La Société
Canadienne
de Météorologie
et d'Océanographie

Canadian
Meteorological
and Oceanographic
Society

19e CONGRÈS ANNUEL
19th ANNUAL CONGRESS

12-14 Juin 1985 June 12-14
Université du Québec à Montréal
Montréal Québec

PROGRAMME et RÉSUMÉS
PROGRAM and ABSTRACTS

NINETEENTH ANNUAL CONGRESS

Canadian Meteorological and Oceanographic Society

The Montreal Centre of the Canadian Meteorological and Oceanographic Society (CMOS) and l'Université du Québec à Montréal (UQAM) will host the Nineteenth Annual CMOS Congress and Annual General Meeting at UQAM from June 12 to 14, 1985. The theme is **"Modelling in Meteorology and Oceanography"**. In addition to invited and contributed papers relating to the general theme, sessions will be held on other aspects of meteorology and oceanography.

Back to back with the CMOS Congress, the American Meteorological Society will hold two conferences at UQAM the following week: the Seventh Conference on Numerical Weather Prediction, from June 17 to 20, and the Second International Conference on the Aviation Weather System, from June 19 to 21.

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

SCIENTIFIC PROGRAM COMMITTEE

Harold Ritchie, Chairman
Conrad East, Vice-Chairman
Han-Ru Cho
Grant Ingram
Norman McFarlane
Brian Petrie
Nathan Yacowar

LOCAL ARRANGEMENTS COMMITTEE

Jean-Guy Cantin, Chairman
Peter Zwack, Secretary - Publicity Convenor
Robert Mailhot, Treasurer - Facilities Convenor
Jocelyne Blouin, Registration Convenor
René Servanckx, Social Activities Convenor
Richard Moffet, Exhibits Convenor
Marie-France Guéraud, Translation Convenor

INVITED SPEAKERS

G.J. Boer, Canadian Climate Centre
P.G. Brewer, Woods Hole Oceanographic Institution
A.D. Christie, Atmospheric Environment Service
G.T. Csanady, Woods Hole Oceanographic Institution
W.F.J. Evans, Atmospheric Environment Service
P.V. Hobbs, University of Washington
D.J.W. Kendall, National Research Council
A.H. Murphy, Oregon State University
J.F. Price, Woods Hole Oceanographic Institution
A. Robert, Recherche en prévision numérique
P.D. Scully-Power, Underwater Research Center

DIX-NEUVIEME CONGRES ANNUEL

Société Canadienne de Météorologie et d'Océanographie

Le Centre de Montréal de la Société canadienne de météorologie et d'océanographie (SCMO) et l'Université du Québec à Montréal (UQAM) seront les hôtes du dix-neuvième Congrès annuel et de l'assemblée générale annuelle de la SCMO, événements qui se tiendront à l'UQAM du 12 au 14 juin 1985. Le Congrès a pour thème **"La modélisation en météorologie et en océanographie"**. Outre les communications présentées par les conférenciers invités et les autres participants sur le thème général, il se tiendra des séances sur d'autres aspects de la météorologie et de l'océanographie.

A la suite du Congrès de la SCMO, l'American Meteorological Society tiendra deux congrès à l'UQAM : le septième Congrès sur la prévision numérique du temps, du 17 au 20 juin, et le deuxième Congrès international sur le service météorologique à l'aviation, du 19 au 21 juin.

Pour le Congrès de la SCMO, le programme scientifique et les arrangements locaux ont été organisés par :

COMITE DU PROGRAMME SCIENTIFIQUE

Harold Ritchie, Président
Conrad East, Vice-Président
Han-Ru Cho
Grant Ingram
Norman McFarlane
Brian Petrie
Nathan Yacowar

COMITE ORGANISATEUR

Jean-Guy Cantin, Président
Peter Zwack, Responsable secrétaire - publicité
Robert Mailhot, Trésorier - Responsable location des lieux
Jocelyne Blouin, Responsable inscription
René Servanckx, Responsable activités sociales
Richard Moffet, Responsable exposition
Marie-France Guéraud, Responsable traduction

CONFERENCIERS INVITES

G.J. Boer, Centre climatologique canadien
P.G. Brewer, Woods Hole Oceanographic Institution
A.D. Christie, Service de l'environnement atmosphérique
G.T. Csanady, Woods Hole Oceanographic Institution
W.F.J. Evans, Service de l'environnement atmosphérique
P.V. Hobbs, University of Washington
D.J.W. Kendall, Conseil national de recherches
A.H. Murphy, Oregon State University
J.F. Price, Woods Hole Oceanographic Institution
A. Robert, Recherche en prévision numérique
P.D. Scully-Power, Underwater Research Center

Summary of Sessions

Note: * indicates sessions with invited speakers. Sessions 1, 6 and all A sessions will be held in Studio Alfred-Laliberté. Rooms for B and C sessions will be announced at the Congress.

Tuesday, June 11

0900-1200		ATMOSPHERE-OCEAN Editorial Board
0900-1200		Chinook Editorial Board
0900-1200		Climatological Bulletin Editorial Board
0900-1200		CMOS Committee on Professionalism
0900-1700		SCOR
1300-1545		CMOS Education Committee for Meteorology
1300-1545		CMOS Scientific Committee
1300-1545		CMOS Centre Chairmen
1600-1800		CMOS National Council (Session I)
1900-2100		Registration and Information - Holiday Inn, Place Dupuis
1900-2100		Ice Breaker Reception - Holiday Inn, Place Dupuis
2000-2300		CMOS National Council (Session II)

Wednesday, June 12

		Registration and Information, near Studio Alfred-Laliberté
0830-1030	1*	Plenary Theme Session: Modelling in Meteorology and Oceanography
1030-1050		Coffee
1050-1230	2A*	Operational Use of Model Output
1050-1230	2B	Estuaries and Embayments I
1050-1230	2C*	Ocean Chemistry and Geochemical Processes I
1230-1330		Lunch
1330-1510	3A	Modelling the Transport and Diffusion of Pollutants I
1330-1510	3B*	Coastal Oceanography I
1330-1510	3C	Surface Waves I
1510-1530		Coffee
1530-1730	4A	Evaluation of Meteorological Models
1530-1710	4B	Coastal Oceanography II
1530-1710	4C	Modelling the Transport and Diffusion of Pollutants II: Emergency Response and Environmental Impact Assessment
1800-1930		Wine and Cheese - UQAM
1930-2300		CMOS Annual General Meeting - UQAM

Thursday, June 13

		Registration and Information, near Studio Alfred-Laliberté
0830-1030	5A*	Modelling the Transport and Diffusion of Pollutants III
0830-1030	5B	Estuaries and Embayments II
0830-1030	5C	Applied Meteorology
1030-1050		Coffee
1050-1230	6*	Plenary Session: Space Shuttle Experiments and CASP Information
1230-1330		Lunch
1330-1510	7A*	Mesoscale Meteorology I
1330-1510	7B	Meteorological Forecasts and Case Studies
1330-1450	7C	Ocean Chemistry and Geochemical Processes II
1510-1530		Coffee
1530-1710	8A	Mesoscale Meteorology II
1530-1730	8B	Surface Waves II

1530-1710	8C	Satellite and Radar Meteorology
1710-1830		Special Interest Group Meetings
		Air Pollution
		Operational Meteorology
1900		CMOS Banquet - Holiday Inn, Place Dupuis

Friday, June 14

		Registration and Information, near Studio Alfred-Laliberté
0830-1030	9A	Cloud Physics and Modelling
0830-1030	9B	Deep-Sea Oceanography I
0830-1030	9C	Boundary-Layer Modelling
1030-1050		Coffee
1050-1230	10A	Atmospheric Dynamics
1050-1210	10B	Deep-Sea Oceanography II
1050-1230	10C	Severe Weather
1230-1330		Lunch
1330-1510	11A*	General Circulation Modelling and Parameterization
1330-1510	11B	Labrador Sea Dynamics
1330-1450	11C	Climatology

Visit to the Canadian Meteorological Centre

Ramses II Exhibition

Résumé des sessions

Note : * indique les sessions des conférenciers invités. Les sessions 1, 6 et toutes les sessions A se tiendront dans le Studio Alfred-Laliberté. Les salles pour les sessions B et C seront annoncées au Congrès.

Mardi le 11 juin

0900-1200		Bureau de rédaction, ATMOSPHERE-OCEAN
0900-1200		Bureau de rédaction du Chinook
0900-1200		Bureau de rédaction du Bulletin Climatologique
0900-1200		Comité de la SCMO sur le professionnalisme
0900-1700		SCOR
1300-1545		Comité de la SCMO sur l'éducation en météorologie
1300-1545		Comité scientifique de la SCMO
1300-1545		Comité des présidents des centres de la SCMO
1600-1800		Conseil national de la SCMO (session I)
1900-2100		Inscription et informations - Holiday Inn, Place Dupuis
1900-2100		Réception d'accueil - Holiday Inn, Place Dupuis
2000-2300		Conseil national de la SCMO (session II)

Mercredi le 12 juin

		Inscription et informations, près du Studio Alfred-Laliberté
0830-1030	1*	Session plénière thématique : Modélisation en météorologie et en océanographie
1030-1050		Café
1050-1230	2A*	Utilisation opérationnelle des sorties des modèles
1050-1230	2B	Estuaires et baies I
1050-1230	2C*	Chimie des océans et processus géochimiques I
1230-1330		Déjeuner
1330-1510	3A	Modélisation du transport et de la diffusion des polluants I
1330-1510	3B*	Océanographie côtière I
1330-1510	3C	Ondes de surface I
1510-1530		Café
1530-1730	4A	Evaluation des modèles météorologiques
1530-1710	4B	Océanographie côtière II
1530-1710	4C	Modélisation du transport et de la diffusion des polluants II : réaction aux urgences et évaluation des conséquences pour l'environnement
1800-1930		Vin et fromage - UQAM
1930-2300		Assemblée générale annuelle de la SCMO - UQAM

Jeudi le 13 juin

		Inscription et informations, près du Studio Alfred-Laliberté
0830-1030	5A*	Modélisation du transport et de la diffusion des polluants III
0830-1030	5B	Estuaires et baies II
0830-1030	5C	Météorologie appliquée
1030-1050		Café
1050-1230	6*	Session plénière : Expériences de la navette spatiale et informations CASP
1230-1330		Déjeuner
1330-1510	7A*	Météorologie à l'échelle moyenne I
1330-1510	7B	Prévisions météorologiques et études de cas
1330-1450	7C	Chimie des océans et processus géochimiques II
1510-1530		Café
1530-1710	8A	Météorologie à l'échelle moyenne II

1530-1730	8B	Ondes de surface II
1530-1710	8C	Radar, satellite et météorologie
1710-1830		Réunions des groupes d'intérêts spéciaux
		Pollution de l'air
		Météorologie d'exploitation
1900		Banquet SCMO - Holiday Inn, Place Dupuis

Vendredi le 14 juin

		Inscription et informations, près du Studio Alfred-Laliberté
0830-1030	9A	Physique et modélisation des nuages
0830-1030	9B	Océanographie des eaux profondes I
0830-1030	9C	Météorologie de la couche limite
1030-1050		Café
1050-1230	10A	Dynamique atmosphérique
1050-1210	10B	Océanographie des eaux profondes II
1050-1230	10C	Phénomènes météorologiques dangereux
1230-1330		Déjeuner
1330-1510	11A*	Modélisation des circulations générales et paramétrisation
1330-1510	11B	Dynamique de la mer du Labrador
1330-1450	11C	Climatologie

Visite au Centre météorologique canadien

Exposition Ramsès II

Program/Programme

Wednesday Morning, 12 June 1985
Mercredi matin, le 12 juin 1985

0830-1030 Studio Alfred-Laliberté
PLENARY THEME SESSION 1: MODELLING IN METEOROLOGY AND OCEANOGRAPHY
Chairman / Président : N. Campbell
SESSION PLENIERE THEMATIQUE 1 : MODELISATION EN METEOROLOGIE ET EN OCEANOGRAPHIE

0830: WELCOMING REMARKS
C. Pichette, Rector, l'Université du Québec à Montréal
MOT DE BIENVENUE
C. Pichette, Recteur, l'Université du Québec à Montréal

0845: STATE OF METEOROLOGY AND OCEANOGRAPHY
N. Campbell, President, Canadian Meteorological and Oceanographic Society
METEOROLOGIE ET OCEANOGRAPHIE : L'ETAT ACTUEL DES DEUX SCIENCES
N. Campbell, Président, La Société canadienne de météorologie et d'océanographie

0900: THE EVOLUTION OF NUMERICAL WEATHER PREDICTION MODELS
André Robert, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

0945: MODELLING THE UPPER OCEAN RESPONSE TO STORMS
James F. Price, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

1030-1050 Coffee / Café

1050-1230 Studio Alfred-Laliberté
SESSION 2A: OPERATIONAL USE OF MODEL OUTPUT
Chairman / Président : F. Lemire
SESSION 2A : UTILISATION OPERATIONNELLE DES SORTIES DES MODELES

1050: Invited Speaker: PROS AND CONS OF PROBABILITY FORECASTS: EVALUATING THE "SCORE"
Allan H. Murphy, Department of Atmospheric Sciences, Oregon State University, Corvallis, Oregon

1130: DEVELOPMENT OF A MOS SYSTEM TO FORECAST PROBABILITY OF PRECIPITATION
N. Brunet, G. Richard, H. Yang, and N. Yacowar, Canadian Meteorological Centre, Atmospheric Environment Service, Dorval, Qué.

1150: VERIFICATION OF PROBABILITY OF PRECIPITATION FORECASTS FOR WINNIPEG, REGINA AND SASKATOON FOR 1983-84

Edward R. Lord, Prairie Weather Centre, Atmospheric Environment Service, Winnipeg, Man.

1210: DEVELOPPEMENT D'UN SYSTEME MOS DE PREVISION DE NEBULOSITE PAR LE CMC
R. Verret, N. Yacowar, H. Yang, and G. Richard, Centre météorologique canadien, Service de l'environnement atmosphérique, Dorval, Qué.

1050-1230
SESSION 2B: ESTUARIES AND EMBAYMENTS I
Chairman / Président : M. El-Sabh
SESSION 2B : ESTUAIRES ET BAIES I

1050: WINTER CIRCULATION IN LAKE ONTARIO
T.J. Simons and C.R. Murthy, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ont.
J.E. Campbell, GLERL/NOAA, Ann Arbor, Michigan

1110: APPROPRIATE PARAMETRISATIONS OF METEOROLOGICAL FORCING FOR USE IN LAKE THERMAL STRATIFICATION MODELS
B. Henderson-Sellers, Department of Mathematics and Computer Science, University of Salford, England

1130: SEICHES IN COASTAL BAYS OFF JUAN DE FUCA STRAIT
Lichen Wang and Paul H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, B.C.

1150: A STUDY OF SOOKE BASIN, B.C.
W. Wolfe, F. Milinazzo, M. Press and R. Marsden, Physics Department, Royal Roads Military College, Victoria, B.C.

1210: TRACKING THE MOVEMENT OF PATTERNS ON THE OCEAN'S SURFACE WITH TIME LAPSE RADAR IMAGERY
M.J. Press and H.J. Duffus, Physics Department, Royal Roads Military College, Victoria, B.C.

1050-1230
SESSION 2C: OCEAN CHEMISTRY AND GEOCHEMICAL PROCESSES I
Chairman / Président : B. D'Anglejan
SESSION 2C : CHIMIE DES OCEANS ET PROCESSUS GEOCHIMIQUES I

1050: Invited Speaker: THE SEASONALITY OF GLOBAL OCEAN CO_2 FLUXES
Peter G. Brewer, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

1130: GEOCHEMISTRY AND AGE OF THE HOLOCENE SAPROPEL IN THE BLACK SEA
S.E. Calvert, Department of Oceanography, The University of British Columbia, Vancouver, B.C.

1150: AN EIGHTY YEAR RECORD OF SEASONALLY MODULATED SEDIMENT

ACCUMULATION RATES BASED ON PB-210 AND PLUTONIUM MEASUREMENTS
J.N. Smith, K. Ellis, Atlantic Environmental Radiation Unit, Atlantic Oceanographic Laboratory, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.
C.T. Schafer, Atlantic Geoscience Centre, Department of Energy Mines and Resources, Bedford Institute of Oceanography, Dartmouth, N.S.

1210: QUANTITATIVE INFLUENCE OF PHOSPHATE ON CALCITE PRECIPITATION FROM SEAWATER
Alfonso Mucci, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1230-1330 Lunch / Déjeuner

Wednesday Afternoon, 12 June 1985
Mercredi aprés-midi, le 12 juin 1985

1330-1510 Studio Alfred-Laliberté
SESSION 3A: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS I
Chairman / Président : C. East
SESSION 3A : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS I

1330: SULPHATE AEROSOL AND SO_2 IN A THREE-DIMENSIONAL FIELD OF CUMULUS CLOUDS: NUMERICAL SIMULATIONS
Michal Niewiadomski, Atmospheric Environment Service, Downsview, Ont.

1350: A THREE-DIMENSIONAL CLOUD CHEMISTRY MODEL
André Tremblay and Henry Leighton, Department of Meteorology, McGill University, Montréal, Qué.

1410: A MESOSCALE PARAMETERIZATION FOR TRANSPORT AND TRANSFORMATION OF POLLUTANTS BY CLOUDS
Chris J. Walcek, Acid Deposition Modeling Project, National Center for Atmospheric Research, Boulder, Colorado

1430: WINTER OBSERVATIONS OF EMISSIONS FROM OIL SANDS EXTRACTION PLANTS
Andrew Davis, Lawrence Cheng, and Dave Rogers, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.

1450: TRANSFORMATION OF SULFUR DIOXIDE TO PARTICULATE SULFATE FROM OIL SANDS EXTRACTION PLANT EMISSIONS
Andrew Davis, Lawrence Cheng, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.
Eric Peake, Kananaskis Centre for Environmental Research, University of Calgary, Calgary, Alta.

1330-1510
SESSION 3B: COASTAL OCEANOGRAPHY I
Chairman / Président : P. LeBlond
SESSION 3B : OCEANOGRAPHIE COTIERE I

1330: Invited Speaker: ELEMENTARY MODELS OF COASTAL PYCNOBATHIC CURRENTS
G.T. Csanady, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

1410: THE WIND-DRIVEN CIRCULATION OFF SOUTHWEST NOVA SCOTIA
Peter C. Smith, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1430: HORIZONTAL AND VERTICAL EXCHANGE RATES ON THE SOUTHEAST SHOAL OF THE GRAND BANK. John W. Loder, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1450: ON THE BEHAVIOUR OF COASTALLY TRAPPED WAVES IN CHANNELS AND DEEP ESTUARIES WITH CONTINUOUS STRATIFICATION AND VARIABLE TOPOGRAPHY
V.G. Koutitonsky, INRS-Océanologie, Rimouski, Qué.
R.E. Wilson, Marine Sciences Research Center, State University of New York at Stony Brook, N.Y.

1330-1510
SESSION 3C: SURFACE WAVES I
Chairman / Président : B. Boczar-Karakiewicz
SESSION 3C : ONDES DE SURFACE I

1330: INTERCOMPARISON OF WIND WAVE PREDICTION MODELS
W. Perrie and B. Toulany, Atlantic Oceanographic Laboratory, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

1350: IMPROVING MODEL PREDICTION OF GREAT LAKES WIND WAVES
Stephen Clodman, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.

1410: WIND SPECIFICATION FOR SPECTRAL OCEAN-WAVE MODELS
M.L. Khandekar, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.
Bassem M. Eid, MacLaren Plansearch Ltd., Halifax, N.S.

1430: DIRECTIONAL WAVE SPECTRUM INTERCOMPARISON STUDY
Barbara-Ann Juszko, Seakem Oceanography Ltd., Sidney, B.C.

1450: BRAGG-SCATTERING AND EQUILIBRIUM RANGES IN WIND-GENERATED WAVES - WITH APPLICATION TO SCATTEROMETRY
Mark A. Donelan and Willard J. Pierson Jr., National Water Research

Institute, Canada Centre for Inland Waters, Burlington, Ont.

1510-1530 Coffee / Café

1530-1730 Studio Alfred-Laliberté
SESSION 4A: EVALUATION OF METEOROLOGICAL MODELS
Chairman / Président : I. Findleton
SESSION 4A : EVALUATION DES MODELES METEOROLOGIQUES

1530: VERIFICATIONS DU MODELE DE PREVISION NUMERIQUE EN EXPLOITATION AU CMC
Réal D'Amours, Centre météorologique canadien, Service de l'environnement atmosphérique, Dorval, Qué.

1550: PROFILS, TRACES ET TENDANCES METEOROLOGIQUES LOCALES TELS QUE PREVUS PAR LE MODELE EN EXPLOITATION AU CMC
Angèle Simard, Centre météorologique canadien, Service de l'environnement atmosphérique, Dorval, Qué.

1610: PREVISIONS NUMERIQUES UTILISANT LES DONNEES SATELLITE GOES
Jacques Hallé, Centre météorologique canadien
Robert Benoit, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

1630: WEDGE VERIFICATION
R. Jones, Canadian Meteorological Centre, Atmospheric Environment Service, Dorval, Qué.

1650: PREVISIONS DE TEMPERATURE MAX-MIN AU CMC PAR METHODE STATISTIQUE
N. Brunet, Centre météorologique canadien, Service de l'environnement atmosphérique, Dorval, Qué.

1710: SEA SURFACE FLUXES DIAGNOSED FROM A GLOBAL NUMERICAL WEATHER PREDICTION SCHEME
D.N. Reed, U.K. Meteorological Office, Bracknell, U.K.

1530-1710
SESSION 4B: COASTAL OCEANOGRAPHY II
Chairman / Président : Y. Gratton
SESSION 4B : OCEANOGRAPHIE COTIERE II

1530: ACE - A SEARCH FOR COASTAL TRAPPED WAVES
Howard J. Freeland and J.A. Church, Institute of Ocean Sciences, Sidney, B.C.

1610: VERTICAL MIXING IN A STRATIFIED UNDER-ICE COASTAL ENVIRONMENT
R. Grant Ingram, Institute of Oceanography, McGill University, Montréal, Qué.

1630: MIXING AND CIRCULATION IN BARROW STRAIT
S.J. Prinsenberg and E.B. Bennett, Department of Fisheries and Oceans,

Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1650: A COUPLED ICE-OCEAN MODEL OF A WIND-DRIVEN COASTAL FLOW
Motoyoshi Ikeda, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1530-1710
SESSION 4C: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS II: EMERGENCY RESPONSE AND ENVIRONMENTAL IMPACT ASSESSMENT
Chairman / Président : A. Staniforth
SESSION 4C : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS II : REACTION AUX URGENCES ET EVALUATION DES CONSEQUENCES POUR L'ENVIRONNEMENT

1530: EVALUATION OF A MULTIPLE-SOURCE REGIONAL EPISODE MODEL
D.L. Bagg and C.S. Matthias, Air Quality Monitoring and Assessment Division, Atmospheric Environment Service, Downsview, Ont.

1550: TRACER DISPERSION IN VALLEY DRAINAGE FLOWS
S.K. Sakiyama and R.P. Angle, Alberta Environment, Pollution Control Division, Edmonton, Alta.

1610: ON THE USE OF LEAD DIOXIDE CYLINDER INFORMATION
Douglas M. Leahey and Michael B. Schroeder, Western Research and Development Ltd., Calgary, Alta.

1630: APPLICATION OF THE ISCLT AIR QUALITY MODEL FROM THE UNAMAP SERIES TO THE DEPOSITION OF METALS IN THE SNOWPACK IN THE VICINITY OF THE METAL SMELTER AT FLIN FLON
S.R. Shewchuk and R. Jahren, Environment Sector, Saskatchewan Research Council, Saskatoon, Sask.

1650: RESULTATS D'UNE EXPERIENCE DE MESURE DE PH QUOTIDIEN
Gilles Desautels, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

Thursday Morning, 13 June 1985
Jeudi matin, le 13 juin 1985

0830-1030 Studio Alfred-Laliberté
SESSION 5A: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS III
Chairman / Président : O. Melo
SESSION 5A : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS III

0830: Invited Speaker: PROBLEMS IN EVALUATION OF COMPREHENSIVE MODELS OF TRANSPORT AND DIFFUSION OF POLLUTANTS
A.D. Christie, Atmospheric Environment Service, Downsview, Ont.

0910: THE NCAR-EPA REGIONAL ACID DEPOSITION MODEL
R.A. Brost, P. Middleton, W.R. Stockwell, C.J. Walcek, and J.S. Chang, Acid Deposition Modeling Project, National Center for Atmospheric Research, Boulder, Colorado

0930: A COMPARISON BETWEEN THE DIAGNOSTIC TRAJECTORIES COMPUTED FROM THE AES-LRTAP MODEL AND THE GROUND-LEVEL TRACER PATTERNS OBSERVED DURING CAPTEX-83
Peter W. Summers and Marvin P. Olson, Air Quality and Inter- Environmental Research Branch, Atmospheric Environment Service, Downsview, Ont.

0950: SENSITIVITY TESTING OF THE UNIVERSITY OF SALFORD PLUME RISE AND DISPERSION MODEL U.S.P.R.
B. Henderson-Sellers and S.E. Allen, Department of Mathematics and Computer Science, University of Salford, England

1010: EVALUATION OF LAGRANGIAN LRT MODELS
C.S. Fung, E. Alp and R.V. Portelli, Concord Scientific Corporation, Downsview, Ont.

0830-1030
SESSION 5B: ESTUARIES AND EMBAYMENTS II
Chairman / Président : G. Ingram
SESSION 5B : ESTUAIRES ET BAIES II

0830: A NUMERICAL MODEL OF THE UNSTEADY CIRCULATION AND SALINITY REGIME IN A SUBARCTIC SHALLOW ESTUARY
Serge Lepage, Institute of Oceanography, McGill University, Montréal, Qué.

0850: VORTICITY WAVES IN VARIABLE BREADTH ESTUARIES
B. Pelchat and Y. Gratton, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.

0910: LATERAL DYNAMIC BALANCE IN THE LOWER ST. LAWRENCE ESTUARY
P. Larouche, Champlain Centre for Marine Sciences and Surveys, Department of Fisheries and Oceans, Québec, Qué.

0930: PRELIMINARY ANALYSIS OF SUBTIDAL SEA LEVEL VARIABILITY IN THE ST. LAWRENCE ESTUARY, SUMMER 1979
V.G. Koutitonsky, INRS-Océanologie, Rimouski, Qué.
R.E. Wilson, Marine Sciences Research Center, State University of New York at Stony Brook, N.Y.

0950: HYDRODYNAMICS OF THE LOWER ST. LAWRENCE ESTUARY
Mohammed I. El-Sabh, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1010: VARIABILITY OF SURFACE CURRENTS IN THE LOWER ST. LAWRENCE ESTUARY
M.I. El-Sabh, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.
M. Gagnon, INRS-Océanologie, Rimouski, Qué.

POSTER: ON LOW FREQUENCY CURRENT VARIABILITY IN THE LOWER ST. LAWRENCE ESTUARY, SUMMER 1979
V.G. Koutitonsky, INRS-Océanologie, Rimouski, Qué.
R.E. Wilson, Marine Sciences Research Center, State University of New York at Stony Brook, N.Y.
M.I. El-Sabh, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.

POSTER: TWO PARAMETERS FOR TIDAL MIXING FRONTS IN THE ST. LAWRENCE ESTUARY
M.I. El-Sabh, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.
T.S. Murty, Institute of Ocean Sciences, Sidney, B.C.

AFFICHAGE : MODELISATION NUMERIQUE DE LA MANCHE
A. Aissaoui, Institut de marine du Collège de Rimouski, Rimouski, Qué.
M.I. El-Sabh, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.
J.-C. Salomon, Université de Bretagne Occidentale, France

0830-1030
SESSION 5C: APPLIED METEOROLOGY
Chairman / Président : R. Fichaud
SESSION 5C : METEOROLOGIE APPLIQUEE

0830: PRELIMINARY RESULTS FROM RAIN ENHANCEMENT EXPERIMENTS IN ALBERTA
B. Kochtubajda, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.

0850: ESTIMATING CROP TOP MICROCLIMATE FROM WEATHER STATION DATA USING PHYSICALLY-BASED MODELS
R.D. Brown and T.J. Gillespie, Department of Land Resource Science, University of Guelph, Guelph, Ont.

0910: A PROBABILISTIC MODEL FOR AREAL MEAN DAILY RAINFALL DISTRIBUTION
Van-Thanh-Van Nguyen, Department of Applied Sciences, Université du Québec à Chicoutimi, Chicoutimi, Qué.

0930: EXPERIMENTS IN GENERATING WATER BUDGET COMPONENT OUTLOOKS
Leo O. Mapanao, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

0950: APPLICATIONS OF AIRBORNE MONITORING OF GASEOUS EXCHANGE
R.L. Desjardins, Land Resource Research Institute, Agriculture Canada, Ottawa, Ont.
J.I. MacPherson, National Aeronautical Establishment, Ottawa, Ont.
P. Alvo, L. Austin, and P.H. Schuepp, Macdonald College of McGill University, Montréal, Qué.

1010: AN OVERVIEW OF ICING RESEARCH AT THE UNIVERSITY OF ALBERTA
K. Finstad, E. Lozowski, E. Gates, K. Wong, K. Szilder, W. Lam, A. Liu, R. Narten, A. Nowak and E. Obreiter, Department of Geography, The University of Alberta, Edmonton, Alta.

1030-1050 Coffee / Café

1050-1230 Studio Alfred-Laliberté
PLENARY SESSION 6: SPACE SHUTTLE EXPERIMENTS AND CASP INFORMATION
Chairman / Président : G. Austin
SESSION PLENIERE 6 : EXPERIENCES DE LA NAVETTE SPATIALE ET INFORMATIONS CASP

1050: Invited Speaker: OCEANOGRAPHY FROM A SPACE SHUTTLE
P.D. Scully-Power, Underwater Research Center, New London, Connecticut

1110: Invited Speaker: OGLOW - AN EXPERIMENT TO MEASURE ORBITER GLOW AND ATMOSPHERIC EMISSIONS FROM SPACE
D.J.W. Kendall, Canada Centre for Space Sciences/NRC, Ottawa, Ont.
S.B. Mende, Lockheed Palo Alto Research Laboratory, California
E.J. Llewellyn, ISAS, University of Saskatchewan, Saskatoon, Sask.
W.A. Gault, CRESS, York University, Downsview, Ont.
R.L. Gattinger, Herzberg Institute of Astrophysics/NRC, Ottawa,Ont.

1130: Invited Speaker: THE SUNPHOTOMETER EXPERIMENT ON MISSION 41G
W.F.J. Evans, J.B. Kerr, C.T. McElroy, G. Shah, D.I. Wardle, Atmospheric Environment Service, Downsview, Ont.
R.W. Nicholls, M. Cann, J.C. McConnell, Centre for Research in Experimental Space Science, York University, Toronto, Ont.
J. Davies, McMaster University, Faculty of Science, Hamilton, Ont.
M. Garneau, S. MacLean, National Research Council of Canada, Ottawa, Ont.

1150: PLANS FOR THE METEOROLOGICAL COMPONENT OF THE CASP FIELD EXPERIMENT
Ronald E. Stewart, G.A. Isaac, H.B. Kruger, and A.J. Chisholm, Atmospheric Environment Service, Downsview, Ont.

1210: STORM RESPONSE IN THE COASTAL OCEAN: THE OCEANOGRAPHIC COMPONENT OF CASP
Peter C. Smith, F.W. Dobson, D.A. Greenberg, W. Perrie, B.D. Petrie, and D.G. Wright, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1230-1330 Lunch / Déjeuner

Thursday Afternoon, 13 June 1985
Jeudi après-midi, le 13 juin 1985

1330-1510 Studio Alfred-Laliberté
SESSION 7A: MESOSCALE METEOROLOGY I
Chairman / Président : W. Hitschfeld
SESSION 7A : METEOROLOGIE A L'ECHELLE MOYENNE I

1330: Invited Speaker: CONCEPTUAL AND DIAGNOSTIC MODELS OF THE PHYSICS AND CHEMISTRY OF RAINBANDS IN EXTRATROPICAL CYCLONES
Peter V. Hobbs, Department of Atmospheric Sciences, University of Washington, Seattle, Washington

1410: FRONTAL WAVES AND INSTABILITIES
John H.E. Clark, Mesoscale Research Section, National Center for Atmospheric Research, Boulder, Colorado

1430: A COMPARISON OF HYDROSTATIC AND NON-HYDROSTATIC WAVE-CISK
G.W. Kent Moore, Department of Physics, University of Toronto, Toronto, Ont.

1450: ON THE MECHANISM FOR HAILSTORM FEEDER CLOUD FORMATION
Lawrence Cheng and Dave Rogers, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.

1330-1510
SESSION 7B: METEOROLOGICAL FORECASTS AND CASE STUDIES
Chairman / Président : N. Yacowar
SESSION 7B : PREVISIONS METEOROLOGIQUES ET ETUDES DE CAS

1330: AUTOMATED WORDED PUBLIC FORECASTS FOR DAYS 3-5
D. Soucy and N. Yacowar, Canadian Meteorological Centre, Atmospheric Environment Service, Dorval, Qué.

1350: NUMERICAL WEATHER ELEMENT DATA TO DAY 5 - AN EXPERIMENTAL OUTPUT FORMAT
M. Dunlop and K. Johnstone, Canadian Meteorological Centre, Atmospheric Environment Service, Dorval, Qué.

1410: CAS DE TORNADE A BLUE SEA LAKE, P.Q.
Patrice Courbin, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1430: THE METROPOLITAN TORONTO TORNADO OF AUGUST 14, 1984
Luigi G. Bertolone, Ontario Weather Centre, Atmospheric Environment Service, Toronto, Ont.

1450: CAS PARTICULIER DE PLUIE VERGLACANTE SUR LE SUD-OUEST DU QUEBEC
Denis Bachand, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1330-1450
SESSION 7C: OCEAN CHEMISTRY AND GEOCHEMICAL PROCESSES II
Chairman / Président : B. D'Anglejan
SESSION 7C : CHIMIE DES OCEANS ET PROCESSUS GEOCHIMIQUES II

1330: EARLY DIAGENESIS OF COPPER AND MOLYBDENUM IN MINE TAILINGS AND NATURAL SEDIMENTS IN RUPERT AND HOLBERG INLETS, BRITISH COLUMBIA
Thomas F. Pedersen, Department of Oceanography, The University of British Columbia, Vancouver, B.C.

1350: DISTRIBUTION DES CONCENTRATIONS EN MERCURE DANS LES EAUX DE L'ESTUAIRE ET DU GOLFE DU SAINT-LAURENT
D. Cossa, C. Gobeil, Centre Champlain des sciences de la mer, Ministère des pêches et des océans, Québec, Qué.
P. Courau, Laboratoire de physique et chimie marines, Université Pierre et Marie Curie, Villefranche-sur-mer, France

1410: VARIATIONS DANS LA COMPOSITION IONIQUE DU FLEUVE SAINT-LAURENT DEPUIS LE DEBUT DE L'INDUSTRIALISATION (1907-1982)
Gilles H. Tremblay and Daniel Cossa, Centre Champlain des sciences de la mer, Ministère des pêches et des océans, Québec, Qué.

1430: NUTRIENTS IN THE ST. LAWRENCE ESTUARY
Kazufumi Takayanagi and Charles Gobeil, Champlain Centre for Marine Science and Surveys, Department of Fisheries and Oceans, Québec, Qué.

1510-1530 Coffee / Café

1530-1710 Studio Alfred-Laliberté
SESSION 8A: MESOSCALE METEOROLOGY II
Chairman / Président : R. Benoit
SESSION 8A : METEOROLOGIE A L'ECHELLE MOYENNE II

1530: A MOVABLE TRIPLY NESTED NUMERICAL MODEL FOR MESOSCALE TROPOSPHERIC CIRCULATION
R.V. Madala and Simon W. Chang, Naval Research Laboratory, Department of the Navy, Washington, D.C.

1550: NUMERICAL SIMULATION OF COASTAL FLOWS AT THE ONSET OF NUCLEAR WINTER
Charles R. Molenkamp, Physics Department, Lawrence Livermore National Laboratory, Livermore, California

1610: MODELING A FIELD OF CUMULUS CLOUDS
Piotr Smolarkiewicz and Terry L. Clark, Convective Storms Division, National Center for Atmospheric Research, Boulder, Colorado

1630: QUEBEC 1534-1984 : DESCRIPTION D'UN RESEAU METEOROLOGIQUE A LA MESO-ECHELLE AFIN DE SUPPORTER LES OPERATIONS DE PREVISIONS
Claude Masse et Denis Poupart, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1650: QUEBEC 1534-1984 : CONSTATATIONS PRELIMINAIRES DE PHENOMENES OBSERVES A L'AIDE D'UN RESEAU A LA MESO- ECHELLE
Claude Masse et Denis Poupart, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1530-1730
SESSION 8B: SURFACE WAVES II
Chairman / Président : V. Koutitonsky
SESSION 8B : ONDES DE SURFACE II

1530: A WAVE CLIMATE STUDY OF THE NORTHERN BRITISH COLUMBIA COAST
Barbara-Ann Juszko, Robin Brown, Bodo de Lange Boom and Dave Green, Seakem Oceanography Ltd., Sidney, B.C.

1550: L'ANALYSE SPECTRALE DES CYCLES D'ETAT DE LA MER
Loys Schmied, Service technique des phares et balises, Secrétariat d'état chargé de la mer, Bonneuil-sur-Marne, France

1610: WAVE MODEL ABNORMALITIES DETECTED BY FIELD MEASUREMENTS
David C. Fu, Oceanroutes, Inc, Palo Alto, California

1630: AN EVALUATION OF A PARAMETRIC OCEAN-WAVE FORECAST SYSTEM
K.A. Macdonald and S. Clodman, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.

1650: EVALUATION OF TWO OPERATIONAL SPECTRAL OCEAN WAVE MODELS: SOWM AND ODGP
Bassem M. Eid, MacLaren Plansearch Limited, Halifax, N.S.,
Vincent J. Cardone and J. Arthur Greenwood, Oceanweather Inc., Cos Cob, Connecticut

1710: FORMATION OF SAND BARS BY SHALLOW-WATER WAVES
B. Boczar-Karakiewicz, INRS-Océanologie, Rimouski, Qué.
J.L. Bona, Department of Mathematics, The University of Chicago, Chicago, Illinois

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1530-1710
SESSION 8C: SATELLITE AND RADAR METEOROLOGY
Chairman / Président : A. Chisholm
SESSION 8C : RADAR, SATELLITE ET METEOROLOGIE

1530: ON THE ANALYSIS AND SYNTHESIS OF CLOUD TEXTURES
Louis Garand and James A. Weinman, Department of Meteorology, The University of Wisconsin, Madison, Wisconsin

1550: STUDY ON THE REMOTE SENSING OF RAINFALL BY RADAR AND SATELLITE FOR FOREST FIRE MANAGEMENT
A. Bellon, Radar Weather Observatory, McGill University, Montréal, Qué.

1610: AN EXAMINATION OF TOVS SOUNDINGS IN THE ATLANTIC REGION
Neil McLennan, Maritimes Weather Centre, Bedford, N.S.

1630: USEFULNESS OF GOES SATELLITE DATA IN THE ANALYSIS OF CONVECTIVE WEATHER OVER CENTRAL ALBERTA
L.D. Stovel and G.S. Strong, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.

1650: THE PRAIRIE WEATHER CENTRE RADAR DATA-BASE AND IMAGE DISPLAY SYSTEM
Anthony J. Keck, Prairie Weather Centre, Atmospheric Environment Service, Winnipeg, Man.

Friday Morning, 14 June 1985
Vendredi matin, le 14 juin 1985

0830-1030 Studio Alfred-Laliberté
SESSION 9A: CLOUD PHYSICS AND MODELLING
Chairman / Président : I. Zawadzki
SESSION 9A : PHYSIQUE ET MODELISATION DES NUAGES

0830: THE MULTI-DIMENSIONAL, POSITIVE-DEFINITE ADVECTION TRANSPORT ALGORITHM. FURTHER DEVELOPMENTS AND APPLICATIONS TO THE ATMOSPHERIC MODELING
Piotr Smolarkiewicz and Terry L. Clark, Convective Storms Division, National Center for Atmospheric Research, Boulder, Colorado

0850: OBSERVATIONS OF MIXING MECHANISMS IN SOUTH AFRICAN CUMULUS CONGESTUS CLOUDS
G.W. Reuter and M.K. Yau, Department of Meteorology, McGill University, Montréal, Qué.

0910: NUMERICAL SIMULATIONS OF MIXING MECHANISMS IN SOUTH AFRICAN CUMULUS CONGESTUS CLOUDS
G.W. Reuter and M.K. Yau, Department of Meteorology, McGill University, Montréal, Qué.

0930: COMPUTATION OF THE SATURATION VAPOR PRESSURE OF SUPERCOOLED LIQUIDS
Michael T. Reischel, NASA/Marshall Space Flight Center, University Space Research Association, Huntsville, Alabama

0950: OBTENTION DU MOUVEMENT VERTICAL DE L'AIR A L'AIDE D'UN SEUL RADAR DOPPLER
Richard Hogue et Isztar Zawadzki, Département de physique, Université du Québec á Montréal, Montréal, Qué.

1010: UTILISATION DE SPECTRES DE GRELONS AFIN D'EVALUER LA

POSSIBILITE DE MESURER CEUX-CI PAR RADAR A POLARISATION CIRCULAIRE
André Méthot et Enrico Torlaschi, Département de physique, Université du Québec à Montréal, Montréal, Qué.

0830-1030
SESSION 9B: DEEP-SEA OCEANOGRAPHY I
Chairman / Président : D. Greenberg
SESSION 9B : OCEANOGRAPHIE DES EAUX PROFONDES I

0830: MOORED MEASUREMENTS OF GULF STREAM CURRENT STRUCTURE NEAR 60°W
R.M. Hendry, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

0850: THERMOHALINE INTRUSIONS IN THE FRONTAL REGIONS OF A GULF STREAM WARM-CORE RING
C.L. Tang, A.S. Bennett and D.L. Lawrence, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

0910: VALIDATION STUDIES OF AN EQUATORIAL OCEAN CIRCULATION MODEL
David Halpern, NOAA PMEL, Seattle, Washington, and George Philander, NOAA GFDL, Princeton University, Princeton, New Jersey

0930: ON THE GEOGRAPHIC DISTRIBUTION OF GEOSTROPHIC DYNAMICS
Keith A. Thomson, Department of Oceanography, The University of British Columbia, Vancouver, B.C.

0950: A REVIEW OF THERMOCLINE MODELS FOR OCEANS AND LAKES
B. Henderson-Sellers, Department of Mathematics and Computer Science, University of Salford, England
A.M. Davies, Institution of Oceanographic Science, Bidston, Wirral, Merseyside, England

1010: WAVE-INDUCED EDDY DIFFUSION
B.G. Sanderson, Department of Physics, Memorial University of Newfoundland, St. John's, Nfld.
P.H. LeBlond, Department of Oceanography, The University of British Columbia, Vancouver, B.C.
A. Okubo, Marine Sciences Research Center, State University of New York at Stony Brook, N.Y.

0830-1030
SESSION 9C: BOUNDARY-LAYER MODELLING
Chairman / Président : Y. Delage
SESSION 9C : METEOROLOGIE DE LA COUCHE LIMITE

0830: THE EFFECT OF BAROCLINICITY ON THE STRUCTURE OF THE NEUTRAL PLANETARY BOUNDARY LAYER

G.R. Rooney and G.D. Stubley, Department of Mechanical Engineering, University of Waterloo, Waterloo, Ont.

0850: STABILITY AND ITS EFFECTS ON WINDS IN THE LOWER ST. LAWRENCE ESTUARY
Gérald Vigeant, Scientific Services Division, Québec Region, Atmospheric Environment Service, Ville St. Laurent, Qué.

0910: ESTIMATES OF ROUGHNESS LENGTH FROM MINISONDE PROFILES IN THE ATHABASCA OIL SANDS AREA
R.C. Rudolph and D.S. Davison, INTERA Technologies Ltd., Calgary, Alta.

0930: INTERCOMPARISON OF FOUR TOP-DOWN WIND PROFILING MODELS
M.D. Moran, E. Alp and L.H. Lam, Concord Scientific Corporation, Downsview, Ont.

0950: DIAGNOSTIC MODELLING OF THE GLOBAL OCEAN SURFACE WINDS
T.W. Yu, W.H. Gemmill, and D.M. Feit, Development Division, National Meteorological Center, NWS, NOAA, Washington, D.C.

1010: STUDIES ON THE NITROGEN LOSS THROUGH VOLATILIZATION OF AMMONIA FROM SURFACE-APPLIED MANURE: EFFECT OF METEOROLOGICAL FACTORS
R. Brunke, P. Schuepp, G. Paquette, Macdonald College of McGill University, Montréal, Qué.
R. Desjardins, Land Resource Institute, Agriculture Canada, Ottawa, Ont.

1030-1050 Coffee / Café

1050-1230 Studio Alfred-Laliberté
SESSION 10A: ATMOSPHERIC DYNAMICS
Chairman / Président : J. Derome
SESSION 10A : DYNAMIQUE ATMOSPHERIQUE

1050: EKMAN LAYER DISSIPATION IN AN EASTWARD-TRAVELLING MODON
Gordon E. Swaters, Departments of Mathematics and Oceanography, The University of British Columbia, Vancouver, B.C.

1110: NECESSARY CONDITIONS FOR BAROTROPIC MODON INSTABILITY, WITH A CALCULATION BASED ON THE 500 MB EDDY ENERGY SPECTRUM
Gordon E. Swaters, Departments of Mathematics and Oceanography, The University of British Columbia, Vancouver, B.C.

1130: STATISTICAL MECHANICAL EQUILIBRIA FOR THE SHALLOW WATER EQUATIONS
T. Warn, Department of Meteorology, McGill University, Montréal, Qué.

1150: EVALUATION DU MOUVEMENT VERTICAL SYNOPTIQUE DANS LES BAS NIVEAUX A L'AIDE DES TENDANCES DE PRESSION EN SURFACE
Laurent Chenard et Peter Zwack, Département de physique, Université du Québec à Montréal, Montréal, Qué.

1210: MOUVEMENT VERTICAL DANS DES SYSTEMES SYNOPTIQUES ANALYTIQUES

André Méthot et Peter Zwack, Département de physique, Université du Québec à Montréal, Montréal, Que.

1050-1210
SESSION 10B: DEEP-SEA OCEANOGRAPHY II
Chairman / Président : R. Hendry
SESSION 10B : OCEANOGRAPHIE DES EAUX PROFONDES II

1050: ON THE WIND STRESS CURL GENERATION OF ANNUAL ROSSBY WAVES IN THE NORTH PACIFIC
Patrick F. Cummins, Lawrence A. Mysak, and Kevin Hamilton, Institute of Applied Mathematics and Statistics, The University of British Columbia, Vancouver, B.C.

1110: INFLUENCE OF VARIABLE DEPTH AND ROTATION ON KELVIN AND POINCARE WAVES
Y. Gratton and F. Saucier, Département d'océanographie, Université du Québec à Rimouski, Rimouski, Qué.

1130: TRENCH WAVE GENERATION BY INCIDENT ROSSBY WAVES
J.Y. Holyer and L.A. Mysak, Institute of Applied Mathematics and Statistics, The University of British Columbia, Vancouver, B.C.

1150: SALT AND HEAT BALANCES IN THE LABRADOR SEA USING A BOX MODEL
M. Ikeda, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1050-1230
SESSION 10C: SEVERE WEATHER
Chairman / Président : H. Allard
SESSION 10C : PHENOMENES METEOROLOGIQUES DANGEREUX

1050: TEMPS VIOLENT PROVOQUE PAR DES PETITS CUMULONIMBUS
Stanislas Siok et Patrice Courbin, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1110: EFFECTS OF A DIRECT CIRCULATION ON TRIGGERING SEVERE THUNDERSTORMS
Denis Vigneux and Stanislas Siok, Centre météorologique du Québec, Service de l'environnement atmosphérique, Ville St. Laurent, Qué.

1130: MESOSCALE SEVERE WEATHER PILOT PROJECT
Gerald D. Machnee, Prairie Weather Centre, Atmospheric Environment Service, Winnipeg, Man.

1150: THUNDERSTORM FORECASTING - EXTENDING OUR CAPABILITIES USING EXISTING DATA SOURCES
G.S. Strong and L.D. Stovel, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta.

1210: A PROPOSAL FOR A COORDINATED STUDY OF SOUTHERN ALBERTA CHINOOKS
T. Mathews, Department of Physics, The University of Calgary, Calgary, Alta.
P.F. Lester, Department of Meteorology, San Jose State University, San Jose, California

POSTER: CATALOGUES OF SEVERE STORMS FOR CANADA'S EAST AND WEST COASTS
P.J. Lewis and M.D. Moran, Concord Scientific Corporation, Downsview, Ont.
V. Swail, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

1230-1330 Lunch / Déjeuner

Friday Afternoon, 14 June 1985
Vendredi après-midi, le 14 juin 1985

1330-1510 Studio Alfred-Laliberté
SESSION 11A: GENERAL CIRCULATION MODELLING AND PARAMETERIZATION
Chairman / Président : P. Merilees
SESSION 11A : MODELISATION DES CIRCULATIONS GENERALES ET PARAMETRISATION

1330: Invited Speaker: MODELLING THE GLOBAL TRANSPORTS OF MASS, MOISTURE AND ENERGY IN THE ATMOSPHERE
G.J. Boer, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

1410: THE KINETIC ENERGY BUDGET OF THE CANADIAN GCM IN TERMS OF THE 2-D WAVENUMBER
Steven J. Lambert, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

1430: PARAMETERIZATION OF CUMULUS CONVECTION IN THE CCC GENERAL CIRCULATION MODEL
N.A. McFarlane, Canadian Climate Centre, Atmsopheric Environment Service, Downsview, Ont.

1450: A THREE DIMENSIONAL MODEL OF THE SUMMER MONSOON
Keith D. Sashegyi, Science Applications Int. Corp, McLean, Virginia
Simon W. Chang, Naval Research Laboratory, Washington, D.C.

1330-1510
SESSION 11B: LABRADOR SEA DYNAMICS
Chairman / Président : D. Lefaivre
SESSION 11B : DYNAMIQUE DE LA MER DU LABRADOR

1330: A DESCRIPTION OF THE LABRADOR CURRENT BASED ON RECENT MEASUREMENTS

John R. Lazier and Daniel G. Wright, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1350: A TWO-LAYER MODEL TO INVESTIGATE LABRADOR CURRENT TYPE PHENOMENA
David A. Greenberg, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1410: THE HUMIDITY EXCHANGE OVER THE SEA (HEXOS) PROGRAMME
Stuart D. Smith, Department of Fisheries and Oceans, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S.

1430: ICE MODEL DOMAIN SIZES FOR BEAUFORT SEA ICE FORECASTING
Eric Leavitt and Ed Krakowski, INTERA Technologies Ltd., Calgary, Alta.,
S. Venkatesh, V.R. Neralla and R. Jessup, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.

1450: COMPARISON OF CODAR AND CURRENT METER MEASUREMENTS IN THE STRAIT OF BELLE ISLE
K. Shirasawa, W. Winsor, A.E. Hay and D. Lawrence, Centre for Cold Ocean Resources Engineering, Memorial University of Newfoundland, St. John's, Nfld.

1330-1450
SESSION 11C: CLIMATOLOGY
Chairman / Président : H. Ritchie
SESSION 11C : CLIMATOLOGIE

1330: A TWO DECADE REVIEW OF THE WEATHER RECORD TAKEN AT THE CLIMATOLOGICAL REFERENCE STATION OF THE SASKATCHEWAN RESEARCH COUNCIL
S.R. Shewchuk, Environment Sector, Saskatchewan Research Council, Saskatoon, Sask.

1350: FREEZE-THAW DAYS IN THE NORTHEASTERN UNITED STATES
Thomas W. Schmidlin, Bernard E. Dethier, and Keith L. Eggleston, Northeast Regional Climate Center, Cornell University, Ithaca, New York

1410: RECHERCHE SUR LES TEMPERATURES SUPERFICIELLES DE L'EAU DANS LE GOLFE DE GASCOGNE ET SA RELATION AVEC LA PLUIE AU PAYS BASQUE
Antón Uriarte, Universidad del País Vasco, San Sebastián, Spain

1430: CLIMATE IMPACT ASSESSMENT OF THE "GREENHOUSE EFFECT" IN THE GREAT LAKES BASIN
Stewart J. Cohen, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

Abstracts

0830-1030 Studio Alfred-Laliberté
PLENARY THEME SESSION 1: MODELLING IN METEOROLOGY AND OCEANOGRAPHY
SESSION PLENIERE THEMATIQUE 1 : MODELISATION EN METEOROLOGIE ET EN OCEANOGRAPHIE

STATE OF METEOROLOGY AND OCEANOGRAPHY / METEOROLOGIE ET OCEANOGRAPHIE : L'ETAT ACTUEL DES DEUX SCIENCES

N. Campbell

No abstract available.

THE EVOLUTION OF NUMERICAL WEATHER PREDICTION MODELS

André Robert

Numerical weather prediction became possible with the advent of electronic computers and most improvements came as a result of increases in the processing speed of these machines. This explains the evolution from barotropic models to multi-level filtered models and later on the models of the primitive meteorological equations. At the same time, there were substantial increases in the horizontal and vertical resolution used in these models as well as in the complexity of incorporated physical processes.

During the same period, there were also some significant improvements in the techniques used to integrate the meteorological equations. Here we can mention the spectral method, the finite element technique, Lagrangian schemes and grid nesting or telescoping. The transform method introduced around 1970 resulted in spectral models that ran fifteen times faster. Semi-implicit schemes gave another factor of six and Lagrangian methods will soon contribute another factor of four.

The initialization of numerical models started off with the balance equation followed later on by dynamic initialization and replaced today by normal mode initialization. In the early days of numerical weather prediction, most models were applied over a limited area. Today many models are global and some of these are used for general circulation studies or for climate modelling. At the other end of the spectrum exist models that are used for mesoscale studies or for research on convective phenomena.

The application of numerical models to the problem of weather forecasting has been quite successful. The accuracy of weather forecasts improved significantly over the last thirty years. Systems were developed over the recent years that allow meteorologists to keep a close watch on any weather element, so that they can provide better services. A number of diagrams will be used to illustrate some of these points.

MODELLING THE UPPER OCEAN RESPONSE TO STORMS
James F. Price

The upper ocean response to a storm is made up of a wide range of phenomenon, some of which have real practical significance. Strong storms can cause substantial cooling of sea surface temperature, and drive currents large enough to threaten ocean structures.

The storm response of sea surface temperature can be treated with simple mixed layer models. If the storm is large, e.g., most midlatitude systems, the mixed layer response can be modelled reasonably well by a one-dimensional model. However, if the storm is small, e.g., a hurricane, then the mixed layer response can be strongly affected by horizontal advection and upwelling. In that case the mixed layer dynamics have to be embedded within a three dimensional model of the mesoscale response.

Modelling the storm response of currents also starts with a prescription for the mixed layer since that sets the depth over which wind stress is absorbed. But the mixed layer is also coupled to the thermocline through the hydrostatic pressure field set up by inertial pumping. Large scale inertial-internal waves can be generated in the thermocline within a few days of a storm passage, and represent an important energy loss from the surface mixed layer.

1050-1230 Studio Alfred-Laliberté
SESSION 2A: OPERATIONAL USE OF MODEL OUTPUT
SESSION 2A : UTILISATION OPERATIONNELLE DES SORTIES DES MODELES

PROS AND CONS OF PROBABILITY FORECASTS: EVALUATING THE "SCORE"
Allan H. Murphy

Uncertainty is inherent in all weather forecasts. Three methods of treating this uncertainty in formulating and/or expressing forecasts are available: (1) ignoring the uncertainty (categorical forecasts); (2) describing the uncertainty in verbal terms (quasi-probability forecasts); and (3) describing the uncertainty in numerical terms (probability forecasts). The pros and cons of these alternative modes of expression of forecasts will be discussed, with particular reference to the following issues or topics:

(a) the correspondence between forecasts and judgments;
(b) the formulation of objective and subjective forecasts;
(c) the verification of forecasts (methods and results); and
(d) the communication, understanding, use, and value of forecasts.

This comparative evaluation of the three modes of expression of uncertainty in weather forecasts reveals that probability forecasts possess substantial advantages of both a fundamental and an operational nature vis-a-vis categorical and quasi-probability forecasts. If time permits, the current status of probability forecasting on a worldwide basis will be briefly reviewed.

DEVELOPMENT OF A MOS SYSTEM TO FORECAST PROBABILITY OF PRECIPITATION

N. Brunet, G. Richard, H. Yang and N. Yacowar

CMC has developed a MOS system to forecast the probability of precipitation amount above several threshold values for 12-hour periods and for the POP for six-hour periods. Forecasts are made for one hundred and thirty four Canadian stations out to 72 hours.
Tests were made to determine the effect of a change in NWP model and in the use of transformed or ranked predictors.
Verifications are available for two years to compare the performance of the CMC MOS system with the operational P.P. system, the forecasts prepared subjectively at the regional forecast offices and a broad comparison with the USWB forecasts.
The development of the system will be discussed and verification results displayed.

VERIFICATION OF PROBABILITY OF PRECIPITATION FORECASTS FOR WINNIPEG, REGINA AND SASKATOON FOR 1983-84

Edward R. Lord

The probability of precipitation (POP) forecasts issued by the Prairie Weather Centre for Winnipeg, Regina and Saskatoon are verified for accuracy and skill with respect to climatology using the normalized Brier Score and the Brier Skill Score. A similar verification procedure is applied to the POP guidance issued by CMC. The principal findings are:

(1) In terms of accuracy, the objective POP guidance was found to be as accurate as the subjective POP forecasts for all time periods into the forecast.
(2) In terms of skill, both the objective POP guidance and the subjective POP forecasts exhibited positive skill with respect to climatology.
(3) No relationship between forecast accuracy and season was found, nor was there any discernable relationship between forecast accuracy and the deviation from a climatologically expected frequency of precipitation.
(4) Categorical (yes/no) forecasts of precipitation (as implied by the POP forecasts) were found to be substantially less accurate than POP forecasts.

These findings indicate that the objective POP guidance from CMC warrants attention when composing POP forecasts in Central Region. The results also show that categorical forecasts of precipitation are unlikely to be more accurate than probability forecasts, even for the first 12 hours of the forecast period.

DÉVELOPPEMENT D'UN SYSTÈME MOS DE PRÉVISION DE NÉBULOSITÉ PAR LE CMC
R. Verret, N. Yacowar, H. Yang et G. Richard

La disponibilité des données au Centre météorologique canadien impose le choix de la quantité de nuage comme valeur prévisionnelle dans le développement d'un système MOS de prévision de nébulosité. Cependant, une étude climatologique comparative de la quantité et de l'opacité des nuages, suggère que sensiblement les mêmes résultats seraient normalement obtenus en utilisant l'opacité des nuages comme valeur prévisionnelle au lieu de la quantité.
Le système MOS de prévision de nébulosité est présenté. Ce système prépare des prévisions pour 133 stations canadiennes, à toutes les 6 heures jusqu'à 60 heures. La vérification de ces prévisions pour l'hiver 1984-85 est aussi présentée et démontre que le système MOS fait preuve d'une bonne habileté.

1050-1230
SESSION 2B: ESTUARIES AND EMBAYMENTS I
SESSION 2B : ESTUAIRES ET BAIES I

WINTER CIRCULATION IN LAKE ONTARIO
T. J. Simons C. R. Murthy and J. E. Campbell

Data from a high-resolution array of self-recording current meters in a north-south cross-section of Lake Ontario are presented. The measurements cover a 140-day period from 4 November 1982 to 23 March 1983. Nearshore current fluctuations are large and generally coherent with wind variations while currents in deep water tend to flow in opposite direction and are quite uniform in the vertical. Time-averaged currents show a pronounced maximum of eastward flow along the south shore balanced by westward flow in the central part of the cross-section, while the net transport near the northern shore tends to vanish. The total transport in the belt of eastward flow is ten times larger than the hydraulic transport associated with the Niagara-St. Lawrence flow, thus suggesting a recirculation of 90% of the river inflow. Corroboration of the south shore current measurements is provided by Lagrangian measurements using satellite-tracked drifters. These observed circulation features are highly correlated with the distribution of toxic contaminants such as mercury and mirex in the sediments of Lake Ontario.

APPROPRIATE PARAMETRISATIONS OF METEOROLOGICAL FORCING FOR USE IN LAKE THERMAL STRATIFICATION MODELS
B. Henderson-Sellers

In long-term simulations of the thermal structure of lakes (and oceans) it is necessary to either resolve or else parametrise the characteristics of the meteorological forcing since these occur on a variety of time and space scales which may be inappropriate for the model schematization. For example, many stratification models attempt to describe

the development of the thermal stratification over a period of years with an implicit timescale of one day. However much of the forcing which produces changes on such a time scale has a natural variability on much shorter time scales (and indeed if climatic changes are taken into account also on much longer time scales). In this paper the various forcing factors are discussed in terms of the timescales over which they influence the water body and those parameters which are important on timescales very different from the one-day timescale of the model are identified. For these parameters, observational data connot be used directly and the forcing mechanism must be parametrised in a form appropriate for use in the model. For example, incoming solar radiation changes on a timescale of seconds. For stratification models, it is sometimes adequate to use daily totals of radiation yet on other occasions (as will be shown) the model results can be substantially improved if mean hourly calculations are undertaken. Similarly it is inappropriate (as a consequence of the excessive computer time that would be required) to incorporate an extensive radiation scheme; simpler schemes which relate surface-incident radiation to cloud cover and atmospheric turbidity must be evaluated.
The meteorological factors discussed here will emphasize the important effects on development and maintenance of the thermocline of two factors: the wind and the surface energy balance (including the effect of atmospheric turbidity and clouds). Results will be expressed in terms of the annual stratification pattern derived from the University of Salford Eddy Diffusion thermocline model, U.S.E.D. (Henderson-Sellers, 1984) and an assessment will be made of the necessary accuracy required by such thermal stratification models for the input (observational) data.

SEICHES IN COASTAL BAYS OFF JUAN DE FUCA STRAIT

Lichen Wang & Paul H. LeBlond

Short-period (a few minutes) sea-level variations have been analyzed in three small bays opening onto the north shore of Juan de Fuca Strait. Spectral analysis of the data and numerical modelling of oscillations in the bays revealed pulses of energy at resonant frequencies. A significant part of the signal also occurs at lower, non-resonant frequencies. Correlations between bays suggest common excitation by travelling edge waves. Other generation mechanisms - wind, atmospheric pressure, swell, internal waves - are also discussed.

A STUDY OF SOOKE BASIN, B.C.

W. Wolfe, F. Milinazzo, M. Press and R. Marsden

Sooke Basin is a small body of water off the Strait of Juan de Fuca having both recreational and industrial importance. From June 1981 to December 1982 an extensive study was made of the area. Monthly CTD measurements were made at a series of stations along the basin. Concurrently two Aanderaa current-meter locations, an Aanderaa weather station and drogued float measurements were also taken. The results showed that as with many coastal regions, the density was controlled by the salinity. Furthermore,

a calculation of the excess fresh water in the basin was highly correlated with local rainfall. An analysis of the current-meter data indicated that the water column responded barotropically during the summer period but was highly baroclinic during times of maximum rainfall. The response of the basin to wind forcing was very small. The currents were dominated by a tidal jet at the mouth of the Basin. The velocity spectra contained considerable energy at six-and four-hour periods indicating that the flow is highly non-linear. The drogue results show several eddy regions which correspond well with the rotation calculated in the surface velocity spectra. The results from this study will be used to interpret a numerical model of the area.

TRACKING THE MOVEMENT OF PATTERNS ON THE OCEAN'S SURFACE WITH TIME LAPSE RADAR IMAGERY
M.J. Press & H.J. Duffus

Time lapse radar imagery of the Strait of Juan de Fuca between Vancouver Island, B.C. and the Olympic Peninsula of Washington State for a period of about 18 months has been recorded on film. Many interesting surface patterns including ripples, waves, tidal wavefronts and internal wave streams can be seen and followed as they respond to local tidal and wind conditions. Selected image sequences have been digitized in an attempt to measure the velocity of movement of the surface layer of water and to determine the statistical characteristics of the observed radar returns. The velocity of surface motion is determined by systematically matching small sections of each image with the succeeding one by finding minima in the structure correlations. While this process is automated, operator intervention is required to interpret mismatches caused by bad radar returns, reflection patterns merging or splitting or the passage of boats and planes. With this technique, motion of internal wave streams and tidal motions such as rotational gyres can be followed successfully.

1050-1230
SESSION 2C: OCEAN CHEMISTRY AND GEOCHEMICAL PROCESSES I
SESSION 2C : CHIMIE DES OCEANS ET PROCESSUS GEOCHIMIQUES I

THE SEASONALITY OF GLOBAL OCEAN CO_2 FLUXES
Peter G. Brewer

Interest in the rising level of atmospheric CO_2 has provoked numerous papers on the cycling of carbon on this planet. It has long been recognized that the annual fluctuations in atmospheric CO_2 levels are driven by seasonal exchanges with the terrestrial biosphere and surface ocean, and various models describe these fluxes. We do not know from direct observation either one of these fluxes very well. Direct observation of the terrestrial biosphere fluxes is difficult, however, with improved knowledge of ocean surface temperatures, winds and biological productivity a greatly improved knowledge of ocean CO_2 fluxes could be within our grasp.

The key to this is to understand the rules, and ocean scientists have reached quite divergent opinions as to what these rules may be. The arguments essentially fall into two categories: that purely physical forces exert the dominant controls, or that biological variables are of primary importance. Our ability to devise experiments to reveal the truth will depend upon our resolution of these conflicts.

In this paper I will review the arguments supporting these claims and present new data and models which help to clarify the issue.

GEOCHEMISTRY AND AGE OF THE HOLOCENE SAPROPEL IN THE BLACK SEA

S.E. Calvert

The modern laminated calcareous muds of the Black Sea contain a few percent organic carbon. A sapropel, containing up to 14% carbon accumulated in the basin during the post-Pleistocene change from a fresh-water lake to the modern marine stage. The age of this sapropel, determined in two cores by accelerator radiocarbon dating of the organic material and assuming a surface age of the detrital carbon of 2,000 years, is 1,700-5,800 and 3,600-6,200 years B.P.

The chemical stratigraphy of the cores shows the presence of four sedimentary units: the modern muds, with relatively high Co, Cu, Ni and Sr contents; an underlying detrital, organic-poor unit; the sapropel, with characteristically high Ba, Co, Cu, Mo, Ni and V contents; and the underlying lake marls with high Mn and Sr and low Mo, Ni and V contents. These different sedimentary facies represent the geochemical responses to conditions during the various stages in the evolution of the Black Sea basin. The sapropel probably formed as a consequence of increased primary production during the period of changing hydrography when saline waters entered the basin at the Bosphorus sill. Although enhanced preservation of the deposited carbon may be favoured under anoxic conditions, it is important to note that the modern sediments in the basin are not organic-rich. Alternative explanations are therefore needed for sapropel formation in such oceanographic settings.

AN EIGHTY YEAR RECORD OF SEASONALLY MODULATED SEDIMENT ACCUMULATION RATES BASED ON PB-210 AND PLUTONIUM MEASUREMENTS

J.N. Smith, K. Ellis and C.T. Schafer

A constant flux, Pb-210 model was used to determine the detailed geochronology of a sediment core collected in a high sedimentation rate, anoxic depositional regime at the head of the Saguenay Fjord, Québec. Annual modulations of 20% to 50% in the sedimentation rate are caused by anomalous inputs of coarser-grained silts and fine sands during high, spring river discharge conditions. These inputs give rise to a seasonal signature in the geochemical and textural parameters observed in the sediment column. The frequency distribution of the Saguenay depositional regime is skewed towards the low sedimentation rate mode; values falling below the mean describe the most common state of the system. A substantial portion of the annual sediment input reaches the basin at the head of the fjord during anomalous transport events associated with landslides and high, river discharges that occur

during brief intervals of time. The flux of sand is an excellent indicator for those short periods of high river discharge during which much of the inventory of this comparatively coarse fraction of the suspended load is transported. A significant correlation occurs between sand flux, peak river discharge and the quantity of precipitation stored as snow, which provides a link between sediment texture and climatological parameters. Detailed analyses of the grain size distribution for a specific core interval allows the reconstruction of a proxy record of river discharge intensity.
The validity of the precise geochronology determined for this core on the basis of Pb-210 is confirmed by Pu-238, Pu-239, 240 and Cs-137 sediment-depth distributions. Modeling of the transport of these weapons fallout tracers through the drainage basin provides estimates of their residence times within different components of the watershed. These results indicate that significant fractionation occurs between Cs-137 and plutonium within the forested drainage basin of the Saguenay River, with plutonium being retained more than twice as efficiently as Cs-137 on soil particles.

QUANTITATIVE INFLUENCE OF PHOSPHATE ON CALCITE PRECIPITATION FROM SEAWATER

Alfonso Mucci

In order to better understand the processes by which metastable calcium carbonate minerals undergo or resist recrystallization during their diagenetic history it is essential to consider the effect of co-solutes on both the dissolution and precipitation of these minerals and their diagenetic reaction products. Any chemical compound which inhibits the transformation of metastable minerals such as high magnesium calcites and aragonite, favors their persistence or at least the absence of diagenetic reaction products. The lack of reactivity of calcite in seawater is most often attributed to the interaction of magnesium ions, phosphate or dissolved organic matter with the surface of carbonate grains.
A constant disequilibrium seeded precipitation technique was used to determine the quantitative influence of phosphate ions on the precipitation kinetics of calcite in artificial seawater. The precipitation rate of a magnesian calcite overgrowth on pure calcite seeds was measured over a wide range of saturation states in the absence and the presence of up to 500 micromolar concentrations of Na_2HPO_4. The precipitation rate data was fitted to an empirical rate law as a function of the degree of supersaturation of the precipitating solution. A three-dimensional regression analysis of the data indicated that the precipitation-inhibition effect of the phosphate ion is not, as it was believed previously, related directly to the total phosphate concentration, but is rather a function of the concentration of the orthophosphate ion, PO_4^{3-}. The orthophosphate ion concentration is dependent upon the total phosphate concentration and the pH of the precipitating solution. A linear log-log relationship between the precipitation rate constant and the orthophosphate ion concentration is indicative of a strong interaction between the orthophosphate ion and the surface of calcite, typical of chemisorption.

1330-1510 Studio Alfred-Laliberté
SESSION 3A: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS I
SESSION 3A : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS I

SULPHATE AEROSOL AND SO_2 IN A THREE-DIMENSIONAL FIELD OF CUMULUS CLOUDS: NUMERICAL SIMULATIONS
Michal Niewiadomski

A 3-D numerical model has been applied to study convective and turbulent transport of sulfur pollutants and their scavenging and processing by cloud and precipitation. Simulations are performed in a domain 50 x 50 x 10 km with 1-km horizontal and 200-m vertical grid steps. The model, the scope of the experiment, and some preliminary results concerning a passive (non-interacting with water) pollutant are briefly described by Niewiadomski (1984).

The fields of velocity, turbulence and cloud parameters have been taken from a 3-D simulation of a field of developed Cu clouds (Smolarkiewicz and Clark, 1985) using an improved version of Clark's (1979) cloud model. That simulation compares favorably with observations.

The attention of this paper is focused on determinating the efficiency of a cumulus field in pollutant processing. The relative importance of various processes (upward transport of SO_2 and sulphate from the polluted boundary layer, their scavenging by clouds and rain, production of sulphate in liquid water by oxidation of dissolved SO_2, vertical transport and "wet deposition" of sulphate by rainfall) is determined. Since the simulations are carried out in a large domain, comparable with one grid cell of large-scale Eulerian models of pollution transport, the results should be helpful in the parameterization of subgrid effects of convective clouds in such models.

References:
1. Clark, T.L., 1979: Numerical simulations with a three-dimensional cloud model: Lateral boundary condition experiments and multi-cellular severe storm simulations. J.Atmos.Sci., 36, 2191-2215.
2. Niewiadomski, M., 1984: 3-D numerical simulation of transport and transformation of pollutants in a field of convective clouds. Proc. 4th Joint Conf. on Applications of Air Pollution Meteorology, Portland, Ore., 238-241.
3. Smolarkiewicz, P.K. and Clark, T.L., 1985: Numerical simulation of the evolution of a three-dimensional field of cumulus clouds. J.Atmos.Sci., in press.

A THREE-DIMENSIONAL CLOUD CHEMISTRY MODEL
André Tremblay & Henry Leighton

Due to the serious impact of acidic rain on our environment it is of some importance to understand the interactions between clouds and the aerosols and gases that play a role in influencing the acidity of cloud and rain. Insight into some of the questions that need to be answered can be obtained from suitable numerical models.

A three-dimensional cloud chemistry model has been developed that is being used to study the redistribution of chemical species in the atmosphere and their wet-deposition at the surface. The cloud chemistry model, which includes sulfur diomide, nitric acid vapour, hydrogen peroxide, ammonia and aerosols, is coupled with a three-dimensional convective cloud model. The convective cloud model provides fields of air velocity, turbulence, water substance and other pertinent microphysical parameters as functions of time which are used as input to the cloud chemistry model. Results of simulations will be presented and compared with in-cloud measurements of the concentrations of some chemical species.

A MESOSCALE PARAMETERIZATION FOR TRANSPORT AND TRANSFORMATION OF POLLUTANTS BY CLOUDS

Chris J. Walcek

A one-dimensional cloud model has been combined with an aqueous chemistry model to predict vertical redistribution, chemical transformation, and removal of trace gases and aerosols by cumulus or stratiform clouds. This parameterization can be utilized by long-range transport and transformation models for predicting these cloud effects. The model assumes that a cloud is composed of polluted boundary-layer air into which mid-tropospheric air has been entrained. The degree of entrainment is quantified, and vertical distributions of temperature, pressure, ice, and water content are also predicted by the cloud model. This information, together with pollutant concentration distributions, is then processed by a zero-dimensional aqueous chemical model which predicts the aqueous composition of the cloud and precipitation.

Utilizing this modeling approach, results are presented which demonstrate the vertical redistribution and deposition of passive and reactive tracers by cloud ensembles. It is found that the composition of cloud water is strongly sensitive to several meteorological parameters as well as the distribution of pollutants in the air from which the cloud forms. Frequently, aqueous chemical reactions which convert sulfur dioxide to sulfuric acid are either reactant or oxidant limited, implying that there is a distinct limit to the amount of acidity which can be generated by an individual storm. It appears that this limit can be reasonably estimated from several meteorological and pollutant variables.

WINTER OBSERVATIONS OF EMISSIONS FROM OIL SANDS EXTRACTION PLANTS

Andrew Davis, Lawrence Cheng and Dave Rogers

Field studies were conducted in northern Alberta during winter conditions in March and December 1983 to determine the transport and diffusion of emissions from oil sands extraction plants. Transformation rates of nitric oxide to nitrogen dioxide in the plumes were also estimated.

Hot buoyant and moist effluent was exhausted into a cold atmosphere, sometimes less than -30°C. Under these very cold conditions a liquid water cloud formed and quickly cooled to environmental temperatures. Initial supercooled liquid water

content reached a value of 1.0 grams per cubic metre or more, but within a short distance no measurable liquid water remained as the moisture was rapidly depleted by growing ice crystals and evaporation to entrained dry air. The ice crystals which were nucleated in the plume grew to precipitation size and fell out of the plume while the gaseous plume remained aloft.
Comparisons of the observed horizontal plume dispersion parameters with the Pasquill-Gifford curves show the parameters slightly larger than those predicted. The extra buoyancy of the hot emissions increases the initial instability of the gases near the stacks. Observed horizontal plume dispersion parameters were greater than expected under the prevailing atmospheric stability conditions, for distances close to the stacks. Generally stable atmospheric conditions allowed SO_2 emissions to be detected as far away as 96 kilometres.
Rates of NO to NO_2 conversion varied considerably from day to day, ranging from 1.0% to 5.3% per minute of travel time. Traverses of the plume showed greatest conversion on the outer edges of the plume and least in the centre. This suggests that turbulent mixing may be an important factor controlling the rate of transformation of NO to NO_2.

TRANSFORMATION OF SULFUR DIOXIDE TO PARTICULATE SULFATE FROM OIL SANDS EXTRACTION PLANT EMISSIONS

Andrew Davis, Lawrence Cheng and Eric Peake

Airborne measurements of plume emissions from oil sands extraction plants in northern Alberta were made in March and December 1983, and June 1984. Transformation of sulfur dioxide to particulate sulfate was determined at different distances from the stacks under various atmospheric conditions.
Sulfur dioxide was measured by a flame photometric detector. A time integrated filter system was used to obtain dry sulfate concentrations. Teflon filters used to collect the sulfate particles were analyzed by an ion chromatograph. From the chemical analyses, it was found that most filters had sulfate concentrations above the detectable level of SO_4^{2-} per filter. Particulate sulfate concentrations increased initially in the plume and then declined at some distance downwind as the plume was dispersed.
From the size distributions of aerosol particles obtained through the use of a laser spectrometer probe, quantitative values of the conversion rate of SO_2 to SO_4^{2-} are estimated. Within the first few hours of travel time, the transformation of SO_2 to SO_4^{2-} was found to have gradually decreased to a generally constant value.
Both results obtained from the chemical analyses and estimated from the aerosol size distributions suggest that heterogeneous conversions may be important, especially at downwind distances close to the stack or if there is an abundance of large aerosol particles present.

1330-1510
SESSION 3B: COASTAL OCEANOGRAPHY I
SESSION 3B : OCEANOGRAPHIE COTIERE I

ELEMENTARY MODELS OF COASTAL PYCNOBATHIC CURRENTS
G. T. Csanady

Departures from Ekman's law of parallel solenoids, i.e., the variation of density along isobaths, give rise to the effect sometimes characterized as JEBAR (Joint Effect of Baroclinity and Relief). Baroclinic flow under these conditions is divergent and a compensating field of barotropic currents (to be called "pycnobathic" currents here) restores continuity. Pycnobathic currents are likely to be significant mainly over the outer continental shelf and upper continental slope.

The simplest models of pycnobathic currents make use of idealized topography (a plane sloping shelf) and prototype prescribed density fields. Examples are currents induced by river inflow in well mixed water, currents associated with a shelf-sea front that cuts through isobaths, and currents arising on the upper continental slope when the deepwater pycnocline has an alongshore gradient. The last named problem has important implications for coastal sea levels and for the effect of the deep ocean on continental shelf circulation.

THE WIND-DRIVEN CIRCULATION OFF SOUTHWEST NOVA SCOTIA
Peter C. Smith

The wind-driven circulation off southwest Nova Scotia is examined in terms of frequency-dependent gains calculated by multiple linear regression analysis of sea level and two current components on the two components of wind stress. At subtidal frequencies (including zero), wind stress in the along- (across-) shelf direction is most (least) effective at driving current and sea level fluctuations. This result is qualitatively consistent with simple analytical and numerical models. However, quantitative comparisons are complicated by the problem of choosing a "representative" wind stress forcing function. Maximum coherence is found with winds measured at the nearby Yarmouth coastal station, but gains calculated using Sable Island winds (300 km to the east) consistently show the most favourable comparison with numerical model results. This suggests that the higher stress levels at Sable Island are characteristic of the offshore wind fields.

HORIZONTAL AND VERTICAL EXCHANGE RATES ON THE SOUTHEAST SHOAL OF THE GRAND BANK
John W. Loder

Historical hydrographic data indicates that a two-layer thermal structure (warm surface, cool bottom water) develops over the Grand Bank of Newfoundland in summer, with slightly enhanced lower layer temperatures over the Southeast Shoal. At least two explanations for the development of this relatively warm bottom water seem plausible. If horizontal heat exchange in the lower layer is negligible, the warmer bottom water may be the result of differential, but weak, vertical exchange across the thermocline, with

greatest exchange in the shallowest water. On the other hand, the lower layer's summertime heat budget may also be satisfied with a spatially-uniform and stronger rate of vertical exchange across the thermocline, provided that there is horizontal exchange with the cooler water surrounding the Shoal. The latter explanation results in a simple relationship between the vertical and horizontal diffusion coefficients over the Shoal. Semi-empirical formulae for these coefficients and observational information are used to assess these explanations, and hence to estimate the time scales for vertical exchange across the pycnocline and horizontal exchange over the Shoal.

ON THE BEHAVIOUR OF COASTALLY TRAPPED WAVES IN CHANNELS AND DEEP ESTUARIES WITH CONTINUOUS STRATIFICATION AND VARIABLE TOPOGRAPHY
V.G. Koutitonsky and R. E. Wilson

Coastally trapped wave motion has recently been invoked to explain low frequency current variability in deep estuaries, modelled as infinite channels with two-layer density profiles. In this study, the behaviour of coastally trapped waves (CTW's) in channels with continuous stratification, and variable cross-sectional topography are examined, using a numerical model which solves the conservation of potential vorticity equation following the motion. Without vertical coastal walls, phase speeds of long topographic waves at a given latitude increase with channel width and vertical stratification, but decrease with bottom curvatures and surface intensification of the buoyancy frequency. The major difference between continental shelf waves and channel waves is a relative phase speed reduction of the latter, produced by a slope reversal at some mid-channel location. Cross-channel velocity eigenfunction distributions reveal surface intensified motion, and bottom trapping increasing with the nearshore local internal radius of deformation. In the presence of coastal walls, CTW's become a mixture of two wave classes: topographic waves produced by bottom slope effects, and baroclinic Kelvin-like waves produced by coastal wall effects. At low wavenumbers, such hybrid waves are found to be predominantly topographic waves for coastal walls shallows then some depth, and Kelvin-like waves for deeper coastal walls. However, at higher wavenumbers, consecutive modes were found to interchange nature, which suggests the appearance of a wave resonance phenomenon.

1330-1510
SESSION 3C: SURFACE WAVES I
SESSION 3C : ONDES DE SURFACE I

INTERCOMPARISON OF WIND WAVE PREDICTION MODELS
W. Perrie and B. Toulany

We describe the way in which Resio's wind wave model, as used by MEDS, responds to the hypothetical test cases of SWAMP I and II (the intercomparison study of 10 wind wave prediction models). Operating characteristics, its parameterizations of nonlinear transfer to the forward face and peak regions of the wind sea spectrum, as well as its handling of wind sea - swell coupling, etc. are presented relative to the other models of SWAMP and associated data.

IMPROVING MODEL PREDICTION OF GREAT LAKES WIND WAVES

Stephen Clodman

Lake wave modelling is being studied by the Atmospheric Environment Service in order to develop an automated procedure for wind wave prediction on the Great Lakes. The model in use is an Eulerian momentum balance non-spectral model originally developed by Donelan. Time series of wind fields over a grid are specified. The wind imparts an increment of momentum to the wave at each gridpoint at each timestep. The increment may tend to increase or decrease the momentum, and may change its direction. A separate "fossil" wave is calculated as an approximation to a swell wave. Once the momentum is calculated, wave direction, significant period and significant height are derived. Shallow-water effects - bottom drag and refraction - may be introduced.

The model has been tested in hindcast case studies against buoy and ship observations on several of the Great Lakes. Some success has been achieved, but it is necessary to make certain choices in order to achieve good results. First one must choose the input wind field. CMC-analyzed wind fields are the most convenient, but these do not allow for mesoscale and boundary-layer effects which have some importance here. A specialized lake wind forecast is probably better, but may be difficult to obtain. In addition, the predicted time lag between wind velocity changes and resulting predicted wave changes is too large. Correcting this requires a basic change in the model.

The use of shallow water effect calculations considerably increases computer time use. Unfortunately, the exclusion of such effects can cause error in Lake Erie, which is shallow, and at shoal locations in other lakes. Nevertheless, it is concluded that shallow water parameterization is usually not needed provided certain limitations are understood.

WIND SPECIFICATION FOR SPECTRAL OCEAN-WAVE MODELS

M.L. Khandekar and Bassem M. Eid

Spectral ocean-wave models based on the energy balance equation are currently used in operational mode in many areas of the world oceans. The wind input for driving a spectral wave model is generally extracted from an operational numerical weather prediction model.

This paper investigates the utility of winds obtainable from an operational weather prediction model at the CMC (Canadian Meteorological Centre, Montréal) for driving a spectral ocean-wave model. Surface winds from the CMC model are analyzed with respect to observed winds at specific locations over the northwest Atlantic Ocean; these winds are further analyzed in relation to wind inputs used for driving two operational spectral wave models. Three storm cases over the northwest Atlantic are studied and differences between observed and model winds are analyzed in terms of marine boundary-layer dynamics.

The goal of this study is to determine an appropriate wind input for an operational spectral wave model to be implemented in the AES (Atmospheric Environment Service) forecasting system.

DIRECTIONAL WAVE SPECTRUM INTERCOMPARISON STUDY

Barbara-Ann Juszko

The directional and non-directional wave characteristics, obtained from two Datawell WAVEC buoys and one Endeco WAVE-TRACK buoy moored at Hibernia from February to April 1984, were compared with concurrent "heave-only" Datawell Waverider measurements, visual observations and wave hindcast model results. The agreement between the data sets was determined under different wind and sea conditions and was found to be generally good for the heave spectral statistics. In addition, the linearity of the directional buoys' response to the wave field, methods of improving the wave direction estimates and the buoys usefulness in measuring non-spectral wave statistics were examined. The Endeco WAVE-TRACK buoy suffered severe icing problems while the good records showed a distinctly non-linear response to the wave field at all frequencies using manufacturer supplied instrument transfer functions. The WAVEC buoys operated well at all frequencies, however, the response became non-linear in storms. The calculated wave directions corresponded with visual observations and, given a variable time lag, with wind directions. A better agreement was obtained using an "apparent direction" statistic. Non-spectral statistics, such as the mean crest front steepness, can be derived from the time series of slope measurements and the latter was found to be directly related to wind speed and to the fourth moment of the heave spectrum. The hindcast model results, provided by F.G. Bercha Ltd., could not resolve multiple spectral peaks and had a reduced frequency resolution which spread the energy in frequency. The predicted directional spectra showed variable agreement, dependent on storm state, with calculated values but did contain considerably less directional spread in each frequency band.

BRAGG-SCATTERING AND EQUILIBRIUM RANGES IN WIND-GENERATED WAVES - WITH APPLICATION TO SCATTEROMETRY

Mark A. Donelan and Willard J. Pierson Jr.

A composite divided-scale model for radar backscatter from the ocean surface is constructed to meet the needs of scatterometry. The primary scattering mechanism is assumed to be Bragg scattering in which the normalized radar backscattering cross-section is proportional to the spectral density of the resonant Bragg water waves. The form of the equilibrium wavenumber spectrum is derived on the assumption that the short-wave energy density reflects a balance between direct wind forcing and dissipation due to breaking and to viscosity. This theoretical equilibrium spectrum, which links the wave spectrum to the wind, is included in a Bragg scattering model, which links backscattering cross-section to the wave spectrum. The effects of tilt and modulation of the Bragg resonant waves by the longer waves are included and the model is tested against aircraft circle flight K_u-band radar backscatter measurements (in the wind speed of 5.5 m/s to 20 m/s) with very encouraging results. The model is then exercised over a much wider wind speed range and also for C and L bands. It is demonstrated that at low wind speeds scatterometry is sensitive to surface water temperature through its effect on the viscous dissipation of short waves. For high wind speeds at anemometer height the backscattering cross-section becomes less sensitive to wind speed and at even higher speeds decreases as the wind speed increases.

The wind speed at which this "roll-over" occurs is dependent on radar wavelength and incidence angle, being as low as 22 m/s for K_u band at 25° incidence. This rather complicated wind speed dependence of radar backscatter contrasts strongly with the current power law models and helps explain many of the inconsistencies that have arisen in the analysis of scatterometer data to date.

1530-1730 Studio Alfred-Laliberté
SESSION 4A: EVALUATION OF METEOROLOGICAL MODELS
SESSION 4A : EVALUATION DES MODELES METEOROLOGIQUES

VÉRIFICATIONS DU MODÈLE DE PRÉVISION NUMÉRIQUE EN EXPLOITATION AU CMC
Réal D'Amours

Une version améliorée du modèle spectral canadien (59 ondes, troncature triangulaire) est en exploitation au CMC depuis juin 1984. Des vérifications des prévisions de différents champs, à plusieurs niveaux sont faites continuellement depuis la mise en service du modèle.

Certains résultats de ces vérifications sont présentés. Quelques erreurs systématiques sont mises en évidence et on tente de montrer leur impact sur la performance des prévisions. Des causes possibles pour ces erreurs sont mentionnées.

PROFILS, TRACES ET TENDANCES MÉTÉOROLOGIQUES LOCALES TELS QUE PRÉVUS PAR LE MODÈLE EN EXPLOITATION AU CMC
Angèle Simard

Des quantités déterminant ou montrant l'évolution des conditions météorologiques en un point dans un modèle numérique et obtenues directement de ce modèle sont présentées sous forme de profils, de traces (séries temporelles), de coupes verticales (altitude versus temps). Plusieurs de ces quantités ne sont habituellement pas disponibles dans un contexte opérationnel et rarement le sont-elles avec autant de résolution temporelle.
Ainsi il est possible d'obtenir tous les flux entrant ou sortant à la surface et permettant une description complète du bilan énergétique terrestre et de son évolution (cycle diurne) et tous les éléments du temps près de cette même surface, pression, vent, température, humidité, précipitation... En altitude, on peut observer le développement de la couche limite, instable durant le jour, stable durant la nuit, la formation de nuages, l'arrivée d'un front et en général toutes les variables météorologiques de base et leurs tendances. Les changements reliés à la radiation terrestre ou infrarouge, aux divers transports turbulents dans la couche limite, à la formation de précipitation ou à la convection peuvent être examinés séparément.
Ce genre de diagnostics s'avère très utile, en particulier, pour l'amélioration des modèles numériques.

PRÉVISIONS NUMÉRIQUES UTILISANT LES DONNÉES SATELLITE GOES

Jacques Hallé et Robert Benoit

Quelques prévisions numériques sont effectuées pour mesurer l'impact de données satellitaires sur l'analyse objective d'humidité. Les données GOES (visible et infrarouge), telles que formattées par le système RAINSAT sur l'est du Canada, sont utilisées avec les analyses conventionnelles de la façon suivante: la température du sommet du nuage (infrarouge) et l'albedo du nuage (visible) sont combinés avec les champs Z et T pour produire un estimé de la distribution tri-dimensionnelle des nuages. Le champ d'humidité est ensuite réanalysé en tenant compte des nuages. Un modèle aux éléments finis (RPN) est ensuite intégré à partir d'abord de l'analyse conventionnelle et ensuite de l'analyse refaite avec les données satellitaires. Pour évaluer l'impact de la nouvelle analyse, les précipitations prévues du modèle sont comparées.

WEDGE VERIFICATION

R. Jones

WEDGE is an acronym for Weather Element Digital Guidance and Evaluation. In operation since 1980, WEDGE presently produces a simulated surface report forecast from Spectral model output for about 940 stations across N. America. Stations can be both fixed and movable; some stations are offshore. Verifications for most Canadian stations (260) are kept for one month on disk. Every month, national verification scores are calculated from these station verifications. All scores as well as the forecasts are available interactively online. Some national scores will be presented and compared to scores from statistical methods of forecasting.

PRÉVISIONS DE TEMPÉRATURE MAX-MIN AU CMC PAR MÉTHODE STATISTIQUE

N. Brunet

On rappellera, au départ, la nature du système de prévisions des températures MAX-MIN actuellement en exploitation au CMC et on en indiquera la performance.
Dans l'espoir d'améliorer ce type de prévisions, le CMC a développé de nouvelles équations de régression en utilisant la méthode MOS (model output statistics). Le prédictant est toujours la température MAX-MIN climatologique. Comme pour la méthode du prog parfait, les observations des MAX-MIN furent utilisées comme prédicteurs potentiels. Les autres prédicteurs potentiels ont été tirés des archives des modèles spectraux V8 et V9 de septembre 1980 à janvier 1984. On indiquera quels sont les prédicteurs qui furent choisis le plus souvent par le module de sélection par étapes.
La vérification des premières prévisions de température MAX-MIN par la méthode MOS sera présentée, ce qui permettra de les comparer aux prévisions opérationnelles.

SEA SURFACE FLUXES DIAGNOSED FROM A GLOBAL NUMERICAL WEATHER PREDICTION SCHEME
D.N. Reed

Sea-surface fluxes of sensible heat, latent heat and momentum have been diagnosed at intervals of 6 hours over 6 consecutive days during the first Special Observing Period of the FGGE year. These were obtained by running a forecast for one time step from analyses obtained by using a version of the U.K. Meteorological Office NWP system. The corresponding surface fluxes have also been obtained from the available ECMWF IIIb analyses for the same period.
A comparison of the fluxes shows that there is broad agreement between the two sets of results, but that there are areas where the agreement is poor. Some of these areas have been examined further by investigating the large differences in fluxes at individual times as well as by considering the time-averaged fluxes. Because of their variability, it is difficult when considering fluxes on the time-scale of these data to compare them with the available time-averaged climatological data. This difficulty may be partly overcome by comparing the calculated fluxes with those derived from oceanographic observations. The possible implications of the differences between the sets of fluxes for the overall reliability of the model-derived fluxes are discussed.

1530-1710
SESSION 4B: COASTAL OCEANOGRAPHY II
SESSION 4B : OCEANOGRAPHIE COTIERE II

ACE - A SEARCH FOR COASTAL TRAPPED WAVES
Howard J. Freeland and J.A. Church

The Australian Coastal Experiment has provided a unique data set for the study of the distribution of currents across a continental shelf and slope, and the propagation of those currents alongshore. This paper will describe an attempt to derive the dispersion relation that characterizes the observed current field in the range of periods from 4 days to 24 days.

The currents observed at three independent lines of moorings are Fourier analyzed and the resulting distributions of complex current amplitudes are expanded in terms of 4 modes. The 4 modes used are the first three dynamical modes resulting from coastal trapped wave theory and one so-called eddy mode. The latter mode is required to minimise contamination of the dynamical modes by leakage from East Australian Current eddies. The resulting complex modal amplitudes are examined for alongshore signal propagation, and a dispersion diagram is constructed.

The dispersion relation derived is a convincing fit to the theoretical dispersion relation, though the observed waves appear to be systematically faster than theory predicts. The eddy mode shows no tendency to propagate alongshore. Each mode shows a red energy spectrum.

VERTICAL MIXING IN A STRATIFIED UNDER-ICE COASTAL ENVIRONMENT
R. Grant Ingram

Vertical fluxes of both salt and nutrients into the brackish upper layer of Manitounuk Sound (Hudson Bay) under a landfast ice cover are estimated using CTD, bottle and current meter results. A skewed fortnightly variation in layer thickness and the rate of vertical mixing was found. Comparison of mixing rates in this area and those observed in the offshore region of SE Hudson Bay (weak tides, landfast ice) and of eastern James Bay (moderate tides, broken pack-ice) showed marked differences. The importance of ice conditions and variability of the tidal and low-frequency current regime on under-ice mixing and primary production are discussed.

MIXING AND CIRCULATION IN BARROW STRAIT
S.J. Prinsenberg and E.B. Bennett

Recent hydrographic and current-meter data (1981-1983) from Barrow Strait, the central part of the Northwest Passage, are interpreted from the viewpoint of water mass mixing and long-term mass and heat transport. As surface water moves from the Arctic Ocean to Baffin Bay during the winter, it loses heat and gains salt from the growing ice cover. Depending on the degree of mixing in the shallow and restricted channels within the Canadian Archipelago, salty and warmer subsurface water is mixed into the surface layer to various degrees before entering Barrow Strait. Here three surface water masses of Arctic origin can be identified and overlay warmer and saltier Baffin Bay water.

From current-meter and hydrographic data in Barrow Strait an eastwards transport of ½ Sverdrup ($.5 \times 10^6$ m^3s^{-1}) for the month of April (1982) is calculated. Variations about the mean are $.25 \times 10^6$ m^3s^{-1} in magnitude and cyclic with period of 4 to 6 days similar to atmospheric pressure variations. Eight months of current meter data shows that the eastwards transport has a seasonal variation which reaches a maximum value of 1.2×10^6 m^3s^{-1} in September and a minimum of $.1 \times 10^6$ m^3s^{-1} in November. The heat transported out of the Arctic through Barrow Strait peaks in August at 2.75×10^{12} W and has a minimum value of $.5 \times 10^{12}$W in December.

A COUPLED ICE-OCEAN MODEL OF A WIND-DRIVEN COASTAL FLOW
Motoyoshi Ikeda

Ice movement driven by winds along the coast is studied using a two-dimensional (vertical-seaward), ice-ocean coupled model. Right-hand alongshore winds are given, when internal ice stresses are important to determine the ice movement. These winds induce right-hand coastal currents and ice movement. A shoreward Ekman flow beneath the ice is a major mechanism to constrain the ice over the shelf, balancing the internal ice pressure gradient.
When the wind ceases, the ice decreases its alongshore velocity, and the ice-covered band becomes wider. The alongshore ice velocity is sensitive to ice shear strength which determines the shear stress at the coast; i.e., weak (strong) shear strength

allows a large (small) ice velocity at the coast, resulting in intense (weak) Ekman flow and downwelling, which induces a fast (slow) coastal current. The alongshore velocity is also sensitive to the relatively small cross-shore component of the wind; i.e., the seaward (shoreward) component reduces (induces) the shear stress and allows large (small) ice velocity.
The results are applied to the ice over the Labrador shelf. Qualitative estimation of iceberg velocity suggests that bergs surrounded by ice approach the coast and drift alongshore at a speed between ice and water velocities.

1530-1710
SESSION 4C: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS II: EMERGENCY RESPONSE AND ENVIRONMENTAL IMPACT ASSESSMENT
SESSION 4C : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS II : REACTION AUX URGENCES ET EVALUATION DES CONSEQUENCES POUR L'ENVIRONNEMENT

EVALUATION OF A MULTIPLE-SOURCE REGIONAL EPISODE MODEL
D.L. Bagg and C.S. Matthias

The Regional Episode Model (REM) was developed at AES to calculate pollutant concentrations from several point sources in areas of complex topography and meteorology. The wind field at source and receptor locations is determined from a number of wind monitors in the area and an interpolation scheme. Plume-rise formulae and dispersion coefficients developed by Briggs are used. The model requires hourly values of source strengths, mixing heights, and wind speed and direction, and calculates hourly-averaged concentrations.

The evaluation is done by applying the model to the city of St. John, New Brunswick. A good data base is available, consisting of 35 major SO_2 sources, as well as 7 meteorological stations, 7 SO_2 monitoring stations, and daily minisonde flights for mixing height determinations. Standard statistical tests are employed to quantify the model performance.

TRACER DISPERSION IN VALLEY DRAINAGE FLOWS
S. K. Sakiyama and R. P. Angle

Sulphur hexafluoride was released into the nocturnal drainage flows of two valleys in the Rocky Mountain foothills southwest of Calgary and the resulting concentrations were measured at several points on transects at various distances from the source. Plume trajectories in the broad, shallow valley of the Elbow River did not follow the deep water channel, whereas in the narrow steep-walled valley of Canyon Creek they were constrained to do so. Dilution rates (CU/Q) at a downwind distance of 1.2 km in the Elbow Valley averaged 5.8×10^{-5} m^{-2} while in Canyon Creek valley, at 700m downwind, the dilution rates averaged 8.3×10^{-5}. These large rates correspond to Pasquill Class C-D dispersion

rather than the meteorologically indicated stability Class F. The NUVAL version of the model IMPACT (Integrated Model for Plumes and Atmospherics in Complex Terrain) was site-tuned using the measured concentrations and concurrent meteorological data. Relative mean absolute errors of 24-50% were obtianed. A Gaussian model with modified stability classes gave relative mean absolute errors of 42-64% in predicting transect maxima.

ON THE USE OF LEAD DIOXIDE CYLINDER INFORMATION
Douglas M. Leahey and Michael B. Schroeder

Lead dioxide exposure cylinders are widely employed in Alberta to provide a measure of air quality in the vicinity of SO_2 emission sources. Dry sulphur deposition onto these exposure cylinders is greater than that onto surrounding soils and vegetation because the cylinders have, by virtue of their chemical properties, a higher affinity for gaseous sulphur compounds. Methods are proposed for estimating dry sulphur deposition onto the surrounding environment from sulphation rates measured using exposure cylinders. Several examples are discussed to illustrate that the proposed methods can provide reliable estimates of local and background dry deposition, and effects of irregular terrain on plume dispersion.

APPLICATION OF THE ISCLT AIR QUALITY MODEL FROM THE UNAMAP SERIES TO THE DEPOSITION OF METALS IN THE SNOWPACK IN THE VICINITY OF THE METAL SMELTER AT FLIN FLON
S.R. Shewchuk and R. Jahren

Studies involving the atmospheric metal particulate deposition to the snowpack in the vicinity (within 15 km) of the metal smelter at Flin Flon were conducted by Frazin et al., 1977 and by the Saskatchewan Research Council in 1983. It was observed in the more recent study that the deposition of most metals to the lake surfaces of the area has been considerably reduced from the earlier period. The reductions were particularly significant for zinc. A likely cause for the reductions was the addition of emission control equipment by the smelter in the early 1980's. Since both emission parameters and meteorological stability arrays are available for the two periods in question, the LSCLT model from the UNAMAP series of air quality models was used to study the qualitative differences observed in the total metal deposition of the area between the two years in question.

RÉSULTATS D'UNE EXPÉRIENCE DE MESURE DE PH QUOTIDIEN
Gilles Desautels

Les résultats des valeurs de pH obtenus à l'aide d'un appareillage simple à plus de 40 sites du sud du Québec en août et septembre 1982 sont examinés. Une comparaison avec les mesures faites à un collecteur standard permet de croire que les mesures sont dignes de confiance. On présente les distributions des précipitations, des pH, des sulfates et des nitrates par événement et pour l'ensemble de l'expérience. La très grande variabilité dans l'espace des mesures demeure le fait dominant.

On note également des comportements différents lors des événements de faibles et de fortes précipitations. Le calcul des moyennes sur des périodes de temps plus longues (semaine ou mois) élimine la variabilité notée au jour le jour. La seconde constatation est la constance du rapport des concentrations en sulfate et en nitrate. De plus, on observe un rapprochement étroit entre l'acidité et ces concentrations. Les sulfates contribuent davantage à l'acidité que les nitrates en cette période de l'année.

0830-1030 Studio Alfred-Laliberté
SESSION 5A: MODELLING THE TRANSPORT AND DIFFUSION OF POLLUTANTS III
SESSION 5A : MODELISATION DU TRANSPORT ET DE LA DIFFUSION DES POLLUANTS III

PROBLEMS IN EVALUATION OF COMPREHENSIVE MODELS OF TRANSPORT AND DIFFUSION OF POLLUTANTS
A.D. Christie

Current initiatives to develop regional-scale models that explicitly simulate the processes of transport, transformation and removal of atmospheric pollutants have resulted in the introduction of a formidable list of potential sources of input and computational error. These sources of error will be briefly reviewed and discussed.

The evaluation of a model depends on the use to which it will be put. It will be shown that environmental and health effects of pollutants on the regional scale provide guidance on the nature of the evaluation desirable. While all evaluation makes use of tests of (local) temporal or (instantaneous) spatial realism of model simulation versus observations for one or more model predictand, the preferred method is constrained by the selected predictand and the availability of appropriate input and evaluation data.

A short discussion of an evaluation strategy will lead to an outline of an observational program needed to permit systematic analysis and subsequent upgrade of comprehensive models.

THE NCAR-EPA REGIONAL ACID DEPOSITION MODEL
R. A. Brost, P. Middleton, W. R. Stockwell, C. J. Walcek and J. S. Chang

The Acid Deposition Modeling Project of NCAR is developing a Regional Acid Deposition Model (RADM) for EPA. We will compare atmospheric concentrations and dry and wet acid deposition from a three-day simulation with OSCAR observations. The NCAR-Pennsylvania State University mesoscale model version 4 (MM4) predicts a spatially and temporally detailed set of meteorological variables such as wind velocity, temperature, humidity, and precipitation. These meteorological variables, in turn, drive the RADM, which predicts transport, diffusion, chemical transformation, and dry and wet deposition of various pollutants. Turbulent diffusion in the planetary boundary is usually calculated

with a parametrization of eddy diffusivities. The dry deposition module was developed by J. Shieh and his coworkers at Argonne National Laboratory. W. R. Stockwell (1985, in preparation) developed the first generation gas chemistry module. C. J. Walcek (1985, submitted to JAS) developed the aqueous chemistry and vertical redistribution parameterization for precipitating clouds. EPA provided the emissions and land use data.

A COMPARISON BETWEEN THE DIAGNOSTIC TRAJECTORIES COMPUTED FROM THE AES-LRTAP MODEL AND THE GROUND-LEVEL TRACER PATTERNS OBSERVED DURING CAPTEX-83

Peter W. Summers and Marvin P. Olson

In the Fall of 1983, the Cross Appalachian Tracer Experiment (CAPTEX-83) was conducted by several Canadian and United States agencies. An inert tracer gas (perflouromonomethylcylohexane - C_7F_{14}) was released at ground level at two locations (Dayton, Ohio and Sudbury, Ontario) and monitored by a network of 80 ground sampling stations out to distances of 1100 km. In addition, seven aircraft were used to provide vertical and horizontal cross-sections of the tracer puff at distances out to 800 km from release. The weather service radiosonde observations were supplemented by additional stations and soundings at six-hourly intervals.

Seven tracer releases were made (5 from Dayton and 2 from Sudbury) all but one lasting for 3 hours. In each case, the tracer was clearly tracked through the network with synoptic maps showing the 6-hour average ground-level concentration every 6 hours up to 2 days after release time. Starting at the tracer release point, air parcel positions were calculated every six hours out to 5 days using the AES-LRTAP model at four levels: 1000 mb, 925 mb, 850 mb and 700 mb. Qualitatively, the features of the tracer pattern were simulated very well by the model with the tracer concentration maxima usually confined to the region between the 1000-mb and 925-mb trajectories. Comparing the arrival times of the tracer at stations along the plume centre-line with the model predictions showed good agreement for the first 24 hours after which the model tended to underestimate the speed of tracer motion. The errors in the direction of motion varied considerably from experiment to experiment and best fit was obtained by different formulations of the model (i.e. with or without a friction turning term at the 1000-mb level) in each case.

The implications of these results on the use of the model for predicting source-receptor relationships will be discussed.

SENSITIVITY TESTING OF THE UNIVERSITY OF SALFORD PLUME RISE AND DISPERSION MODEL U.S.P.R.

B. Henderson-Sellers & S.E. Allen

Model validation is an important step prior to any model receiving acceptance in the regulatory application of air pollution control techniques. In the field of plume rise and plume dispersion modelling few adequate data bases are available. A recent extensive field observational programme undertaken at the Plains Site (EPRI, 1983) provides one such excellent data archive. Preliminary studies have highlighted the imperfections in many of the present generation of models. These may be due partly to the concatenation of a plume rise model with a dispersion model with inevitable problems at a mismatched interface.

The University of Salford Plume Rise model (U.S.P.R.) overcomes some of these difficulties by incorporating both plume rise and plume dispersion as a natural sequence of mixing processes. Its validity has been confirmed to a large degree for both positively and negatively buoyant effluents (Henderson-Sellers and Allen, 1983) and its correspondence to other, simplified regulatory models stressed. In this paper further testing of the model against the EPRI data base is undertaken, together with a sensitivity analysis for several of the model parameterization schemes. Both the physical parameters (e.g. the importance of the roughness length) and numerical parameters (the need to establish a sufficiently small step length to ensure numerical stability) are analysed in an attempt to highlight the order of importance (with respect to model improvements) for future research.

EVALUATION OF LAGRANGIAN LRT MODELS

C.S. Fung, E. Alp and R.V. Portelli

This paper documents a study conducted on behalf of the Canadian Electrical Association (CEA) to review and evaluate current Lagrangian long-range transport models for the prediction of transport and deposition of acidic pollutants. The study consisted of a literature review to identify all available Lagrangian models and a systematic screening and evaluation of the models to determine, on theoretical grounds, the relative strengths of each component of the respective models and the overall balance of the components within each model. The models found to be strongest on technical grounds were then examined in detail with a view to recommending one model for implementation on the CEA LRT modelling system. This paper will present the theoretical evaluation of the 35 available Lagrangian LRT models identified in the literature review and deal with the relative strengths of the two most advanced models.

0830-1030
SESSION 5B: ESTUARIES AND EMBAYMENTS II
SESSION 5B : ESTUAIRES ET BAIES II

A NUMERICAL MODEL OF THE UNSTEADY CIRCULATION AND SALINITY REGIME IN A SUBARCTIC SHALLOW ESTUARY
Serge Lepage

A one-dimensional numerical model was developed to simulate velocity, salinity and water-level fluctuations in a shallow tidal estuary. In this model, the equations of continuity, momentum and salt balance are solved using a leap-frog explicit scheme. The dynamic equations are coupled to the salt balance equation through a salinity-density relationship. At the end of each tidal cycle, a dispersion coefficient is calculated to be incorporated in the calculation during the subsequent cycle. This coefficient is related to local dynamic conditions in the estuary and varies from the river mouth to the upstream limit of salt intrusion.
The model was applied to the Eastmain River, James Bay, a subarctic shallow estuary. This estuary was considerably modified when, in July 1980, 80% of its former discharge was diverted into the La Grande River. The model was run over 175 tidal cycles to reproduce the transient conditions observed in the estuary from July to September 1980. Good correlations were obtained between the model results and the field observations of salinity and longitudinal velocity.

VORTICITY WAVES IN VARIABLE BREADTH ESTUARIES
B. Pelchat and Y. Gratton

Study of infra-red satellite pictures of the St Lawrence estuary reveals the existence of a wave-like perturbation propagating at the interface between warm and cold surface waters. The amplitude and the wavelength of the perturbation seem to grow as the estuary widens. The objective of this work is to look at the influence of variable breadth and depth on the propagation of low-frequency vorticity waves. By going to polar coordinates, the St Lawrence estuary can be represented by a trapezoid for which the horizontal equations of motion are separable. Exact analytical solutions are presented.

LATERAL DYNAMIC BALANCE IN THE LOWER ST. LAWRENCE ESTUARY
P. Larouche

Salinity, temperature and current data taken at a section near the mouth of the St. Lawrence estuary during the high spring runoff of 1979 are described.

A statistical analysis (singular asymptotic decomposition) of the data suggests that mean concentration differences in the lateral direction are greater than those due to the temporal evolution of

the same parameter at one point of the section during the study period. When the lower St. Lawrence estuary is compared with other estuaries on the lateral stratification/circulation diagram, it is classified as the most stratified.

Finally, an analysis of lateral dynamic balance in the surface layer indicates that among the studied accelerations, the predominant ones are the horizontal pressure gradient and the Coriolis acceleration followed by the secondary circulation and centrifugal accelerations. The lateral acceleration contributes significantly to the balance at times.

PRELIMINARY ANALYSIS OF SUBTIDAL SEA LEVEL VARIABILITY IN THE ST LAWRENCE ESTUARY, SUMMER 1979

V.G. Koutitonsky and R.E. Wilson.

Some aspects of low-frequency sea level fluctuations ($w < 0.7$ cpd) are examined from simultaneous tide records in the St Lawrence estuary, and the northwestern Gulf of St Lawrence, over a two-month period in the summer of 1979. Power spectra, coherences and phases, and frequency domain empirical orthogonal function analysis were computed to determine spatial and temporal scales of variability. Progress in the study of sea level response to possible forcing functions, such as local winds, fresh water runoff, and non-local forcing at the mouth, is discussed.

HYDRODYNAMICS OF THE LOWER ST LAWRENCE ESTUARY

Mohammed I. El-Sabh

Close examination of extensive satellite imageries, currents and CTD measurements taken in the lower St.Lawrence estuary in 1978 demonstrates the complexity of the circulation dynamics and reveals a number of features which have not been reported previously in the literature. Within the time-scale of 10-15 days, the estuary is subject to large perturbation and alternates between two modes of circulation pattern. The first mode, associated with periods of high sea level, is characterized by the presence of cold surface water mass at the head of the Laurentian trough, a series of cold and warm gyres with scales of about 50 km and several lateral density fronts, including the Pointe-des-Monts cold front. The second mode, corresponding to periods when sea level is falling, features two distinct water masses separated by a longitudinal front with a wavelike shape at mid-estuary; the southern half of the estuary is characterized by cold, more saline and denser waters compared to the northern part. The effect of freshwater discharge, meteorological and astronomical forces on such variability are discussed.

VARIABILITY OF SURFACE CURRENTS IN THE LOWER ST LAWRENCE ESTUARY

M.I. El-Sabh and M. Gagnon

Current measurements of 3-month duration from May 1980 taken at 4 stations along a transverse line near Ile du Bic in the lower St.Lawrence estuary were subject to time series analysis. Harmonic and spectral analysis of the current-meter data, together with the movement of two parachute drogues placed simultaneously at 10 m, one near Ile du Bic and the other near Bersimis, confirm the complex character of residual circulation in the region. The results are described and discussed in relation to freshwater discharge and other forces and comparison with the 1979 current measurements taken eastward of Rimouski are presented.

POSTER

ON LOW FREQUENCY CURRENT VARIABILITY IN THE LOWER ST LAWRENCE ESTUARY, SUMMER 1979

V.G. Koutitonsky, R.E. Wilson and M.I. El-Sabh

In a continuing effort to understand the complex dynamics governing low frequency current fluctuations in the lower St Lawrence estuary (LSLE), a set of current-meter data recorded at 10 stations over a period of 80 days in the LSLE during the summer of 1979 were re-examined. Mean value estimates revealed significant 20 cm/s subsurface currents directed seaward at opposite shores, and southward at the mouth, and a 2 cm/s upstream current near the bottom at a mid-channel location. At all other locations, mean value estimate errors exceeded the estimate itself due to the presence of non-linear trends. Complex empirical orthogonal function (EOF) analysis of these trends showed high spatial coherence between all series in mode 1, which accounted for 88% of the total variance. The geographical modal distribution revealed the presence of an anticyclonic gyre near the mouth, the variability of which appears to be buoyancy driven, through the injection of large freshwater pulses issuing from the Saguenay fjord with a 2 month return period. These are probably the result of fresh water regulations for hydroelectricity. Rotary spectra of the detrended currents near the surface indicated high levels of kinetic energy in a broad frequency band (12 to 18 days), and strong polarization for some series. Winds at opposite shores were found to be predominantly energetic in the same frequency band, with major axes of variability aligned alongshore, probably due to orographic effects. A frequency domain rotary empirical function analysis showed high spatial coherence between all subsurface currents, and between local winds and currents as well, for periods between 12 and 18 days. Mode 1 explained over 65% of the energy in that band, with rotary components of currents lagging those of the winds. Finally, transfer functions were computed between winds and currents, and wind-driven current were subtracted from each series. The polarity of the residual series were then compared to that of dynamical modes of free coastally trapped waves in channels, computed numerically for bottom topography and buoyancy frequency profiles representative of the area.

POSTER

TWO PARAMETERS FOR TIDAL MIXING FRONTS IN THE ST LAWRENCE ESTUARY
M.I. El-Sabh and T.S. Murty

Two parameters were used to predict frontal regions separating areas of tidally mixed waters from areas showing pronounced summer stratification in the St Lawrence estuary. The first parameter ($H/U^3 \sim 100$) was developed by Simpson and Hunter (1974) and does not include stratification effects. The second criterion ($HN/U \sim 0.5$) was developed by Maxworthy (1984) and expresses the fact that an oceanic front exists at a place where the ambient density stratification can just be mixed up by the kinetic energy in the largest eddies that can overturn this stratification. The data for the computations of these parameters came from various oceanographic cruises as well as from detailed time-dependent two-dimensional numerical tidal model. The results are compared with satellite imageries taken over the area and discussion is made regarding which of the two parameters can better represent tidal fronts in the St Lawrence estuary.

AFFICHAGE

MODÉLISATION NUMÉRIQUE DE LA MANCHE
A. Aissaoui, M.I. El-Sabh et J.-C. Salomon

L'objectif de ce modèle est la détermination des courants de marée et des courants résiduels de la Manche, dont les limites de l'extrémité ouest sont à 4°30'W de Greenwich et 1°30' à l'est de ce dernier. Le modèle étudie des mailles carrées de 3 km de chaque côté, avec une orientation nord-sud. C'est un modèle à deux dimensions ayant pris la référence du niveau moyen sur St-Malo, vu que c'est le plus gros marnage dans toute la Manche. La comparaison des hauteurs d'eau avec les mesures est faite avec trois ports de la région, soit: St-Malo, St-Hélier et Cherbourg.
La circulation des courants est comparée avec les mesures obtenues à l'aide des traceurs radio-actifs ainsi que d'autres travaux précédents. Vu la grosseur de la maille, les bancs découverts et les murs dus à certaines roches ont été négligés dans ces calculs.

0830-1030
SESSION 5C: APPLIED METEOROLOGY
SESSION 5C : METEOROLOGIE APPLIQUEE

PRELIMINARY RESULTS FROM RAIN ENHANCEMENT EXPERIMENTS IN ALBERTA
B. Kochtubajda

Airborne glaciogenic seeding experiments for rainfall augmentation from summertime cumulus clouds have been performed in Alberta for a number of years. These experiments involve a seeding aircraft, an instrumented cloud physics research aircraft, and meteorological radars. Test clouds satisfying pre-defined seeding criteria are treated with one of three possible seeding applications: droppable AgI flares, dry ice pellets, or a placebo. Microphysical and radar measurements are obtained to document the effects of the treatment on precipitation development. Results from cloud seeding experiments conducted during the 1982-1984 field programs will be summarized.
The results analyzed to date suggest that the clouds that have been investigated do not naturally produce high concentrations of ice crystals, and precipitation is not naturally initiated. The cloud seeding experiments have shown that AgI and CO_2 are effective in producing ice crystal concentrations higher than natural concentrations, and that precipitation can be initiated if the cloud lifetime is 20 minutes or longer. Microphysical differences in AgI treated clouds and CO_2 treated clouds have been observed. Radar analyses have shown distinctive echo differences between natural and seeded clouds.

ESTIMATING CROP TOP MICROCLIMATE FROM WEATHER STATION DATA USING PHYSICALLY-BASED MODELS
R.D. Brown and T.J. Gillespie

An integrative system of physically-based mathematical models has been used to determine the temperature (T) and wind (u) at the top of a mature corn crop using data recorded at a nearby weather station as input.
The basic concept in modelling is to derive the profiles of T and u above the weather station to the maximum height to which profile theory holds (~.1 x PBL). Horizontal homogeneity is assumed at this height and these derived values are used as inputs to profiles over the corn field. Profiles of T and u are then generated down to the top of the corn field using estimated values for roughness and sensible heat flux for corn.
Two days of hourly data, one representing a sunny, moderately windy day, the other representing a cloudy, windy day, were tested. Estimated values had a good agreement with measured values of T and u with standard errors of estimate (S.E.E.) of 0.36°C and 0.12m s^{-1} respectively. Maximum errors were 1.5°C and 0.4m s^{-1}.

A PROBABILISTIC MODEL FOR AREAL MEAN DAILY RAINFALL DISTRIBUTION

Van-Thanh-Van Nguyen

Information on rainfall distributions over time and space are both important in various types of hydrologic studies concerning the determination of runoff characteristics. In reality, rainfalls are measured at a point. Hence, it is necessary to establish some relationships for the transformation of point rainfall to average rainfall over a catchment area in order to provide a more reliable input for rainfall-runoff models. The least equivocal method for deriving values of areal correction factors seems to be directly from frequency curves of areal and point rainfalls. Knowledge of the probability distribution of areal mean rainfall, therefore, is of paramount importance in solving this complex practical problem in hydrology.

The purpose of this paper is to suggest two analytical methods for determining the probability distribution of the mean daily rainfall depth over an area. The areal mean rainfall is considered as the weighted average of n point rainfall measurements in the area. The proposed methods rely on the assumption that daily point rainfalls observed at different raingages are exponentially distributed random variables. Analytic expressions for the distribution functions for areal mean rainfall are then derived for anisotropic and isotropic rainfall processes, and for correlated and uncorrelated point rainfall depths.

The application of these methods will be illustrated by an example using daily rainfall data from the recording raingage network in the Montréal region in Canada. The computed distributions of areal mean rainfalls will be compared to the observed data. It can be calculated that the suggested methods have several advantages over commonly used fitting approaches because, with these analytical methods, it is not necessary to guess which theoretical distribution best fits to the observed frequency distribution of areal mean daily rainfalls.

EXPERIMENTS IN GENERATING WATER BUDGET COMPONENT OUTLOOKS

Leo O. Mapanao

Since 1980, a weekly water budgetting procedure based on near-real time data, has been operational in the Hydrometeorology Division. To extend its utility for planning and decision-making in water resources management, drought monitoring, agriculture and energy management, we propose a probabilistic - climatological approach to generate 90-day outlooks of the water budget components.

In testing the model, temperature, precipitation, solar radiation, and wind mileage records for 50 Canadian stations were used. To run the model, only the "days with measurable precipitation" during each of the 73 pentads per year are monitored. The model can be operational in a microcomputer environment.

Some single station results and verifications are presented.

APPLICATIONS OF AIRBORNE MONITORING OF GASEOUS EXCHANGE

R.L. Desjardins, J.I. MacPherson, P. Alvo, L. Austin & P.H. Schuepp

Monitoring of gaseous exchange between the atmosphere and crops or forests by aircraft-based eddy correlation technique has been pioneered during the last few years by a cooperative project between Agriculture Canada, the National Aeronautical Establishment of NRC and Macdonald College (McGill).

In 1984, a total of 48 hours of flying time were logged over agricultural land in Manitoba and in the Ottawa valley and over forest sites in Northern Ontario. Fluxes of momentum, sensible heat and CO_2 were monitored for all these areas; for the last part of the flight program a newly-designed IR gas analyzer permitted simultaneous monitoring of water vapour flux.

Analysis of this data base centres on the following objectives: (a) evaluation of instrument performance and comparison between airborne and ground-based flux measurements; (b) statistical evaluation of repeated runs over homogeneous terrain; (c) tentative evaluation of the technique for assessment of forest productivity; (d) development of analysis techniques for the mapping of flux data resulting from grid-type flight patterns.

Mean CO_2 flux densities over wheat in Manitoba (around July 12, 1984), ranged from -20 to -30kg/(ha hr), in good agreement with ground-based data. The grid-type pattern flown over an intensely hail-damaged area near Brunkild, Man. has not yet been fully analyzed but straight line trajectories over severely damaged and undamaged land showed flux densities of +1 and -24kg CO_2/(ha hr), respectively. However, initial energy balance tests showed the sum of sensible and latent heat considerably below estimated net radiation, probably due to underestimation of vapour flux for reasons not yet elucidated.

The potential of the technique for assessment of biomass productivity, for independent verification of regional hydrological models through large-scale mapping of vapour source and sink distributions, and as an input into general circulation models will be discussed.

AN OVERVIEW OF ICING RESEARCH AT THE UNIVERSITY OF ALBERTA

K. Finstad, E. Lozowski, E. Gates, K. Wong, K. Szilder, W. Lam, A. Liu, R. Narten, A. Nowak and E. Obreiter

The Division of Meteorology and the Department of Mechanical Engineering of the University of Alberta have become a major centre of icing research, dealing with problems of ice accretion in aviation and marine systems, and on land structures. A number of experiments and computer models are concentrated on various specific aspects of the accretion process, with a view to both better understanding of the basic physics, and to the development of an operational-style predictive model.

Facilities for the growth of experimental ice accretions consist of two closed-loop icing wind-tunnels, one of which is under construction, and a portable outdoor tunnel designed specifically for marine icing simulations. Other experimental

projects are investigating the variations of local density within rime ice, the effects of turbulence and other factors on local convective heat transfer from an accreting cylinder, and the mechanics of brine droplet impact and freezing.

The modelling aspects include numerical simulation of droplet trajectories, pressure distributions and heat transfer about an accreting object, and the stochastic growth of rime ice feathers. All of the investigations are leading toward the development of parameterization methods for use in the operational model.

Co-operative efforts are also being carried out with research groups in Finland and Norway.

1050-1230 Studio Alfred-Laliberté
PLENARY SESSION 6: SPACE SHUTTLE EXPERIMENTS AND CASP INFORMATION
SESSION PLENIERE 6 : EXPERIENCES DE LA NAVETTE SPATIALE ET INFORMATIONS CASP

OCEANOGRAPHY FROM A SPACE SHUTTLE

P.D. Scully-Power

No abstract available.

OGLOW - AN EXPERIMENT TO MEASURE ORBITER GLOW AND ATMOSPHERIC EMISSIONS FROM SPACE

D.J.W. Kendall, S.B. Mende, E.J. Llewellyn, W.A. Gault & R.L. Gattinger

An experiment flown as part of the complement of Canadian experiments (CANEX) during the STS-41G mission in October, 1984, was one designed to measure the orbiter glow phenomenon and atmospheric emissions from space. This experiment, whose acronym was OGLOW, was performed by the Canadian Payload Specialist, Marc Garneau, and consisted of an image intensified 35 mm camera, a series of narrow bandpass filters and Fabry-Pérot interferometers, and a transmission grating and slit assembly. High spectral resolution results were obtained on two occasions with the filters and interferometers of the orbiter glow phenomenon, a weak luminosity that appears on spacecraft surface facing the direction of motion. There is considerable concern that this luminosity will adversely effect sensitive optical instruments that are being proposed for astronomical and remote sensing applications. Of specific concern to Canada is an instrument, called WAMDII (Wide Angle Michelson Doppler Imaging Interferometer), which is being built to measure temperatures and winds in the upper atmosphere ($>$70 km) by observing weak emissions from this atmospheric region. This instrument

is scheduled to fly on a shuttle mission in 1989. The filters flown as part of the OGLOW experiment covered the same wavelengths as those that will be utilized for WAMDII. Of secondary interest was a measurement of the atmospheric emissions themselves, and several observations were obtained of nightglow, twilightglow and auroral emissions using both the filters and the grating assembly. Finally a series of sunset results were obtained showing a prominent lower atmospheric aerosol layer.

THE SUNPHOTOMETER EXPERIMENT ON MISSION 41G

W.F.J. Evans, J.B. Kerr, C.T. McElroy, G. Shah, D.I. Wardle, R.W. Nicholls, M. Cann, J.C. McConnell. J.Davies, M. Garneau and S. MacLean

An advanced sunphotometer experiment was conducted on the CANEX mission by the first Canadian astronaut. The instrument employed was a more sophisticated version of the commercial sunphotometer used to measure acid haze in the Canadian air pollution network and on experimental aircraft studies of volcanic haze in the stratosphere. The equipment consisted of a dual channel six wavelength sunphotometer, a TRS-80 model 100 portable computer and an analog to digital data acquisition system interface.

The zero atmosphere calibration of the sunphotometer was determined from measurements of the sun through the side hatch window of the shuttle. The results of these space calibrations will be compared with ground based calibrations conducted using classical methods requiring measurements from mountain tops. Transmission measurements of the shuttle windows which were required to interpret the flight data will be described.

Solar occultation measurements were conducted by pointing the instrument at the sun during sunsets from the shuttle. These measurements were later used in determining altitude profiles of ozone, nitrogen dioxide, water vapour and stratospheric aerosol. Preliminary results for some of these constituents will be presented.

Proposal for future flight measurements with the sunphotometer system will be described. These include extended measurements of altitude profiles for constituents studied on 41G as well as for additional new constituents, and photolysis rates of atmospheric gases important in aeronomy.

PLANS FOR THE METEOROLOGICAL COMPONENT OF THE CASP FIELD EXPERIMENT

Ronald E. Stewart, G.A. Isaac, H.B. Kruger and A.J. Chisholm

Winter storms commonly lash the Canadian East Coast. Because of strong winds and often heavy precipitation, activities are disrupted on the mainland as well as offshore. To improve the prediction of these storms and their associated mesoscale features, a long-term program (Canadian Atlantic Storms Program) has been proposed, the first phase of which consists of a field project from Jan. 15 to March 15, 1986. The principal objective of this field experiment is to study and improve the prediction of the mesoscale structure

of the storms, but through cooperation with the U.S. GALE project it is anticipated that progress will also be made in predicting the storms themselves. The field experiment emphasizing the Nova Scotia/Sable Island region, will involve enhanced rawinsonde, satellite, radar, and surface (land and ocean) observations, as well as information from aircraft. Research and forecasting operations will be linked to both assess the impacts of improved data on forecasts as well as to guide the research effort.

STORM RESPONSE IN THE COASTAL OCEAN: THE OCEANOGRAPHIC COMPONENT OF CASP

Peter C. Smith, F.W. Dobson, D.A. Greenberg, W. Perrie, B.D. Petrie and D.G. Wright

The passage of intense winter storms over the continental shelf produces strong responses in sea level, current and surface wave fields. While the average response in the coastal sea is associated with the large-scale [O(1,000 km)] synoptic forcing, the extreme responses may be related to mesoscale [O(100 km)] variability. As part of the Canadian Atlantic Storms Program, an oceanographic field experiment is proposed for the winter of 1985/86 which, together with the meteorological component of CASP, will provide a unique opportunity to advance our understanding of these phenomena. The major elements of the experiment include an eleven mooring array of current meters and bottom pressure gauges in the nearshore region of the Scotian Shelf east of Halifax, an array of Wave Rider and Wavec pitch-and-roll buoys nested within the current/pressure array near Halifax, and a string of sea level gauges distributed along the Nova Scotia coastline. Data from these instruments will be collected from December, 1985 through March, 1986 and analyzed over the next two to three years.

The primary scientific objectives of the field program are:

a) measurement of the current and sea level response to storms on scales down to those of the mesoscale forcing; and

b) measurement of the directional surface wave response to mesoscale winds and the effects of propagation into shallow water.

Interpretation of the field observations will be guided by the CASP modelling objectives including:

c) the development of numerical models for the wind-driven circulation; and

d) the improvement of surface wave hindcast and forecast models by the introduction of shallow water effects and high resolution meteorological forcing.

1330-1510 Studio Alfred-Laliberté
SESSION 7A: MESOSCALE METEOROLOGY I
SESSION 7A : METEOROLOGIE A L'ECHELLE MOYENNE I

CONCEPTUAL AND DIAGNOSTIC MODELS OF THE PHYSICS AND CHEMISTRY OF RAINBANDS IN EXTRATROPICAL CYCLONES

Peter V. Hobbs

The heaviest precipitation in extratropical cyclones is often contained in mesoscale rainbands. A classification of these rainbands will be presented and conceptual models, based on field observations and measurements, will be described for each of the main types of rainband. The conceptual models include airflow characteristics and the sub-structures and microphysical structures of the bands. Dynamical mechanisms that might be responsible for the rainbands will be discussed.

The conceptual models have provided the basis for diagnostic numerical models for the formation of precipitation in various types of rainbands. Results from these models will be compared with field measurements.

The numerical models are now being expanded to include the interactions of sulfur and nitrogen compounds to form acid precipitation. Preliminary results from these studies will be described.

FRONTAL WAVES AND INSTABILITIES

John H.E. Clark

Dual-Doppler measurements often reveal waves of100km wavelength propagating along the cold fronts. This study attempts to explain them as a manifestation of hydrodynamic instability of the frontal zone.
In contrast to studies by Orlanski, the front considered here has a finite thickness and is bounded by stratified cold and warm air masses. An approximate but accurate scheme for imposing the dynamic and kinetic conditions at the sloping boundaries of fronts is formulated.
The results reveal that the most rapidly growing waves can have properties very similar to those observed by Parsons and most importantly, suggest the importance of considering finite, rather than infinitesimally thin fronts as a means of obtaining a meaningful scale selection mechanism. Some speculations on the role of convective heat on the waves are offered in conclusion.

A COMPARISON OF HYDROSTATIC AND NON-HYDROSTATIC WAVE-CISK

G.W. Kent Moore

Conditional Instability of the Second Kind (CISK) is a parameterization in which the latent heat released by convection is related to the vertical velocity field at the top of the boundary layer. In wave-CISK, it is postulated that the convergence field associated with internal waves is sufficient fo produce CISK. A realistic treatment of

the vertical velocity field is crucial to the success of this parameterization. Conventional wave-CISK models have been hydrostatic and the most unstable waves in them are the small-scale high-frequency ones. For these waves the hydrostatic approximation is invalid. It therefore seems appropriate to consider a model in which the vertical velocity of these small-scale waves is treated correctly, i.e. a non-hydrostatic one.
In this paper a comparison of a hydrostatic and non-hydrostatic wave-CISK model is made. The lack of scale selection in the hydrostatic model is shown to be the result of a lack of coupling between the horizontal and vertical scales of motions of the waves. The non-hydrostatic model has an explicit coupling in it and this results in a preferred horizontal scale for the growth of the waves. For all cases considered, the most unstable wave had an aspect ratio of order one. Thus the inclusion of non-hydrostatic effects provides a mechanism by which convection can be organized on the mesoscale.

ON THE MECHANISM FOR HAILSTORM FEEDER CLOUD FORMATION

Lawrence Cheng & Dave Rogers

In this paper a mechanism for the formation of hailstorm feeder clouds is presented. It is generally believed that hail embryos originate within the feeder clouds in the new growth zone of mature hailstorms, or else they form in the main storm and recirculate through complex trajectories. The feeder clouds form recurrently near the forward flank of the storm and move with the mid-level winds along a course which intercepts the propagation path of the main storm. Potential hail embryos which grow in the feeder clouds are directed into the main updraft of the storm, where the millimetre-size hail embryos can rapidly grow to observed hail size.
The observed location of feeder cloud formation is within the diffluent flow immediately upwind of the stagnation point associated with the mid-level flow around the storm. The extent of the feeder clouds differs from storm to storm. There are storms with an extensive line of feeder clouds, and there are also storms with feeder clouds which are almost indistinguishable from the main storm.
The gust front associated with the precipitation downdraft generates strong vertical wind shear at the front flank region of the mature storm. The vertical wind shear induces Helmholtz instability for small-scale wave growth. The shear instability adds to existing convective instability and increases low-level convergence, and hence forces ascent of air along the margin of the gust front. Small-scale waves generated by the wind shear can attain sufficiently large amplitudes to induce condensation and the latent heat released may reinforce the waves. Thus, it is hypothesized that the location, recurrency rate and the extent of the feeder line is influenced by the different coupling of the storm generated outflow and the low-level environmental inflow.
Aircraft observations and numerical simulations utilizing a 2-dimensional slat-symmetric, parameterized cloud model will be used to substantiate the above hypothesis.

1330-1510
SESSION 7B: METEOROLOGICAL FORECASTS AND CASE STUDIES
SESSION 7B : PREVISIONS METEOROLOGIQUES ET ETUDES DE CAS

AUTOMATED WORDED PUBLIC FORECASTS FOR DAYS 3-5

D. Soucy and N. Yacowar

CMC is preparing automated worded public forecasts for days 3-5 for over one hundred and forty Canadian locations and for all public forecast regions.
Weather element forecasts of temperature, sky cover and probability of precipitation are prepared by regression and analog techniques and the terminology generated is based on the forecast weather element matrix.
Verification statistics are available for all elements.
It is planned to implement this system to produce and transmit the operational weather forecasts for days 3-5 in 1986.

NUMERICAL WEATHER ELEMENT DATA TO DAY 5 - AN EXPERIMENTAL OUTPUT FORMAT

M. Dunlop and K. Johnstone

Since 1981 meteorological fields have been routinely abstracted from the operational Canadian Meteorological Centre (CMC) numerical model output datasets, and post-processed into meteorological station forecasts. (Weather Element Digital Guidance Evaluation or WEDGE). These model predictions are routinely formatted and verified.

With the recent availability of model output data to day 5 from the 00 GMT execution of the CMC model, a new type of format for the data was developed. The basic idea behind the new format was to make the data as compact as possible and still present a meaningful objective explanation of what the model was predicting.

The basic idea of the WEDGE system, in keeping to a minimum the amount of post-processing of the meteorological fields was maintained.

While the original WEDGE system formats approximately 950 station forecasts, only Canadian stations were included in the new format.

Future plans include the verification of the data on a routine basis.

CAS DE TORNADE À BLUE SEA LAKE, P.Q.

Patrice COURBIN

Le 15 juillet 1984, une cellule orageuse très intense s'est scindée en deux éléments distincts en pénétrant sur le Québec. Une investigation a démontré qu'une tornade a été associée à chaque élément. Celle du sud, d'intensité F3 ou F4 sur l'échelle de Fujita, a partiellement dévasté plusieurs villages dont la municipalité de Blue Sea Lake. L'utilisation opérationnelle des photos satellitaires, des données radar et des données de foudre lors de cette situation est discutée.

THE METROPOLITAN TORONTO TORNADO OF AUGUST 14, 1984

Luigi G. Bertolone

Shortly after 7:30 p.m. EDT on August 14, 1984, a slow moving tornado struck a densely populated area of Metropolitan Toronto causing extensive damage to houses and factories.

The tornado rotated cyclonically under the parent cloud and it dissipated as it moved away from the cloud centre.

It travelled through a distance of 2.8 km and was in view for about 10 minutes, moving with a translational speed of approximately 17 km/h.

The unusal characteristic of this tornado is the motion from east-northeast to west-southwest. Statistics on tornado motion published by the U.S. Department of Commerce indicate that motion into the southwest quadrant, although not unheard of, is very rare. Only nine tornadoes out of nearly six thousand conterminous U.S. tornadoes investigated during the period 1950 to 1978 moved toward the west-southwest.

The pertinent meteorological features of this tornadic storm are examined and presented. Furthermore, a discussion of the highly unusual direction of motion of the tornado is made.

CAS PARTICULIER DE PLUIE VERGLAÇANTE SUR LE SUD-OUEST DU QUÉBEC

Denis BACHAND

Dans la nuit du 13 au 14 décembre 1983, une tempête de verglas s'abattait sur le sud-ouest du Québec; elle devait laisser une accumulation de 15 à 25 mm de glace sur la région de Montréal et causer des dégâts considérables en plus d'importantes pannes d'électricité. La présente étude s'intéresse aux aspects synoptiques de cette tempête et à sa prévisibilité. Un phénomène très particulier s'est produit dans la région de Montréal: la pluie qui tombait déjà depuis quelques heures est devenue verglaçante dans la soirée du 13 décembre alors que les températures officielles se situaient encore légèrement au-dessus du point de congélation.

1330-1450
SESSION 7C: OCEAN CHEMISTRY AND GEOCHEMICAL PROCESSES II
SESSION 7C : CHIMIE DES OCEANS ET PROCESSUS GEOCHIMIQUES II

EARLY DIAGENESIS OF COPPER AND MOLYBDENUM IN MINE TAILINGS AND NATURAL SEDIMENTS IN RUPERT AND HOLBERG INLETS, BRITISH COLUMBIA

Thomas F. PEDERSEN

The distribution and behaviour of Cu and Mo in interstitial waters collected from Cu-and Mo-rich mine tailings and natural sediments in Rupert and Holberg Inlets (Vancouver Island, B.C.) is discussed. Dissolved Fe, Mn, SO_4, ΣH_2S distributions and solid-phase Cu, Mo, Mn and organic carbon data are used to constrain the interpretation of Cu and Mo diagenesis in both tailings and natural sediment facies. Cu is released to solution at or near the sediment-water interface in both facies either by decomposing labile organic material or as a result of oxidation of sulphide minerals within the tailings. Mo is significantly enriched (up to 0.6 $\mu mol\ L^{-1}$) in tailings porewater probably due to dissolution of soluble Mo oxides produced initially by oxidation of MoS_2 during milling of the ore.

In natural sediments, both Cu and Mo are consumed from solution at depth probably by precipitation as their sulphides or in solid solution with an iron sulphide phase. Similar reactions appear to be occurring at depth in the tailings. The benthic flux of copper from the tailings into overlying seawater is similar in magnitude to that observed in natural sediments; there is no indication from the present data that remobilization of copper from the tailings is perturbing the pre-mine Cu distribution in Rupert Inlet. Unlike Cu, the benthic flux of Mo is unique to the tailings, but is insufficient to produce a measurable anomaly in inlet waters, due to the short water residence time and the relatively high Mo concentration characteristic of seawater.

DISTRIBUTION DES CONCENTRATIONS EN MERCURE DANS LES EAUX DE L'ESTUAIRE ET DU GOLFE DU SAINT-LAURENT

D. Cossa, C. Gobeil & P. Courau

Les concentrations en mercure ont été mesurées dans des échantillons d'eau (filtrée et non-filtrée) provenant de l'embouchure du Fleuve, de l'Estuaire et du Golfe du Saint-Laurent. Les concentrations dans les eaux douces sont de 17 ± 3pM dont 12,5pM sous forme dissoute. Dans l'Estuaire Moyen les teneurs varient de 4pM, à son extrémité est, jusqu'à 200pM à l'intérieur de la zone de turbidité, alors que la phase dissoute contient au maximum 14,5pM. Dans l'Estuaire Maritime et dans le Golfe l'échelle de variation s'étale de <3pM à 6pM. En règle générale, la distribution des concentrations en mercure est reliée à celle de la matière en suspension.

VARIATIONS DANS LA COMPOSITION IONIQUE DU FLEUVE SAINT-LAURENT DEPUIS LE DÉBUT DE L'INDUSTRIALISATION (1907-1982)

Gilles H. Tremblay & Daniel Cossa

Les tendances depuis le début de l'industrialisation jusqu'à aujourd'hui des concentrations en Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-} et HCO_3^- des eaux du fleuve Saint-Laurent à son embouchure ont été examinées. Le Saint-Laurent naturel se classe dans le groupe des bicarbonates calciques du sous-groupe sulfato-magnésien. Nous montrons que, depuis 1907, les concentrations ioniques particulièrement en Na^+, Cl^- et SO_4^{2-} et à un degré moindre en Ca^{2+} et Mg^{2+} ont augmenté sensiblement. Nous calculons qu'en 1982 plus de la moitié du Na^+, Cl^- et SO_4^{2-} charriés par le Fleuve est de source anthropique. L'approche de l'état stationnaire dans la composition ionique du Fleuve semble se dessiner depuis le milieu des années 1970.

NUTRIENTS IN THE ST. LAWRENCE ESTUARY

Kazufumi Takayanagi & Charles Gobeil

We have determined the distribution and behavior of dissolved phosphate, nitrate and silicate in the upper and lower St. Lawrence Estuary. The samples were collected during three different cruises: October 1983 and April 1984 for PO_4^{3-}, NO_3^- and Si and October 1984 for PO_4^{3-} and Si.

In the upper St. Lawrence Estuary, which is classified as a partially mixed estuary, all the nutrients were conservative during the periods sampled. The concentration of phosphate increased with increasing salinity with the concentrations of 0.35μM for October 1983 and 0.25μM for October 1984 as a riverine endmember and the concentration 1.2μM as an oceanic endmember. The concentration of nitrate also increased with increasing salinity from 8μM in the riverine endmember to 12μM in the oceanic endmember. Although the concentration of silicate in the oceanic endmember was constant at about 10μM in all three occasions, it varied significantly in the riverine endmember. The concentration was 45μM in April 1984 while it was 10μM in both October 1983 and October 1984. A relatively high concentration of nutrients in the oceanic endmember is attributed to the fact that the source of oceanic water in the upper Estuary is a nutrient-rich deep water of the lower Estuary.

In the lower Estuary, which is a 300m deep stratified estuary, the distributions of all three nutrients are similar to those in the open oceans. The concentrations of all the nutrients, in general, increased with depth from about 0.5 to 2.5μM, from 5 to 25μM, and from 10 to 50μM for phosphate, nitrate and silicate, respectively. A good linear relationship was found between AOU and phosphate with a mole ratio of 159:1, as well as AOU and nitrate with a mole ratio of 163:16. However, these ratios are slightly off from the predicted stoichiometric values. AOU is about 20% enriched in the lower St. Lawrence Estuary.

1530-1710 Studio Alfred-Laliberté
SESSION 8A: MESOSCALE METEOROLOGY II
SESSION 8A : METEOROLOGIE A L'ECHELLE MOYENNE II

A MOVABLE TRIPLY NESTED NUMERICAL MODEL FOR MESOSCALE TROPOSPHERIC CIRCULATION

R.V. Madala & Simon W. Chang

In order to improve weather forecasting capabilities of the Navy, a movable triply nested multilayer primitive equation numerical model is being developed at the Naval Research Laboratory. Staggered grid systems are used to discretize the atmosphere in both horizontal and vertical directions. The three grid networks in the horizontal have resolution of 30, 90 and 270 km. The two inner grid networks are movable. In the vertical direction the atmosphere is represented by a number of sigma layers with variable thicknesses. The finite difference form of the governing equations conserves mass, momentum and energy in the absence of sources and sinks of energy. At the interfaces of the grid systems the finite-difference form is written in such a way that there is no spurious generation of energy. A split-explicit method is used for temporal integration.
Model physics include the release of latent heat in convective and non-convective clouds, using a modified Kuo formulation. The boundary layer can be parameterized by the bulk method or resolved explicitly, depending on desired vertical resolution in the lower troposphere.
A number of experiments are conducted to test the model on mid-latitude cyclogenesis and tropical cyclone cases.

NUMERICAL SIMULATION OF COASTAL FLOWS AT THE ONSET OF NUCLEAR WINTER

Charles R. Molenkamp

The Colorado State University Mesoscale Model (Y. Mahrer and R. A. Pielke, 1977, Beitr. Phys. Atmos., 50, 98-113) has been used to simulate the development of the field of atmospheric motion along the continental coastline at the onset of nuclear winter. After an initialization period with no thermal forcing, a full diurnal cycle for the normal sea breeze circulation is calculated. The onset of nuclear winter is represented by continuing the simulation for an additional day assuming that there is no incident solar radiation. Comparison of the flow fields under normal conditions with those that evolve when solar energy does not penetrate into the troposphere permits a preliminary estimate of the likelihood of precipitation developing along the coastline and the amelioration of continental cooling due to thermal buffering of the ocean.

MODELING A FIELD OF CUMULUS CLOUDS

Piotr Smolarkiewicz and Terry L. Clark

The simulation of a three-dimensional field of cumulus clouds was reported by Smolarkiewicz and Clark (J. Atmos. Sci., 1985, in

press). The detailed description of the model applied and the results of basic sensitivity tests were presented. The model included realistic surface-layer forcing (based on mesonet data), time-dependent environmental conditions (based on available soundings), and real topography. Through a comparison with observations, it was shown that the simulation of a field of small cumuli with short life-times (20±10 min) was realistic.
In order to gain a deeper understanding of the interactions between the cloud and the environment, we continue the analysis of the model results in terms of the eddy fluxes of heat, momentum, moisture, and cloud water and kinetic energy conversion terms. We show that the horizontally-averaged eddy flux of moisture carries important information about cloud activity. We also show that certain aspects of the simulation can be understood in terms of Le Chatelier's principle. In particular, this general principle can help to understand cloud initiation. While cloud modeling studies have traditionally initialized the calculations with a single positively buoyant eddy, the steady-state PBL is filled with continuously evolving eddies. A small fraction of these eddies results in clouds. Application of Le Chatelier's principle, suggests that any entrainment of dry air through the top of the boundary layer will tend to produce compensatory updrafts resulting in increased upward moisture flux, and this enhanced flux will locally favor cloud development.

QUEBÉC 1534-1984: DESCRIPTION D'UN RÉSEAU MÉTÉOROLOGIQUE À LA MÉSO-ÉCHELLE AFIN DE SUPPORTER LES OPÉRATIONS DE PRÉVISIONS
Claude MASSE et Denis POUPART

De juin à septembre 1984, le fleuve St-Laurent a été le théâtre de plusieurs activités dans le cadre du 450ième anniversaire de la découverte du Canada. Un réseau d'observations supplémentaire fut temporairement implanté sur la section du fleuve entre le Cap-de-la-Madeleine et les Escoumins. Cette présentation portera sur la planification et la nature de ce réseau d'observations et traitera de son utilité à des fins de prévision dans un environnement opérationnel. Finalement, on y décrira brièvement les banques de données disponibles préparées à l'aide de ce réseau.

QUÉBEC 1534-1984: CONSTATATIONS PRÉLIMINAIRES DE PHÉNOMÈNES OBSERVÉS À L'AIDE D'UN RÉSEAU À LA MÉSO-ÉCHELLE
Claude MASSE et Denis POUPART

Un réseau d'observations à la méso-échelle a été utilisé dans un contexte opérationnel afin de produire des prévisions météorologiques détaillées sur les secteurs du fleuve St-Laurent compris entre Grondines et les Escoumins. Quelques cas mettant en relief d'importantes variations spatio-temporelles de certaines variables météorologiques seront présentés; en particulier, le vent de surface montre une grande variabilité résultant de l'interaction entre l'écoulement synoptique et d'autres facteurs dont, notamment, le relief particulièrement accidenté sur ce secteur du fleuve.

1530-1730
SESSION 8B: SURFACE WAVES II
SESSION 8B : ONDES DE SURFACE II

A WAVE CLIMATE STUDY OF THE NORTHERN BRITISH COLUMBIA COAST
Barbara-Ann Juszko, Robin Brown, Bodo de Lange Boom and Dave Green

From October 1982 to May 1984, two Datawell Waveriders, two Adamo Rupp WRIPS buoys, one Endeco WAVE-TRACK and one Datawell WAVEC directional buoy were deployed in Queen Charlotte Sound, Hecate Strait and Dixon Entrance. The purpose of the study was a) to acquire operational experience in Canada with the various systems, b) to develop the software for directional wave data processing and c) to obtain concurrent data records for an analysis of the wave climate and for model input. The Waverider systems showed consistently good operation and data return. The WAVEC buoy produced good quality data when operating though there was some question about the ruggedness of the buoy design. The WAVE-TRACK directional buoy suffered from a number of hardware problems. The data were generally poor with spurious low-frequency energy contaminating the spectra and questionable wave directions.
The WAVEC data were processed using a Longuet-Higgins directional analysis while the WAVE-TRACK data underwent a Band-Pass analysis supplied by Endeco Inc. The former proved to be the more efficient and more reliable processing method as the Band-Pass analysis was computationally much slower, had poor frequency resolution and the calculated directions were often incorrect.
The seasonal and regional wave conditions, at all sites, agreed well with those expected given wind and site considerations. Background swell energy was prevalent in both Dixon Entrance and Queen Charlotte Sound. The maximum significant wave height and largest single wave were 11.4 and 18.5 metres in Queen Charlotte Sound, 10.7 and 19.8 metres in Hecate Strait and 9.0 and 15.2 metres in Dixon Entrance. There was an indication for a regional variation in the ratio of maximum/significant wave height. Wave height exceedances compared with averages from Hibernia although they were associated with a shift to longer periods. Detailed analysis results will be published.

L'ANALYSE SPECTRALE DES CYCLES D'ÉTAT DE LA MER
Loys SCHMIED

Un cycle d'état de la mer décrit, en particulier, la croissance et l'amortissement d'une tempête lorsqu'on l'observe en un point fixe.

Nous avons déjà mis en valeur le rôle prépondérant joué par la pseudo-cambrure $\tilde{PS} = \frac{2\pi\ H1/3}{g\ (TH1/3)^2}$ au cours de chacune des deux phases caractéristiques d'un cycle d'état de la mer.

Nous décrivons ici, du point de vue de l'analyse spectrale, l'évolution d'un cycle d'état de mer à fetch limité, au Havre dans la Manche. L'évolution du coefficient de surélévation γ, du modèle JONSWAP, caractérise l'évolution du cycle. Cette évolution correspond au comportement que nous avions déjà décrit dans le plan (TH1/3, H1/3).

WAVE MODEL ABNORMALITIES DETECTED BY FIELD MEASURMENTS

David C. Fu

A spectral wave prediction model was developed for a pipeline corridor transitting from shore to a deep-water site and was used in conjunction with a deep-water model operating in the offshore region. Measured wave spectra, coincident with times of model predictions, were analyzed at depths of 8, 36 and 123 m in the vicinity of the corridor and compared with predictions of the models. Two phenomena were observed in this comparison: that traditional boundary condition assumptions for shallow and deep-water modeling can result in an underestimation of energy in both regions, and that wave growth can change significantly with only minor shifts in wind direction.

Contrary to the normal assumption that wave energy is greater in deep than in shallow-water zones, the intercomparison showed strong evidence that the reverse of this can be true and that significant wave energy propagates seaward into the deep-water zone. This phenomenon impacts both shallow-and deep-water modeling results. Most shallow-water models assume waves propagate (or transform) shoreward from offshore; most deep-water models assume no wave propagation from shore in the offshore direction (although wave growth is considered). In both cases, energy at the model grid points nearest land is significantly underestimated.

The second phenomenon, associated with diurnal changes in wind direction, was detected while using simple numerical simulations of wave growth in the deep-water zone. Supported by field measurements (yet not predicted by frequently used operational models) wave growth was observed to change significantly with only minor wind direction shifts at constant wind speed. Both phenomena are discussed, and new techniques are proposed involving the interface between deep-and shallow-water wave models, the modification of the boundary conditions, the reduction of time intervals for windfield data input and other refinements.

AN EVALUATION OF A PARAMETRIC OCEAN-WAVE FORECAST SYSTEM

K. A. Macdonald and S. Clodman

An ocean-wave forecast system has been developed by the Meteorological Services Research Branch of the Atmospheric Environment Service and has been tested operationally by forecasters at the Canadian Forces Meteorological and Oceanographic (MetOc) Centre in Halifax. The model is based upon the Bretschneider wave forecast equations which relate key wave parameters (significant wave height, period and speed) to the surface wind field. Discrimination is maintained between developing, wind-generated sea waves and decaying swell waves based upon the wave-wind speed differential. It is a deep-water model which ignores the bottom effects that occur in shallow-water and shoal areas.

The model is driven by wind fields supplied by the Canadian Meteorological Centre (CMC) for the 1000-mb level. Starting from a calm sea condition 72h prior to the start of the forecast period the wave model uses a moving fetch procedure to integrate the effects of the space and time variability of the analyzed winds. Forecast sea conditions are obtained by extending the procedure using forecast wind fields from the operational CMC spectral model.

Objective verification and subjective evaluation by MetOc forecasters concludes that the wave model produces synoptically realistic patterns of significant wave height consistent with the wind input supplied to it. Most errors in the forecast wave heights can be traced to inaccuracies in the winds with the most common error being to overforecast wave heights in the warm sector of baroclinic developments where the forecast 1000-mb level winds are often 50% stronger than the actual surface winds. On the other hand in unstable northwesterly flow situations wave heights are predicted with considerable accuracy. Based on the results of operational testing there is widespread support for implementing the wave forecast system and having it become the primary guidance for MetOc's wave forecasters.

EVALUATION OF TWO OPERATIONAL SPECTRAL OCEAN WAVE MODELS: SOWM AND ODGP

Bassem M. Eid, Vincent J. Cardone and J. Arthur Greenwood

Two spectral ocean wave models, which are in real-time operation, namely the U.S. Navy's SOWM which is presently run at the Fleet Numerical Oceanography Center (FNOC) and the ODGP (Ocean Data Gathering Program) model being run by Oceanweather Inc. are considered in this study.

Wave models may be evaluated in a number of ways. The principal difficulties in evaluating a model through validation of its hindcasts against wave data are: that errors in wind fields always contribute some error to the hindcast; and that there are uncertainties in wave measurements taken in the ocean because of instrumental, calibration and sampling errors.

The SWAMP [Sea Wave Modelling Project, Hasselmann (1983)] set aside those problems by intercomparing ten different spectral wave models only in a number of test cases involving idealized patterns.

SWAMP has provided the framework for the systematic intercomparison of numerical wave prediction models. However, execution of the complete set of seven SWAMP cases and generation of results in the precise SWAMP format is a considerable undertaking. For this reason, the SOWM and ODGP were not represented in the SWAMP. This study has provided the resources for the evaluation of these models against the ten SWAMP models for the basic SWAMP test cases of fetch-and duration-limited growth in a unidirectional wind, and duration growth in a shifting wind.

Although the ODGP model evolved from the SOWM, the two models are sufficiently similar such that it is difficult to distinguish the growth behaviour in the idealized case of pure duration-wise growth in a steady, unidirectional wind, at least at the SWAMP test wind speed and friction velocity. However, the more detailed treatment of directional growth and directional relaxation processes in the ODGP model was found to lead to significant differences between the models in the pure fetch-limited test and in the test of duration limited growth following a wind shift.

The second part of the evaluation is carried out by comparing the SOWM and ODGP predictions (both winds and waves) against actual measurements at three sites off the East Coasts of the United States (NOAA Buoy #44004) and Canada (Scotian Shelf and the Grand Banks). The two models are evaluated in both hindcast and forecast modes.

FORMATION OF SAND BARS BY SHALLOW-WATER WAVES
B. Boczar-Karakiewicz and J.L. Bona

The presented work describes surface waves in comparatively shallow water and their mutual interaction with the topography over which they propagate. A motivation of this study is to understand the deformation of movable beds along coastal zones of large water bodies. Effort is concentrated on a two-dimensional situation wherein deep-water plane periodic wavetrains impinge on shallow-water zones.

In the controlled environment of a laboratory wavetank, experiments have shown that periodic wave trains typically undergo a change of form as they progress. Over a bed of loose sediment, such as sand, the passage of waves has also an effect on the bottom. An initially featureless bed will eventually organise an equilibrium configuration of bars and troughs.

The system in view, comprising both the fluid and the bed surfaces is described in a mathematical model. The dispersive shallow-water theory is used for the non-linear incident wave. The bed topography is derived via a continuity equation using the mass transport velocity. The resulting coupled system of non-linear differential equations admits complex bed-wave interactions.

Numerical approximations provided quantitative predictions which were compared with observations in laboratory and in the field. Waves and related bed configurations were reasonably reproduced by the model. In spite of disparate scales, the formation of sand bars has been found to be strikingly similar ranging from scales of laboratory experiments, through coastal zones of big lakes and oceans, to the continental shelf. Thus, the formation of sand bars may depend upon some relatively simple and universal wave-bottom interaction. However, no simple explanation can cover all situations, even if ideas put forth in the present work appear to have an interesting range of applicability.

1530-1710
SESSION 8C: SATELLITE AND RADAR METEOROLOGY
SESSION 8C : RADAR, SATELLITE ET METEOROLOGIE

ON THE ANALYSIS AND SYNTHESIS OF CLOUD TEXTURES
Louis Garand and James A. Weinman

We show that an homogeneous digital cloud image, as obtained by satellite, can be characterized by a few numbers only. These morphological parameters contain the essential structural and stochastic information of the scene. The structural parameters are simply the major components of the power spectrum. Their interference pattern yields a rough first guess. The stochastic parameters are extracted by assuming a binomial form for the probability distribution of the grey levels and by treating the image as a Markov process: the brightness at any location depends on the brightnesses at neigh-

boring sites only. Starting with the Fourier first guess having the desired histogram, a Monte Carlo algorithm switches pixels in pairs until convergence to the stochastic parameters is obtained. The result is an image very similar to the original one with a data compression factor of several hundreds.

Morphologies of marine stratocumulus are analysed. Quantitative objective cloud classification is a natural application of the model.

STUDY ON THE REMOTE SENSING OF RAINFALL BY RADAR AND SATELLITE FOR FOREST FIRE MANAGEMENT

A. Bellon

Satellite rainfall fields over an area of 2.5 X $10^5 km^2$ have been derived for 14 sequences of summertime weather (82 hours) by assigning a rainfall rate to visible-infrared data pairs. Verification of these amounts with those from the network of hourly raingauges (~130 gauges per sequence or 1 gauge/1900km^2) yielded CSI, POD and FAR scores of 60%, 80% and 30% for 1mm rainfalls and of 50%, 70% and 33% for 2mm. Rainfall patterns over the same region have been derived using an interpolation scheme based on exponentially decreasing weighting with distance of point gauge measurements. Rainfall patterns based on lower gauge densities have been simulated by skipping over gauges and then comparisons have been made between the measurement at the unused gauge and that of the interpolated field. It has been shown that the skill of the satellite is equivalent to the accuracy of an interpolated gauge field at a distance of 30 to 40 km from a gauge, or to the accuracy of a network with 1/3 the existing number of hourly raingauges in southern Québec and Ontario. It is thus concluded that over the more sparsely instrumented forested regions of our provinces, rainfall estimates from satellite are more skillful than those from the available gauge networks.

AN EXAMINATION OF TOVS SOUNDINGS IN THE ATLANTIC REGION

Neil McLennan

One of the limiting factors in weather forecasting on the East Coast is the lack of reliable sub-synoptic scale data over the Atlantic Ocean. This fact is especially noticeable when the full three-dimensional aspect of the atmosphere is considered. High quality, real-time data from the TOVS instrument on board the NOAA orbiting satellites can help to fill this void.

This form of TOVS data was made available to the Maritimes Weather Centre for evaluation in the spring of 1985. This paper examines the potential use of this data in an operational role and some of its uses in answering forecast problems.

USEFULNESS OF GOES SATELLITE DATA IN THE ANALYSIS OF CONVECTIVE WEATHER OVER CENTRAL ALBERTA

L. D. Stovel and G. S. Strong

GOES satellite data were examined in order to assess their usefulness in the diagnosis and forecasting of convective weather over the Prairies. High-resolution GOES-West infrared and visible satellite data were obtained for two case study days : one with severe convective storms, another of moderate intensity. Good qualitative agreement was obtained between cold and bright clouds (as seen by the satellite) and regions of high radar reflectivity. However, errors of up to 15 km in the Earth-positioning of the satellite were recognized for one of the cases, based on the appearance of various topographic features under cloud-free conditions.

Comparisons of contoured visible and infrared data for both polar-orbiting and geostationary satellite data indicated very good agreement; discrepancies were attributable to differences in time, angle of view, and pixel dimension. Bivariate histograms of the visible and infrared GOES data were used to obtain the progression of cloud type during the day. Linear correlations between the infrared and visible data (spatially averaged to remove discrepancies between the pixel sizes) yielded correlations of about 0.80 for severe convection and 0.70 for moderate convection. Correlations decreased during the decay stage of the convection, due to the increased presence of large amounts of cirrus.

THE PRAIRIE WEATHER CENTRE RADAR DATA-BASE AND IMAGE DISPLAY SYSTEM

Anthony J. Keck

A Radar Image Data-base Manager and Image Display System has been developed at the Prairie Weather Centre. The system's function and capabilities are described. The implication of the system pertaining to mesoscale meteorology is discussed. The impact of the experience in developing the system on the design of future data presentation systems is discussed.

0830-1030 Studio Alfred-Laliberté
SESSION 9A: CLOUD PHYSICS AND MODELLING
SESSION 9A : PHYSIQUE ET MODELISATION DES NUAGES

THE MULTI-DIMENSIONAL, POSITIVE-DEFINITE ADVECTION TRANSPORT ALGORITHM. FURTHER DEVELOPMENTS AND APPLICATIONS TO THE ATMOSPHERIC MODELING
Piotr Smolarkiewicz and Terry L. Clark

Using an iterative approach based upon the "upstream" scheme, Smolarkiewicz (J. of Comp. Phys., 1984) described a class of fully multi-dimensional, nonlinear, computationally efficient positive definite advective transport algorithms. The central idea of the original approach (Smolarkiewicz, Mon. Wea. Rev., 1983) was that, given any consistent and stable conservative advection scheme, one could expand each of its terms in a Taylor series to determine the analytical form of the truncation error. After the first application of the advection scheme, the scheme is reapplied using especially defined "anti-truncation-error" fluxes based upon the most recent values of the scalar. Such a procedure may be repeated an optional number of times. Each corrective iteration increases the order of accuracy in space while the accuracy in time is determined by the order of truncation of the Taylor series expansion applied in the first stage of the formal procedure. While applied to the "upstream" scheme, the method results in the algorithm which maintains all desirable properties, i.e., stability, consistency, and positive-definiteness, but numerical diffusion is greatly reduced. Currently, the approach has been generalized for diffusion equation and non-Cartesian forms of the continuity equation. While in the previous work the inclusion of corrective terms associated with the time dependence of the velocity field was discussed, an improved solution that is universally applicable to all schemes that are uncentered in time has recently been found. The alogrithm obtained is second-order accurate in time and optionally accurate in space for any arbitrary velocity field including time-dependent divergent flow. The algorithm has been incorporated into Clark's hydrodynamical model and tested in simulations of the flows over mountains and the development of small cumulus clouds.

OBSERVATIONS OF MIXING MECHANISMS IN SOUTH AFRICAN CUMULUS CONGESTUS CLOUDS
G.W. Reuter and M.K. Yau

Aircraft measurements are analysed to determine the entrainment process in convective clouds. The observations were collected in 15 developing cloud towers sampled in South Africa on three different days. The Paluch method, which is based on a comparison of the values of the total water mixing ratio and the wet equivalent potential temperature in the cloudy air and the nearby environment, was used to identify

the origin of the cloudy air at the observation level. The results indicate that entrainment at the cloud top is the dominant mechanism for diluting the clouds. Observations of strong downdrafts near the cloud edges suggest that the diluted air from the cloud top can penetrate several kilometres downwards.

NUMERICAL SIMULATIONS OF MIXING MECHANISMS IN SOUTH AFRICAN CUMULUS CONGESTUS CLOUDS
G.W. Reuter and M.K. Yau

The entrainment mechanisms of deep convective clouds in South Africa are simulated by using both axially and slab symmetric cumulus models having very high spatial and temporal resolutions. The simulated clouds on three different days show a structured organization with small-scale features such as in-cloud downdrafts. The mixing processes are examined by analyzing the time variation of dynamic and thermodynamic quantities along computed parcel trajectories. The calculations indicate that most of the entrainment occurs at the cloud top. Evaporative cooling and perturbation pressure cause downdrafts that transport highly diluted air from the cloud top down to lower levels. The penetrative downdrafts are mainly located near the edges of the cloud.

In the presence of wind shear the downshear side of the clouds become cooler and more diluted, and have stronger downdrafts compared to the upshear side. The asymmetric organization is attributed to turbulent exchange of horizontal momentum near the cloud top.

COMPUTATION OF THE SATURATION VAPOR PRESSURE OF SUPERCOOLED LIQUIDS
Michael T. Reischel

An equation for the computation of the saturation vapor pressure of solvent over a supercooled solution is presented. The equation relates the mole fraction and saturation vapor pressure of the supercooled solvent to the saturation vapor pressure of the pure solid solvent. For pure water the results of the calculation are within 0.4% of a recent empirical equation (considered accurate to 3% down to -35°C), and within 2% of an extrapolation of the Goff-Gratch equation to -100°C. The vapor pressure over supercooled mercury is calculated from an equation for the saturation vapor pressure over solid mercury. The results of this calculation are also presented.

OBTENTION DU MOUVEMENT VERTICAL DE L'AIR À L'AIDE D'UN SEUL RADAR DOPPLER
Richard Hogue et Isztar Zawadzki

Une évaluation du mouvement vertical de l'air à l'intérieur des systèmes précipitants est obtenue à partir du champ de réflectivité et de la vitesse radiale des gouttes d'eau issue d'un seul radar Doppler. Ce calcul est réalisé en se basant sur des équations de continuités appliquées à l'air ainsi qu'aux contenus d'eau liquide (pluie et nuage) présents à l'intérieur des cellules convectives. Les résultats obtenus à l'aide des différentes hypothèses simplificatrices permettant de résoudre ces équations seront discutées. Mentionnons, l'équilibre entre la

génération de précipitation et le taux de condensation de la vapeur d'eau, ainsi que la paramétration microphysique de l'évaporation. Pour un même cas, la comparaison des résultats obtenus avec ceux tirés d'une analyse Doppler radar-triple par le National Severe Storm Laboratory (Norman, Oklahoma), sera effectuée.

UTILISATION DE SPECTRES DE GRELONS AFIN D'ÉVALUER LA POSSIBILITÉ DE MESURER CEUX-CI PAR RADAR À POLARISATION CIRCULAIRE
André Méthot et Enrico Torlaschi

Des données de tailles de grêlons échantillonnées au sol, par le "Alberta Research Council", sont utilisées afin de tester la capacité du radar à polarisation circulaire pour l'estimation de leurs fonctions de distribution de tailles. Ces données, regroupées par échantillons sur des périodes de trente secondes, consistent en deux mesures pour chaque grêlon qui sont interprétées comme l'axe mineur et l'axe majeur de grêlons de forme oblate sphéroïdale. Pour chaque échantillon de trente secondes la distribution de taille observée et les propriétés intégrales (taux de précipitation équivalent, contenu en eau liquide équivalent) qui en découlent sont calculées. Par simulation numérique du fonctionnement d'un radar à polarisation circulaire qui émet dans la bande "S" nous calculons la valeur des paramètres observables correspondants à chaques échantillons. La section efficace de rétrodiffusion de chaque particule diffusante est calculée à l'aide de la théorie de Mie. Les paramètres observables ainsi obtenus sont utilisés pour déduire les trois paramètres d'un modèle de distribution de taille de type gamma. Les distributions de type gamma et les distributions observées ainsi que leurs propriétés intégrales respectives sont comparées.

0830-1030
SESSION 9B: DEEP-SEA OCEANOGRAPHY I
SESSION 9B : OCEANOGRAPHIE DES EAUX PROFONDES I

MOORED MEASUREMENTS OF GULF STREAM CURRENT STRUCTURE NEAR 60°W
R.M. Hendry

An array of five current-meter moorings instrumented at four depths between approximately 400 and 4000 m was maintained in the Gulf Stream near 58°-60°W and 39°-40°N over a year-long interval beginning in April 1983. The results constitute one of the first sets of time series measurements of Gulf Stream currents spanning thermocline and abyssal depths. The maximum speed of daily-average horizontal flow observed at the 400-m level was 0.94 ms^{-1}, compared with about 0.4 ms^{-1} at 800, 1300 and 4000 m nominal depths. Mean currents from all records were to the east or northeast with measured speeds of approximately 0.3 ms^{-1} at 400 m, diminishing uniformly with depth to about 0.06 ms^{-1} at 4000 m. The time-varying horizontal currents also showed a simple vertical structure, with a unidirectional equivalent barotropic mode dominant in an empirical orthogonal eigenfunction decomposition. Since the mean and time-dependent currents associated with the near-surface Gulf Stream penetrate coherently to abyssal depths and arguably to the bottom near 5200-m depth, topographic effects can influence the dynamics of the Stream.

THERMOHALINE INTRUSIONS IN THE FRONTAL REGIONS OF A GULF STREAM WARM-CORE RING

C.L. Tang, A.S. Bennett and D.L. Lawrence

Hydrographic data collected with a towed depth-cycling instrument, Batfish, in the frontal regions of warm-core ring 82-H during and immediately after its formation were analyzed to study small-scale structure and processes. Two types of thermohaline intrusions were observed: sub-surface tongue-like intrusions and intrusive cold filaments. A sub-surface intrusion of shelf water origin was found in the slope water region outside the frontal zone at 70-m depth. It moved in a southeast direction towards the front, and had a width of 4 km, a thickness of 20 m, and a length of at least 40 km, and possibly as long as 120 km. Alongside the sub-surface intrusion, a cold filament 10 km wide extending from the surface to 120-m depth was observed. As the sub-surface intrusion and the filament reached the frontal zone, they were swept and carried away by the strong current of the front, preventing further intrusion into the ring. Small scale interleaving occurs along the side walls of the sub-surface tongue and filament, with more intense interleaving associated with stronger intrusions, which suggests a double diffusive generation mechanism.

VALIDATION STUDIES OF AN EQUATORIAL OCEAN CIRCULATION MODEL

David Halpern and George Philander

One of the initial goals of NOAA's Equatorial Pacific Ocean Climate Studies (EPOCS) program formulated in 1978 was the development of a numerical model to simulate the evolution of upper ocean thermal and flow fields. Recognizing that validation of oceanic global circulation models is a necessary element of model development, EPOCS simultaneously supported model development and collection of oceanic observations. The success of this approach is illustrated *via* an intercomparison of current and temperature observations within 15-200 m depths at 0°, 110°W and model results during a 21-month interval (January 1982 - October 1983), which included highly anomalous features associated with the 1982-83 El Niño Southern Oscillation episode. The agreement of the essential characteristics, such as the 100-m deepening of the thermocline and the disappearance of the Equatorial Undercurrent, was, perhaps, not too surprising since this equatorial ocean-atmosphere event was the most intense of this century. Because El Niño events are linked to the annual cycle of atmospheric and oceanic fields, the ability of the model to simulate the annual cycle of upper ocean properties is important in assessing the utilization of the model; the correspondence between model results and observations during a 15-month non-El Niño interval will be discussed.

ON THE GEOGRAPHIC DISTRIBUTION OF GEOSTROPHIC DYNAMICS

Keith A. Thomson

Quasi-synoptic expendable bathythermograph (XBT) sections are used to investigate the geographic distribution of the three classes of ocean dynamics known as quasi-geostrophy, intermediate geostrophy and planetary geostrophy. These regimes are more distinct in the ocean than in the atmosphere because a greater scale separation exists. The XBT data, obtained from the Canadian Armed Forces, the United States Navy, and the National Oceanographic Data Center's XBT (1984) file, provide a global perspective which includes the Pacific, Atlantic and Indian Oceans. The salinity fields are determined from mean temperature-salinity and salinity-depth curves in order to obtain the quasi-synoptic density fields. Different regions of low-wavenumber variability are identified from these sections. In each region, wavenumber spectra of temperature and geopotential anomaly fluctuations are used to determine the dominant length scales of variability and characteristic geostrophic velocities. Four non-dimensional parameters are evaluated which represent, respectively: the ratio of advective forces to Coriolis forces (the Rossby number, $R=U/f_oL$); the flow scale relative to the Earth's radius (the sphericity parameter, $\beta^*=\beta_oL/f_o$); the dominant component of the potential vorticity (the Burger number, $B=(Ri/L)^2$, where Ri is the internal Rossby deformation radius); and the dominance of turbulent or wave-like processes (the Rossby wave steepness parameter, $M=R/\beta^*=U/\beta_oL^2$). The geographic distribution of the above geostrophic regimes is examined using these four scaling parameters as evaluated in each of the geographic regions where sufficient quasi-synoptic XBT data are available.

A REVIEW OF THERMOCLINE MODELS FOR OCEANS AND LAKES

B. Henderson-Sellers & A.M. Davies

In water bodies of all sizes, the vertical temperature profile and the way it changes over both seasonal and diel stratification cycles is determined by a wide range of influences. Under different circumstances, these forcing processes may be an imbalance in the surface energy budget, penetration of shortwave radiation, convection, turbulent mixing, advection, currents and physico-chemical characteristics of the water (e.g. turbidity, salinity) (see e.g. Woods, 1984). It is important to differentiate between the processes determining the energy budget on the system scale (such as surface energy balance) and those modifying it on smaller spatial scales such as the turbulent kinetic energy (TKE) balance, although it should be noted that the associated temporal scales may often be similar.

On the system scale it is necessary to evaluate the surface energy budget in order to assess the available energy. Most of this energy is absorbed at the surface but some of the shortwave radiation penetrates deeper into the water body, thus creating a stable thermal profile. However, under certain circumstances it is possible that the SEB can become negative, resulting in convection. Mixing takes place until a

stable thermal profile is re-attained. During this penetrating convection, not only is heat transferred downwards to alter the stored energy profile, but on a smaller (energy) scale, this convection may provide an additional source term in the TKE balance which itself is responsible for small scale moderation of mixed layer depth, current structure, etc. The other sources of TKE are located in the two shear layers: at the water surface and at the thermocline interface.
Two basic model types exist for stratification modelling in lakes and oceans: eddy diffusion models and mixed layer models. The latter assume the existence of a mixed layer during the stratification period a priori, hence restricting them to a subset of possible boundary conditions; whilst the former predict this mixed layer depth. It is perhaps this difference in conceptualization that provides the largest contrast but which nevertheless helps to illuminate the relative importance of the various processes involved.
Models of thermal stratification which utilise the integral energy (mixed layer) concept differ in their inclusion, neglect or difference in parametrisation in each of these different sources of TKE and in how the net TKE is partitioned; whilst all available models use a preselected (closure) representation for the turbulent transfer term for heat. These various formulations are reviewed here and their application and limits of applicability outlined.

WAVE-INDUCED EDDY DIFFUSION

B. G. Sanderson, P. H. LeBlond and A. Okubo

Eddy diffusivities are usually employed by oceanographers to describe effects of small-scale advective motion that is regarded as being too complicated to be practically treated by any other means. In this work the situation is reversed and a study of deep water waves is used to find related eddy diffusivities. The Lagrangian equations are used to find solutions for small amplitude waves that interact and evolve with time. Substitution of these solutions into the Lagrangian diffusion equation shows how these waves disperse a passive scalar quantity. The approach can be extended to examine the eddy diffusion due to other wavelike advective motion.

0830-1030
SESSION 9C: BOUNDARY-LAYER MODELLING
SESSION 9C : METEOROLOGIE DE LA COUCHE LIMITE

THE EFFECT OF BAROCLINICITY ON THE STRUCTURE OF THE NEUTRAL PLANETARY BOUNDARY LAYER

G.R. Rooney and G.D. Stubley

The presence of baroclinicity (vertically varying horizontal pressure gradients) in the planetary boundary layer is known to have significant effects on the profiles of mean wind, and has therefore been the subject of much study. Disparities exist between theoretical analyses and observational evidence.

Many previous theoretical studies of the effects of baroclinicity in neutral planetary boundary layers have been based on classical Ekman Theory. They have adopted turbulence closures and have specified boundary conditions which assume that the turbulence in the boundary layer diminishes with height.

It will be shown with the use of a higher order turbulence closure model (the two-equation, kinetic energy-dissipation rate model), that turbulence is produced and present throughout the entire boundary layer and is extinguished only when a temperature inversion is encountered. The results will show that the flow structure, and boundary-layer height are determined by the height of the inversion.

The model can predict results which are compatible with observational evidence and is therefore a useful tool for experimentalists.

STABILITY AND ITS EFFECTS ON WINDS IN THE LOWER ST. LAWRENCE ESTUARY

Gérald Vigeant

Comparing about 20,000 wind observations taken aboard ships in transit across the lower St. Lawrence estuary between 1953 and 1981 with those simultaneously recorded at the weather station of Sept-Îles, the results confirm previous studies stressing the role of stability in the behaviour of winds above relatively large water bodies. Using the average windspeed prevailing over the area and also the difference between the air temperature representative of the airmass and the surface water temperature, an algorithm is proposed in order to simulate adequately this particular behaviour of over-water winds. Although the proposed algorithm remains to be validated theoretically, results show a significant improvement in the determination of over-water windspeed.

ESTIMATES OF ROUGHNESS LENGTH FROM MINISONDE PROFILES IN THE ATHABASCA OIL SANDS AREA

R.C. Rudolph and D.S. Davison

Minisonde data collected in the Athabasca oil sands during the period 1975 to 1979 were analyzed to determine regional values of roughness length (Z_o). A rigorous selection procedure reduced the working data set to a small fraction of the original size. A least squares technique was used to determine Z_o from profiles of wind and temperature typically measured near the 50, 100 and 150 m levels, based on values of the gradient Richardson number.

Z_o values calculated with allowances for diabatic and displacement height effects were generally near 6 m with uncertainties of the same magnitude. The large value for Z_o was attributed primarily to form drag from terrain features in the area in near-neutral but unstable conditions. No significant differences in Z_o were noted with release site or wind direction. The study suggested that Z_o may be stability-dependent in terrain where form drag is important.

An error analysis using reasonable uncertainties for wind speed, balloon height and temperature gradient measurements showed that probable errors in the estimate of Z_o were comparable to the observed variability in Z_o.

INTERCOMPARISON OF FOUR TOP-DOWN WIND PROFILING MODELS

M.D. Moran, E. Alp and L.H. Lam

There are obvious difficulties encountered when trying to assess the wind energy potential for a site which has no history of surface wind observations. One approach to get around this problem is to use surface geostrophic wind values as surrogates for local wind observations. A vertical profiling model may then be employed together with a lengthy series of geostrophic wind values to estimate the wind energy potential at different heights above the ground from historical data. This paper describes a study carried out for the Atmospheric Environment Service in which the performance of 4 different wind profiling models was evaluated using one year of three-hourly observations from a tall, instrumented communications tower at Starbuck, Manitoba. Two power-law models, a surface-layer similarity model, and a Rossby-number similarity model were examined. Input data required included surface geostrophic wind speed and direction, vertical stability, and surface roughness. Vertical stabilities were obtained using either Richardson number or STAR approaches. The results indicated that none of the models were superior to the others in profiling down from the geostrophic level under all atmospheric conditions, although some models did better for certain specific conditions.

DIAGNOSTIC MODELLING OF THE GLOBAL OCEAN SURFACE WINDS

T.W. Yu, W.H. Gemmill and D.M. Feit

Boundary layer formulations based on Rossby number similarity theory (Clarke and Hess, 1975) have been employed to develop an operational, diagnostic model for estimating surface wind speeds and directions over the global oceans. The model has been subjectively and objectively evaluated for an extended period, using global meteorological and oceanographical analysis and forecast fields produced at the National Meteorological Center. Favorable comparison of surface winds produced by this model to other available surface wind fields is demonstrated by a set of verification statistics which relate the various wind fields to observations. These statistics are presented for the mid-latitudes and include root mean square wind speed and direction errors, as well as correlation coefficients. In addition, results of the model analyses and forecasts from a few selected cases are presented and discussed. While the model winds are in good agreement with ship observations and buoy data over the mid-latitude oceans, the physics of the model is not adequate for use in the tropics.

A number of approaches to improve the model over the tropical oceans are reviewed along with verification and evaluation of the various techniques. In particular, results are presented of the diagnostic model modified to include a variable mixed-layer height. The height of the mixed-layer varies due to buoyancy fluxes at the ocean surface and cloud entrainment effects at the top, and serves to couple momentum and thermodynamic energy over the tropical oceans.

The model-generated ocean surface wind analyses and forecasts have been made available to interested Weather Service Forecast offices of the National Weather Service. Their favorable response indicates that routinely produced model winds in real-time can make a significant contribution to the field forecast operations. Operational use of the model as well as plans for further improvement are also discussed.

STUDIES ON THE NITROGEN LOSS THROUGH VOLATILIZATION OF AMMONIA FROM SURFACE-APPLIED MANURE: EFFECT OF METEOROLOGICAL FACTORS
R. Brunke, P. Schuepp, G. Paquette and R. Desjardins

The volatilization of ammonia from surface-applied manure has been monitored during 46 days in 1984, using the trajectory method (developed by Wilson and Thurtell) and newly-developed eddy sampling techniques. Supplementary data were obtained on mean wind, temperature of air and soil, IR emission from soil, humidity and - for some data sets - sensible and latent heat fluxes by eddy correlation technique, permitting evaluation of the observed strong short-term fluctuations in volatilization as a function of meteorological variables.
Observed volatilizations ranged up to 8 kg NH_3/(ha hr). The paper will discuss meteorological effects on this transfer, particularly its link to evaporation, as well as some relative merits of the sampling technique for environmental pollutants.

1050-1230 Studio Alfred-Laliberté
SESSION 10A: ATMOSPHERIC DYNAMICS
SESSION 10A : DYNAMIQUE ATMOSPHERIQUE

EKMAN LAYER DISSIPATION IN AN EASTWARD-TRAVELLING MODON
Gordon E. Swaters

A perturbation solution for an eastward-travelling modon in the presence of a bottom Ekman boundary layer is presented. The modon radius, translation speed and wavenumber are allowed to be functions of a slow time and the geostrophic pressure is expanded in the small damping coefficient ($E^{1/2}/2\varepsilon$), where E and ε are the vertical Ekman and Rossby numbers, respectively). The modon radius, translation speed and wavenumber are assumed to satisfy the modon dispersion relationship throughout the decay. The modon amplitude and translation speed decay exponentially and the modon wavenumber increases exponentially as the slow time increases. The resulting dissipation in the streamfunction and vorticity is qualitatively similar to the McWilliams et al. (1981) numerical solution, although it is unable to describe the eventual transition to Rossby waves. For oceanic and atmospheric scales the decay takes place over a 100-and 10-day time-scale respectively, with the modon travelling about 5 modon radii before complete dissipation.

NECESSARY CONDITIONS FOR BAROTROPIC MODON INSTABILITY, WITH A CALCULATION BASED ON THE 500 MB EDDY ENERGY SPECTRUM
Gordon E. Swaters

Necessary conditions for the growth of normal-mode small-amplitude perturbations of barotropic modons are presented. For eastward-travelling modons an unstable perturbation field must contain spectral components with wavenumber magnitudes ($|\eta|$) greater than the modon wavenumber (κ) in order to satisfy a derived instability integral. For westward-travelling modons an unstable perturbation field must have spectral components satisfying $|\eta|<\kappa$. Conversely, sufficient stability conditions are provided when the perturbation field contains no spectral components satisfying the above respective constraints. These results imply that the slope of the marginal stability curve proposed by McWilliams et al. (1981) for eastward-travelling modons should begin to increase as $\kappa/|\eta|$ increases for $\kappa/|\eta|>1$. The instability integral is calculated for the seasonally and annually-averaged 500 mb eddy kinetic energy spectrum. These calculations suggest that eastward-travelling modons are stable for midlatitude 500 mb energetics. Westward-travelling modons may satisfy the instability integral.

STATISTICAL MECHANICAL EQUILIBRIA FOR THE SHALLOW WATER EQUATIONS
T. Warn

Statistical mechanical equilibria of the shallow water equations, valid in the limit of weak flow, are found. These imply an energy transfer to short scales during relaxation, regardless of the nature of the initial state. The situation is therefore quite unlike that described by the quasi-geostrophic version of the equations in which energy flow to short scales is prohibited. The transfer occurs via the divergent part of the flow. If this mechanism persists in more general forced-dissipative flows at large Reynolds number, a weak direct energy cascade would be implied. The cascade would disappear in the limit of vanishingly small Rossby number but could be significant for finite values.

ÉVALUATION DU MOUVEMENT VERTICAL SYNOPTIQUE DANS LES BAS NIVEAUX À L'AIDE DES TENDANCES DE PRESSION EN SURFACE
Laurent Chenard et Peter Zwack

Nous évaluons une nouvelle méthode de calcul du mouvement vertical synoptique dans les bas niveaux. Cette méthode utilise uniquement les données en surface: la température, la pression, les vents et, une donnée très souvent négligée, la tendance de pression. Notre méthode est basée sur la théorie quasi-géostrophique, dans l'atmosphère libre, et tient également compte de l'effet dominant du pompage d'Ekman sur le mouvement vertical des niveaux compris entre la surface et 700 mb. Théoriquement, la méthode de calcul est valide sous certaines conditions. Ces contraintes sont imposées par l'évolution des champs de température et le tourbillon dans la couche étudiée. En utilisant les données FGGE IIIb, nous montrons que, dans la majorité des cas, les conditions nécessaires à cette méthode de calcul se trouvent réalisées dans l'atmosphère. Par

la suite, nous comparons nos résultats avec le mouvement vertical obtenu par une autre méthode utilisant les données en altitude. Ce dernier nous a été fourni avec les données FGGE IIIb. Puis, nous exposons les corrélations existant entre le mouvement vertical de notre méthode avec les champs d'humidité relative. Finalement, nous discutons des avantages de cette méthode de calcul du mouvement vertical et de son application dans les opérations météorologiques, autant du point de vue diagnostique que prévisionnel.

MOUVEMENT VERTICAL DANS DES SYSTÈMES SYNOPTIQUES ANALYTIQUES
André Méthot et Peter Zwack

Nous évaluons le mouvement vertical au sommet de la couche limite et dans la basse atmosphère libre à l'aide de configurations analytiques de champs d'isobares au sol et de leurs tendances dans le temps. Ces tendances de pression au sol sont obtenues en supposant un déplacement du système sans développement. Le mouvement vertical au sommet de la couche limite est donné par le "Pompage d'Ekman" en négligeant les effets orographiques. Nous intégrons l'équation de continuité avec la condition de mouvement vertical nul au sol. La divergence horizontale du vent dans la couche limite est estimée par le tourbillon qui est lui-même approximé par le laplacien de la pression au sol. Le fait d'utiliser la pression au sol est motivé par l'idée que la distribution spatiale des isohypses est suffisamment invariante avec la verticale dans la couche limite. Pour le calcul du mouvement vertical au-dessus de la couche limite, nous utilisons encore l'équation de continuité avec comme condition à la frontière, la valeur du mouvement vertical au sommet de la couche limite. La divergence du vent dans l'atmosphère libre est estimée à l'aide d'une forme simplifiée de l'équation du tourbillon quasi-géostrophique où la tendance du tourbillon géostrophique est déduit du laplacien de la tendance de pression au sol. Les contributions de l'advection de tourbillon et de la tendance de tourbillon thermique sont négligées. Malgré ces simplifications, les champs de mouvement vertical calculées jusqu'à 750 mb, s'avèrent réalistes pour les systèmes analytiques qui ressemblent suffisamment aux systèmes réels. Avec cet exercice, on montre qu'il est très difficile, voir même très risqué de se prononcer sur la distribution horizontale du mouvement vertical à l'aide d'analyses visuelles du champs de pression à moins d'avoir développé des habiletées particulières après plusieurs années d'expérience.

1050-1210
SESSION 10B: DEEP-SEA OCEANOGRAPHY II
SESSION 10B : OCEANOGRAPHIE DES EAUX PROFONDES II

ON THE WIND STRESS CURL GENERATION OF ANNUAL ROSSBY WAVES IN THE NORTH PACIFIC
Patrick F. Cummins, Lawrence A. Mysak, and Kevin Hamilton

The Rossby wave field generated by the annual cycle of the observed wind stress curl over the North Pacific Ocean has been obtained through numerical integration of the linearized reduced-gravity vorticity equation in spherical coordinates. The dominant source

region of Rossby waves is adjacent to the eastern boundary between 20°N and 35°N. A second, less significant generation region has been identified over the central North Pacific between 35°N and 45°N from 150°W to 160°W. The remainder of the model domain exhibits mostly Ekman pumping of the pycnocline.
Due to the variation of phase velocity with latitude, the waves which emanate from the eastern boundary are refracted such that the wavenumber vector, initially zonally aligned, becomes oriented to the northwest. Associated with this is a turning of the group velocity and of wave rays towards the southwest.

INFLUENCE OF VARIABLE DEPTH AND ROTATION ON KELVIN AND POINCARE WAVES
Y. Gratton. and F. Saucier

Recently, Hyde (1984) introduced asymptotic solutions to first order, for Kelvin and Poincaré waves in a zonal channel in which the environment varies linearly: a beta-plane with constant depth and a f-plane with variable depth. The validity of his asymptotic solutions demands that the waves are of high frequency, that the Froude number of the mean state is very small and that the bottom slopes are also small. We show that exact solutions exist which are valid everywhere.

TRENCH WAVE GENERATION BY INCIDENT ROSSBY WAVES
J.Y. Holyer and L.A. Mysak

The response of a two-layer fluid in a coastal trench to the incidence of low-frequency Rossby waves from the open ocean will be discussed. While both barotropic and baroclinic incident waves have been incorporated into the theory, the focus of the presentation will be on the nature of the response in the trench to first-mode baroclinic Rossby waves. In particular, it will be shown that in both the Izu and Peru trenches, deep (lower-layer) longshore currents of $O(5\ cm\,s^{-1})$ are generated by annual-period Rossby waves whose interfacial amplitude is 5 m. The longshore current speed is particularly large (up to $8\ cm\,s^{-1}$) when the longshore wave number (ℓ) and frequency (ω) of the incident wave are close to the complex (ω,ℓ) roots of the free trench-wave dispersion relation for a β-plane.
In view of the published evidence (summarized in Magaard, 1983) of annual-period Rossby waves in the vicinity of the Izu trench, it is conjectured that forced trench waves of the type described here may be detected in this trench from measurements of subthermocline currents.

SALT AND HEAT BALANCES IN THE LABRADOR SEA USING A BOX MODEL
M. Ikeda

A four-layer box model is employed to estimate water exchange rates between the Labrador Sea and the adjacent areas. These exchange rates are constrained to be compatible with the annual cycles and interannual variabilities of temperature and salinity observed at OWS Bravo. Air-sea interactions are calculated from the weather data at Bravo.

The model suggests that the freshening in 1968-71, compared with 1964-67, was produced by an increase in the exchange with the fresher Labrador and West Greenland Currents. Deep (~ 1500 m) convection events, observed in the 1966-67 and 1971-72 winters, are simulated and attributed to the atmospheric anomalies (lower air temperature, stronger winds and lower humidity).

1050-1230
SESSION 10C: SEVERE WEATHER
SESSION 10C : PHENOMENES METEOROLOGIQUES DANGEREUX

TEMPS VIOLENT PROVOQUÉ PAR DES PETITS CUMULONIMBUS
Stanislas SIOK et Patrice COURBIN

Les modèles classiques d'orages violents associent généralement l'intensité des orages au développement vertical des cumulonimbus. Cependant, des nuages convectifs d'extension verticale et d'intensité radar relativement faibles peuvent également provoquer des vents dévastateurs. Ces phénomènes, qui sont à l'échelle méso-β , ne sont pas encore résolus par les modèles numériques opérationnels. Cette étude présente cinq cas d'orages violents provoqués par des cumulonimbus de 20 000 pieds ou moins alors que la tropopause était à plus de 30 000 pieds et qui se sont produits sur le sud du Québec en 1983. Certaines caractéristiques communes, notamment une onde courte prononcée à 500 mb et des vents forts au sommet de la convection, pourraient se révéler utiles pour les prévisions.

EFFECTS OF A DIRECT CIRCULATION ON TRIGGERING SEVERE THUNDERSTORMS
Denis VIGNEUX and Stanislas SIOK

On the third and fifth of August 1984 an elongated and broken line of thunderstorms formed in a very warm, humid and convectively unstable air mass, just south of a pre-existing band of clouds observed in the morning. The dynamic factors on the synoptic scale for the support of these thunderstorms were not significant. It seems that differential heating associated with cloud shading from the pre-existing cloud band generated a direct circulation similar to a low-level convergence line favoring the generation of thunderstorms, some of which were severe. This continental phenomenon is similar to the sea-breeze front observed on the Atlantic cost. Satellite imagery and surface observations seem to be two very useful tools for the short-term forecasting of such thunderstorms.

MESOSCALE SEVERE WEATHER PILOT PROJECT
Gerald D. Machnee

A Mesoscale Pilot Project was carried out in southern Manitoba between May 14, 1984 and September 14, 1984. The main purpose was to assess the impact of a mesonetwork on Severe Weather Forecasting. Other purposes were to: a) test network density necessary for ground

truthing radar and satellite observations, b) evaluate the mesonetwork in producing better short-range forecasts, and c) establish a data bank for future research.

The project was run in conjunction with an Environment 2000 program. Eight stations in the Red River Valley were selected and observations were done from noon to 8:00 PM CDT on a Monday-to-Friday basis.

The data related to severe weather have been analyzed and several case studies have been done. Some conclusions have been drawn and the project has also raised points for future research.

THUNDERSTORM FORECASTING - EXTENDING OUR CAPABILITIES USING EXISTING DATA SOURCES

G.S. Strong and L.D. Stovel

A frequent complaint of forecasters, both for numerical weather prediction, and at the forecast desk level, is "not enough data". The complaint is especially true when it comes to predicting precipitation events and intensity from mesoscale features, such as severe convective storms or explosive east coast development. Short-term operational mesoscale networks now being planned, such as the Canadian Atlantic Storms Project (CASP), will help resolve those atmospheric processes for which we lack data and understanding, but will only allay the complaints temporarily.

Meanwhile, more effort can be devoted to improving our forecast capability through extended use of existing data sources. Two unrelated data bases, GOES satellite data and Alberta Forestry Lookout observations, were used to demonstrate this approach. The results provided an increased understanding and forecasting capability of severe thunderstorms in Alberta.

A PROPOSAL FOR A COORDINATED STUDY OF SOUTHERN ALBERTA CHINOOKS

T. Mathews and P.F. Lester

It is proposed that a joint effort should be launched to improve the prediction of chinook-related wind storms in the Canadian Rockies. Specific scientific tasks are to determine the relation between surface wind storms and (a) the vertical and horizontal extension of upstream blocking, (b) the time and spatial variation of the leeside boundary layer, (c) the structure and intensity of the hydrostatic lee wave, especially near the tropopause and (d) the structure of the "chinook arch". Supporting objectives are to determine the effects of the chinook on (a) air quality, (b) snowmelt and evaporation, (c) run-off, (d) biological systems and (e) vertical ozone transport. Several research programs are underway and these will be briefly described.

POSTER

CATALOGUES OF SEVERE STORMS FOR CANADA'S EAST AND WEST COASTS
P.J. Lewis, M.D. Moran and V. Swail

Catalogue summaries of severe storms which occurred off the east and west coasts of Canada during the period 1957 to 1983 have recently been compiled for the Atmospheric Environment Service. Storms were selected for inclusion on the basis of extreme observed wind speed. Both the east coast storm catalogue and west coast storm catalogue contain summaries of 125 storms; the summary for each individual storm includes information on areal extent, storm duration, maximum reported wind, minimum central pressure, and significant effects, as well as a capsule storm history, a storm track map, and a representative surface weather map. The east coast study area extends from the east coast of North America to 45°W and from 40°N to 75°N. The west coast study area encompasses the region enclosed by the coasts of Alaska, British Columbia, Washington, and northern Oregon, latitude 45°N and longitude 160°W. Decadal composite storm track maps and complete lists of all periods of storm-force winds (i.e., > 48 knots) from 1946 to 1983 have also been included in each catalogue. These storm catalogues should be useful for a variety of applications, including forecasting, climatological studies, extreme event analysis and risk assessment, emergency measures planning, structural design standards, field program design (e.g., CASP), and wave hindcasting.

1330-1510 Studio Alfred-Laliberté
SESSION 11A: GENERAL CIRCULATION MODELLING AND PARAMETERIZATION
SESSION 11A : MODELISATION DES CIRCULATIONS GENERALES ET PARAMETRISATION

MODELLING THE GLOBAL TRANSPORTS OF MASS, MOISTURE AND ENERGY IN THE ATMOSPHERE
G.J. Boer

The climate may be said to be the response of the amosphere-ocean system to the imposed forcing due to solar radiation. Just how and why the atmosphere and ocean act as they do to provide the required poleward transports of heat and other quantities is the central question of the study of the general circulation.
It is notable that model atmospheres need not act in the same way as the real atmosphere in order to satisfy the balance implied by the imposed forcing. Models without topography, with very limited resolution, without moisture or with no or swamp oceans all succeed in transporting heat and coming to some climatological balance but the transports are not those of the real atmosphere.
The global fluxes and balances of mass, moisture and energy based on FGGE III-b data are presented. These are the first global data to allow a novel approach which decomposes the fluxes into

rotational and divergent components as well as into the more usual mean and transient parts. The resulting flow of mass, moisture and energy in the global atmospheric system is vividly portrayed. The corresponding fluxes in a ten-year annual cycle simulation with the Canadian Climate Centre general circulation model are also displayed and the ability of the model to realistically reproduce observed atmospheric transport mechanisms is investigated. The results give information on the role of the mean and transient motions in global budgets, on the ability of current GCM's to correctly simulate atmospheric transports and on our knowledge of the "observed" behaviour of the atmosphere.

THE KINETIC ENERGY BUDGET OF THE CANADIAN GCM IN TERMS OF THE 2-D WAVENUMBER
Steven J. Lambert

The vertically integrated kinetic energy budget for the four mid-season months of a simulation from the CCC GCM operating in an annual cycle mode will be presented. These results will be compared to observations taken during the FGGE year.

PARAMETERIZATION OF CUMULUS CONVECTION IN THE CCC GENERAL CIRCULATION MODEL
N.A. McFarlane

A new cumulus parameterization scheme has been developed for use in the CCC general circulation model. This scheme was designed as a replacement for the moist convective adjustment scheme currently used in the model.

In the new scheme shallow cumulus clouds do not produce precipitation and are assumed to behave like turbulent eddies with extended vertical dimensions resulting from condensation. Their effects are represented in terms of enhanced vertical diffusion. Deep clouds are represented in terms of a bulk mass flux formulation with a quasi-equilibrium closure condition similar in nature to that of Arakawa and Schubert (1974).

The main features of the formulation will be discussed briefly and some results from GCM climate simulations incorporating it will be presented.

A THREE-DIMENSIONAL MODEL OF THE SUMMER MONSOON
Keith D. Sashegyi and Simon W. Chang

A three-dimensional, five-layer, primitive equations model in sigma coordinates has been used to study the Indian summer monsoon. The regional model with topography is integrated for six days from an initial zonal average wind field for cases with and without a prescribed convective heat source. The resolution is one degree in longitude and two degrees in latitude. The planetary boundary layer is modelled by a single layer. The horizontal structure of the heat source is the same as the distribution of observed average July rainfall, but with a rainfall rate of five times, due to the shorter integration period. The initial zonal average flow field is initialized and maintained with nudging of the wind.

Without the prescribed convective heat source, the response is largely confined to the lower troposphere. The SE trades are deflected across the equator by the East African topography, as a low-level jet. The jet doesn't penetrate futher north than 8°N, curving southward on its eastward path over the Arabian Sea to cross the extreme southern tip of India. With the monsoon heat source included the low level cross equatorial flow is stronger and broader. The low-level jet penetrates further north to 16°N in a broadstream of south westerly flow across the Arabian Sea, before turning into a SW flow over the Bay of Bengal.

The study demonstrates that the summer monsoon circulation is primarily driven by the large-scale convective heating in the presence of topography. In particular, the low-level wind maximum off the coast of Somalia is dynamically related to the lower tropospheric Northern Hemisphere cyclonic gyre forced by the convective heating. The sensitivity of flow to the vertical heating structure is also tested.

1330-1510
SESSION 11B: LABRADOR SEA DYNAMICS
SESSION 11B : DYNAMIQUE DE LA MER DU LABRADOR

A DESCRIPTION OF THE LABRADOR CURRENT BASED ON RECENT MEASUREMENTS
John R. Lazier and Daniel G. Wright

The main features of the Labrador Current are described by presenting analyses of current-meter measurements, obtained between 1978 and 1984 at Hamilton Bank, of twelve temperature and salinity sections across the shelf and slope near the meters, and of the historical temperature and salinity data. The temperature and salinity data show 80% of the current concentrated in a baroclinic jet lying above the 500-m isobath over the continental slope. The strong current is marked by high horizontal gradients in temperature, salinity and density bordered by relatively small gradients over the continental shelf and over the deep oean. The velocity record from near the jet shows this flow varies seasonally with the minimum in spring and the maximum in late autumn, presumably driven by fresh water runoff from the Arctic. This annual variation is shown to correlate well with the seasonal change in sea level at Nain, Labrador and with the difference in sea level between the coast and the open ocean. Over the inner shelf the seasonal maximum occurs in late spring in phase with the local runoff maximum. Fresh water transport across the whole current relative to a salinity of 34.9 varies between 1 and 3 x $10^5 m^3/s$ while the total transport varies between 2 and 10 x $10^6 m^3/s$. The concentration of the flow in a baroclinic jet over the continental slope rather than over the relatively flat shelf is interpreted to be a consequence of the inability of the shallow shelf waters to sustain large baroclinic or barotropic flows. The strong front associated with the jet must lie in deeper water to support a horizontal pressure gradient sufficient to accommodate all the water supplied.

A TWO-LAYER MODEL TO INVESTIGATE LABRADOR CURRENT TYPE PHENOMENA
David A. Greenberg

A numerical model is being used to look at circulation along a shelf break. The simulation involves two layers, of constant density, variable but non-zero thickness, responding to pressure, Coriolis, interfacial friction and bottom friction forces. The topography of the area modelled is uniform along its length (600 km), starting with a shore (no flow condition), a 100-km wide shelf, then a 30-km wide shelf break region leading to the deep sea (1,000-m deep, 70-km wide) with an open boundary. Various boundary conditions are imposed depending on the phenomenon under investigation. To date, flows driven by boundary set-up and different initial conditions have been investigated. When using radiation-type boundary conditions, results are stable, even in extended runs (80 days). To properly model the Labrador Current, it may be necessary to allow for a more complicated situation, including features such as disappearing layers, more complex shelf topography or wind forcing.

THE HUMIDITY EXCHANGE OVER THE SEA (HEXOS) PROGRAMME
Stuart D. Smith

There are very few good direct measurements of humidity exchange from which the latent heat flux over the sea can be parameterized, and uncertainty in latent heat flux is one of the barriers to the understanding of global climate. A co-ordinated series of international experiments is being carried out to overcome a number of difficulties which have limited the quantity and quality of available measurements.

The core of the programme is measurement of water vapour flux and aerosols at the Dutch research platform "Meetpost Noordwijk". In 1983 a flow-distortion study of a model platform in a wind tunnel with a simulated atmospheric boundary layer was carried out by John Wills of National Maritime Institute in the U.K. The eddy flux was found to be within a few percent of its undisturbed value 16 m upwind from the platform. A pilot experiment during November, 1984 demonstrated the feasibility of combining newly-developed flux and aerosol measuring systems from the Netherlands, the USA and Canada on the platform with an overflight of a British boundary-layer research aircraft. In 1985 a series of experiments will be run in a wind and wave simulation tunnel in Marseille, France. The main field experiment at Meetpost Noordwijk in the fall of 1986 will take advantage of experience gained in the previous experiments, and will be supported also by aircraft- and ship-based measurements. Concurrent with the experimental work is ongoing development of an atmospheric surface layer model of vertical water vapour and droplet transports.

ICE MODEL DOMAIN SIZES FOR BEAUFORT SEA ICE FORECASTING

Eric Leavitt, Ed Krakowski, S. Venkatesh, V.R. Neralla and R. Jessup

A finite-element ice dynamics model is employed to determine appropriate domain sizes for forecasting ice motion during the winter within the Canadian Beaufort Sea. The problem is to find a domain size such that errors in boundary conditions are minimized over the model domain during the forecast period.

The appropriate model domain is a complicated function of ice characteristics, forcing winds, ocean currents and boundary conditions.

The dependence on ice characteristics means that at times only the local area needs to be considered, while at other times far field conditions may determine the local ice motion. At such times the entire Beaufort Sea needs to be included in the model domain. This latter point is illustrated using a finite-element ice dynamics model for a period when the ice remained motionless in the Canadian Beaufort Sea although local winds were easterly and greater than 10 knots. The results show that ice conditions or boundary conditions along the Alaskan coast can prevent the ice from moving in the Canadian Beaufort.

COMPARISON OF CODAR AND CURRENT-METER MEASUREMENTS IN THE STRAIT OF BELLE ISLE

K. Shirasawa, W. Winsor, A.E. Hay and D. Lawrence

Near-surface current measurements made by Coastal Ocean Dynamics Applications Radar (CODAR) and concurrent moored current-meter measurements in the Strait of Belle Isle from June 28 to July 9, 1983, are compared. It is demonstrated that the CODAR radial velocities agree well with those obtained by current meters at 14-and 15-m depth at both the central part and the eastern end of the Strait. It is indicated by the linear regression fit that amplitudes of current-meter velocities are 6 to 39% lower than those of CODAR-derived velocities, with correlation coefficients of 0.77 to 0.88. The computed K_1 and M_2 tidal constituents from CODAR and current-meter measurements agree well. The differences in amplitude and in phase between CODAR and current meters are within 8 cm/s and 16°, respectively. Comparison of CODAR-derived radial components with those obtained with a narrow beam fixed phase antenna shows that the correlation coefficient of the linear regression fit is 0.95. It is concluded that the CODAR direction finding algorithm works reasonably well. The flow pattern of low-frequency radial currents at 14-m and 15-m depth throughout the experimental period shows that the along-strait component appears to be highly coherent with the large-scale atmospheric pressure difference across the Strait.

1330-1450
SESSION 11C: CLIMATOLOGY
SESSION 11C : CLIMATOLOGIE

A TWO-DECADE REVIEW OF THE WEATHER RECORD TAKEN AT THE CLIMATOLOGICAL REFERENCE STATION OF THE SASKATCHEWAN RESEARCH COUNCIL

S.R. Shewchuk

For the period 1964 to the present the Saskatchewan Research Council has operated a Climatological Reference Station on the grounds of the University of Saskatchewan. A review is provided of all of the major meteorological parameters for the Saskatoon area observed at this location. Major meteorological parameters summarized include; precipitation, snow cover, air temperature, humidity, soil temperatures (to 300 cm), wind speed and direction, sunshine hours, solar radiation (both direct and diffuse) and evaporation. In addition to the class A pan evaporation is also measured for agrometeorology programs by the Livingston cell and Bellani plate. Temperature trends both for the air and for the soil indicate that this region of Canada has undergone significant warming within the last several years. The twenty-year annual mean air temperature is 1.6 degrees C. However, within the last five-year period the annual mean air temperature has risen to 2.5 degrees C with most of the increase due to warmer winter periods.

FREEZE-THAW DAYS IN THE NORTHEASTERN UNITED STATES

Thomas W. Schmidlin, Bernard E. Dethier & Keith L. Eggleston

The fluctuation of temperature across the freezing point of water affects soil freezing, surface runoff, erosion, trafficability, and mechanical weathering. The frequency of freeze-thaw cycles is an important climatic parameter for agriculturalists, engineers, geologists, and geographers.

Freeze-thaw cycles, or days, have been defined in various ways. We define a freeze-thaw day as a weather observation day with a maximum temperature of 0°C or above and a minimum temperature of -2.2°C or below in a standard shelter at 1.6m height. A minimum temperature between -2.2°C and 0°C is not considered to be an effective freeze in most applications.

The thirty winters during 1950-80 are examined at 220 stations in nine northeastern states. Average annual freeze-thaw days range from over 90 at high elevations in the north to less than 50 along the New York and New Jersey coasts. Freeze-thaw days are most common during January in the south. Inland stations show a January minimum and a peak during March. Freeze-thaw days are most numerous with average monthly temperatures near -1°C and rarely occur at mean monthly temperatures below -13°C or above 11°C.

The number of freeze-thaw days occurring with less than 7.5cm of snow cover is about 95% of the total number of freeze-thaw days along the southern coasts and less than 50% of the total in northern snowy climates. The air at 10cm height experiences 37% more freeze-thaw days than the air at 160cm, due to a larger daily temperature range. Hilltops experience fewer freeze-thaw days than valley bottoms.

RECHERCHE SUR LES TEMPÉRATURES SUPERFICIELLES DE L'EAU DANS LE GOLFE DE GASCOGNE ET SA RELATION AVEC LA PLUIE AU PAYS BASQUE
Antón Uriarte

On donne une explication des notables variations des pluies tout au long de la Côte Cantabrique du nord de l'Espagne en se basant sur les différences thermiques des eaux du Golfe.
On explique la forte intensité des pluies au Pays Basque à la fin de l'été en reliant ce fait au réchauffement des eaux dans l'extrémité orientale du Golfe de Gascogne.
On étudie, enfin, les pluies côtières catastrophiques de l'été 1983 en Pays Basque, dues en partie à la configuration isothermique préalable du Golfe.

CLIMATE IMPACT ASSESSMENT OF THE "GREENHOUSE EFFECT" IN THE GREAT LAKES BASIN
Stewart J. Cohen

Climate impact assessments are designed to identify and predict the impacts of climatic change or variability on the environment and on society. There have been a number of historical case studies of impacts of previous events (e.g. drought), especially on agriculture. In recent years, there has been a growing interest in the possible effects of CO_2-induced climatic change, which is expected to increase global temperatures by the mid-21st century. Unfortunately, future impacts are more difficult to analyze because of uncertainties regarding the exact nature of the future climate, and possible changes in non-climatic factors.

An impact study of the Great Lakes Basin is now in progress, involving several research groups within government and universities. A suggested framework for this study is presented. A key element is the projection of future lake levels. Using four scenarios of climatic change, preliminary estimates of net basin supply of water have been determined. All four scenarios include warmer temperatures, but there are differences in precipitation and wind speed. Decreases of 28%, 12%, and 8% have been projected for three of the scenarios, respectively. The fourth projects an increase of 7%. This wide range of results must be considered as impact studies continue, since there would probably be different impacts in each scenario.

TWENTIETH ANNUAL CONGRESS / CHS:86

The Saskatchewn Centre of the Canadian Meteorological and Oceanographic Society and the Associate Committee on Hydrology of the National Research Council will host the Twentieth Annual CMOS Congress/Canadian Hydrology Symposium:86 from June 4 to 6, 1986 at the University of Regina. The theme is "Drought: The Impending Crisis?"

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VINGTIÈME CONGRÈS ANNUEL / SCH:86

Le Centre de la Saskatchewan de la Société canadienne de météorologie et d'océanographie et le Comité associé d'hydrologie du Conseil national de recherches seront les hôtes du Vingtième congrès annuel de la SCMO et du Symposium canadien d'hydrologie:86, qui se tiendront du 4 au 6 juin 1986, à l'Université de Regina. Le thème en est: "La sécheresse: une menace à l'horizon?".

On peut obtenir d'autres renseignements auprès de:
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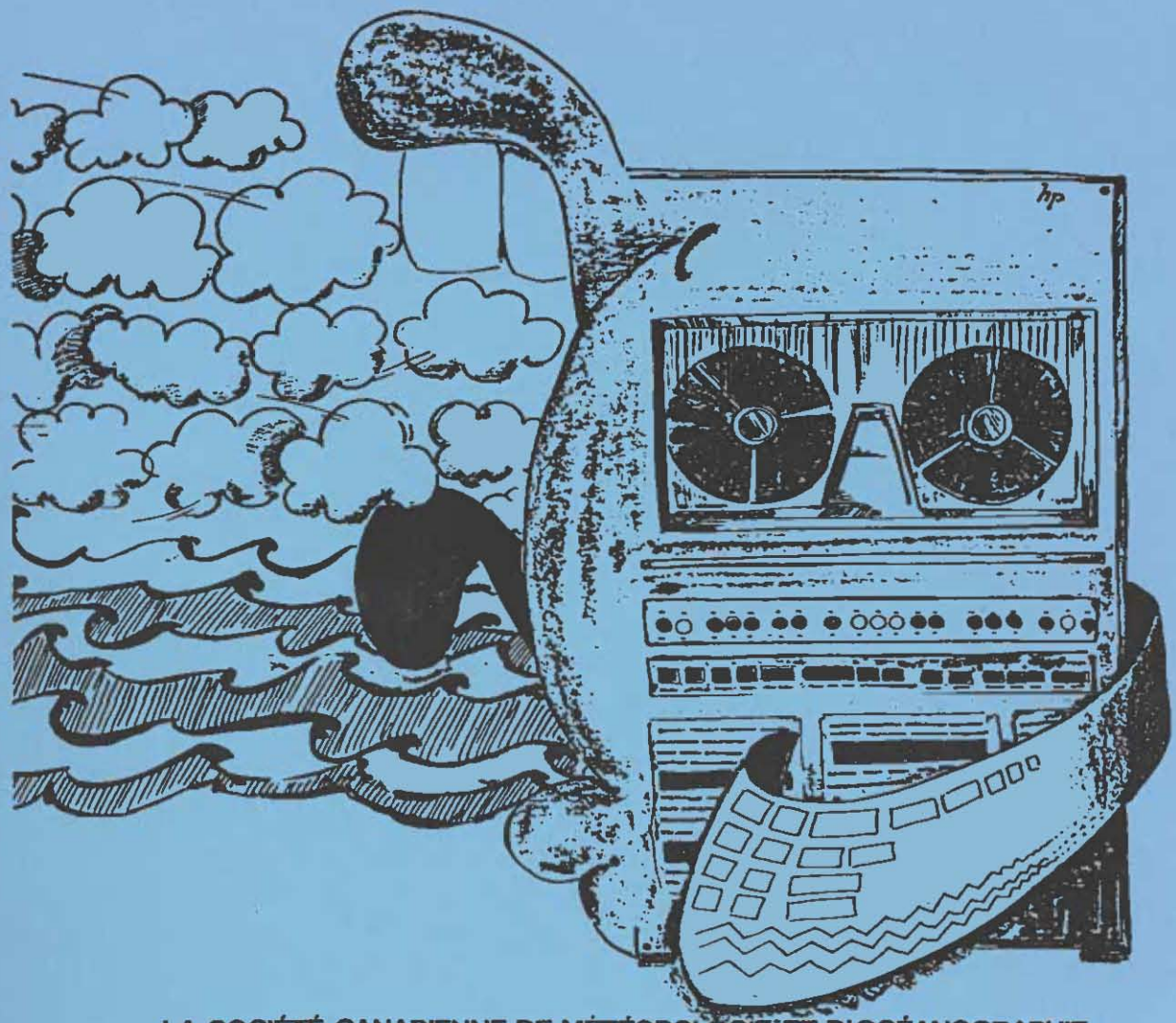
(306) 359-6413



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SEVENTH CONFERENCE ON NUMERICAL WEATHER PREDICTION june 17-20
SECOND INTERNATIONAL CONFERENCE ON THE AVIATION WEATHER SYSTEM june 19-21
AMERICAN METEOROLOGICAL SOCIETY

PLAN DE LOCALISATION
LOCATION PLAN