K. Dewey and Paul H. LeBlond

The continental shelf off the southwest coast of Vancouver Island supports the most productive fishery in British Columbia. Studies in the late 1970's and early 1980's discovered strong upwelling of nutrients onto this shelf, into bottom waters, through a canyon adjacent to Juan de Fuca Canyon.

We examine observations of turbulent mixing, water properties, and currents in this region to determine the rate at which the nutrients are mixed into surface waters, and transported over the shelf. Our observations of turbulence are confined to the middle two weeks in June 1985, during an upwelling period. Mixing at mid-shelf was most intense in the bottom boundary layer, but the turbulence at mid-depths was too weak to induce significant cross-isopycnal mixing. However, the intensity of turbulence in waters near shore, inside the 60-m contour, is significantly greater, and it is likely that the nutrients are mixed upward in this region. Once the nutrients are mixed into the near-surface waters, they are transported onto banks or into the Tully Eddy. Currents in both these regions for much of the spring and summer tend to trap nutrient-rich near-surface waters and support plankton blooms.

INFLUENCE OF FRESHWATER RUNOFF ON UNDER-ICE MIXING IN SOUTHEAST HUDSON BAY
R. Grant Ingram and S. LePage

In spite of low winter runoff levels, the areal extent of the under-ice freshwater plume of the Great Whale River is much larger than for higher discharges in open water. Ice type and distribution, neap-spring tidal current variations and large-scale atmospheric forcing are found to generate contrasting turbulence levels in the ice-water boundary layer. Acoustic current-meter profiles taken over a range of environmental conditions are used to characterize the variable mixing and its importance on nutrient flux to the ice-water interface. which determines levels of under-ice algal production. The potential environmental impact of hydroelectric development on the coastal waters of Hudson and James bays is discussed.

CIRCULATION AND MIXING PROCESSES IN THE MIDDLE ST. LAWRENCE ESTUARY
C. Bélanger, Y. Gratton and J.A. Gagné

Data sets from the summers of 1977, 1986 and 1987 were used to study the physical properties of the portion of the Middle St. Lawrence estuary between Ile-aux-Lièvres and Ile-Verte. The objective is to try to iden-

tify the oceanographic limits of the region with the geographic limits of the herring larval retention area. Preliminary results show that herring larvae tend to stay within the well-mixed side of a strong longitudinal turbidity and density front. The formation and lateral (cross-estuary) motion of this front are discussed.

1020-1200: (Aberdeen) **Wednesday / Mercredi**
SESSION 7C: CLIMATE II
SESSION 7C : CLIMAT II

AN APPRAISAL OF PHYTOPLANKTON-CLOUD ALBEDO-CLIMATE FEEDBACK USING A MEAN ANNUAL GLOBAL ENERGY BALANCE MODEL
Howard W. Barker and John A. Davies

The hypothesis that Earth's biosphere is a self–regulating "organism", the Gaia hypothesis of Lovelock (1986), opens intriguing avenues of investigation on possible climatic feedback mechanisms. Recently, Charlson et al. (1987) proposed one such feedback linking dimethylsulphide gas (DMS) produced by oceanic phytoplankton to cloud condensation nuclei (CCN), cloud drop density (CDD), cloud albedo and thus global climate. Using a mean annual global energy balance climate model this paper presents results of an initial investigation of DMS–cloud albedo feedback as a possible climatic stabilizing agent.

If CCN production is positively correlated with sea surface air temperature, cloud albedo feedback may be significant in stabilizing climate change. For negative correlation the converse is true. Two cloud adjustment mechanisms are considered: variable vertical optical depth with constant areal extent, and constant optical depth with variable areal extent. Our parameterization produces approximately equal strengths for these mechanisms. As expected, the DMS–cloud albedo feedback is most effective when active between the equator and 30 degrees south. First order estimates are given of the required changes in globally averaged CDD over oceans to counteract surface temperature changes due to changes in the solar constant and atmospheric carbon dioxide concentration. For example, a 35–50% change in mean CDD is needed to maintain a constant surface temperature when the solar constant is changed by 1%. Changes in CDD of this magnitude are often observed from one cloud to another and on time-scales less than seasonal. However, it is unknown whether such changes in mean annual zonally averaged CDD due to changes in phytoplankton population are realistic.

SURFACE ALBEDO ESTIMATES FROM NIMBUS-7 ERB DATA AND A TWO-STREAM APPROXIMATION OF THE RADIATIVE TRANSFER EQUATION
Howard W. Barker and John A. Davies

Solar zenith angle dependent surface albedo is determined by equating top of the atmosphere (TOA) fluxes evaluated from Nimbus–7 data with TOA fluxes predicted by a two–layer/two stream radiative transfer model of the atmosphere. Uncertainties in surface albedo are determined for effective water vapour paths between 10 and 30 mm and tropospheric aerosol broadband optical depths between 0 and 0.1. Surface albedos to direct and global irradiance are evaluated for solar zenith angles smaller than 82 degrees. Results

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are presented for two locations in Western Australia, the Sahara/Arabian desert, and a site in Saudi Arabia. They are compared with values from independent estimates, theoretical models and some GCMs. For zenith angles less than 60 degrees and sparse vegetation, effects of aerosols derived from the surface can probably be neglected. At low sun or for abundant vegetation, neglect of aerosol backscatter can lead to significant errors in surface albedo estimates. Seasonal mean values of precipitable water vapour and ozone are adequate for albedo estimates. Surface albedo estimates agree quite well with estimates from the δ–Eddington solution of the radiative transfer equation applied to sand and with estimates from a geometric model. Differences between our surface albedo estimates and those found in GCMs may be important to simulations of regional climate.

A STUDY OF THE EFFECTS OF VERTICAL MOTION ON OZONE OVER THE NORTH POLAR VORTEX

Lewis L. Poulin and W.F.J. Evans

The relationship between the total ozone field and the vertical motion field has been investigated for the northern polar latitudes in March, 1986. Stratospheric vertical motion has been computed by the adiabatic method for: (a) each of the 900 locations on a grid centred at the north pole and extending down to latitude 40°N; (b) each of the 100-mb, 50-mb and 30-mb levels; (c) twice-daily observing times during the period March 9, 1986 to March 23, 1986. Maps of the distributions of height, temperature and vertical motion on the three pressure surfaces are compared with the total ozone fields obtained from the TOMS satellite for March 1986 in order to study the effects of the dynamics of the wintertime north polar stratospheric vortex on the ozone.

A COMPARISON OF INCOMING SOLAR RADIATION AT MARINE AND CONTINENTAL STATIONS

F. W. Dobson and S. D. Smith

In modelling solar radiation from surface weather observations, different approaches have been successful with marine and land-based data. We apply a simple model, developed for the marine environment, to a marine and a high-latitude continental station to illustrate systematic differences in the dependence of the insolation on solar elevation, cloud and season. Relative to the continental station, the marine station has less insolation at low solar elevations, particularly in winter, but more insolation at high solar elevations. Two mechanisms are discussed to explain these differences.

BULK MODELS OF SOLAR RADIATION AT SEA

F.W. Dobson and S.D. Smith

With a view to improving climate prediction, we test various models for estimating solar radiation at sea from standard

meteorological observations against long time series of solar radiation measurements at several Ocean Weather Stations and at an offshore island meteorological station. The widely-used Budyko formula is found to err by up to 32% in estimating long-term mean insolation, and has even larger errors in reproducing seasonal variations.

Various models which estimate solar radiation from solar elevation and from hourly cloud amount and type, using empirical or simple physical formulae, are evaluated. None of these models estimates mean isolation better than an existing formula which relies only on noon solar elevation and mean cloud amount, although the hourly models do reproduce seasonal, monthly and daily variations better. None of the formulae which use standard surface observations is able to achieve the ± 10 W/m^2 accuracy in long-term mean insolation which is required for climate prediction.

1320-1440: (Connaught) **Wednesday / Mercredi**
SESSION 8: POSTERS II
SESSION 8 : AFFICHAGES II

The listing of posters is found on pages 50-69.
La liste des affiches est aux pages 50-69.

Thursday 9 June
Jeudi le 9 juin

0830-0950: (Ballroom) **Thursday / Jeudi**
SESSION 9: THEME PLENARY III
SESSION 9 : PLÉNIÈRE III

DOPPLER WEATHER RADAR AND THE CANADIAN SCENE
C.L. Crozier

In 1985 the first Doppler weather radar was established in Canada at King City, near Toronto, Ontario, by the Cloud Physics Research Division of the national weather service. The ensuing period has been a learning experience as this C-band facility has been developed, evaluated and adapted to research and operational weather service applications. A significant display of Doppler observations and analyses is now being provided regularly to the Ontario Weather Centre and others in real time. A selection of 6 of 12 available displays is routinely transmitted to these remote user sites. Hard copy and colour

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TV displays have been developed to provide a storage of about 1.5 hours of observations and the capability for interactive user display manipulation, including facilities to select displays, step and hold, animate, magnify and isolate areas.

Doppler technology has provided a new dimension to the radar observations of the past. The nature of the observations and present display techniques requires an adjustment in the user perception of the displays, and training and experience to adequately detect, interpret, and effectively apply the greatly enhanced mesoscale detail that becomes available.

First experiences with the Doppler facility have demonstrated its effectiveness in providing new insights into the detection, location and tracking of mesocyclonic circulations associated with severe thunderstorms and tornadoes, gust fronts, and low level wind shears of hazardous proportion. The ability to distinguish with reasonable confidence in incipient storms those that will become severe storms from those of a milder nature looks possible. Analyses for two seasons indicates that 80% of the major damaging summer storms have been identified pre-event from Doppler data compared with 30% for prior seasons. Wind profiles in the planetary boundary layer and the precise location of frontal surfaces can be continuously monitored in many circumstances. The mesoscale dynamics revealed in large-scale winter storms can explain hitherto unpredictable local anomalies. Clear air echoes observed within 40 km in summer have identified sea breezes and local convection.

The potential for the effective application of Doppler weather radar in some other areas of Canada is promising.

MESOCYCLONE AND RELATED SEVERE THUNDERSTORM DETECTION BY CONVENTIONAL AND DOPPLER WEATHER RADAR

L.R. Lemon

Radar is a very important tool in the identification of severe thunderstorm hazards. Recent United States surveys suggest that as many as 80% of the National Weather Service warnings are based on radar. Many of the currently used conventional radar criteria for severe thunderstorms are empirically determined without benefit of reliability studies and are unrelated to severe storm structure, physics and typical morphology. These typically perform poorly. Recently some progress has been made in recognizing severe convective storm structure and types and in deriving related warning criteria that are both subjective and objective.

A new operational tool is at hand. Severe storm and tornado warnings in real time by use of Doppler radar were forecast nearly a quarter century ago by Atlas (1963) and Chermitte (1964). That forecast is on the verge of being verified on a large scale in the United States by means of the installation of the Next Generation Weather Radar (NEXRAD). Much of the single Doppler radar usefulness for severe storm identification rests on recognition of the mesocyclone and tornadic vortex signatures (TVS) and their relationship to severe weather production. This presentation reviews severe thunderstorm classification, conventional radar recognition based on that classification, as well as the

application of Doppler radar to mesocyclone and TVS detection. The structure and life cycle of the typical supercellular mesocyclone and the recently recognized low shear, boundary-layer mesocyclone are considered. Finally the potential of the NEXRAD is also considered.

1020-1200: (Ballroom) **Thursday / Jeudi**
SESSION 10A: SEVERE WEATHER II
SESSION 10A : TEMPS VIOLENT II

OBSERVABLE CHARACTERISTICS OF THE SEVERE STORM ENVIRONMENT
Arjen Verkaik

The storm environment is a very special place in which many different cloud features and air motions combine to produce a more-or-less unified, single entity. It is useful to view this entity not as a cloud or specific thing but rather as an evolving process wherein the various parts are interacting with each other and contributing to a totality. What is seen at any one moment is then a set of visual manifestations of that process, excerpted from an ongoing spectrum of changing features.

The organization and intensity of severe storms results in a large degree of control over the near environment, which leads to a visual and dynamic integrity that is both observable and interpretable. This has widespread implications for the observer in evaluating the event as well as for the scientist in assessing the meteorological significance of separate components relative to their overall context.

The three most common severe convective events are the severe squall line, multicell storm, and supercell. Although their visual and structural features are distinct, a more fundamental interpretation based on the near-surface airflow patterns exhibits an inflow, outflow, and core region common to each storm type. The inflow is dominated by continuous cloud development above a low but relatively uniform rain-free base while the outflow region contains cooler air, higher bases (often with precipitation), and little vertical development. The core is the small, active location of the strongest updrafts and often coincides with the inflow/outflow interface at the surface. Near and beneath this part of the system, rapidly changing cloud features can signify fluctuations in overall intensity, shifts in dominance of either inflow or outflow, or the onset of a major change in structure, storm type, system propagation, etc. A keen awareness of cloud details and changes, when viewed within the context of each system's mesoscale structure, provides a highly accurate perception of both current and future weather conditions on the local scale and affords the observer a simple, fast, and available means of acquiring a working knowledge of such storms.

The author will present numerous slides of convective cloud systems to illustrate major storm characteristics, types, and transitions from one type to another. Visual features which provide clear evidence of the system's structure and probable evolution will be emphasized.

A SURVEY OF SEVERE SUMMER STORMS OBSERVED BY KING WEATHER RADAR
T.R. Nichols, P.I. Joe and C.L. Crozier

Mesocyclones, gust fronts, strong low-level jets and large vertical wind shears are associated with severe convective storms. Each of these features has a distinctive signature that may be identified using Doppler radar. This paper presents examples of these signatures observed by the King City Doppler Radar. These cases will show how the correct interpretation of the patterns leads to improved detection of severe events which subsequently should result in enhanced short-range forecasts and warnings.

THE DETECTION OF MESOCYCLONES WITH THE KING CITY DOPPLER RADAR
P.I. Joe, C.L. Crozier and T.R. Nichols

Mesocyclones have been intimately linked with severe weather and in particular tornadoes. A real-time Doppler radar analysis technique for their detection has been developed for the 5-cm King City radar. The pattern recognition algorithm looks for large shears in the radial velocity data, and correlates their intensity, spatial geometry, temporal and vertical evolution with model mesocyclones. Early results show that mesocyclones that lead to tornado development in southern Ontario can be much *weaker* than those found in Oklahoma where much of the tornado research has been done. Lead times of 40 to 50 minutes may be possible if early identification is made. The algorithm appears to be very sensitive and able to detect very weak mesocyclones and tornadoes. Not all severe storms have mesocyclones and the technique can distinguish those storms that have the potential to be tornadic. This will be most beneficial to the severe weather forecaster in issuing tornado warnings. These results also indicate that Doppler radar detection techniques for severe weather can *not* be directly transferrable from one locale to another.

EVALUATION OF THE IMPACT OF DOPPLER RADAR ON SEVERE THUNDERSTORM FORECASTING 1985 - 1987
Michael Leduc

Real-time Doppler products have been available to the Ontario Weather Centre since early 1985. Initial problems with resolution and mode of display were overcome in the first year. These improvements were followed by the development of pattern recognition techniques which made possible visual detection of mesoscale features such as convergence mesocyclones and gust fronts.

The study of hard-copy radial velocity outputs with resolutions of six metres/ second (m/s) revealed four Doppler signatures frequently associated with damaging thunderstorms:

1- strong low-level convergence (greater than three m/s kilometre)
2- mesocyclones with isodopes of velocity difference greater than eighteen m/s

3- gust fronts with radial velocities greater than twenty-four m/s
4- descending jets with radial velocities greater than 24 m/s

An important part of the pattern recognition technique involved meshing Doppler signatures with conventional data. Positive storm identification was best achieved by comparing the observed data to a conceptual model of the severe storm.

Forty individual severe storms were identified within range of the King City Doppler in 1987. The operational severe weather meteorologist scored a fifty-three percent probability of detection on these storms. Post analysis of the Doppler data, however, revealed that a seventy-five percent score could have been achieved if the criteria described above had been recognized in real time. Similar scores were calculated for twelve severe storms from 1986.

OPERATIONAL PRODUCT USAGE PATTERNS ON THE DAR³E WORKSTATION ASSOCIATED WITH SEVERE CONVECTIVE OUTLOOKS IN NORTHEAST COLORADO

Kenneth F. Heideman

An advanced workstation was installed at the Denver Weather Service Forecast Office (WSFO) late in 1986. This workstation, called the Denver AWIPS-90 Risk Reduction and Requirements Evaluation (DAR³E), is being used at the public weather forecast desk to gain experience that might be useful in developing future advanced workstations throughout the National Weather Service. Therefore, it is important to get an understanding of the impact of DAR³E on the operational environment. Toward that end, an ongoing evaluation of DAR³E has been established by the Program for Regional Observing and Forecasting Services (PROFS). One component of this evaluation is an analysis of the type of information and data that forecasters choose to display on the DAR³E system. There are nearly 800 meterological products available to forecasters on the workstation, including numerical model analyses and forecasts, upper-air and surface analyses, profiler data, and radar and satellite imagery that can be displayed on scales ranging from the Northern Hemispheric to the local. This study documents the results of an in-depth product usage analysis on DAR³E before, during, and after several severe convective outbreaks in northeastern Colorado during the summer of 1987. For each day in the sample the data compiled consists of the total number of product requests made on the workstation, the number of product requests during each hour, the fraction of all requests made for the major product types (i.e., numerical models, satellites, radar, etc.), the percentage of all numerical model product requests ascribed to each of the numerical models, and the fraction of all requests for products on each scale. This data was also compiled for two sets of four consecutive fair-weather control days. The comparison of results for the severe and control days provides a measure of the impact of severe storms within the operations of the Denver forecast office itself. Preliminary results indicate that forecasters interacted with the DAR³E workstation more frequently and consistently when the threat of severe convection materialized, and modified their overall product selection patterns as changing weather patterns dictated. Additional detailed findings will be available at the time of the conference.

MODELLING THE CIRCULATION IN NEWFOUNDLAND'S OFFSHORE
Hisashi Hukuda and Richard J. Greatbatch

Greenberg and Petrie have recently shown that a barotropic model can reproduce many of the observed circulation features on the Newfoundland shelf and slope. We describe preliminary results using simplified models designed to elucidate the essential dynamics behind Greenberg and Petrie's result. We also hope to provide estimates of the exchange of water at different depths between the shelf and the deep sea by solving a vertical structure problem at each point in the model domain.

THE BAROTROPIC TIDE IN FJORDS: WHERE DOES ALL THE ENERGY GO?
Brad de Young and Steve Pond

As the barotropic tide propagates into and out of a fjord, it loses energy to friction, internal tides and high-frequency internal waves. Estimates of these energy sinks are provided for three British Columbia inlets. Friction is negligible in two but important in one inlet depending upon the length and depth of the sill. Most of the energy lost goes into the internal tide although less than half of this energy propagates away from the sill. From 10 to 50% of the energy lost goes into internal tides propagating away from the sill. Simple models of the internal tide predict the correct energy transfer to satisfy an energy budget but do not agree with observations of the internal tidal energy flux away from the sill. Energy loss from the internal tide in or near the generation zone would account for the discrepancy. The energy flux of the high-frequency internal wave field is relatively small, about 2% of the energy lost.

NUMERICAL SIMULATION OF CSWs ON THE LABRADOR SHELF
Savithri Narayanan

To describe the observed current variability on the Labrador Shelf at sub-inertial frequencies, a two-dimensional frequency domain barotropic shelf-wave model is developed. The sensitivity of this model to friction parameterization and boundary conditions are analysed. A method of decomposing the simulated circulation into dominant shelf-wave modes is developed. The results from an application of the model to the Labrador Shelf are presented.

DESCRIPTION AND DYNAMICAL INTERPRETATION OF LOW-FREQUENCY MOTION OVER THE LABRADOR/NEWFOUNDLAND SHELF

D. Wright, B. De Young and D. Greenberg

Between July, 1985 and July, 1987 the Bedford Institute of Oceanography collected an extensive set of bottom pressure and current meter observations over the Labrador/Newfoundland Shelf. During some periods, data are available covering the region from Hudson Strait to St John's, Newfoundland. Preliminary analysis of this data has revealed strongly coherent motions along the entire length of the shelf. Complex empirical orthogonal functions will be used to illustrate the kinematic structure of the large-scale coherent motions over the shelf. Multiple regression in the frequency domain will then be used to estimate the relative contributions to motions over the Grand Bank of "locally" forced motions and motions propagating into the region across a backward (relative to the direction of long coastal trapped wave propagation) boundary. By varying the distance to the backward boundary (i.e. using different inputs to the regression model) we will estimate how far backward a numerical model domain must extend in order for motions generated outside the model domain to have negligible predictable influence on motions over the Grand Bank. Results will be interpreted in terms of simple theoretical and numerical models.

WIND-DRIVEN UPWELLING IN THE NORTHWEST GULF OF ST. LAWRENCE

M. Couture and Y. Gratton

Satellite thermal images of the St Lawrence system revealed strong temperature gradients along the coast of the Northwest Gulf of St. Lawrence. A preliminary study of the winds for the same periods suggested that these cold spots could be the signatures of wind-driven coastal upwellings. A simple, nonlinear, reduced-gravity model was used to study the surface-layer response to the winds. The model predicts both the location and extent of the observed upwellings.

1020-1200: (Connaught) **Thursday / Jeudi**

SESSION 10C: LIMEX

SESSION 10C : LIMEX

LIMEX'87 THE PILOT LABRADOR ICE MARGIN EXPERIMENT

L. McNutt, C.L. Tang, S. Digby Argus, C.E. Livingstone, F. Carsey and W. Winsor

The Labrador Ice Margin Experiment (LIMEX) is an international, multidisciplinary program designed to address questions related to the dynamics of pack-ice cover on the Canadian East Coast. LIMEX'87, the Canadian-led pilot study, took place in March 1987 over the northern Grand Banks. The pilot experiment coincided with a severe ice event when the ice, initially 200 km from the coast, was compacted to a 20-km band against the shore, trapping several ships.

The experiment examined air-sea-ice interactions, oceanography associated with the ice-pack, and the remote sensing of sea ice. Objectives included: the role of oceanic and atmospheric processes influencing ice conditions; the remote sensing of ice and ocean conditions from aircraft and satellites; the refinement of air-sea-ice models to predict ice extent, ice compaction and motion; and the evaluation of mechanical properties of the pack.

To meet the objectives, surface and remotely sensed data were collected including the first C-band Synthetic Aperture Radar (SAR) data for the region. Surface data included: oceanographic measurements from the Bedford Institute of Oceanography (BIO) CSS BAFFIN and from sites within the pack; observations and measurements of ice characteristics related to microwave behaviour and engineering properties; and measurements of atmospheric variables. Remotely sensed data were obtained from aircraft and satellites. Airborne data included: C-band (SAR) data, scatterometer profiles and aerial photography from the Canada Centre for Remote Sensing CV-580; X-band Side Looking Airborne Radar (SLAR) from the Atmospheric Environment Service (AES) and International Ice Patrol(IIP); passive microwave imagery from a Naval Ocean Research and Development Activities (NORDA) aircraft; and photography obtained by C-CORE and Husky/Bow Valley. Satellite data included Landsat MSS, NOAA AVHRR, Nimbus SSMR, and Geosat.

THE USE OF SAR FOR ICE FEATURE AND PROCESS DETECTION IN EAST COAST PACK-ICE

S. Digby Argus and C. Livingstone

During March 1987 a joint remote sensing and oceanographic experiment, the Labrador Ice Margin Experiment (LIMEX'87), took place over the northern Grand Banks. This paper presents data from the newly commissioned Canada Centre for Remote Sensing (CCRS) C-Band synthetic aperture radar (SAR) system, obtained as part of the experiment. The SAR data, which is the first to be acquired over sea ice for this region, demonstrates the potential of C-band SAR for monitoring a number of operationally important features and ice surface characteristics. The imagery is of particular interest because the period of data acquisition coincided with a dramatic change in ice extent, concentration and ice conditions, which created severe problems for east coast navigation.

Changes in the ice conditions for 13-26 March were dramatic. Initially, ice extended 100 to 200 km from the coast over the Grand Banks. On March 15, at the start of the surface data acquisition the ice was compacted against the shore during a period of poor visibility. Surface measurements found the pack to consist of a 10/10ths coverage of small floes or cakes consolidated into larger units by frozen brash ice. By March 20, the ice was reduced to a 10-20 km band along the coast and temperatures above 0°C allowed swell to progressively penetrate through the pack.

Airborne radar imagery acquired as part of this experiment reinforced the role of radar, particularly the SAR, in providing ice-edge information in cloud-obscured situations. In addition, the SAR imagery was demonstrated to provide operationally important information on surface characteristics not available from other sensors. This information includes swell penetration into the pack, the location of shear zones, ice velocity zones, ice movement within the pack and ice characteristics such as floe structure and size.

UPWELLING AT THE ICE EDGE OFF THE NEWFOUNDLAND COAST

C.L. Tang

During the LIMEX '87 cruise, CTD and Batfish data were collected in an area 60 km to the south of Cape Race just outside the ice edge. The data reveal clear signatures of upwelling. Temperature and salinity contour lines are raised by 50 m in a strip 10 km wide parallel to the ice edge. Accompanying the upwelling is a streamer composed of a different water mass alongside the upwelling zone. The upwelling can be explained by the different stresses induced by winds on the surface of the water. The stress underneath the ice is greater than that in the open water. As a result, the transport in the Ekman layer underneath the ice (away from the ice edge) is greater than that on the open ocean side (towards the ice edge). The difference is compensated by an upward transport from below the surface around the ice edge. The results of an analytical model and a numerical model give good agreement with the observations. (This work is supported by the Federal Panel on Energy R&D (PERD).)

AN ICE MOTION ALGORITHM: A CASE STUDY OF ITS APPLICATION TO THE EAST COAST DURING LIMEX

T.K. Hirose, J.S. Paterson, L. McNutt and S. Argus

An algorithm for automatically tracking sea-ice motion from time sequential imagery is under development at the Canada Centre for Remote Sensing. This algorithm is designed for use in a wide variety of ice conditions, and has provided excellent results when applied to SEASAT data from the Beaufort Sea.

In this algorithm, the corners of floes are selectively chosen from a coarse-resolution image pair. A few initial matches are found using two-dimensional area correlation. The displacement of the initial matching locations are used by nearby locations on the first scene to guide the search for its match on the second scene. After the initial verification of the results for Beaufort Sea data, the next step in the validation process is to test the algorithm on multispectral data sets, and in different geographic locations.

The Labrador Ice Margin Experiment (LIMEX) conducted in March, 1987, provided an excellent opportunity to collect Marginal Ice Zone (MIZ) data in Canadian waters. This data set from the east coast of Newfoundland included the first multitemporal airborne C-Band Synthetic Aperture Radar (SAR) from this area, and NOAA AVHRR imagery.

This paper discusses the nature of the data obtained during this experiment, the ability of the algorithm to automatically track the sea-ice motion, and the effects of the sensor resolutions and the geophysical properties of the sea ice on the algorithm results.

SESSION 11A : NWP / GCM

APPLICATION OF THE SEMI-LAGRANGIAN METHOD TO A MULTILEVEL SPECTRAL PRIMITIVE EQUATIONS MODEL
Harold Ritchie

Largely because of its very attractive stability properties, the semi-Lagrangian time integration scheme is being used in numerical weather prediction models in combination with an increasing number of spatial discretizations. Numerous investigators have tested it in grid point models and have shown that it permits the use of time steps that are much larger than those permitted by the Courant-Friedrichs-Lewy (CFL) stability criterion for the corresponding Eulerian models. This leads to improved model efficiency, since fewer steps are needed to complete the forecast. Similar results were recently obtained for a single-level (shallow water equations) spectral model.
The objective of thus study is to apply the semi-Lagrangian method to the multilevel spectral primitive equations model developed at Recherche en prévision numérique. This is done in a version of the model in which the equations of horizontal motion are expressed in vector momentum form. For time steps that far exceed the CFL limit, the stability and accuracy of the semi-Lagrangian version are examined by comparing its performance with that of a conventional Eulerian spectral treatment of the vorticity-divergence formulation of the model.

A BAROCLINIC TWO-TIME-LEVEL SEMI-LAGRANGIAN MODEL
Jean Côté and Andrew Staniforth

The two-time-level semi-Lagrangian method has been found to be the most efficient time integration method for the shallow-water equations in a wide range of contexts: finite-element (Temperton and Staniforth), spectral (Côté and Staniforth) and grid-point (Purser and Leslie) models. In this method the timestep is not restricted by any stability constraint and therefore can be chosen on the basis of accuracy alone. The benefits resulting from the gain of efficiency in the time integration method can be reinvested in the increase of spatial resolution.

We present the recent progress towards the extension of the two-time-level semi-Lagrangian method to the baroclinic primitive equations.

MODÉLISATION DE LA VAPEUR D'EAU DANS UN MODÈLE SPECTRAL DE L'ATMOSPHÈRE
René Laprise

Des tests sont faits avec une version de recherche du modèle canadien de circulation générale qui utilise une discrétisation verticale en

termes d'éléments finis constants. On remarque les avantages et inconvénients de représenter la vapeur d'eau par la variable de l'humidité spécifique ou une fonction transcendentale de celle-ci. Les effets sur la circulation à grande échelle et sur les taux de précipitation sont aussi notés. Il semblerait que les propriétés de conservation dans un sens intégral et de précision dans un sens local soient mutuellement exclusives lorsque seules les composantes à grande échelle sont représentées.

GEOSTROPHIC ADJUSTMENT AND WIND-DRIVEN SPIN-UP IN COARSE RESOLUTION UPPER-OCEAN MODELS

J.Y. Cherniawsky and L.A. Mysak

Geostrophic adjustment in one- and two-layer upper-ocean primitive-equations models with initially zonal pressure gradients is examined with and without an idealized wind-stress forcing. The models are set on a B-grid in spherical coordinates in a subpolar-subtropical domain spanning 15^0 to 67^0N and 65^0 west to east. Several versions of the two-layer model on a coarse, $4^0 x 5^0$, grid are examined: 1) with horizontally varying temperatures and with Niiler and Krauss (1977) type wind-driven entrainment at the base of the top layer, 2) as 1) but without entrainment, 3) as 2) but with uniform temperatures and salinities (i.e., a two-layer reduced gravity model). One-layer versions of the model 3) above were also run on two finer, $2^0 x 2.5^0$ and $1^0 x 1.25^0$, grids and compared to the $4^0 x 5^0$ version.

In all cases, the initial response to the imposed pressure gradients is in the form of inertia-gravity waves which set up zonal currents and decay within 10-20 days. These currents produce areas of high/ low pressure anomalies in the middle of the eastern/western boundaries causing cyclonic propagation of numerical-viscous Kelvin waves (as in Hsieh et al., 1983). The Kelvin waves propagate the depth anomalies around the perimeter of the basin and therefore set up the double-gyre circulation. The subsequent response is in the form of westward propagating planetary waves, which are more discernible in the higher-rersolution ($2^0 x 2.5^0$ and $1^0 x 1.25^0$) model runs. With wind forcing, the planetary waves help to intensify the gyres, forming classical Munk-type western boundary currents. Without wind forcing, these waves accompany the dissipation process. The initiation of the first planetary wave coincides with an arrival of the negative anomaly (Kelvin wave) in the south-eastern corner. In the absense of forcing, their period is therefore equal to the propagation time of the model Kelvin waves around the perimeter of the basin. As predicted by theory (Batteen and Han, 1981; Hsieh et al., 1983; Wajsowicz, 1986) all waves are strongly affected by the coarse grid size and, to a lesser extent, by the artificially high eddy viscosity of the models.

PARAMETERIZATION OF MOIST CONVECTION IN THE CCC ATMOSPHERIC GENERAL CIRCULATION MODEL

N.A. McFarlane

It is well known that latent heat release in cumulus convection plays an important role in the evolution of the atmospheric circulation in synoptic and planetary scales. All existing numerical models used for weather prediction or atmospheric general circulation studies include some form of parameterization of the effects of moist convection.

Most of the parameterization schemes in current use are designed to account for the effects of precipitating moist convection in which there is net latent heat release in an atmospheric column. Recently it has been recognized that the effects of shallower convection in which there is little net heat release and precipitation may also be important in determining the nature of the larger scale atmospheric circulation, particularily in tropical regions.

A new parameterization of moist convection designed to account for both deep (precipitating) and shallow (non-precipitating) cumulus clouds has been developed for use in the CCC atmospheric general circulation model. A brief outline of the parameterization technique will be given and results of testing in the GCM will be presented to illustrate the effect of both types of convection on model simulations of the tropical circulation.

1320-1500: (Ontario) **Thursday / Jeudi**

SESSION 11B: FORECAST OPERATIONS I

SESSION 11B : PRÉVISION OPÉRATIONNELLE I

AN EVALUATION OF EXPERIMENTAL PROBABILISTIC RADAR REFLECTIVITY FORECASTS ISSUED DURING THE PROFS 1987 REAL-TIME FORECAST EXERCISE

Herb A. Winston

The Program for Regional Observing and Forecasting Services (PROFS), located in Boulder, Colorado, conducted a Real-Time Forecast Exercise (RT87) during the 1987 convective season. The purpose of this exercise was three-fold: to create a data base consisting of data from a wide variety of state-of-the-art sensors (Doppler radar, profiler, etc.), numerical guidance, and severe weather verification data; to integrate these data into the DAR^{3}E (pre-AWIPS-90) prototype workstation through specifically designed imagery and graphical products; and to have these data and products available to forecasters so that they could make experimental regional and mesoscale forecasts of convectively related weather phenomena.

Several types of experimental forecasts were made during the exercise, one of which included probabilistic hourly radar forecasts of low-level reflectivity signatures. Though not presently part of National Weather Service operational practice, these forecasts were made to test the forecaster's ability to predict the gross position and orientation of thunderstorms as they develop, mature, and die out.

This paper will discuss the methodology by which the radar forecasts were made during RT87. Examples of the forecasts will be presented along with verifying reflectivity fields. Preliminary statistical results of the radar forecasts will be presented using Donaldson's POD, FAR, and CSI scores as well as Signal Detection Theory (SDT) analysis.

SWIFT - A PRELIMINARY EVALUATION

John M. Bullas and J. Carr McLeod

SWIFT (Severe Weather Intelligent Forecasting Terminal) is an experimental knowledge-based system for forecasting the occurrence of severe convective weather on the Canadian Prairies, developed for the Atmospheric Environment Service by McDonald-Dettwiler, Richmond, B.C., and the Alberta Research Council. The system incorporates a statistical-dynamical model for convective forecasting and heuristics to modify the output and identify geographical areas where severe convective weather is probable. The expected severity of convective weather is also an output, based on Convective Day Categories (Strong, 1979).

An evaluation of the methodology and algorithms has been conducted, using an archived dataset from the summer of 1987. The findings are presented.

A LOW CLOUD EXPERT ADVISORY TERMINAL FORECASTER

Peter Zwack, Yves Chartier, André Cotnoir, Jean Goulet, Evelyne Haussen-Tropper and Monroe Newborn

Weather forecasting is a very complex task that requires the assimilation of an enormous and variable quantity of data including observations that are of either qualitative or quantitative nature, as well as, a myriad of analyses and forecasts of a number of different meteorological fields each of which having a different form and reliability depending on their source and the meteorological situation. In integrating all the data, the forecaster applies, usually in a qualitative sense, a number of complex physical laws in combination with more or less precise empirical rules. Since the importance of the different physical phenomena as well as the empirical rules varies from one region to another, it is quite difficult to transfer acquired expertise.

With the goal of helping the forecaster to accomplish these complex tasks as well as to develop a system for training, an expert advisory system for FT's is being developed at le Centre de recherche informatique de Montréal in collaboration with Météoglobe Canada, Inc and the Atmospheric Environment Service of Environment Canada. In order to be easily transferable to other geographical locations, the system is being designed as much as possible on the physical principles underlying meteorological phenomena but will also use empirical rules and experience in situations in which either the physics is not understood or the physical parameters are not available. We will present a prototype expert advisory system that produces the low cloud portion of the FT in collaboration with the forecaster who is required to provide a limited amount of information, the most important of which is to choose which numerical model he considers to be the best among those available.

FULL RESOLUTION METEOROLOGICAL SATELLITE DATA RECEPTION FOR CANADA

B. Bar-Haim and B. Wannamaker

Since 1963, the Atmospheric Environment Service of Environment Canada has been receiving the data of the near-polar orbiting meteorological spacecraft. Over that time, the satellite instrumentation has improved and the demand for satellite data products has increased beyond the capabilities of the present receiving system. AES stations in Downsview and Edmonton now serve meteorological, oceanographic and other data users across the country. The replacement system now being implemented is described. It is designed to maintain operational reception and distribution of products from the TIROS series of satellites into the mid-1990's. The benefits of the improved data available from the new system to some of the users are discussed.

A REAL-TIME SYSTEM FOR OPERATIONAL RECEPTION AND PROCESSING OF METEOROLOGICAL SATELLITE DATA

R.G. Humphries, L.W. Diehl, L. Laba and P.D. Erickson

Many countries are interested in economic means of expanding their current environmental data collection network and to use available technologies to improve their ability to forecast and detect severe weather. Meteorological satellites provide a source of such data for applications encompassing meteorology, oceanography, hydrology, and resource management.

To meet the requirement for frequent and timely coverage over large geographic areas a real-time satellite data reception and processing system has been developed and installed throughout the world.

The hardware architecture is based on proven off-the-shelf hardware that supports multitasking, high throughput and has demonstrated a high reliability. Since data from both polar-orbiting and geostationary meteorological satellites are frequently required, the system has a built in redundancy that allows reception of both data streams.

The online, reception, preprocessing and storage is handled automatically in real time. All processing software is developed with a structural modular design and written in a high-level user-oriented language.

Of primary interest to the operator is the set of applications that is available interactively through the system workstation. The basic building block the user works with is an image. This image can be preprocessed to the state where it is sectorized, reprojected and enhanced through look-up tables. One can then do image combination, apply pseudo-colours, roam, zoom window, create animated loops and call up algorithms to display products such as sea surface temperatures or cloud top temperatures. The workstation attributes are low cost and it can be configured for different types of interaction as well as be located on-site or remotely.

This new generation system is currently installed or being installed in countries such as Peru, Brunei Darussalam, Korea and Canada. Although there is a certain commonality among these various groups in the use of the satellite receiver system, each one also has its own unique set of applications.

1320-1500: (Connaught) **Thursday / Jeudi**
SESSION 11C: LIMEX / LEWEX
SESSION 11C : LIMEX / LEWEX

A TWO-DIMENSIONAL COUPLED ICE-OCEAN TURBULENT CLOSURE MODEL IN THE MARGINAL ICE ZONE
M. Ikeda

A one-dimensional turbulent closure model (Ikeda, JGR 1986), by which mixed layer development under melting sea ice was studied, has been extended to include variabilities in the cross-ice edge direction. The ocean is initially motionless and has no horizontal variability in ocean interior, whereas ice covers only a half portion. A uniform wind stress is imposed suddenly to drive the coupled system. The surface mixed layer is developed as time increases; i.e., a top few tens of metres are well mixed. With an initial water temperature above a freezing point, the fresh mixed layer forms in the ice-covered portion. An off-ice (on-ice) wind advects the ice toward the warm (cold) area, and more (less) melting tends to occur. A wind with the ice to the right (left) looking downstream produces upwelling (downwelling) under the ice edge, owing to a difference in Ekman transport. The model will provide numerical solutions which are compared with ice distribution, ice movement, oceanic structures etc. observed in LIMEX 89.

WAVE-ICE INTERACTION STUDY DURING LIMEX/LEWEX '87
B.M. Eid, C.M. Morton, W.D. Winsor, J.H. Lever and V.J. Cardone

The Labrador Ice Margin Experiment (LIMEX) and the Labrador Extreme Wave Experiment (LEWEX) took place in March 1987. Large amounts of data were collected in the Marginal Ice Zone (MIZ) and in the open waters adjacent to the ice edge.

In this study, in situ meteorological data were collected from different sources and from an automatic weather station onboard the **CSS Baffin.** Wind and wave fields were hindcast for the entire duration of the experiment using the ODGP spectral ocean wave model. In addition, the C-CORE ice motion package was employed on ice floes to measure (6 degrees of freedom) wave-induced ice motion at different locations in the MIZ. The motion package records were analyzed to produce time series plots of wave parameters as well as wave spectra. These data were complemented by waverider buoy measurements obtained from DTNSRD group.

In addition, in situ ice-strength and ice-thickness measurements were conducted during LIMEX period. An aerial photographic record of the ice-field conditions encountered during the LIMEX cruise was collected. A description of ice conditions and ice types encountered during motion package deployments was obtained from the aerial photographs.

A model describing the wave propagation, attenuation and dispersion in the MIZ was developed and tested using above data. Preliminary results are presented.

LOAD COMBINATIONS AND RISK ASSESSMENT FOR ICE STRUCTURE INTERACTIONS IN THE MARGINAL ICE ZONE

Ian J. Jordaan and Willima D. Winsor

A number of different sea-ice load scenarios can be anticipated for structures that will be designed to operate in the marginal ice zone for eastern Canada's offshore. They include the quasi-static loads that will be caused by a pack-ice field pushing past a structure and the dynamic loads will originate from single floes colliding with the structure. Dynamic loads might originate from ice particles forced on the structure by combinations of wind, waves, and current action. Load combinations by several environmental factors are also considered. For example, multi-year floes or icebergs confined within the pack-ice require different countermeasures planning than a free-floating hazard.

The probabilities of occurrence associated with the different sea-ice scenarios are derived from historical environmental distribution data for ice coverage, floe sizes, ice thickness and ice types within the ice zone. Here the research relies on the ice data collected during the LIMEX '87 Project. It also considers an ice engineering field program for the upcoming LIMEX '89 sea-ice cruise. The paper indicates the type of analysis involved in estimating the joint probabilities for load magnitude and return period of the different classifications for sea-ice loading events.

The probable loads and return periods are the statistical data required to conduct a risk assessment for an ice-resisting design. Risk analysis provides a method of establishing whether the ice load will prove to be the overall design load consideration and which ice conditions will have to be addressed during normal operations of the structure. The load magnitude statistics will identify which ice-load scenarios will cause the larger loads than those imposed by other environmental factors. The return periods will identify what loads can be considered an acceptable risk and which ice loads must be resisted by the structural design.

THE LABRADOR EXTREME WAVES EXPERIMENT (LEWEX) DATA REPORT
A.S. Bhogal

In March 1987, an international oceanographic remote sensing experiment took place off the east coast of Newfoundland. The Labrador Extreme Waves Experiment (LEWEX) was organized by Canada and eight nations from Europe and North America.

LEWEX was designed to address several objectives. These included assessment of the adequacy of various wave models in wind and wave forecasting, determination of the capability of aircraft radar remote sensors to observe certain oceanographic features, intercomparisons of wave directional spectra obtained from several instrumented buoys, and examination of wave penetration into ice.

Some of the resources fully committed to the field included the CCRS CONVAIR 580 aircraft (C-band synthetic aperture radar (SAR)), the NASA P-3 (radar ocean wave spectrometer (ROWS) and surface contour radar, (SCR)) and the Canadian vessel QUEST and the Dutch ship TYDEMAN (in-situ instruments). The ROWS is a near-nadir conically scanning short pulse radar and the SCR is a pencil-beam range-scanning radar. All three aircraft instruments are capable of measuring ocean waves which in the case of LEWEX, offered the opportunity for sensor intercomparisons. Other data acquired during the experiment include C-band radar imagery of waves in the ocean and ice.

In this paper, a summary of the field work involved in support of research objectives for LEWEX will be presented, together with a summary of the principal data products that resulted.

1530-1710: (Ballroom) **Thursday / Jeudi**
SESSION 12A: REMOTE SENSING
SESSION 12A : TÉLÉDÉTECTION

AN ELECTRONICALLY SCANNED MICROWAVE IMAGING RADIOMETER
Cameron Grant and Greg Healy

Microwave imaging is rapidly becoming a competitive form of remote sensing, in particular, for ice reconnaissance. Its competitive surge into the research marketplace is primarily due to its relatively high performance/cost ratio. Microwave imaging approaches all-weather compatability with conditions likely to arise in a winter environment (i.e. snow, fog, etc. excluding rain). Here we discuss the merits of a new concept in microwave imaging technology, that is, a radiometer capable of scanning a physical ice scene, electronically, producing near real - time colourometric images. The sensor consists of few moving parts, which will, in the long run, prove to be fast and reliable.

The Electronically Scanned Microwave Imaging Radiometer that we are developing uses a custom-built sensor driven by a simple

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IBM PC-AT computer. Together they form a rather compact package easily incorporated into the smallest of control consoles. The prototype was initially designed to operate on a stationary platform such as our experimental facility on Grindstone Island in the Thousand Islands. With little modification, the package is easily adapted to a naval platform (a ship) and with even further modification possibly adapted to an airborne or spaceborne platform. A technical outline describing the major components and their functions within the radiometer will be a major part of the presentation. We will also present a variety of data sets showing the capabilites of the sensor to delineate diverse ice conditions, quickly, inferring that the radiometer may indeed become an invaluable navigational aid.

MULTIFREQUENCY SPACEBORNE PASSIVE MICROWAVE OBSERVATIONS OF THE OCEAN AND ATMOSPHERE

I.G. Rubinstein and R.O. Ramseier

Models for the estimation of the sea ice cover, open-ocean wind speeds and atmospheric attenuation at 37 and 18 GHz developed and tested for the Scanning Multichannel Microwave Radiometer (SMMR on NIMBUS-7) were modified to be used for the Special Sensor Microwave Imager (SSM/I launched in June 1987).

The results of the preliminary operational validation of the algorithms are very encouraging. The results of this validation campaign and comparisons with other sources of data, for several selected events will be presented in this paper. The potential for utilization of this type of data for forecasting and climatological studies will also be discussed.

USE OF CLOUD INFORMATION TO IMPROVE TOVS RETRIEVALS

J.D. Steenbergen, T.-C. Yip and B.T. Greaves

"Optimal estimation" methods of retrieving temperature and water vapour profiles from TOVS (TIROS-N Operational Vertical Sounder) measurements use a priori information about the mean and covariance of the solution to select the statistically most likely solution which fits the observations. When the true profile is very different from the a priori mean (background) profile, the solution is drawn toward the background profile.

We are working on a retrieval scheme which uses non-linear optimal estimation to produce temperature and relative humidity profiles simultaneously from raw (cloudy, slant-path) TOVS radiances, which we hope will be implemented at the Canadian Meteorological Centre. When a constant background relative humidity profile is used, we have observed that retrieved relative humidity profiles in clear conditions are too wet in the lower troposphere (as compared to radiosondes). On the other hand, retrieved relative humidity profiles in overcast conditions (which contain no information from the sounder below the cloud top, since the TOVS has only infrared water vapour channels) are much too dry.

We have carried out a preliminary investigation on the use of information from cloud imagery to improve the relative humidity retrievals. The cloud

amount estimated from AVHRR was used to select an appropriate background profile. Separate background profiles for clear, scattered, broken, and overcast conditions were obtained from an independent set of radiosonde measurements. The background relative humidity profile was of course much wetter in overcast conditions than in clear conditions. The biases in the retrievals compared to radiosondes were reduced in both clear and heavy cloud conditions, particularly in the lower troposphere.

TIME SERIES AVHRR AND SHIP TEMPERATURE DATA FOR THE JACQUES-CARTIER PASSAGE

A.R. Condal, Y. Carbonneau, D. Lefaivre and V.G. Koutitonski

As part of the program COHJAC (D. Lefaivre IML, V.G. Koutitonski INRS-Océanologie), infrared AVHRR data are used to produce satellite temperature maps for the Jacques-Cartier Passage. All of our AVHRR data (April to September 1986-87-88) have been acquired from the archives of the Aerospace Meteorology Division of the Atmospheric Environment Service in Downsview, Ontario. These temperature maps are compared and merged with in situ temperature values provided by the IML research vessels. Infrared AVHRR data provide a synoptic view of the horizontal spatial structure. Ship and satellite observations thus provide unique and complementary data. The necessary algorithms to correct geometrically and radiometrically the AVHRR data have been developed over the last three years at the Remote Sensing Laboratory of Laval University. The accuracy of such algorithms, their dependance on the season and region will be discussed. Paired ship/satellite observations, with contemporaneous defined as location within ±2 km and time within ±6 h, together with a temporal analysis for the 1986-87 season will be presented. This remote sensing research which complements and expands the COHJAC program already under way at IML, also provides the necessary information for selecting an appropriate atmospheric correction algorithm for the region. This in turn will permit a more accurate determination of water temperatures in such a coastal marine environment as the Gulf of St. Lawrence.

PASSIVE MICROWAVE SNOW AND ICE SIGNATURES FROM THE ST. LAWRENCE RIVER

Caren Garrity

During the winter and spring of 1985/86 and 1987/88, experiments were conducted to monitor the microwave emissions from freezing and melting freshwater ice and snow in the Thousand Islands region of the St. Lawrence river. A 37-GHz radiometer was mounted on a tower 4.8 m above the ice surface for the first season. The hardware was updated for the 1987/88 season whereby a circular polarized horn antenna was added, which allows the first measurements of different polarizations of its kind to be made. The new horn provides better resolution. A new microwave platform provided a base for the radiometer about 6 m from the surface.

Emission from an ice surface is, in principle, well understood. However, parameters such as surface roughness need to be quantified. Small-scale roughness is caused by snow melting and freezing on the ice surface. Snow is often the main medium influencing the microwave emission from an ice surface, especially if the snow contains free liquid water. The horizontal emissivity is more sensitive to changes in snow electrical and physical properties than the

vertical emissivity. The difference between the two provides useful information about snow-covered ice. When the snow has crust layers the polarization is large. The free liquid water content in the snow influences the brightness temperature (TB) (emissivity times the physical temperature of the penetrated medium). For snow wetness values between 0.1 and 1%, TB increases, whereas for those between 1 and 3% TB remains constant; above these values TB decreases. The effect of snow grain size, and more importantly grain shape, will change these values owing to the way the liquid water is distributed around the grains. The effect of snow wetness, grain size plus shape, thickness and structure with depth on emissivity at 37 GHz are quantified as a function of polarization and incidence angle.

1530-1650: (Ontario) **Thursday / Jeudi**
SESSION 12B: FORECAST OPERATIONS II
SESSION 12B : PRÉVISION OPÉRATIONNELLE II

IMPROVEMENT OF NUMERICAL WEATHER ELEMENT FORECASTS
N. Brunet, D. Soucy, R. Verret and N. Yacowar

Weather element forecasts may be available from several sources. The sources may include direct model output and statistical forecasts based on Analogue, Model Output Statistics (MOS) or Perfect Prog (PP) systems. They may be based on the output of different driving models. In the past, decisions on the acceptance of a particular weather element forecast system were based on its overall performance as compared with that of other techniques. The current studies attempt to make optimum use of all available information.

Rule-based systems are being developed to extract the best information available from the competing systems. This information will be combined systematically to arrive at the best final forecast. The object is to increase the sharpness of the forecasts and to minimize the post-sample forecasting error.

This approach differs from normal post-processing procedures that adjust the forecast output according to past verification data. These adjustments may take into account bias and reliability of previous forecasts as well as some form of error feedback to reduce forecast errors.

Probability of Precipitation (POP) forecasts are available over 6-, 12- and 24-hour periods based on MOS, PP and Analogue systems. Rules were developed to ensure temporal consistency over the various time periods. Once consistency has been assured, the Perfect Prog and MOS forecasts are compared and combined according to a rule-based system. Calibration techniques are also used to compare the distribution of forecast ranges of the different systems and the distribution of the observed events. The results are used to optimize the final product.

Tests are also being carried out to determine whether forecasts of sky cover, precipitation or wind speed might be used to improve temperature forecasts that may not contain these elements explicitly.

AN ANALYSIS OF THE IMPACT OF DIFFERING CLIMATOLOGICAL REGIMES ON PROBABILISTIC PRECIPITATION FORECASTS
Denice C. Walker

The work described here is part of an on-going, systematic study of 20 years of National Weather Service (NWS) probability of precipitation (PoP) forecasts. The data base for this study includes 64 stations that have been selected on the basis of the consistency and completeness of their forecast and verification records. These 64 stations will be stratified on the basis of their wet-season climatology, that is, either warm-season wet or cool-season wet, and they will be further stratified as having either a high or low average seasonal amount of precipitation. The goal is to obtain a full range of climatological probabilities for precipitation and to insure that stations with similar climatological regimes will be grouped together. This series of stratifications will facilitate more appropriate within-group and between-group comparisons. The final stratification will be by severity of precipitation event, ranging from significant events, say precipitation greater than 0.5 inches in 12 h, to extreme events, say precipitation greater than 5.0 inches in 12 h. The method of evaluation used will be Signal Detection Theory (SDT). This scoring technique has been widely used in many scientific disciplines but has only recently been introduced as a statistical means of evaluating meteorological forecasts. As this study is currently in progress, detailed results are not available at this time but will be presented in full at the conference in June.

DETERMINATION OF MOST PROBABLE PREDICTED 50-KPA PATTERN BY EMPIRICAL ORTHOGONAL FUNCTIONS
Amir Shabbar

In the Atmospheric Environment Service experimental long-range forecast, the output from numerical weather prediction models (up to 10 days) and time-lagged correlations of the 50-kPa height anomalies are the main input. The forecaster uses this input to predict the main action centres at the 50-kPa level. Until recently the forecaster used teleconnection statistics to determine the anomaly pattern over the Northern Hemisphere. This study describes a new and more elegant technique that eliminates small-scale or spatially inconsistent 50-kPa anomalies and produces a spatially consistent pattern.

The first five unrotated monthly empirical orthogonal functions (eof) of the 50-kPa heights (based on 1946-84 data) are used to filter out small-scale features. Subjectively forecast action centres of height anomaly are fitted to the first five eofs by the method of least squares. The resulting reconstructed 50-kPa height anomalies are then used to specify Canadian surface temperatures.

INTERACTIVE, MACHINE-ASSISTED DVORAK TYPHOON CLASSIFICATION
B.W. Wannamaker

Tropical typhoons are a major source of property damage both directly through high winds and rainfall and indirectly through storm surges and waves. Initial detection, monitoring and forecasting of these severe storms is a major task of operational forecasters in lower latitudes. Initial detection and monitoring have been greatly facilitated by the development of worldwide coverage of geostationary meteorological satellites. In 1983, V. Dvorak developed a set of decision trees with which a skilled observer could interpret satellite cloud photographs to estimate storm intensity and forecast future development. An approach is described to implement this technique on an interactive image display system. This will allow faster operational procedures and eliminate costly, time-consuming photographic processing and interpretation. The interactive, machine-assisted analysis will make more effective use of observers of varying skill levels. Implementation of the newer, experimental Dvorak II method is also described.

1530-1700: (Connaught) **Thursday / Jeudi**
SESSION 12C: OCEAN-CLIMATE INTERACTION
SESSION 12C : INTERACTION OCÉAN-CLIMAT

A SIMPLE COUPLED STEADY-STATE ARCTIC ICE-OCEAN MODEL
A.J. Willmott and L.A. Mysak

A thermodynamic reduced-gravity ocean model forced by the steady-state surface wind stress and air temperature was used to determine the climatological ice-edge position, ice thickness, ocean circulation and temperature field in a high-latitude meridional channel. The ice model used is purely thermodynamic; however, it is assumed that the surface wind stress is transmitted to the water below the ice and thereby drives an under-ice circulation. The temperature distribution of the upper ocean is specified along the southern zonal boundary of the model domain, and the heat equation is integrated from this boundary poleward along streamlines for the mass transport. As a column of warm fluid moves poleward, it reaches a critical latitude at which the heat loss to the atmosphere is so large that this flux can no longer be balanced by horizontal advection of heat in the upper ocean. As a consequence, at this critical latitude the ocean water freezes from the surface downward.

The model is applied to the Greenland and Norwegian Seas, between 60° and 80°N, and between the east coast of Greenland and 15°E. The predicted ice-edge position compares favourably with the 90% ice concentration isoline obtained from an analysis of 32 years of Arctic Sea ice data.

A QUASI-GEOSTROPHIC CIRCULATION MODEL OF THE NORTHEAST PACIFIC OCEAN
P.F. Cummins and L.A. Mysak

A limited-area quasi-geostrophic numerical model with mesoscale resolution has been developed to study the circulation in the Northeast Pacific Ocean. The model domain extends from the British Columbia/Alaska coast out to 170°W and down to 45°N, and incorporates a realistic coastline and bottom topography. A long-term integration was conducted using a steady climatological wind stress curl field to drive the circulation. Several statistical properties of the solution are determined and compared with observations.

A cyclonic circulation develops in the model basin with a meandering Alaska Current feeding, at the head of the Gulf of Alaska, into an intense boundary current corresponding to the Alaskan Stream. The head of the Gulf is a region where anticyclonic closed streamline features are occasionally generated with characteristics resembling those of the Sitka eddy. In the downstream region, the boundary current separates and is subject to lateral meandering due to topographic waves. The occurrence of perturbations with similar characteristics in the Alaskan Stream has recently been seen in satellite IR imagery.

A MECHANISTIC MODEL OF ISOPYCNAL DIFFUSION IN THE OCEAN
Charles Lin

A two-dimensional (latitude/height) box ocean model is formulated to examine the mechanistic role of isopycnal diffusion (i.e. diffusion along constant density surfaces) as compared to that of lateral diffusion. Isopycnal diffusion is parameterized using the rotated eddy diffusivity tensor (Redi, 1982: J. Phys. Oceanogr., 12, 1154-1158). A large-scale surface temperature anomaly forces a steady solution, which is obtained analytically. The presence of isopycnal diffusion substantially increases the vertical penetration in the steady state; the vertical heat flux is increased by an order of magnitude in some locations. The time-scale of the transient response is also modified, and the nature of this response is scale dependent. It is thus not possible in general to reproduce the transient response with isopycnal diffusion by adjusting diffusivities in a lateral diffusion formulation. Implications of the results to ocean models used in energy balance climate models and carbon cycle models are also considered.

ISOPYCNAL AND LATERAL DIFFUSION IN A BOX OCEAN CIRCULATION MODEL
William Gough and Charles A. Lin

A multi-level primitive equation ocean circulation model (the Cox-Bryan model) is adapted to a box ocean geometry to examine the effects of lateral and isopycnal diffusive parameterizations. The geometry is an idealized representation of the Atlantic Ocean between 20°-50°N and 10°-60°W with a 2° x 2° horizontal resolution; 10 levels are used in the vertical over a depth of 4000 m. There is no bottom topography. The model is forced with seasonally varying surface wind stress and initialized with three

dimensional temperature and salinity fields interpolated to the model grid. Isopycnal diffusion is parameterized using the rotated eddy diffusivity tensor (Redi, 1982: J. Phys. Oceanogr., 12, 1154-1158). The initial experiment consists of two 50-year spin-up from rest simulations using lateral and isopycnal diffusion. The isopycnal and horizontal diffusivities are equal, as are the vertical and diapycnal diffusivities. The effects of the two diffusive parameterizations on the model dynamics, passive and active tracer distributions are presented.

NUMERICAL EXPERIMENTS WITH A TWO-LAYER UPPER-OCEAN BOX MODEL: WIND-DRIVEN SPIN-UP AND MIXING OF INITIAL TEMPERATURE GRADIENTS

J. Cherniawsky, L.A. Mysak, C.A. Lin and C.W. Yuen

A two-layer dynamic and thermodynamic upper-ocean circulation model with a Niiler and Krauss (1977) type entrainment at the base of the top (mixed) layer was spun up from rest for 20 years using an idealized wind-stress forcing function. The model was set up in a 4°x5° B-grid spanning 15 to 67°N and 65° west to east. The initial zonal profiles of the layer depths, temperatures and salinities correspond to those in the top 1000 m of the North Atlantic Ocean, interpolated from the Levitus Atlas (1982).

After 90 days of wind forcing, the mixed layer deepens from an initial depth of 30 m to a maximum of about 120 m, while the mean mixed layer temperature cools down by about 2°C. The maximum in the mixed layer depth is located initially at 45°N, the latitude of the maximum wind stress, but within 90 days is shifted 1-2° south by the Ekman drift. The deepening, southward motion and cooling of the mixed layer are comparable to analytical model results of de Szoeke (1980).

After 20 years of steady wind forcing, the model has a) a well developed double-gyre circulation with volume transports of 39 Sv in the subtropical gyre (somewhat less than the theoretical 46 Sv) and 9 Sv in the subpolar gyre, b) a maximum total depth of about 860 m located in the northwest corner of the subtropical gyre and a shallow (about 20 m, a minimum allowable depth) subpolar gyre with deeper (>200 m) boundary layers and, c) become vertically and horizontally homogenized, with the total temperature range dropping to less than 1°C in both layers. The width of the frictional western boundary layer is 960 km (~2Δx), in good agreement with the theoretical formula of Munk (1950).

RESULTS OF A TWO-LAYER UPPER-OCEAN CLOBAL GENERAL CIRCULATION MODEL FORCED AT THE SURFACE

C.W. Yuen, C.A. Lin, L.A. Mysak and J.Y. Cherniawsky

The quasi-equilibrium results of a long-term integration of an upper-ocean global general circulation model forced at the surface will be presented. The purpose of this study is to understand the large-scale model behaviour before coupling the ocean model to the Canadian Climate Centre atmospheric general circulation model for climate studies of time-scales from years to decades. The model represents the upper-ocean by two vertically homogeneous

layers of variable thickness. The upper layer is the ocean mixed layer, and the lower layer represents a vertical average of the thermocline. A thermodynamic sea-ice model is also incorporated. The ocean model is forced at the surface by seasonally varying observed wind stress and heat fluxes as defined by an atmospheric equilibrium temperature. The upper mixed layer interacts with the lower layer through the (wind and buoyancy driven) entrainment and detrainment processes. The deep ocean beneath the lower layer is assumed to be at rest. Heat loss from the lower layer to the deep ocean is modelled as Newtonian cooling. The horizontal resolution of the model is 4^{o} latitude by 5^{o} longitude. Preliminary results have been obtained from a 50-month run using initial conditions taken from results of a previous 40-year spin-up experiment. The simulation shows that the overall mixed layer temperature and depth are well simulated. The currents are found to be too weak, however; this can probably be improved by using a higher horizontal resolution. The mixed layer temperature is found to be strongly constrained by the imposed atmospheric equilibrium temperature. Heat budget studies on the upper and lower ocean layers will also be presented.

0830-0950: (Ballroom) **Friday / Vendredi**
SESSION 13: THEME PLENARY IV
SESSION 13 : PLÉNIÈRE IV

UNDERSTANDING THE SEVERE STORM HAZARD: WHERE DO WE GO FROM HERE?
Michael J. Newark

The history of climatological research in severe, local summer storms shows that progress has been made in understanding the distribution across Canada of certain phenomena such as hailstorms and tornadoes. However, this work is still in its infancy and much remains to be done to advance our understanding of the hazards due to such storms. This paper briefly reviews what has been done, and examines the challenges yet to come.

THE DESTRUCTIVE EFFECTS OF WINDS
A.G. Davenport

The paper discusses the destructive effects of wind on individual structures as well as on urban infrastructure. In the former the issues focus on structural design, in the latter on the questions of emergency planning, insurance and disaster mitigation.

The paper will discuss the mechanisms of structural failure and the meteorological factors involved. The latter include the strength of the wind, and the climate of strong wind, the turbulence intensity, and the influence of terrain and topography. The need to take into account the influence of wind direction is pointed out.

The importance of the dynamic, resonant response of structures to wind, at their own natural frequencies is discussed, as well as the relationship of the size of the structure to the size of gusts or turbulent length scales.

Severe windstorm damage inevitably involves the destruction of more than one building. At this scale other issues become paramount, in particular the ability for the community to recover from the disaster. Answers are needed to questions, such as: What is the extent and damage pattern of severe storms? What is the best strategy for improving the survival? What role does insurance play? What role does forecasting play?

1020-1200: (Ballroom) **Friday / Vendredi**
SESSION 14A: IMPACT AND RESPONSE
SESSION 14A : RÉPERCUSSIONS ET INTERVENTION

WEATHER AWARENESS AND EMERGENCY RESPONSE
Jerrine Verkaik

The Hage Report (Review of the Weather Warning System Associated with the Edmonton Tornado of July 31, 1987) and, more explicitly, the briefs submitted to it by AES Ontario Region and the Severe Weather Team, have all emphasized the importance of public education and awareness in improving response to severe weather events. The danger exists, however, that public education and awareness will continue to receive only lip service from the meteorological community. As suggested in the Report to the Minister of State for Science and Technology, "Public Awareness of Science and Technology in Canada":

> Although government experts 'support' the notion of public awareness and communication, in reality the majority of them focus on their vertical constituency or scientific peers.

Furthermore, although the findings of the Hage Review speak strongly of the overriding importance of correcting deficiencies in communication and public awareness, the order and structure of the recommendations weaken what should have been a forceful statement on the importance of increasing public awareness. It is not surprising that the media coverage of the report zeroed in on the recommendation for Doppler Radar, even though greater improvements in emergency response are likely to come through increased public awareness. We can ill afford to allow the need for public education to be lost in the race to acquire ever greater technological sophistication, no matter how valuable the technology is thought to be.

On the other hand, neither can we afford to launch into a string of knee-jerk public awareness programs. In so doing we run the risk of compounding our errors. To avoid falling into this trap, the author will present a critical analysis of the pattern and nature of the interaction of the professional meteorological community with both the media and the public. The results of this analysis will then be set in the context of the public's relationship to weather and weather forecasting. This analysis will clarify the underlying rationale which should direct our efforts, yielding a set of prerequisites and priorities to guide our decision-making. Specific suggestions for public awareness materials and programs will be proffered.

PROJECT TORNADO - A COOPERATIVE EFFORT TO INCREASE TORNADO PREPAREDNESS IN ONTARIO

Barry Greer, Michael Leduc and James Ellard

On May 31, 1985, when a series of nine tornadoes swept through Southern Ontario, the watches and warnings issued by the Ontario Weather Centre gave as much lead-time notification as science and technology would permit. The warnings were not as effective as they could have been, however, because the media and the general public had no clear understanding of either the nature of the storms or the implications of our alerting system. The mandate for public education on emergencies is a mandate AES shares with municipal, provincial and other federal agencies. In order to address this issue, AES Ontario Region organized a loosely knit coordinating committee with representation from federal and provincial emergency measures organizations, police, media, military and education authorities.

As a result of this committee a tornado preparedness workshop was held in March 1988 in Wellington county of Southern Ontario. The workshop was organized by the Wellington-Dufferin District Health Council but included participation from all levels of government: Environment Canada, Emergency Planning Ontario, and strong representation from Wellington County including township and town officials.

The purpose of the exercise was to run through a hypothetical tornado disaster in Wellington County and examine the response of the public agencies to realistic scenarios presented to them. In this way municipal authorities could test their emergency plans. A principal focus of this exercise was a video produced for AES designed to show clearly the sequence of forecasting events which precede a major tornadic event and the dramatic and often confusing elements of the storm itself.

An overview of some of the exercises presented and the facets of emergency preparedness tested by this workshop will be presented. Other Ontario region initiatives in the public education field will be discussed all related to the underlying principle that an educated public is necessary for an effective warning system.

CONDUCTING FIELD SURVEYS OF STORM DAMAGE CAUSED BY SEVERE THUNDERSTORMS AND TORNADOES

Richard Hogue and Jasmin Kern

On average, about eighty reports of wind or hail damage due to severe local summer storms are received by the Ontario Weather Centre each year. We will examine the procedures followed by the Weather Centre in response to these reports. The factors which determine whether an investigation is carried out will be presented. These include whether injuries or death were involved, the dollar value of the damage, the cost of the investigation and the availability of staff, media inquiries, and political pressure.

We will look at the nature of the investigation and how we obtain information such as the time of the storm and its track. This question is answered by such things as investigating damage to structures and trees from the ground

and from the air and by gathering data by personal interviews. We will also look at some of the problems encountered in obtaining this information (personal biases of interviewees, the delicate problem of interviewing someone whose home has been destroyed).

We will discuss the problem of deciding whether a storm was tornadic or not. The complications include the difficulty of interpreting debris patterns, especially by AES staff who have little knowledge of structual design and precise wind effects on structures. We will explain the use of Doppler radar in this decision.

Finally, we will look at the additional benefits of the investigations. Those include the production of accurate climatologies of storm tracks which are used to determine true risk probabilities and precise maps of damage areas used for insurance purposes. Also, accurate times and tracks of storms allow for precise ground truthing of radar data. This last benefit is the most important one from a forecasting point of view.

THE WEATHER AS A FACTOR IN CANADIAN DISASTERS

Bob Jones

Two reference documents were surveyed for descriptions of all disasters (over 20 deaths) in Canadian history, "Canadian Disasters" by René Schmidt and Mel Hurtig's "Canadian Encyclopedia". A total of 52 different disasters were identified, one third of which were caused by meteorological factors. These disasters are described and the weather-related causes shown.

A 3-D HEMISPHERIC TRACER MODEL AND ITS APPLICATIONS

J. Pudykiewicz

Numerical simulation of atmospheric tracers has recently become an important part of the geophysical sciences. The best known examples are the models of the tropospheric chemistry on a regional scale related to the problem of acid rain and the models simulating stratospheric chemistry being used to address the problem of the depletion of the ozone layer.

In the present paper we are presenting the general formulation of the Canadian hemispheric tracer model designed to handle a wide variety of problems ranging from stratospheric chemistry to the simulation of radioactive tracers. The model is an integral part of the operational weather prediction system .

The new tracer model is very flexible and could be executed in the diagnostic mode using objectively analysed meteorological fields or in a predictive mode. It is important to note that the predictive version of the system will be driven by the Finite Element Regional Model for the runs on the mesoscale grid used to simulate episodic processes. The hemispheric spectral model will be used for

the simulation of the long-term effects of the atmospheric tracers.
The most important applications of the hemispheric tracer model are related to the long-term simulation of radioactive tracers and simulation of atmospheric chemistry on the scale of the Northern Hemisphere.
The model was employed successfully to simulate the hemispheric scale dispersion of radioactive Iodine and Cesium from the Chernobyl accident. An older version of the model is being implemented as an operational Emergency Response System in the Canadian Meteorological Centre.
The current research with a 3-D hemispheric tracer model is related mostly to the implementation of complex chemistry and a sophisticated predictive cloud scheme.

1020-1200: (Ontario) **Friday / Vendredi**
SESSION 14B: COASTAL OCEANOGRAPHY III
SESSION 14B : OCÉANOGRAPHIE CÔTIÈRE III

INTERPRETING SATELLITE SEA-SURFACE TEMPERATURE IMAGES WITH WIND AND CURRENT DATA IN JACQUES CARTIER PASSAGE
D. Lefaivre, A. Condal, V.G. Koutitonsky, P. Ouellet and D. Hains

Sequences of daily sea-surface temperature images from NOAA satellites are interpreted jointly with sea-surface wind data and measured currents in the water column. The analysis is part of the COHJAC project (Circulation, Oceanography and Hydrography of Jacques Cartier Passage). The sea-surface wind is calculated from the air pressure gradients measured at ground stations on the coast of the Gulf of St. Lawrence. The currents were measured at three locations along the northern part of the Gulf during five months in the summer of 1986. Upwelling and mixing events due to wind forcing can now be identified clearly.

THE VORTICITY BALANCE ON THE B.C. CONTINENTAL SHELF
H.J. Freeland

A small coherent array of current-meter moorings was deployed on the southern Vancouver Island continental shelf from March to July 1985. The array was specifically designed to allow the estimation of vorticity and its spatial derivatives.

Objective analysis was used to estimate vorticity, its time and space derivatives, the streamfunction and velocity fields. This was accomplished using covariance functions previously estimated at this location using historical data bases. The vertical velocity was estimated in two ways, firstly by assuming the equation of conservation of salt and secondly by the, so-called, Bryden relationship which relates vertical velocity to the rate of

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turning in the vertical of the horizontal velocity vector. Both methods yield very similar time series for vertical velocity.

Estimates will be presented of the magnitudes of each of the terms in the vorticity balance equation, and the way in which these terms combine to effect a balance will be discussed. The observations exhibit a substantial mean vorticity of about f/15, the source of this vorticity will also be discussed.

SATELLITE OBSERVATIONS OF A BASIN EDDY IN THE LOWER ST. LAWRENCE ESTUARY

G. Mertz, Y. Gratton and J.A. Gagné

The lower St. Lawrence Estuary is unique in being large enough to accomodate the development of unstable waves into baroclinic eddies. These eddies are generated by the strong estuarine jet driven by fresh water influx from the St. Lawrence River. We present satellite images capturing a basin-wide (50-km diameter) cyclonic eddy and the break-up of its thermal signature. We modify Hart's (1974) mixed barotropic baroclinic instability model to include the effects of topography and show that barotropic energy conversion processes are important here. The factors likely to be important in initiating eddy development, promoting eddy visibility, and the contribution of eddies to low-frequency current variance are discussed.

A FINITE-ELEMENT TIDAL MODEL FOR THE SOUTHWEST COAST OF VANCOUVER ISLAND

M.G.G. Foreman

In order to predict tidal currents for an upcoming field program associated with the Marine Survival of Salmon Project, a three-dimensional finite-element tidal model has been developed for the southwest coast of Vancouver Island. Model resolution ranges from approximately 40 km offshore to 2 km at the coast. Eight tidal constituents are included in the simulation. In accordance with techniques devised by Lynch and Werner, the vertically averaged equations are solved with bottom stress represented in terms of the bottom velocity, rather than the vertically averaged velocity. Vertical profiles of the horizontal velocities are produced and velocities at specific depths are compared to current observations in the region. Particular attention is given to the diurnal constituents as they contain substantial contributions in the form of continental shelf waves.

NON-LINEAR BALANCE AND GRAVITY-INERTIAL WAVE SATURATION IN A SIMPLE ATMOSPHERIC MODEL

Richard Menard

The slow manifold in the state space of a primitive equation model is defined as a hypothetical invariant manifold on which there is no gravity-wave activity. A numerical experiment with a highly truncated, forced-dissipative version of the shallow water equations was conducted and it suggests that for realistic atmospheric parameters, high-frequency inertial-gravity waves are almost always present in the solution, even in the limit of small Rossby numbers and long times. The waves are intermittent in character and appear to be generated naturally by the non-linear interactions of the system. This behaviour is at variance with the existence of the slow manifold but favours the existence of a "fuzzy" slow manifold. The high-frequency component leads to systematic differences between actual flow and high-order balanced states, suggesting that there is an inherent limitation to the amount of information about the divergent part of the flow that can be gleaned from the rotational motion. The information is expected to be a rapidly decreasing function of Rossby number.

DEVELOPMENT OF MARGINALLY UNSTABLE BAROCLINIC VORTICES

P. Gauthier and T. Warn

The weakly nonlinear dynamics of a baroclinic wave in a two-layer model near minimum critical shear is described in terms of a nonlinear critical layer problem which is completely integrable in the absence of dissipation. Inviscid subliminal disturbances are found to equilibrate at leading order, even though the absolute potential vorticity of the lowest layer is transferred irreversibly to smaller and smaller scales and always transient. The inviscid equilibrium amplitude of the fundamental is found to be larger than the weakly dissipative value found by Pedlosky (1982), indicating that the limits $t\to\infty$ and vanishing dissipation are not interchangeable. With weak or vanishing supercriticality, the inviscid behaviour depends on the form of the initial disturbance. The fundamental may either equilibrate or oscillate periodically. In the latter circumstance, absolute potential vorticity contours reversibly wrap and unwrap and there is no tendency to mix the potential vorticity. Finally, the analytical solution is used to judge the reliability of numerical results obtained from truncated models. Even with a fairly high number of modes, these can become inaccurate in a relatively short period of time.

NON-SEPARABLE QUASI-GEOSTROPHIC BAROCLINIC INSTABILITY

G.W. Kent Moore and W.R. Peltier

We address the problem of the stability of non-separable baroclinic mean states against quasi-geostrophic perturbations. A general methodology is developed that allows us to construct solutions to such problems without requiring any simplifying assumptions. To illustrate this methodology, both meridionally periodic and frontal mean states are examined for stability against three-dimensional fluctuations.

A previous investigation of frontal stability (Moore and Peltier 1987) which was based upon the use of the primitive equations, demonstrated that frontal zones are unstable to a cyclone-scale mode of baroclinic instability. This mode had not been detected in any previous stability analysis. No evidence of this new mode is found in the results for the quasi-geostrophic problem reported here. In fact, it is shown that the dynamical constraints implied by the quasi-geostrophic approximation forbid the existence of such modes. We also show that recently reported quasi-geostrophic stability analyses that make simplifying assumptions regarding the meridional structure of the basic state (based upon asymptotic considerations) seriously overestimate the degree of instability present.

The present study therefore serves to re-emphasize the fact that the stability characteristics of non-separable mean states can be rather complex. The only way to truly understand them is to solve the stability problem without approximating either the field equations employed in the analysis or the structure of the mean state whose stability is under investigation.

ROSSBY WAVE GENERATION BY MOVING CURRENTS

Rose G. Wood

This paper examines the generation of baroclinic Rossby waves by a steady zonal current, which either translates at a constant speed or oscillates sinusoidally in latitudinal position. A linear, reduced gravity ocean model is used, with parameters appropriate to the mid-latitude North Pacific. In this way, movements of the North Pacific Current can be investigated as a generation mechanism for oceanic Rossby waves. An analytical solution is found for forcing by a steadily moving current, while a numerical model yields solutions for oscillating current forcing. All the results indicate a strong relationship between the wave crest orientation of the response and the speed of motion of the current. This is elucidated by reference to the work of Lighthill (1967) on moving forcing effects.

THE APPLICABILITY OF GRADIENT TRANSPORT MODELS TO HORIZONTAL DIFFUSION IN THE OCEAN

Brian G. Sanderson and B.K. Pal

A study of the scale dependence of turbulence intensity and Lagrangian integral time-scale is made using experiments covering a wide range of scales in the ocean. Gradient transport models are found to be marginally applicable for describing the ensemble averaged horizontal dispersion of patches of drifters. It is argued that the scale dependence of horizontal dispersion of drifters should be different from Okubo's (1971) result (which was based on dye data).

TWENTY-THIRD ANNUAL CONGRESS

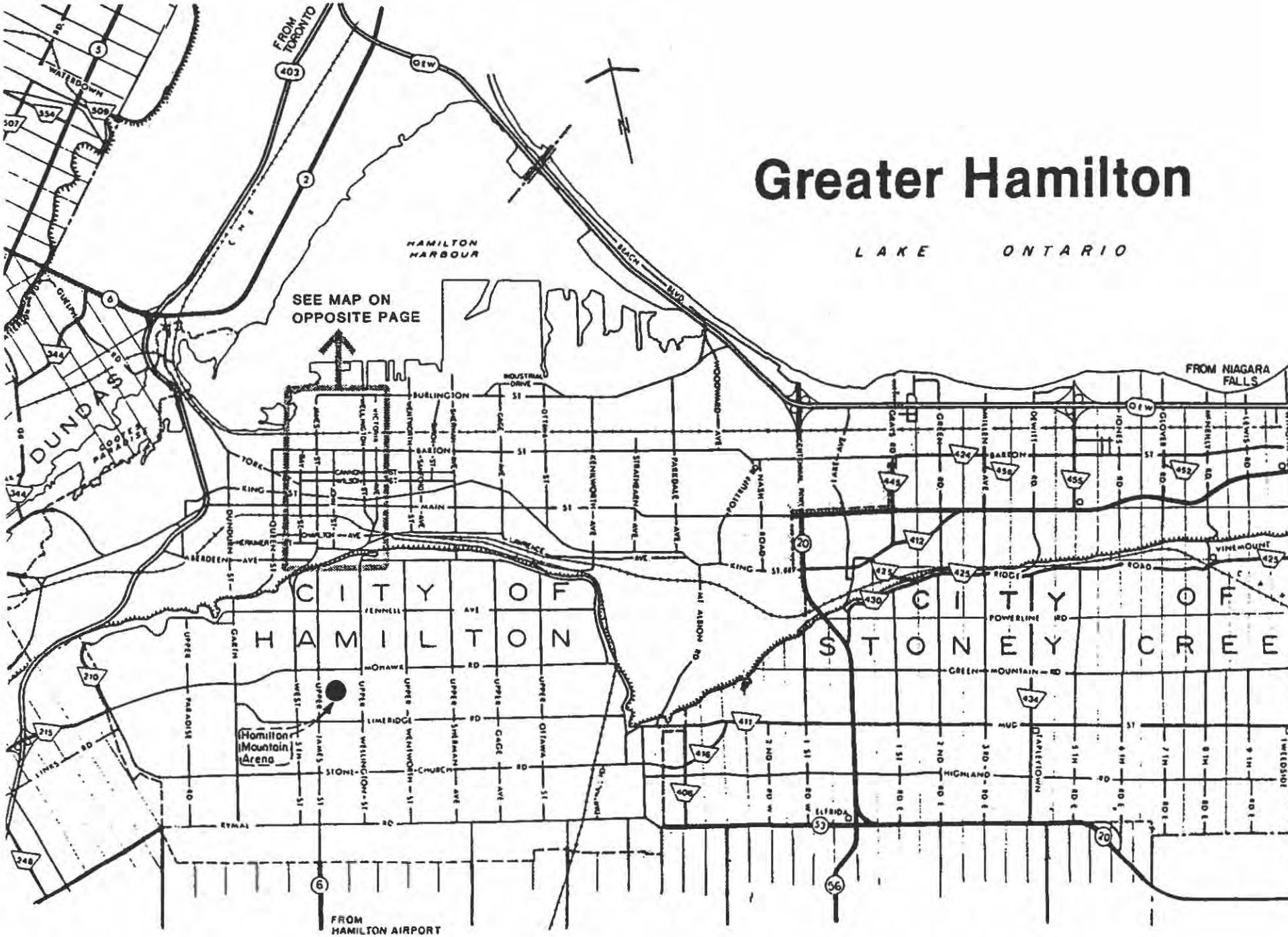
The Rimouski Centre of the Canadian Meteorological and Oceanographic Society will host the Twenty-third Annual CMOS Congress. The Congress will be held at the Université du Québec à Rimouski on June 6-9, 1989. The theme is OCEANIC AND ATMOSPHERIC HAZARDS: MODELLING AND OBSERVATIONS.

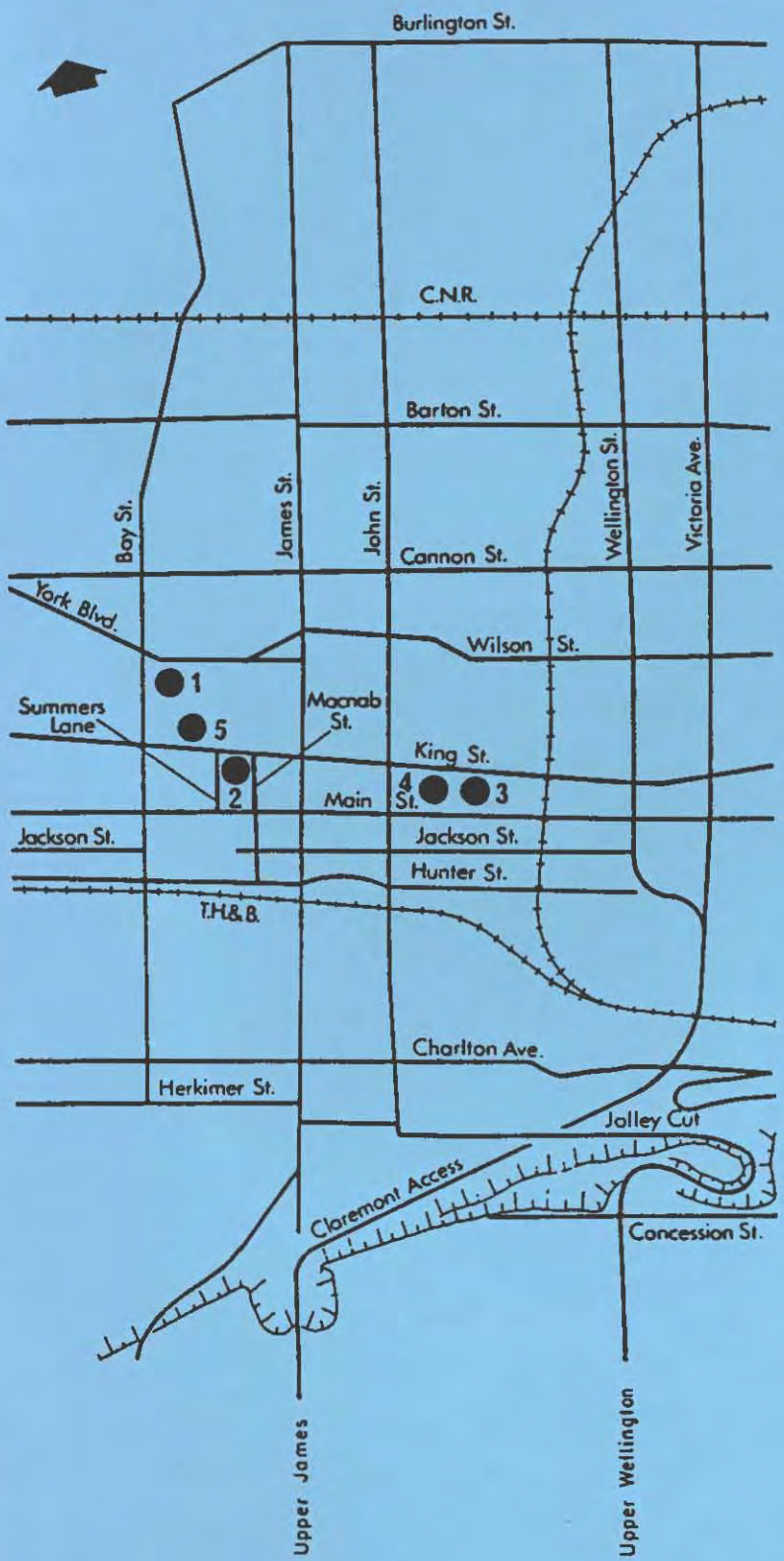
For further information, please contact Dr. Yves Gratton (Chairman, Scientific Program Committee) or Dr. Vladimir Koutitonsky (Chairman, Local Arrangements Committee). The phone number of Dr. Gratton is 418-724-1761 and Dr. Koutitonsky is 418-724-1763. Both are at the Département d'Océanographie, Université du Québec à Rimouski, Rimouski, Québec G5L 3A1.

VINGT-TROISIÈME CONGRÈS ANNUEL

Le Centre de Rimouski de la Société canadienne de météorologie et d'océanographie sera l'hôte du vingt-troisième congrès annuel de la SCMO, du 6 au 9 juin 1989, à l'Université du Québec à Rimouski. Les thème en sera : CATASTROPHES OCÉANIQUES ET ATMOSPHÉRIQUES : MODÉLISATION ET MESURES.

On peut obtenir d'autres renseignements auprès de M. Yves Gratton (Président du comité du programme scientifique) au 418-724-1761 ou de M. Vladimir Koutitonsky (Président du comité organisateur) au 418-724-1763. Tous deux se trouvent au Département d'Océanographie, Université du Québec à Rimouski, Rimouski, Québec G5L 3A1.


Greater Hamilton
LAKE ONTARIO
HAMILTON HARBOUR
SEE MAP ON OPPOSITE PAGE
FROM TORONTO
FROM NIAGARA FALLS
FROM HAMILTON AIRPORT
CITY OF HAMILTON
CITY OF STONEY CREE
DUNDAS
WATERDOWN
BURLINGTON ST
BARTON ST
KING ST
MAIN ST
KING ST
RIDGE ROAD
MOHAWK RD
LIMERIDGE RD
STONE CHURCH RD
RYMAL RD
GREEN MOUNTAIN RD
HIGHLAND RD
MUD ST
POWERLINE RD
Hamilton Mountain Arena



DOWNTOWN HAMILTON

1 COPPS COLISEUM
The Victor K. Copps Trade/Arena "affectionately known as Copps Coliseum" is the latest project of the Downtown Redevelopment Programme. Copps Coliseum seats 18,000 and features an NHL ice surface that can expand into an Olympic size ice surface.

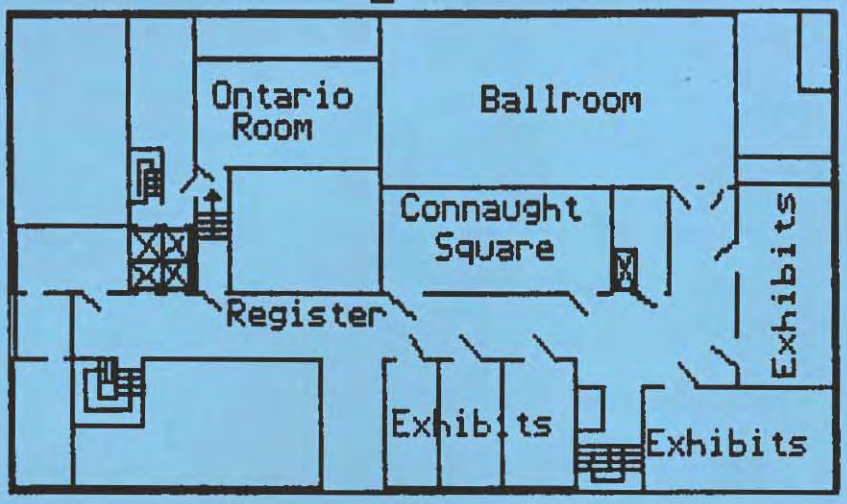
2 HAMILTON CONVENTION CENTRE
The Hamilton Convention Centre is a multi-purpose building. The Centre has been the host to conventions, trade-shows, seminars and banquets.

3 HOLIDAY INN/TERMINAL TOWERS
Two shopping levels, coffee shop, Holiday Inn Hotel, dining and dancing.

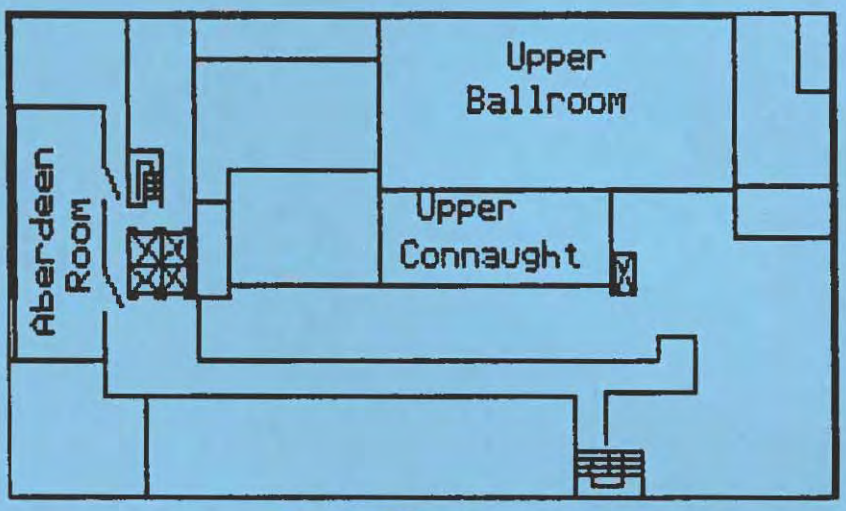
4 ROYAL CONNAUGHT HOTEL
Hamilton's grand hotel featuring accommodations, shopping, dining and dancing.

5 SHERATON HOTEL
The Sheraton Hotel is Hamilton's newest addition to the downtown core which, features accommodations, shopping, dining and dancing.

Meeting Rooms



2nd Floor



3rd Floor

0 10m
Scale