20th Annual Congress/ 20^e Congrès Annuel

CHS:86 SCH:86

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

Canadian Hydrology Symposium/ Symposium Canadien d'Hydrologie

DROUGHT

CMOS ACH

THE IMPENDING CRISIS ?

LA SÉCHERESSE : LA CRISE EST-ELLE IMMINENTE?

Joint Program with Abstracts/ Programme Conjoint avec Résumés

UNIVERSITY OF REGINA
REGINA, SASKATCHEWAN

3–6 June 1986/
3–6 juin 1986

PROGRAM WITH ABSTRACTS / PROGRAMME AVEC RÉSUMÉS

20th Annual CMOS Congress / 20e Congrès annuel de la SCMO
Canadian Hydrology Symposium CHS:86 / Symposium canadien d'Hydrologie SCH:86

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Editor / Rédacteur en chef - E.J. Truhlar

Technical Editor / Rédaction technique - I. Savdie

PRINTED IN CANADA / IMPRIMÉ AU CANADA

TWENTIETH ANNUAL CONGRESS

Canadian Meteorological and Oceanographic Society

The Saskatchewan Centre of the Canadian Meteorological and Oceanographic Society (CMOS) will host the Twentieth Annual CMOS Congress and Annual General Meeting at the University of Regina from June 4 to 6, 1986. The theme is "Drought: The Impending Crisis?". In addition to invited and contributed papers relating to the general theme, sessions will be held on many other aspects of meteorology and oceanography.

The Canadian Hydrology Symposium, CHS:86, sponsored by the Associate Committee on Hydrology of the National Research Council of Canada, will be held concurrently at the same location.

The CMOS Scientific Program Committee is:

G.A. McBean, Chairman
R.G. Humphries
D.G. Steyn
H.J. Freeland
R.E. Stewart
J. Maybank
B.E. Goodison

The CHS Program Committee was chaired by J.M. Wigham.

The CMOS–CHS joint Local Arrangements Committee is:

R.F. Hopkinson, CMOS Co–Chairman
D.L. MacLeod, CHS–86 Co–Chairman
W. Nicholaichuk
K. Jones
J. Whiting
R. Herrington
A. Paul
R.A. Halliday
A. Banga

VINGTIÈME CONGRÈS ANNUEL

Société canadienne de météorologie et d'océanographie

Le Centre de Saskatchewan de la Société canadienne de météorologie et d'océanographie (SCMO) sera l'hôte du vingtième Congrès annuel et de l'Assemblée générale annuelle de la SCMO, événements qui se tiendront à l'Université de Regina du 4 au 6 juin 1986. Le Congrès a pour theme "La sécheresse : la crise est-elle imminente?". Outre les communications presentées par les conférenciers invités et les autres participants sur le thème général, il y aura des séances sur d'autres aspects de la météorologie et de l'océanographie.

Le Comité associé d'hydrologie du Conseil national de recherches du Canada organisera conjointement le Symposium canadien d'Hydrologie, SCH:86, au même endroit.

COMITÉ DU PROGRAMME SCIENTIFIQUE

G.A. McBean, Président
R.G. Humphries
D.G. Steyn
H.J. Freeland
R.E. Stewart
J. Maybank
B.E. Goodison

Le président du Comité du programme scientifique SCH:86 est
J.M. Wigham.

COMITÉ ORGANISATEUR DE CMOS ET CHS:86

R.F. Hopkinson, CMOS coprésident
D.L. MacLeod, CHS–86 coprésident
W. Nicholaichuk
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R. Herrington
A. Paul
R.A. Halliday
A. Banga

The Canadian Meteorological and Oceanographic Society and the Associate Committee on Hydrology are very grateful to the following organizations for sponsorships or grants:

La Société canadienne de météorologie et d'océanographie et le Comité associé d'hydrologie sont reconnaissant aux organisations suivant pour leurs assistances :

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Nous remercions aussi les organisations supportives :

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- Atmospheric Environment Service
- Inland Waters Directorate
- Water Resources Branch
- National Hydrology Research Institute

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Summary of Sessions

Note: All sessions will be held in the Education Building of the University of Regina. Session 1 will be held in the Main Auditorium (ED 106). All A sessions will be held in Wing # 1 (ED 106.1) of the Main Auditorium. All B sessions will be held in Room ED 1.11.
The Registration and Information Desk will be held in the Carpeted Room of College West on June 3 and in the Rotunda area of the Education Building thereafter.

Tuesday, June 3

(AH – Administration Humanities Bldg; ED – Education Bldg)

0900–1200	CMOS Educational Committee for Oceanography (ED 1.15)
0900–1200	Chinook Editorial Board (AH South Lounge A)
0900–1200	Climatological Bulletin Editorial Board (AH South Lounge B)
1300–1615	CMOS Publications Management Committee (ED 4.83)
1300–1615	CMOS Scientific Committee (AH South Lounge B)
1300–1615	CMOS Centre Chairmen and Chapter Correspondents (AH South Lounge A)
1300–1615	CMOS Air Pollution Meteorology Special Interest Group (ED 1.15)
1300–1615	CMOS Operational Meteorology Special Interest Group (ED 1.11)
1430–1630	CMOS Education Committee for Meteorology (ED 1.1)
1630–1930	CMOS Council (Session I) (AH South Lounge)
1930–2300	Registration and Information (College West)
1930–2300	Ice Breaker Reception (College West)
2100–2300	CMOS Council (Session II) (AH South Lounge)

Wednesday, June 4

0900–1000	1	OPENING PLENARY SESSION: DROUGHT: THE IMPENDING CRISIS
1000–1030		Coffee
1030–1200	2	PLENARY SESSION: OCEANOGRAPHY AND METEOROLOGY
1200–1330		Lunch
1330–1510	3A	BOUNDARY–LAYER MODELLING
1330–1510	3B	DEEP–SEA OCEANOGRAPHY
1510–1530		Coffee
1530–1730	4A	FORECAST STUDIES
1530–1730	4B	DYNAMIC METEOROLOGY
1530–1700		CMOS Floating Ice Special Interest Group (ED 1.1)
1730–1930		CMOS Hydrology Special Interest Group (Dinner Meeting, College West, Private Dining Room)
1930–2300		CMOS ANNUAL GENERAL MEETING (AH Boardroom)

Thursday, June 5

0830–1030	5A	MESOSCALE AND BOUNDARY–LAYER STUDIES
0830–1030	5B	METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS (MOIST)
1030–1050		Coffee
1050–1230	6A	EVAPORATION
1050–1230	6B	CANADIAN ATLANTIC STORMS PROGRAM (CASP)
1230–1330		Lunch
1330–1510	7A	PRECIPITATION STUDIES I
1330–1510	7B	COASTAL OCEANOGRAPHY I
1330–1510		CMOS Committee on Professionalism (ED 1.1)
1510–1530		Coffee
1530–1730	8A	PRECIPITATION STUDIES II
1530–1730	8B	COASTAL OCEANOGRAPHY II
1830–1900		Cash Bar – Sheraton Centre
1900–2200		CMOS Banquet – Sheraton Centre

Friday, June 6

0800–0830		CMOS Council (College West Carpeted Room)
0830–1030	9A	GENERAL METEOROLOGY I
0830–1030	9B	CLIMATE
1030–1050		Coffee
1050–1230	10A	GENERAL METEOROLOGY II
1050–1230	10B	SEA STATE AND SEA ICE

Résumé des sessions

Note : Toutes les sessions se tiendront dans l'Édifice de l'éducation de l'Université de Regina. Session 1 se tiendra dans l'Auditorium (ED 106). Toutes les sessions A se tiendront dans la salle ED 106.1 et toutes les sessions B se tiendront dans la salle ED 1.11.
Le bureau d'inscriptions et de renseignements se trouvera dans le "Carpeted Room" de College West le 3 juin et dans le vestibule central ensuite.

Mardi le 3 juin

(AH – Administration Humanities Bldg; ED – Education Bldg)

0900–1200	Comité de la SCMO d'éducation en océanographie (ED 1.15)
0900–1200	Conseil du rédaction du Chinook (AH South Lounge A)
0900–1200	Conseil du rédaction du Bulletin climatologique (AH South Lounge B)
1300–1615	Comité de gestion des publications de la SCMO (ED 4.83)
1300–1615	Comité scientifique de la SCMO (AH South Lounge B)
1300–1615	Comité des présidents des centres et des correspondants des sections de la SCMO (AH South Lounge A)
1300–1615	Groupe d'intérêts spéciaux : météorologie de la pollution de l'air (ED 1.15)
1300–1615	Groupe d'intérêts spéciaux : météorologie d'exploitation (ED 1.11)
1430–1630	Comité de la SCMO d'éducation en météorologie (ED 1.1)
1630–1930	Conseil de la SCMO (session I) (AH South Lounge)
1930–2300	Inscription et renseignements (College West)
1930–2300	Réception d'accueil (College West)
2100–2300	Conseil de la SCMO (session II) (AH South Lounge)

Mercredi le 4 juin

0900–1000	1	Session plénière thématique: La sécheresse: la crise est-elle imminente?
1000–1030		Café
1030–1200	2	Session plénière: océanographie et météorologie
1200–1330		Déjeuner
1330–1510	3A	Modélisation de la couche limite
1330–1510	3B	Océanographie des eaux profondes
1510–1530		Café
1530–1730	4A	Études des prévisions
1530–1730	4B	Météorologie dynamique
1530–1700		Groupe d'intérêts spéciaux : glaces flottantes (ED 1.1)
1730–1930		Groupe d'intérêts spéciaux : hydrologie, diner (College West, Private Dining Room)
1930–2300		Assemblée générale annuelle de la SCMO (AH Boardroom)

Jeudi le 5 juin

0830–1030	5A	Études de l'échelle moyenne et de la couche limite
0830–1030	5B	Les influences météorologiques et océano-graphiques sur les routes du saumon (MOIST)
1030–1050		Café
1050–1230	6A	Évaporation
1050–1230	6B	Programme canadien d'étude des tempêtes dans l'Atlantique
1230–1330		Déjeuner
1330–1510	7A	Études sur la précipitation I
1330–1510	7B	Océanographie côtière I
1330–1510		Comité de la SCMO sur le professionnalisme (ED 1.1)
1510–1530		Café
1530–1730	8A	Études sur la précipitation II
1530–1730	8B	Océanographie côtière II
1830–1900		Réception – Sheraton Centre
1900–2200		Banquet de la SCMO – Sheraton Centre

Vendredi le 6 juin

0800–0830		Conseil de la SCMO (College West Carpeted Room)
0830–1030	9A	Météorologie générale I
0830–1030	9B	Climat
1030–1050		Café
1050–1230	10A	Météorologie générale II
1050–1230	10B	État de la mer et des glaces de mer

Program / Programme

Wednesday Morning, 4 June 1986
Mecredi matin, le 4 juin 1986

0900–1000: (ED 106)
SESSION 1: WELCOMING REMARKS AND PLENARY SESSION
Chairman / Président : W. Nicholaichuk
SESSION 1: MOT DE BIENVENUE ET SESSION PLÉNIÈRE

WELCOMING REMARKS / MOT DE BIENVENUE
D.L. MacLeod, Associate Committee on Hydrology
S.D. Smith, CMOS
L. Barber, University of Regina

DROUGHT, A GLOBAL PERSPECTIVE
G.A. McKay, University of Saskatchewan

1000–1030 Coffee / Café

1030–1200 (ED 106.1)
SESSION 2: PLENARY SESSION, OCEANOGRAPHY AND METEOROLOGY
Chairman / Président : S.D. Smith
SESSION 2: SESSION PLÉNIÈRE, OCÉANOGRAPHIE ET MÉTÉOROLOGIE

1030: RECENT DEVELOPMENTS IN OCEAN CIRCULATION
Peter B. Rhines, School of Oceanography, University of Washington, Seattle, WA

1115: CO_2 –INDUCED EQUILIBRIUM AND TRANSIENT CLIMATE CHANGES
M. Schlesinger, Department of Atmospheric Sciences, Oregon State University, Corvallis, OR

1200–1330 Lunch / Déjeuner

Wednesday Afternoon, 4 June 1986
Mercredi apres-midi, le 4 juin 1986

1330-1510 (ED 106.1)
SESSION 3A: BOUNDARY-LAYER MODELLING
Chairman / Président: T.R. Oke
SESSION 3A : MODÉLISATION DE LA COUCHE LIMITE

MODELLING OF TURBULENCE CHARACTERISTICS OVER LOW HILLS
A.C.M. Beljaars*, J.L. Walmsley and P.A. Taylor, Boundary Layer Research Division, Atmospheric Environment Service, Downsview, Ont.(*on leave from the Royal Netherlands Meteorological Institute, De Bilt, Netherlands)

THE EFFECT OF VERTICAL RESOLUTION ON BOUNDARY-LAYER PARAMETERIZATION
Yves Delage, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

ONE-LEVEL MESOSCALE NUMERICAL MODELLING OVER THE LOWER FRASER VALLEY OF BRITISH COLUMBIA
Keith W. Ayotte and D.G. Steyn, Dept. of Geography, University of British Columbia, Vancouver, B.C.

APPLICATION OF A 3-D MESOSCALE MODEL TO WINDFIELD PREDICTION IN THE LOWER FRASER VALLEY, B.C.
I.G. McKendry and D.G. Steyn, Dept. of Geography, University of British Columbia, Vancouver, B.C.

1330-1510 (ED 1.11)
SESSION 3B: DEEP-SEA OCEANOGRAPHY
Chairman / Président: P. Rhines
SESSION 3B: OCÉANOGRAPHIE DES EAUX PROFONDES

ON THE GEOGRAPHIC VARIABILITY OF MESOSCALE STATISTICS AND INFERRED DYNAMICS IN THE PACIFIC AND ATLANTIC OCEANS
K.A. Thomson, Dobrocky Seatech Ltd., Sidney, B.C.

SIMULATION OF RADARSAT SPACEBORNE SAR BY AIRBORNE SAR FOR IMAGING OCEAN WAVE PROPERTIES AND SHIP TARGETS
A.S. Bhogal, F.G. Bercha and Associates (Ontario) Ltd., Ottawa and N.G.S. Freeman, RADARSAT Project Office, Ottawa, Ont.

A COMPARISON BETWEEN GEOSTROPHIC AND DIRECTLY MEASURED SURFACE WINDS OVER THE NORTHEAST PACIFIC OCEAN
R.F. Marsden, Department of Physics, Royal Roads Military College, FMO Victoria, B.C.

CHARACTERISTICS OF CURRENT FIELD IN THE NORTHEASTERN GRAND BANKS
C.L. Tang, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

THE INTERACTION OF TOPOGRAPHY WITH THE BAROTROPIC AND BAROCLINIC LABRADOR CURRENT
David Greenberg, Brian Petrie and Dan Wright, Bedford Institute of Oceanography, Dartmouth, N.S.

1510–1530 Coffee / Café

1530–1730 (ED 106.1)
SESSION 4A: FORECAST STUDIES
Chairman / Président: R.F. Hopkinson
SESSION 4A : ÉTUDES DES PRÉVISIONS

THE EFFECT ON THE BRIER SKILL SCORE OF SMOOTHING PROBABILITY FORECASTS
L.J. Wilson and R. Sarrazin, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.

A NUMERICAL MODEL FOR THE PREDICTION OF MESOSCALE PRECIPITATION AND APPLICABLE TO THE HP 1000 MINICOMPUTER
R. Gabison, Forecast Research Division, Atmospheric Environment Service, Downsview, Ont.

FORECASTING MESOSCALE CONVECTIVE REGIONS: I. DOWNSCALE SYNOPTIC EFFECTS AND AN OPERATIONAL TECHNIQUE
G.S. Strong, Atmospheric Sciences Department, Alberta Research Council, Edmonton, Alta

MARWORDS – AN EXPERIMENT IN COMPUTER-WORDED FORECASTS
J. Carr McLeod, Meteorological Services Research Branch, Atmospheric Environment Service, Downsview, Ont.

SURFACE WIND AND STRESS EVALUATIONS USING THE V9HR AND FEM OPERATIONAL MODELS
S.L. Csanady, Meteorological Services Research Branch,
Atmospheric Environment Service, Downsview, Ont.

1530–1730 (ED 1.11)
SESSION 4B: DYNAMIC METEOROLOGY
Chairman / Président: P. Merilees
SESSION 4B : MÉTÉOROLOGIE DYNAMIQUE

SEMI–LAGRANGIAN ADVECTION ON A GAUSSIAN GRID
Harold Ritchie, Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

FORECASTING OF EAST COAST STORMS WITH A HIGH–RESOLUTION REGIONAL MODEL DURING CASP
C. Chouinard, R. Benoit, J. Mailhot and M. Roch,
Recherche en prévision numérique, Service de l'environnement atmosphérique, Dorval, Qué.

INSTABILITY OF PLANETARY WAVES IN A HIGH VERTICAL RESOLUTION MODEL
Charles A. Lin, Department of Physics, University of Toronto,
Toronto, Ont.

DYNAMICS OF THE STRATOPAUSE SEMIANNUAL OSCILLATION
Kevin Hamilton, Department of Meteorology, McGill University,
Montréal, Qué.

THE GROWTH AND DECAY OF ATMOSPHERIC KINETIC ENERGY
Steven J. Lambert, Canadian Climate Centre, Downsview, Ont.

OBSERVATIONAL STUDIES OF ATMOSPHERIC NORMAL MODES
Kevin Hamilton, Department of Meteorology, McGill University,
Montréal, Qué.
Rolando R. Garcia, National Center for Atmospheric Research,
Boulder, Colorado

GENERAL CIRCULATION MODEL SIMULATION OF NORMAL MODES: STRUCTURES AND ENERGETICS
Kevin Hamilton, Department of Meteorology, McGill University,
Montréal, Qué.

0830–1030 (ED 106.1)
SESSION 5A: MESOSCALE AND BOUNDARY–LAYER STUDIES
Chairman / Président: R.E. Stewart
SESSION 5A: ÉTUDES DE L'ÉCHELLE MOYENNE ET DE LA COUCHE LIMITE

MESOSCALE CIRCULATIONS FORCED BY THE MELTING OF SNOW IN THE ATMOSPHERE
Kit K. Szeto and Charles A. Lin, Department of Physics, University of Toronto
Ronald E. Stewart, Atmospheric Environment Service, Downsview, Ont.

MESOSCALE STRUCTURE OF THE BOUNDARY LAYER DURING STREX
G.A. McBean, Canadian Climate Centre, Institute of Ocean Sciences, Sidney, B.C.

THE CLIMATOLOGY OF SEA BREEZES IN THE LOWER FRASER VALLEY, B.C.
D.G. Steyn, Department of Geography, University of British Columbia, Vancouver
D.A. Faulkner, Pacific Region, Atmospheric Environment Service, Vancouver, B.C.

THE ATMOSPHERIC BOUNDARY LAYER DURING BLOWING SNOW
J.W. Pomeroy and D.H. Male, Division of Hydrology, University of Saskatchewan, Saskatoon, Sask.

THE VAPOUR FLUX OF 2,4–D ISO–OCTYL ESTER AFTER APPLICATION TO A WHEAT FIELD
S.R. Shewchuk, Saskatchewan Research Council, Saskatoon, Sask.
R. Grover, Agriculture Canada, Regina, Sask.

EVALUATIONS OF METEOROLOGICAL AND AIR QUALITY DATA COLLECTED NEAR A FOREST CLEARING
D.M. Leahey and M.C. Hansen, Western Research, Calgary, Alta

0830–1030 (ED 1.11)

SESSION 5B: METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS (MOIST)

Chairman / Président: J.W. Loder

SESSION 5B : LES INFLUENCES MÉTÉOROLOGIQUES ET OCÉANOGRAPHIQUES SUR LES ROUTES DU SAUMON (MOIST)

OVERVIEW OF PROJECT MOIST: METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS

Lawrence A. Mysak, Institute of Applied Mathematics, University of British Columbia, Vancouver, B.C.

THE HOMING MIGRATION OF FRASER RIVER SOCKEYE SALMON IN RELATION TO ENVIRONMENTAL CONDITIONS

C. Groot, Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station, Nanaimo, B.C.
T.P. Quinn, School of Fisheries, University of Washington, Seattle, WA

A NUMERICAL MODEL FOR THE INTERANNUAL VARIABILITIES IN THE NORTHEAST PACIFIC OCEAN

William W. Hsieh, Department of Oceanography, University of British Columbia, Vancouver, B.C.

ON THE PHYSICAL OCEANOGRAPHY OF THE "INSIDE PASSAGE", BRITISH COLUMBIA

B.A.Terhart, K.A. Thomson and P. Welch, Department of Oceanography, University of British Columbia, Vancouver, B.C.

VERTICAL MOVEMENTS OF ADULT SOCKEYE SALMON IN B. C. COASTAL WATERS IN RELATION TO TEMPERATURE AND SALINITY

Thomas P. Quinn and B.A. Terhart, Fisheries Research Institute, University of Washington, Seattle, WA

SATELLITE–MEASURED SUMMER SEA SURFACE THERMAL PATTERNS IN THE STRAIT OF GEORGIA, BRITISH COLUMBIA

Andrew Thomas and Bert Mueller, Department of Oceanography, University of British Columbia, Vancouver, B.C.

1030–1050 Coffee / Café

1050–1230 (ED 106.1)
SESSION 6A: EVAPORATION
Chairman / Président: B.E. Goodison
SESSION 6A : ÉVAPORATION

AIRBORNE OBSERVATIONS OF REGIONAL EVAPORATION AND WATER–USE EFFICIENCY MEASUREMENTS
P.H. Schuepp[1], R.L. Desjardin[2], J.I. MacPherson[3], J. Boisvert[2] and L. Austin[1] (1 – Macdonald College, McGill University, Montreal; 2 – Land Resource Research Institute of Agriculture Canada, Ottawa; 3 – National Aeronautical Establishment, National Research Council, Ottawa)

OPERATIONAL MEASUREMENTS OF EVAPOTRANSPIRATION FROM A BOREAL FOREST DRAINAGE BASIN USING AN ENERGY BALANCE/ EDDY CORRELATION TECHNIQUE
B.D. Amiro, Environmental Research Branch, Atomic Energy of Canada Ltd, Pinawa, Man.

EDDY FLUXES OVER A DECIDUOUS FOREST IN SOUTHERN ONTARIO
H.H. Neumann and G. den Hartog, Atmospheric Environment Service, Downsview, Ont.

TEMPORAL VARIABILITY OF RURAL–SUBURBAN BALANCES
H. Cleugh and T.R. Oke, Department of Geography, University of British Columbia, Vancouver, B.C.

1050–1230 (ED 1.11)
SESSION 6B: CANADIAN ATLANTIC STORMS PROGRAM (CASP)
Chairman / Président: G.A. McBean
SESSION 6B : PROGRAMME CANADIEN D'ÉTUDE DES TEMPÊTES DANS L'ATLANTIQUE (CASP)

THE CASP FIELD EXPERIMENT: A PRELIMINARY OVERVIEW OF THE METEOROLOGICAL COMPONENT
R.E. Stewart[1], R.W. Shaw[2] and G.A. Isaac[1], Atmospheric Environment Service (1, Cloud Physics Research Division, Downsview; 2, Bedford Institute of Oceanography, Bedford, N.S.)

STORM RESPONSE IN THE COASTAL OCEAN: PRELIMINARY RESULTS FROM THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)
Peter C. Smith and Carl Anderson, Bedford Institute of Oceanography, Dartmouth, N.S.

OPERATIONAL EXPERIENCE WITH GRAPHICAL DISPLAY STATIONS DURING THE CANADIAN ATLANTIC STORMS PROGRAM
J.D. Abraham, Maritimes Weather Centre, Atmospheric Environment Service, Bedford, N.S. and K.A. Macdonald, Forecast Research Division, Atmospheric Environment Service, Downsview, Ont.

A CANADIAN PAM FACILITY AND ITS DEPLOYMENT IN CASP
Peter A. Taylor, James R. Salmon* and Robert E. Mickle, Boundary Layer Research Division, Atmospheric Environment Service, Downsview, Ont. (* contractor)

WAVE MODEL BUILDING FROM CASP
Fred Dobson and Will Perrie, Bedford Institute of Oceanography, Dartmouth, N.S.

1230–1330 Lunch / Déjeuner

Thursday Afternoon, 5 June 1986
Jeudi apres–midi, le 5 juin 1986

1330–1510 (ED 106.1)
SESSION 7A: PRECIPITATION STUDIES I
Chairman / Président: G.S. Strong
SESSION 7A : ÉTUDES SUR LA PRÉCIPITATION I

THE THREE–PEAK DISTRIBUTION IN EQUILIBRIUM RAIN
Roland List, Department of Physics, University of Toronto, Toronto, Ont.

THEORY OF UNDERWATER SOUND GENERATION BY RAIN
Jeffrey A. Nystuen, Institute of Ocean Sciences, Sidney, B.C.

THE RELATIONSHIP BETWEEN PRECIPITATION AND UNDERWATER SOUND
J.A. Scrimger, JASCO Research, Sidney, B.C.
G.A. McBean, Canadian Climate Centre, Institute of Ocean Sciences, Sidney, B.C.

EVALUATION OF THE EFFECT OF CLOUD SEEDING ON RAINFALL IN SOUTHWESTERN ALBERTA, 1977 AND 1980–84
Keith D. Hage and Nacim Aktary, Meteorology Division, Department of Geography, University of Alberta, Edmonton, Alta

PRECIPITATION DEVELOPMENT IN NATURAL AND SEEDED CUMULUS CLOUDS IN SOUTHERN AFRICA
D.R. Hudak and Roland List, Department of Physics, University of Toronto, Toronto, Ont.

1330–1510 (ED 1.11)
SESSION 7B: COASTAL OCEANOGRAPHY I
Chairman / Président: P. Greisman
SESSION 7B : OCÉANOGRAPHIE CÔTIÈRE I

THE INFLUENCE OF WINTER COOLING ON FJORD DEEP WATER RENEWAL
Dario Stucchi, Institute of Ocean Sciences, Sidney, B.C.

LOW–FREQUENCY CURRENT FLUCTUATIONS IN THE STRAIT OF GEORGIA, BRITISH COLUMBIA
Michael W. Stacey, Stephen Pond and Paul H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, B.C.

THE VERTICAL STRUCTURE OF CURRENTS ON THE NORTHWEST SHELF OF AUSTRALIA AT SUBTIDAL FREQUENCIES
Ian Webster, Department of Physics, Memorial University of Newfoundland, St John's, Nfld

THE ENERGY SOURCE FOR COASTAL TRAPPED WAVES ON THE NEW SOUTH WALES CONTINENTAL SHELF
Howard J. Freeland and John A. Church, Institute of Ocean Sciences, Department of Fisheries and Oceans, Sidney, B.C.

THE EFFECT OF A BAROCLINIC SHEAR CURRENT ON CONTINENTAL SHELF WAVES
David Holland and Ian Webster, Department of Physics, Memorial University of Newfoundland, St John's, Nfld

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1510–1530 Coffee / Café

1530–1730 (ED 106.1)
SESSION 8A: PRECIPITATION STUDIES II
Chairman / Président: R. List
SESSION 8A : ÉTUDES SUR LA PRÉCIPITATION II

A CLIMATOLOGY OF HAIL FOR THE SOUTHEASTERN PRAIRIES OF CANADA
S. LaDochy, Department of Geography, University of Winnipeg, Winnipeg, Man.
A.H. Paul, Department of Geography, University of Regina, Regina, Sask.

AREA AND MAGNITUDE OF CONVECTIVE RAIN PATTERNS
H.C. Vaughan, J.T. Jensen and G.R. White, Departments of Agronomy/Earth Science, Iowa State University, Ames, IA

AN ANALYSIS OF 3– AND 7–DAY GROWING SEASON RAINFALL IN SOUTH–CENTRAL CANADA
Michael B. Richman and Peter J. Lamb, Climate and Meteorology Section, Illinois State Water Survey, Champaign, IL

PATTERNS OF THE MESOSCALE CIRCULATION AND PRECIPITATION OVER THE GREAT LAKES
Andrej Saulesleja, Hydrometeorology Division, Canadian Climate Centre, Downsview, Ont.

BUCKET SURVEYS REVIVED – THE SASKATCHEWAN EXPERIENCE
R.F. Hopkinson, Scientific Services Division, Atmospheric Environment Service, Regina, Sask.

SNOW COVER DETERMINATION ON THE CANADIAN PRAIRIES USING MICROWAVE RADIOMETRY
B.E. Goodison, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.
I. Rubinstein and F.W. Thirkettle, Ph.D. Associates, Downsview, Ont.

1530–1730 (ED 1.11)
SESSION 8B: COASTAL OCEANOGRAPHY II
Chairman / Président: H. J. Freeland
SESSION 8B : OCÉANOGRAPHIE CÔTIÈRE II

THE INFLUENCE OF BUOYANCY FLUX FROM INLETS ON CONTINENTAL SHELF CIRCULATION
Andrew J. Weaver and William W. Hsieh, Department of Oceanography, University of British Columbia, Vancouver, B.C.

OPEN BOUNDARY CONDITIONS IN COASTAL NUMERICAL MODELLING
Louise Royer, Department of Oceanography, Dalhousie University, Halifax, N.S.

ON THE SIGNIFICANCE OF NONLINEAR FRICTION IN TIDAL RECTIFICATION MODELS
Daniel G. Wright and John W. Loder, Atlantic Oceanographic Laboratory, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

LAGRANGIAN FLOWS IN DIXON ENTRANCE: EVIDENCE FOR TIDAL RECTIFICATION
Paul Greisman, Dobrocky Seatech Ltd., Sidney, B.C. and W.R. Crawford, Institute of Ocean Sciences, Sidney, B.C.

LOCALIZED TIDAL STRESS: A GENERATING MECHANISM FOR MESOSCALE EDDIES IN WIDE, COASTAL SEA STRAITS
A. Visser, Marine Sciences Research Center, State University of New York at Stony Brook, N.Y., M. Bowman, Department of Oceanography, University of British Columbia, Vancouver, B.C., and W. Crawford, Institute of Ocean Sciences, Sidney, B.C.

OCEANIC TURBULENCE ON THE CONTINENTAL SHELF
R.K. Dewey[1], W.R. Crawford[2], P.H. LeBlond[1] and A.E. Gargett[2]
(1–Department of Oceanography, University of British Columbia, Vancouver, B.C.; 2–Institute of Ocean Sciences, Sidney, B.C.)

STEADY WIND–DRIVEN UPWELLING IN THE PRESENCE OF A BAROCLINIC COASTALLY TRAPPED JET
A.E. Hay and E.D. Kinsella, Department of Physics and Institute for Cold Ocean Science, Memorial University of Newfoundland, St John's, Nfld

Friday Morning, 6 June 1986
Vendredi matin, le 6 juin 1986

0830–1030 (ED 106.1)
SESSION 9A: GENERAL METEOROLOGY I
Chairman / Président: J.C. McLeod
SESSION 9A : MÉTÉOROLOGIE GÉNÉRALE I

THE RAIN CHEMISTRY OF SASKATCHEWAN
S.R. Shewchuk, Saskatchewan Research Council, Saskatoon, Sask.

MODEL SIMULATIONS OF THE CHEMISTRY OF A RAINBAND
H.G. Leighton, J. Pitre, A.–M. Valton and M.K. Yau, Department of Meteorology, McGill University, Montréal, Qué.

RADIATIVE FEEDBACK DUE TO POLAR STRATOSPHERIC CLOUDS
J.–P. Blanchet, Canadian Climate Centre, Downsview, Ont.

LOW–RELIEF TOPOGRAPHY AND APPARENT OROGRAPHIC ENHANCEMENT OF STORM RAINFALL TOTALS ALONG THE MANITOBA ESCARPMENT
R.A. McGinn, Department of Geography, Brandon University, Brandon, Man. and A.C. Giles, McGill University, Montréal, Qué.

SUMMER OBSERVATIONS OF THE AIR TEMPERATURE DISTRIBUTION IN AN URBAN CANYON WITH AN ASPECT RATIO OF UNITY
Y. Nakamura, Department of Geography, University of British Columbia, Vancouver, B.C. (on leave from Department of Architecture, Kyoto University, Kyoto, Japan)

0830–1030 (ED 1.11)
SESSION 9B: CLIMATE
Chairman / Président: L.A. Mysak
SESSION 9B : CLIMAT

TOGA – THE FIRST YEAR
N. Boston, Pacific Ocean Sciences, Burnaby, B.C.

THE INFLUENCE OF HEAT TRANSFER FROM THE KUROSHIO REGION ON THE ATMOSPHERIC CIRCULATION
Y.P. Zhao, Institute of Oceanology, Academia Sinica, Qingdao, China
G.A. McBean, Canadian Climate Centre, Institute of Ocean Sciences Sidney, B.C.

AN EMPIRICAL STUDY OF THE TROPICAL MIDLATITUDE ATMOSPHERIC TELECONNECTION
Kevin Hamilton, Department of Meteorology, McGill University, Montréal, Qué.

CLIMATE IMPACT ASSESSMENTS OF THE GREENHOUSE EFFECT: FUTURE RESEARCH NEEDS IN THE GREAT LAKES REGION
Stewart J. Cohen, Applications and Impact Division, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

THE RAGS OBSERVATORY FOR MONITORING OF GREENHOUSE CLIMATE CHANGE
W.F.J. Evans, Atmospheric Environment Service, Downsview, Ont.

A STUDY OF DROUGHT ONSET DUE TO INTERACTIONS BETWEEN SOIL MOISTURE AND THE ATMOSPHERIC BOUNDARY LAYER
Trevor Scholtz and Kevin Walsh, MEP Company, Toronto, Ont.
Larry Marht, Oregon State University, Corvallis, OR

1030–1050 Coffee / Café

1050–1230 (ED 106.1)
SESSION 10A: GENERAL METEOROLOGY II
Chairman / Président: D.G. Steyn
SESSION 10A : MÉTÉOROLOGIE GÉNÉRALE II

THE PRESCRIBED FOREST BURN AT CHAPLEAU: A FIELD EXPERIMENT FOR NUCLEAR WINTER STUDIES
W.F.J. Evans and L. Poulin, Atmospheric Environment Service, Downsview, Ont.

SIMULATION OF SOLAR TIDES IN THE CANADIAN CLIMATE CENTRE GENERAL CIRCULATION MODEL
Francis Zwiers, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.
Kevin Hamilton, Department of Meteorology, McGill University, Montréal, Qué.

MONTHLY PREDICTION BY THE ANALOGUE METHOD
A. Shabbar, Canadian Climate Centre, Downsview, Ont.

SIMULATING PRAIRIE WHEAT GROWTH WITH THE CERES MODEL
Earle A. Ripley, Department of Crop Science and Plant Ecology, University of Saskatchewan, Saskatoon, Sask.

1050–1230 (ED 1.11)
SESSION 10B: SEA STATE AND SEA ICE
Chairman / Président: W.S. Appleby
SESSION 10B : ÉTAT DE LA MER ET DES GLACES DE MER

SIMULATIONS OF FIRST–YEAR SEA–ICE CLIMATOLOGY AT THREE ARCTIC LOCATIONS
R. Gabison, Forecast Research Division, Atmospheric Environment Service, Downsview, Ont.

A NOMOGRAM FOR PREDICTING THE MOVEMENT OF OIL SLICKS
V.R. Neralla, Forecast Research Division, Atmospheric Environment Service, Downsview, Ont.

OBSERVATION AND MODELLING OF ICEBERG DRIFT
Stuart D. Smith, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

A SECOND–GENERATION SHALLOW WATER RESIO WAVE MODEL
Will Perrie, Wolfgang Rosenthal and Bechara Toulany, Bedford Institute of Oceanography, Dartmouth, N.S.

POSTERS / AFFICHAGE

ENVIRONMENT CANADA'S NATIONAL CLIMATE DATA ARCHIVE
Mike Webb and Frank Manning, Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ont.

POTENTIAL ECONOMIC IMPACT ON PRAIRIE AGRICULTURE OF IMPROVEMENTS IN SHORT–RANGE CLIMATE PREDICTION AND MEDIUM–RANGE WEATHER FORECASTS, AND THE POSSIBLE INFLUENCE OF RADARSAT AND OTHER SPACEBORNE SENSOR DATA
A.K. McQuillan, RADARSAT Project Office, Ottawa, Ont.

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CANADIAN HYDROLOGY SYMPOSIUM
SYMPOSIUM CANADIEN D'HYDROLOGIE

Preliminary Program/Programme Préliminaire

Wednesday 4 June 1986
Mercredi le 4 juin 1986

1030–1200	**Plenary Session** **Session Plénière**

1030	SURFACE WATER R.B. Goodwin
1115	GROUNDWATER R. Farvolden

1330–1630	3 simultaneous sessions – 30 min for each presentation 3 sessions simultanés – 30 min pour chaque présentation

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CHS SESSION A: (ED 106.2)

Climatological Aspects of Droughts on the Canadian Prairies
B. Dey

Is the Prairie Climate Becoming Drier?
E.A. Ripley

Climatology of Prairie Drought in a General Circulation Model
N.E. Sargent

Water Budget Model Statistics for Drought Monitoring
L.O. Mapanao and P.T.Y. Louie

The Value of Satellite Rainfall Estimation Techniques for Drought Monitoring
W.D. Hogg et al.

CHS SESSION B: (ED 1.20.1)

An Overview of Water Management Operations in the South Saskatchewan River Basin in Alberta
B. Kuhnke

Effects of Drought in the Operation of Lake Diefenbaker
D.R. Richards

Interprovincial Water Management in Drought Periods
A.J. Chan and R.B. Goodwin

The Implications of Apportionment to Water Management in the Poplar River Basin
W.L. Dybvig

Water Management in the St Mary and Milk River Basins in Time of Drought – A Saskatchewan Perspective
A. Banga et al.

CHS SESSION C: (ED 1.7)

Developing and Managing Livestock Water Sources to Ensure Water Supplies During Prolonged Drought Periods
E. Caligiuri

The Impact of Drought on Canadian Spring Wheat Production
D.W. Stewart

The Potential for Increasing Water Supply in the Saskatchewan River System by Forest Harvesting
R.H. Swanson and P.Y. Bernier

Carriage Losses in Natural Channels in Southern Alberta
W.A. Rozeboom and S.J. Figliuzzi

The Variation of Low Flow Channel Regime Components in a Multiple Use River
W. Obedkoff

Thursday 5 June 1986
Jeudi le 5 juin 1986

0900–1630 3 simultaneous sessions – 30 min for each presentation
3 sessions simultanés – 30 min pour chaque présentation

CHS SESSION A: (ED 106.2)

Agricultural Drought: Precipitation Deficiency and NOAA AVHRR Indices Comparisons
N.A. Prout et al.

An Operational Palmer Drought Severity Index Program for Canadian Synoptic Stations
P.Y.T. Louie

Weather Based Drought Early Warning and its Role in Government Policy
J.A. Dyer

Cyclic Variations in Canadian and United States Drought
S. Hameed and R.G. Currie

The Effects of Climate on Prairie Lakes
J. Whiting

An Analysis of Snowcovers at a Site in the Drought–Prone Region of the Prairies
H. Steppuhn

Reduction of Drought Effects on the Prairies by Snow Management
W. Nicholaichuk and D.M. Gray

Combined Subsoiling and Snow Management for Drought Attenuation
R.S. Granger and D.M. Gray

Median Drought Flows at Ungauged Sites in Southern Ontario
P.J. Pilon and R. Condie

Impacts of Drought Flows on Receiving Water Assessment in Ontario
L.A. Logan

CHS SESSION B: (ED 1.20.1)

Frequency of Hydrological Droughts
J.D. Rogers

Low Flow Estimation from Scarce Data
J.S. Mattison and S.O. Russell

Cause and Effect of Low Flows on the Peace–Athabasca Delta
I. Muzik

Low Flow Characteristics of Selected Streams in Southern Manitoba
P.M. Pelletier et al.

Recent Low Flow Years on the Oldman River
S. Ferner

Groundwater Level Observation Well Network in Saskatchewan, Canada
H. Maathuis

A Water Supply System for Nokomis, Saskatchewan
W.A. Meneley

A Conjunctive Water–Use Strategy Implemented in Humboldt, Saskatchewan
A.M. Vermette and J. Lebedin

Irrigation Potential Using Groundwater in Saskatchewan
U. Roeper and T. Rey

Irrigation with Groundwater
J.A. Gillies et al.

CHS SESSION C: (ED 1.7)

Viability of Irrigation in the Prairie Provinces Under a Non–Guaranteed Water Supply Condition
W.H. Jones and V.B. Yarotsky

Choice of Irrigation Development Technology for Drought Proofing: A Case Study of Small Scale vs. Large Scale Irrigation
K.K. Klein et al.

Trade–Offs Between Irrigation Development and Power Generation in Saskatchewan
K. O'Grady et al.

Drought Monitoring, Designation and Response – An Overview of Organization, Methodology and Procedure
E.G. O'Brien

Drought Perception: An Analysis of Selected Press Coverage of the 1980 Drought on the Canadian Prairies
J.D. Rogers

Economic Evaluation of the Prairie 1984–85 Drought
R.A. Fautley and S.N. Kulshreshtha

An Economic Overview of Drought Impacts on the Manitoba Economy
L.M. Arthur and D.F. Kraft

The Value of Water–Based Recreation Losses Associated with Drought: The Case of Lake Diefenbaker 1984
R.D. Bjonback

Choice of Appropriate Drought Mitigating Policy: A Case Study of Irrigation Development and Ad Hoc Drought Relief Aid
S.N. Kulshreshtha et al.

Investigation of the Economic and Social Impacts of the 1984 and 1985 Agricultural Droughts on the Prairies and the Economic Mitigation Effects on Various Government Programs
R.A. Fautley

Friday 6 June 1986
Vendredi le 6 juin 1986

0900–1000 2 simultaneous sessions – 30 min for each presentation
2 sessions simultanés – 30 min pour chaque présentation

CHS SESSION A: (ED 106.2)

The Groundwater Resources of Saskatchewan's Deep Buried–Valley Aquifers
G. van der Kamp

Establishing a Groundwater Rechard Research Program in Saskatchewan
J.A. Gillies

CHS SESSION B: (ED 1.20.1)

Influence of Cloud Cover on Moderating Evaporation Demands in a Prairie Environment
O. Mudiare et al.

Testing Reservoir Reliability
M.V. Thompson and J. Snidal

1030–1115 HYDROLOGY OF DROUGHTS (ED 106)

E.F. Durrant

1115–1200 CHS:86 WRAP–UP AND REVIEW (ED 106)

Identifying Research Needs
J. Maybank

Abstracts / Résumés

0900–1000: (ED 106) **Wednesday / Mercredi**
SESSION 1: WELCOMING REMARKS AND PLENARY SESSION
SESSION 1: MOT DE BIENVENUE ET SESSION PLÉNIÈRE

DROUGHT: A GLOBAL PERSPECTIVE
G.A. McKay

Drought is ubiquitous, but most prevalent in semi-arid lands. Developing countries with a strong dependence on domestic agriculture are particularly vulnerable. The highly diversified economies of developed countries mitigate its effects, but do not eliminate major human and economic stress.

Drought is the result of an abnormal water deficiency. Its effects differ among crops, and entities such as water resources, forests, economies, thereby complicating definition. It occurs in many time- and space-scales, the impact increasing with the size of the area affected, duration, intensity and vulnerability. Interdependencies make regional droughts a global affair. Climate is invariably a factor, but the end-issues are environmental and socio-economic. Increasing demands on water and land resources result in continually increased vulnerability.

Defending against drought requires emergency- to long-term planning and the pooled wisdom of many disciplines. Major water development projects must be examined carefully to ensure one problem is not exchanged for another. Conservation and adaptation to climate variability are basic components of enduring strategies.

1030–1200 (ED 106.1) **Wednesday / Mercredi**
SESSION 2: PLENARY SESSION, OCEANOGRAPHY AND METEOROLOGY
SESSION 2: SESSION PLÉNIÈRE, OCÉANOGRAPHIE ET MÉTÉOROLOGIE

RECENT DEVELOPMENTS IN OCEAN CIRCULATION
Peter B. Rhines

There has been much progress recently in theory and numerical simulation of the general circulation. Models with simple, layered representations of the density field have large-scale ("planetary-geostrophic") dynamics that is strongly nonlinear yet the problem can sometimes be reduced to one of linear propagation along characteristics. Both steady and time-dependent solutions are found for the wind-driven subtropical gyres, and for idealized representations of the deeper circulations driven by

heating, cooling and evaporation. An esential element of the new theories is that they combine the inward propagation of air-sea boundary conditions with internal readjustment by mesoscale eddy mixing. Numerical circulation models have been "aimed" at these ideas, and considerably enrich the story. By explicitly calculating eddy stirring they can spell out the detail of critical flow regions like boundary currents, shallow regions where the constant potential-density horizons crop out at that sea surface and tropical regions of eddy generation.

Perhaps the most important result of the work with theory is that it has led us to make maps of the potential vorticity field, Q, of the actual general circulation; Q is essentially the product of the Coriolis frequency and the vertical stability. These maps are full of detail, both of kinematic nature (for potential vorticity is a "tracer" that is nearly conserved following the paths of flow) and dynamically (for the circulation itself is largely determined from knowledge of Q). We now have a large suite of tracers that mark the circulation: dilute chemicals, biological communities and the basic field variable, Q, itself.

CO_2-INDUCED EQUILIBRIUM AND TRANSIENT CLIMATE CHANGES
M. Schlesinger

Abstract not available.

1330–1510 (ED 106.1) **Wednesday / Mercredi**

SESSION 3A: BOUNDARY-LAYER MODELLING
SESSION 3A : MODÉLISATION DE LA COUCHE LIMITE

MODELLING OF TURBULENCE CHARACTERISTICS OVER LOW HILLS
A.C.M. Beljaars, J.L. Walmsley and P.A. Taylor

In the past few years, extensive studies have been done to measure and model the mean flow over low hills. A high-resolution model (MS3DJH) has been developed to describe the flow over three-dimensional hills. This model has proven to be very successful in predicting the mean wind, which is very useful for windmill siting. For fluctuating load on wind turbines, the diffusion of pollutants, and dry deposition of chemical components in complex terrain, it is not sufficient to know the mean flow; the turbulence characteristics also have to be determined.

To predict turbulent stresses and turbulent intensities, a more sophisticated closure is needed than for the mean flow. In this paper results are shown from a Mixed Spectral Finite Difference (MSFD) model with mixing length and E-ε closure. The equations are linearized around an unperturbed upstream profile. This makes it possible to Fourier transform in the two

horizontal coordinates, which leads to a very efficient code even for high resolution runs. The resulting ordinary differential equations in the vertical are solved with a finite-difference technique. The latter gives sufficient flexibility in closure schemes. The E-ε closure is based on the eddy diffusivity concept where the diffusivity is expressed in the turbulent kinetic energy E and the dissipation rate ε. Prognostic equations are used for E and ε.

Shear stress profiles are compared with data from the Askervein field experiment. Results show that in the outer layer (at distances from the surface of the order of the horizontal hill size) an equation for the shear stress is also needed to allow for sufficient memory effects. With this closure, including equations for E-ε and τ, the measured stress profiles are reproduced reasonably well.

THE EFFECT OF VERTICAL RESOLUTION ON BOUNDARY-LAYER PARAMETERIZATION
Yves Delage

Atmospheric circulation models for numerical weather prediction or climate study carry in general very few layers in the boundary layer. What are the effects of this low resolution and what benefits are expected from a more detailed representation of the boundary layer?

Different formulations are studied with various vertical resolutions on selected stability regimes. Results should help modelers choose a boundary-layer parameterization scheme with appropriate resolution.

ONE-LEVEL MESOSCALE NUMERICAL MODELLING OVER THE LOWER FRASER VALLEY OF BRITISH COLUMBIA
Keith W. Ayotte and D.G. Steyn

This paper describes the authors' use of a one-level, sigma coordinate numerical model to simulate surface winds above the Lower Mainland of British Columbia. The model makes use of 850- and 700-mb pressure surfaces and temperature fields as upper boundary conditions. As well as the background synoptic forcing, the model takes into account spatially varying surface roughness and diabatic heating. The vertical temperature structure is parametrized through temperature at the surface. This vertical structure is vertically integrated to produce surface fields.

Model runs presented are compared with measured surface winds (10-m) from a twenty-three station network over the model domain. Aspects of measured vertical temperature structure and presented with regard to their effects on initialization techniques and subsequent development of time-dependent fields.

APPLICATION OF A 3-D MESOSCALE MODEL TO WINDFIELD PREDICTION IN THE LOWER FRASER VALLEY, B.C.
I.G. McKendry and D.G. Steyn

The summertime low-level windfield over the Lower Fraser Valley is strongly influenced by thermal forcing associated with the local distribution of land, sea and elevated terrain. The resultant circulations have important

implications for air quality. Preliminary results from the application of the Colorado State University mesoscale model to the summertime case are presented. Several problems associated with model initialization and terrain representation are also discussed.

A scheme for model validation by statistical comparison with continuous surface wind data from a network of 23 sites as well as tethersonde soundings from a single location is described. In order to establish the competence of the model in this environment, the scheme is used to compare model predictions with observed low-level windfields associated with significant atmospheric oxidant episodes.

1330–1510 (ED 1.11) Wednesday / Mercredi

SESSION 3B: DEEP-SEA OCEANOGRAPHY
SESSION 3B: OCÉANOGRAPHIE DES EAUX PROFONDES

ON THE GEOGRAPHIC VARIABILITY OF MESOSCALE STATISTICS AND INFERRED DYNAMICS IN THE PACIFIC AND ATLANTIC OCEANS

K. A. Thomson

Quasi-synoptic expendable bathythermograph (XBT) sections have been acquired from the Canadian Armed Forces, the United States Navy and the National Oceanographic Data Center for the Pacific and Atlantic Oceans. On the basis of these sections and the results of previous studies using non-synoptic data sets, six geographic regions were defined: the high eddy activity regions of the Northwest Pacific and Northwest Atlantic, and the low eddy activity regions of the Northeast Pacific, Northeast Atlantic, South Pacific, and South Atlantic. Spatial series of four parameters were obtained for each section: the mixed-layer temperature, the average temperature from 150 to 200 m, the average temperature from 350 to 400 m and the geopotential anomaly (0-4000 kPa). Average wavenumber spectra for the mesoscale pertubations of each parameter were estimated for the six geographic regions, the combined high-energy areas and the combined low-energy areas.

The geographic variability of the dominant length scales and the spectral shapes of each parameter will be discussed and the differences between the high and low eddy energy areas will be examined. The dynamics of each region, and the high and low energy areas will be inferred by evaluating the Rossby Wave steepness parameter ($M = V/\beta L^2$) and comparing the spectral power laws of the temperature and velocity spectra to existing models of geophysical turbulence.

SIMULATION OF RADARSAT SPACEBORNE SAR BY AIRBORNE SAR FOR IMAGING OCEAN WAVE PROPERTIES AND SHIP TARGETS

A.S. Bhogal and N.G.S. Freeman

RADARSAT is Canada's first proposed earth resources satellite scheduled for launch in mid-1991. It will provide information on Canada's vast natural environment including oceans, ice, crops, forests and geological structures. In order to see how well airborne SAR can simulate spaceborne SAR, an analysis of extended swath optical data in X and L bands acquired during the Cape Sable experiment was carried out. Ship returns and parameters like incidence angle and slant range to target were evaluated. A spatial series analysis of SAR imaged wave fields was also carried out on the Cape Sable digital data in order to compute the wave number spectra of the radar return power and the direction of propagation of the waves. The dominant wavelengths were also computed. These results were then compared against those from a WAVEC buoy moored in the area at the time of the experiment. Results from the ship detection experiment indicate that radar returns in the L-band optical are generally the strongest. The strength of the signal returns appears to be independent of aircraft altitude or incidence angle. The L-band returns are the strongest when there is significant ship motion because the L-band integration time is longer thus causing greater image defocus or azimuthal smear. The results from airborne SAR have been related to those expected from spaceborne SAR by the slant range to velocity ratio which will be about 150 seconds for RADARSAT. The characteristics of wave fields imaged by airborne SAR show good agreement with those from WAVEC buoy power spectra when subscenes are extracted from the middle portion of SAR digital images. The variability in the estimate of wave parameters within a particular SAR scene was assessed by using nine different subscenes chosen at regular intervals throughout the scene. In both the range and azimuth directions, the standard deviation was 10m for wavelength and 5^{o} for wave direction; however, the signal-to-noise ratio for the X-band was considerably lower in the near and far edge subscenes due to antenna pattern banding and low intensity, respectively.

A COMPARISON BETWEEN GEOSTROPHIC AND DIRECTLY MEASURED SURFACE WINDS OVER THE NORTHEAST PACIFIC OCEAN

R.F. Marsden

A grid of geostrophic wind estimates, sampled at six-hourly intervals over thirty-two years, was compared to a long time series of directly measured surface winds at Ocean Weather Station P and at four coastal land observation sites. A cross-spectral analysis revealed that coherences were high over the open ocean for periods greater than four days. The coherence level decreased for shorter periods. For periods less than 2.5 days the geostrophic wind could not be considered a good predictor of the open ocean surface winds. The coherences between the geostrophic winds and surface winds measured at the coastal stations showed considerable variability compared to those measured at Station P. A bulk regression analysis also revealed considerably lower correlations between geostrophic and surface winds at the land stations. A

regression of both wind types against sea-level at Tofino was performed to determine the wind direction forcing the largest fluctuations. A rotation of the wind to an empirically determined alongshore direction showed that, at this orientation, the geostrophic winds and the directly measured winds were in close agreement. A frequency-dependent empirical orthogonal function analysis indicated modal separations into a joint oscillation of wind and sea-level, an oscillation of sea-level alone, and an oscillation of wind alone.

CHARACTERISTICS OF CURRENT FIELD IN THE NORTHEASTERN GRAND BANKS
C.L. Tang

Currents in the Grand Banks are characterized by high variability and small mean motion. The kinetic energy of fluctuating currents is greater than that of mean currents by one order of magnitude. The weak mean flows are associated with small mean horizontal density gradients on the Grand Banks. The fluctuating flows are concentrated in three frequency bands corresponding to tides, inertial motion and several-day low frequency motion. The generation mechanisms, depth variation and seasonal variation of the currents are discussed. The effects of the meandering of the Labrador Current on the current field is speculated. A field program to study current variability in the Hibernia area is described.

THE INTERACTION OF TOPOGRAPHY WITH THE BAROTROPIC AND BAROCLINIC LABRADOR CURRENT
David Greenberg, Brian Petrie and Dan Wright

Two numerical models give indications of how the Labrador Current interacts with topography. The first model simulates the barotropic flow on and around the Newfoundland Shelf including the Flemish Cap, as driven by different flows on the northern boundary of the model, taken across the southern Labrador Shelf. The deep sea is restricted to a maximum depth of 2,000 m. The preferred path of the barotropic Labrador Current is through Flemish Pass with only minor flows around Flemish Cap or on the inner shelf. Much of the transport is dispersed into the deep sea, but this must be reconciled with boundary conditions.

The second model is an idealized, two layer, rectangular model with dimensions roughly those of the Labrador Shelf and adjacent deep sea, with the depth of the deep sea set to 1,000 m. This model indicates how topography and stratification combine to produce a strong current in the surface layer and much weaker currents in the bottom layer at the shelf break.

THE EFFECT ON THE BRIER SKILL SCORE OF SMOOTHING PROBABILITY FORECASTS

L.J. Wilson and R. Sarrazin

The Brier Skill Score is frequently used to measure the skill of weather forecasts expressed in probabilistic terms. The score is attractive because it is simple to calculate and it measures skill relative to a standard, unskilled forecast, usually a climatological frequency of occurrence. When climatology is the standard, the Brier Skill Score gives the percentage of predictand variance explained by the forecast.

Two important attributes of probability forecasts are their reliability, the degree to which the forecast probabilities agree with the observed frequency of occurrence of the event; and their sharpness, the power of the forecast for decision-making, usually related to the tendency of the probabilities to approach the limits of 0% and 100%. With a given imperfect forecast system, reliability and sharpness are both present to some degree, and it is possible to design forecast products to be more reliable at the expense of sharpness and vice versa. The Brier Skill Score, a quadratic scoring rule, weights large errors more heavily than small errors, and therefore relatively higher scores to forecasts which are reliable.

We conducted an experiment using forecast data to determine the effect of smoothing of a set of probability forecasts on the Brier Skill Score. Empirical precipitation (POP) forecast equations were developed and run on a one-year sample of forecast data from the high-resolution spectral model. Reliabiliity curves and the Brier Skill Score were computed from the results, and a polynomial was fit to the reliability curves. The curves were then adjusted to near-perfect reliability and the scores recomputed.

Results showed that the Brier Skill Score can be increased by up to 15% simply by smoothing the forecasts so that significant unreliability is prevented. The improvements were greater for larger forecast projection times, and for stations where the forecast element is a relatively rare event.

These results should be useful in the interpretation of the Brier Skill Score especially when it is used to choose between methods which exhibit different reliability and sharpness characteristics such as MOS and perfect prog methods.

A NUMERICAL MODEL FOR THE PREDICTION OF MESOSCALE PRECIPITATION AND APPLICABLE TO THE HP 1000 MINICOMPUTER

R. Gabison

A nested-grid mesoscale precipitation prediction model has been developed and applied to the snow belt region of Ontario and to Newfoundland. The horizontal grid has 18 x 18 grid points, 31.75 km apart. The vertical resolution consists of 17 levels, 25 mb apart and extending from 1000 to 600 mb. The model has been designed to run on the HP 1000 minicomputer where it executes in approximately 20 minutes.

In the Planetary Boundary Layer, Ekman winds, topography, surface roughness, momentum, moisture and heat flux divergence are some of the main forcing terms. Vertical motion is determined by means of low-level convergence in the PBL, by differential vorticity advection, by the Laplacian of the thermal advection and by sensible and latent heat. Both large-and small-scale precipitation formulation are included in the model. The latter is determined by a Kuo convective scheme.

The model has been extensively tested over the Ontario snow belt. In the context of the CASP experiment, the winter of 1985/1986 is being used to assess the model's performance over Newfoundland. The formulation of the model over both regions and its performance over the Ontario snow belt are presented in this paper.

FORECASTING MESOSCALE CONVECTIVE REGIONS: I. DOWNSCALE SYNOPTIC EFFECTS AND AN OPERATIONAL TECHNIQUE

G.S. Strong

Most meteorologists agree that the mesoscale pre-convective environment is organized by synoptic-scale processes, and that the larger scale may even exert some control over the severe storm throughout its life cycle. Dynamic theory and diagnostic studies show that interactions do occur between the scales of motion, with the implication that energy is exchanged both upscale and downscale. In the past, however, convective research has concentrated on the "visible" mature storm period, and has tended to neglect the pre-storm period and larger scale environment. This may have inadvertently restricted opportunities to determine why storms formed, and how they might be predicted.

The SESAME AVE-V mesoscale data set (Oklahoma, 1979) provided a unique opportunity to examine a severe convective complex in detail. For this study, emphasis was on the pre-storm environment and our current forecasting capability. Analyses of vertical motion, surface convergence, low-level moisture, surface heating, and jet streaks, are compared qualitatively with satellite imagery, radar composites, and surface observations of this storm period. The results reveal that low-level ascent and surface convergence existed up to six hours prior to first radar echoes. Furthermore, it is shown that the location, relative size, intensity, and motion of this and other convective complexes, can be predicted with a high degree of accuracy at least

3-6 hours in advance. The prediction method is accomplished without the benefit of the mesoscale upper-air data, using a technique developed for forecasting hailstorms in Alberta.

MARWORDS - AN EXPERIMENT IN COMPUTER-WORDED FORECASTS
J. Carr McLeod

An experiment in the generation of computer-worded forecasts is described. The experiment consisted of the analysis of a large number of complex marine forecasts (FPCN25 CWEG) for vocabulary and syntactic structure. Coding was completed on various CPUs using a PROLOG dialect.

This paper will present the results of early tests of the software. The system's ability to generate acceptable worded forecasts and to group meteorologically similar regions will be demonstrated.

Finally, plans for the extension of the structure of this system to other operational products will be presented.

SURFACE WIND AND STRESS EVALUATIONS USING THE V9HR AND FEM OPERATIONAL MODELS
S.L. Csanady

The investigation was mainly concerned with the verification of "surface" winds from the V9HR and FEM models over the CASP grid area.

Based on five selected test cases during the winter months in 1985 the V9HR "surface" winds were found to be too evenly distributed in the 5-15 knots range and never contained higher speeds than 30 knots. Conversely in one test case 5% of the total grid points were forecast over 30 knots by the finite-element |FEM| model as well as by the first computational level of the V9HR model.

An attempt has been made to explain the apparent shortcomings of these transformed "surface" winds in terms of the Monin-Obukhov similarity theory and relate differences to parametrization of surface variables in the two models.

The stress evaluations also produced some deficiencies in terms of theoretical interpretation, inasmuch as verification stresses were consistently higher than V9HR stresses even though the ~ 80-m V9HR winds were consistently higher than the verifying winds.

SEMI-LAGRANGIAN ADVECTION ON A GAUSSIAN GRID

Harold Ritchie

The treatment of advection is related to the stability, accuracy and efficiency of models used in numerical weather prediction. In order to remain stable, conventional Eulerian advection schemes must respect a Courant-Friedrichs-Lewy (CFL) criterion, which limits the size of the time step that can be used in conjunction with a given spatial resolution.

In recent years, tests with grid-point models have shown that semi-Lagrangian schemes permit the use of large time steps (roughly three to six times those permitted by the CFL criterion for the corresponding Eulerian models), without reducing the accuracy of the forecasts. This leads to improved model efficiency, since fewer steps are needed to complete the forecast.

Can similar results be achieved in spectral models? This paper examines the semi-Lagrangian treatment of advection on the Gaussian grid used in spectral models. Interpolating and noninterpolating versions of the semi-Lagrangian scheme are applied to the problem of solid body rotation on the globe, and their performance is compared with that of an Eulerian spectral treatment. It is shown that the semi-Lagrangian models produce stable, accurate integrations using time steps that far exceed the CFL limit for the Eulerian spectral model.

FORECASTING OF EAST COAST STORMS WITH A HIGH RESOLUTION REGIONAL MODEL DURING CASP

C. Chouinard, R. Benoit, J. Mailhot and M. Roch

As part of CASP (Canadian Atlantic Storms Program), RPN has set up a modified version of the Canadian regional finite-element model for the short-term (36 hours) forecasting of East Coast winter storms. The model was executed daily during the CASP field phase (15 January - 15 March 1986).

The main features of the CASP version include a domain with higher horizontal resolution (reaching 100 km in the region of interest as compared to 190 km in the current continental version), a modified physics package (Kuo scheme, split phase precipitation, ...) and improved surface analyses and geophysical fields (better definition for sea surface temperature, orography, geography, ...). Another key modification concerns the injection of high-resolution GOES satellite data to enhance the initial moisture analysis (particularly in data-sparse areas) and thereby affect the condensation process during the early hours of the integration.

Interesting cases of storm development will be examined and comparisons will be made between the continental and the meso-scale version of the model. The impact of selected model features on the forecasts will be assessed.

INSTABILITY OF PLANETARY WAVES IN A HIGH VERTICAL RESOLUTION MODEL
Charles A. Lin

A high vertical resolution model is used to investigate the instability of free and forced planetary waves. The model is linear, quasi-geostrophic, β-plane, and has at least 25 levels in the vertical. The high vertical resolution, together with the use of a height-dependent Newtonian cooling coefficient, permit accurate simulations of planetary wave structure. The basic state consists of a zonal flow with linear vertical shear, and superposed finite amplitude stationary planetary waves of zonal wavenumber 2, with no meridional variation. In the case of forced waves, the forcing is provided by large-scale topography of the same zonal wavenumber. The perturbation consists of harmonics of the basic zonal wavenumber, with a non-trivial meridional structure in general.

The linear response to the baroclinic zonal flow alone is an unstable mode of synoptic zonal scale, with no meridional variation. The response to the combined zonal flow and planetary wave consists of a mode with a broad zonal Fourier spectrum, with significant amplitudes at the planetary scale. A meridional scale is also selected. The scale selection mechanism is interpreted in terms of zonal and meridional perturbation heat fluxes. The ratio of the real part of the eigenvalue of the unstable mode to its imaginary part is used as a measure of the degree of stationarity of the mode. Comparisons of the perturbation wave structures obtained from free and forced planetary waves in the basic state are made.

DYNAMICS OF THE STRATOPAUSE SEMIANNUAL OSCILLATION
Kevin Hamilton

An attempt was made to use observations to determine the nature of the eddy contributions to the mean zonal momentum balance in the region near the tropical stratopause that is dominated by the semiannual oscillation (SAO). Since direct observations of the eddy wind field in this region are very limited, an indirect procedure was employed. The first step in this process was the computation of diabatic heating rates using observed temperatures in a sophisticated radiative transfer code. These heating rates were then employed to calculate the residual mean meridional circulation. The advection of mean zonal momentum and the Coriolis torque associated with the residual circulation could then be computed. The difference between this contribution to the zonal mean momentum balance and the actual observed acceleration of the zonally-averaged zonal wind was ascribed to the Eliassen-Palm (EP) flux convergence associated with eddies of all types.

Meridional profiles of the inferred EP flux convergence were produced for each month of the year at the 1.0-and 0.4-mb levels. At both levels there was an indication of the presence of an equatorially-centred westerly contribution to the EP flux convergence. This is consistent

with the suggestion of Hirota and others that the westerly accelerations in the SAO are provided by a dissipating equatorial Kelvin wave. In fact at 1.0 mb the total EP flux convergence at the equator is always westerly; this suggests that the dominant contribution to the easterly acceleration near the equator comes from advection by the residual circulation, in accord with the model results of Holton and Wehrbein. However, there is an indication of significant easterly eddy forcing of the mean flow away from the equator in the winter hemisphere. This forcing is presumably due to the equatorward propagation of planetary waves generated in the extratropics. This easterly eddy forcing becomes more significant at the 0.4-mb level, and the total EP flux convergence on the equator becomes easterly during the easterly acceleration phase of the SAO.

THE GROWTH AND DECAY OF ATMOSPHERIC KINETIC ENERGY

Steven J. Lambert

A statistical study of the spectral kinetic energy budget equation was done to determine the processes which are important in explaining the day-to-day changes in the kinetic energy. Results will be presented for fifteen zonal wavenumbers for the Northern and Southern Hemispheres using three years of data from the ECMWF/WMO data set.

OBSERVATIONAL STUDIES OF ATMOSPHERIC NORMAL MODES

Kevin Hamilton and Rolando R. Garcia

The spectrum of atmospheric motions is known to include some fairly regular, global-scale, zonally travelling waves that can be identified with the resonant normal modes of an idealized atmosphere with no mean winds or meridional temperature gradient. The most familiar example is the "five-day wave" which is believed to be the (1,1) Rossby normal mode. In the first part of the investigation reported here, seventeen years of twice-daily Northern Hemisphere sea-level pressure analyses were subjected to space-time spectral analysis to examine the interannual variability of the (1,1) Rossby mode. The most striking result of this analysis was an indication that the amplitude of the (1,1) mode depends on the phase of the Southern Oscillation. In particular, the five-day wave tends to be stronger (weaker) in years with anomalously warm (cold) tropical Pacific sea surface temperatures.

Virtually all previous work in the field of atmospheric normal modes has focussed on the relatively long-period Rossby waves. However, the theory does predict the existence of much shorter period Kelvin and gravity wave modes. In the present investigation long time series of hourly barometric observations from several tropical stations were employed in a search for these high frequency modes. Evidence was found for spectral peaks in these data that can be identified with various Kelvin and gravity wave normal modes.

GENERAL CIRCULATION MODEL SIMULATION OF NORMAL MODES: STRUCTURES AND ENERGETICS
Kevin Hamilton

Atmospheric simulations produced by the Canadian Climate Centre general circulation model (GCM) were examined to detect the presence of atmospheric Rossby normal modes such as the "five-day" and "sixteen-day" waves. Space-time spectra of the simulated fields were computed; these revealed peaks at the theoretically predicted scales and frequencies for at least the first three gravest modes of both zonal wavenumbers one and two. By filtering time series of simulated geopotential and wind in narrow bands around these peaks, the vertical and meridional structure associated with these prominent oscillations was revealed. These structures were in very good agreement with those theoretically predicted for the Rossby normal modes.

The filtered time series from the GCM are now being analyzed to determine the major sources of excitation and dissipation for the normal modes.

0830–1030 (ED 106.1) **Thursday / Jeudi**

SESSION 5A: MESOSCALE AND BOUNDARY-LAYER STUDIES
SESSION 5A: ÉTUDES DE L'ÉCHELLE MOYENNE ET DE LA COUCHE LIMITE

MESOSCALE CIRCULATIONS FORCED BY THE MELTING OF SNOW IN THE ATMOSPHERE
Kit K. Szeto, Charles A. Lin, and Ronald E. Stewart

The melting of snow extracts latent heat of fusion from the environment. A nonlinear two-dimensional and time-dependent numerical model is used to study the response of the atmosphere to this cooling-by-melting mechanism under various basic conditions.

The melting-induced circulations consist essentially of a forced response resembling a gravity current and transients which are gravity waves. The gravity current is driven by the density contrast between the melting-chilled air and the ambient air. Embedded in the gravity current are smaller scale motions due to convective and/or shear instabilities. In all cases examined, the strongest perturbations in the wind field occur in the vicinity of the 0°C level. This is because melting of snowflakes occurs only in a shallow layer just beneath the 0°C level.

Model results agree well with available observations: the melting-induced dynamics alone can reproduce most of the kinematic characteristics of the severe frontal squall line observed by Carbone (1982). Applications to other mesoscale precipitation systems are also made.

MESOSCALE STRUCTURE OF THE BOUNDARY LAYER DURING STREX
G.A. McBean

During the Storm Transfer and Response Experiment (STREX) aircraft measurements were made in the boundary layer over the ocean for a variety of meteorological conditions. In this paper the mesoscale variations in the winds, temperature, humidity and turbulence will be presented for a cold air outflow from the coast and for a post cold front situation. The relationships between the turbulence and the mean structure will be discussed. The results will be compared with other studies and models.

THE CLIMATOLOGY OF SEA BREEZES IN THE LOWER FRASER VALLEY, B.C.
D.G. Steyn and D.A. Faulkner

Hourly wind speed and direction data over a ten-year period from two stations in the lower Fraser Valley, B.C. are analysed in order to characterize sea breezes in the region. A set of criteria based on the diurnal reversal of wind direction, the Biggs and Graves lake-breeze index, and the number of sunshine hours is used to identify sea-breeze days. Statistics are presented that describe the occurrence, duration and intensity of the sea breezes. An analysis of mean daily hodographs shows two distinct seasonal regimes with differing interaction between the sea breeze and topographically induced local winds.

THE ATMOSPHERIC BOUNDARY LAYER DURING BLOWING SNOW
J.W. Pomeroy and D.H. Male

Blowing snow is surface snow which has been entrained by the wind. Wind transport of snow particles below 3-cm height is primarily by saltation and involves horizontal momentum transfer from the wind to the particles and periodic impact of the particles with the snow surface. Above 3 cm, suspended transport dominates and involves suspension of particles by the vertical component of atmospheric turbulence. The exposure of snow particles to the atmosphere during transport increases the particle ventilation rate from that of surface snow. This is often concomitant with an atmospheric water vapour deficit. Enhanced mass transfer of water from solid to vapour results.

The sublimation rate of blowing snow is calculated by assuming the snow particle is at the "wet bulb" temperature and the atmosphere adjacent to the particle surface is saturated with water vapour. Turbulent diffusion of water vapour away from the particle surface is determined by the particle ventilation rate, the undersaturation of water vapour in the ambient atmosphere and the ambient air temperature. The sublimation rate is modelled by calculating the vertical profiles of blowing snow drift density, particle size distribution, vertical turbulence, air temperature and humidity and integrating over the boundary layer.

To calibrate and evaluate this model, measurements ware made at Loreburn, Saskatchewan. These include wind speed, air temperature, dew-point tempera-

ture, blowing snow drift density and the flux of blowing snow particles collected at several heights from 0.03 to 3 m and averaged over 7½ minute periods. The results show well developed vertical gradients of water vapour density which are indicative of near-surface evaporation and a tendency for stable temperature gradients during blowing snow. Wind velocity profiles are modified by horizontal momentum transfer to saltating snow particles near the surface. Sublimation rates from blowing snow even under cold midwinter conditions can exceed the maximum evaporation rates from melting surface snow.

THE VAPOUR FLUX OF 2,4-D ISO-OCTYL ESTER AFTER APPLICATION TO A WHEAT FIELD
S.R. Shewchuk and R. Grover

The vapour flux of iso-octyl ester of 2,4-dichlorophenoxyacetic acid to the atmosphere was measured from a wheat field. Air samplers were placed at six levels along a profile from 30 to 200 cm above the crop canopy. These samplers showed distinct gradients of concentration for the first seven days after application. The highest concentration was measured during the afternoon period of day one when 1604 ng m-3 was measured 30 cm above the crop canopy. The vertical flux of the ester showed distinct diurnal variation with maxima reached in the early afternoon of days 1 and 2. The crop canopy intercepted 52% of the applied ester and acted as the major source of vapour losses.

Direct drift losses during application were measured. They were 0.2% of the total amount applied. Turbulent transfer coefficients were determined by both the aerodynamic and energy balance approaches with standard instrumentation. The total or cumulative vapour losses of the iso-octyl ester over a 5-day period was 93.5 g ha-1 or 20.8% of the applied amount.

EVALUATIONS OF METEOROLOGICAL AND AIR QUALITY DATA COLLECTED NEAR A FOREST CLEARING
D.M. Leahey and M.C. Hansen

Horizontal and vertical wind patterns were observed near a forest clearing in northern Alberta during the summer of 1984. Wind measurements above and below forest canopy were supplemented with measurements of SO_2 concentrations.

Influences of the clearing on wind flows were clearly evident. During daytime hours air below the forest canopy converged in the clearing, resulting in strong upward vertical velocities in its vicinity. This converging air tended to diverge and subside near tree-top level. Regions within the canopy between rising and subsiding air were characterized by strong horizontal jets. During the night, cool air tended to diverge from the clearing into the forest. This divergence was accompanied by subsiding air.

An analysis of turbulent wind fluctuations demonstrated that the air was more turbulent above than within the canopy. In consequence, pollutant plumes moving through the forest should be more dilute at elevations near the canopy top. This expectation was confirmed by observations of SO_2 which showed that highest concentrations tended to occur near the ground.

Estimates of sulphur deposition are often made based on direct or indirect estimates of eddy fluxes. Procedures are based on the assumption of simplest possible atmospheric flow patterns, with average vertical velocities being vanishingly small. The procedures also assume that SO_2 concentrations will be greater near the level of measurement, which is usually at about ten metres, than nearer the ground. Neither assumption appears to be appropriate in the forest environment investigated in this study.

0830–1030 (ED 1.11) **Thursday / Jeudi**

SESSION 5B: METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS (MOIST)

SESSION 5B : LES INFLUENCES MÉTÉOROLOGIQUES ET OCÉANOGRAPHIQUES SUR LES ROUTES DU SAUMON (MOIST)

OVERVIEW OF PROJECT MOIST: METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS

Lawrence A. Mysak

A brief overview will be given of an ongoing three-year (1984-87) study of climate and fisheries: interannual variability of the northeast Pacific Ocean and its influence on homing migration routes of Fraser River sockeye salmon. In this study, which is a cooperative venture between UBC's Department of Oceanography and DFO's Fisheries Research Branch at Nanaimo, B.C., we are bringing together meteorological, oceanographic and biological information in an attempt to understand, and ultimately predict, the "Johnstone Strait Diversion" (JSD). This is the percentage of Fraser River sockeye salmon that return in any given year to spawn in the Fraser River tributaries via the north end of Vancouver Island (as opposed to the percentage that return via Juan de Fuca Strait in the south). During the summer of 1958 and 1983, the anomalously large JSD's appeared to be related to local warming events which in turn are closely linked with major El Niño-Southern Oscillation episodes in the tropical Pacific. Up to the present time this study has involved: (1) the analysis of historical environmental and fisheries data, (2) the development of a large-scale numerical ocean circulation model of the northeast Pacific, (3) the analysis and interpretation of oceanographic and sockeye tracking data collected during summer 1985 from the "inside passage" of British Columbia (the water between Vancouver Island and the mainland), and (4) the collection and analysis of seining, echo-sounding, and satellite imagery data from the inside passage. In the subsequent papers of the MOIST session, these different aspects of the study will be described.

THE HOMING MIGRATION OF FRASER RIVER SOCKEYE SALMON IN RELATION TO ENVIRONMENTAL CONDITIONS

C. Groot and T.P. Quinn

Sockeye salmon (Oncorhynchus nerka) homing back to the Fraser River from their ocean feeding grounds can take either of two routes around Vancouver Island, British Columbia, Canada. Until 1977, the majority homed via the southern route through the Strait of Juan de Fuca (average 80%, range 65%-98%). Since 1978, more sockeye have migrated via the northern route through Johnstone Strait (average 53%, range 22%-85%).
In this paper we will evaluate the extent to which oceanographic conditions in offshore waters influenced the migratory routes of Fraser sockeye around Vancouver Island. First, information will be presented on the migratory pathways that Fraser River sockeye take when they approach the British Columbia coast, to identify the important area(s) where oceanographic conditions could affect the homing migration. Second, the relationship between northern diversion rates and a number of oceanographic factors will be discussed. Third, we will speculate on the mechanisms by which ocean conditions might influence and direct the homeward migration of Fraser River sockeye.

A NUMERICAL MODEL FOR THE INTERANNUAL VARIABILITIES IN THE NORTHEAST PACIFIC OCEAN

William W. Hsieh

The GFDL Bryan-Cox primitive equation model is used to study interannual variabilities in the northeast Pacific Ocean. Numerical experiments are run to study the mid-latitude oceanic fluctuations produced by changes in the wind stress, in the surface heat flux, and in the equatorial water temperature during an El Niño. The relative importance of these different generation mechanisms is examined. At a later stage, direct simulation of oceanic conditions will be attempted by forcing the model with observed atmospheric data.

ON THE PHYSICAL OCEANOGRAPHY OF THE "INSIDE PASSAGE", BRITISH COLUMBIA

B.A. Terhart, K.A. Thomson and P. Welch

Data collected from two conductivity-temperature-depth surveys conducted during 24-28 June 1985 and 26-30 August 1985 in support of project MOIST - Meteorological and Oceanographic Influences on Sockeye Tracks - are used to describe the salient oceanographic features of the "inside passage". Using these data, four oceanographic regimes are clearly defined on the basis of salinity structure. Rigorous tidal mixing over constricted sills produces tidal-mixed fronts which separate these regions. Geostrophic surface velocities, determined by applying a simple two-layer model to five cross-channel sections, agree reasonably well with the few current measurements in the area and show a northwestward surface flow from the Strait of Georgia to Queen Charlotte Sound. Temperature-salinity diagrams are used to discuss water types and mixing ratios in the four oceanographic regions.

VERTICAL MOVEMENTS OF ADULT SOCKEYE SALMON IN BRITISH COLUMBIA COASTAL WATERS IN RELATION TO TEMPERATURE AND SALINITY

Thomas P. Quinn and B. A. Terhart

Adult sockeye salmon returning to the Fraser River can approach via one of two routes: along the west coast of Vancouver Island and through the Strait of Juan de Fuca or between Vancouver Island and the British Columbia mainland through Johnstone Strait. The ratio of sockeye using the two routes varies from year to year, and several hypotheses have been proposed to explain this interannual variability. While sea surface temperature and salinity have been correlated with sockeye migration route selection, no direct information has been available on the behavior of sockeye in relation to these oceanographic features. To further understand the factors influencing sockeye migrations, we tracked sockeye with ultrasonic depth-sensing transmitters in three regions with different oceanographic profiles. In Queen Charlotte Strait and Johnstone Strait, the upper waters were weakly stratified and cold. In Discovery Passage they were unstratified and cold, and in the Strait of Georgia they were stratified but warmer and less saline than in Johnstone Strait. In both the weakly stratified and unstratified cold waters, the sockeye displayed a marked preference for the near-surface waters (1-5 m). In the warmer, less saline waters, they generally spent less time near the surface and often swam near the thermocline which was typically between 10 and 20 m. We infer that the sockeye did not have particular temperatures or salinities that they preferred, but rather attempted to use vertical structure of these features to facilitate orientation to odors learned years earlier as juvenile salmon migrating to the ocean.

SATELLITE-MEASURED SUMMER SEA SURFACE THERMAL PATTERNS IN THE STRAIT OF GEORGIA, BRITISH COLUMBIA

Andrew Thomas and Bert Mueller

An intensive program to record and process Advanced Very High Resolution Radiometer (AVHRR) data from polar-orbitting NOAA satellites during the summer of 1985 resulted in a time series of 60 infrared images covering the period June 15 to August 31. These images were geometrically corrected and navigated to show the Strait of Georgia and then land masked and cloud masked. Calibrated Band 4 temperatures of these images were used for qualitative examination and intercomparison of surface thermal patterns. The 1.1-km (nadir) resolution of the imagery resolves most of the larger scale features in the Strait. A strong frontal system developes between warmer stratified water resident in the Strait and colder, vertically mixed water advected into the north and south ends of the Strait from Discovery Passage and the San Juan Islands, respectively. The position of the fronts is most likely controlled by the phase of the tide and wind events, the dominant processes governing surface currents and water distribution in the Strait. The Fraser River plume appears as a cold zone in the early part of the image series, but intense solar heating in July and August of this highly stratified area makes it appear as a warmer zone in the latter part of the series. Temperature fluctuations in all areas of the Strait are highly correlated, indicating

large spatial-scale forcing processes dominate the surface regime. Smaller scale zones of cooler surface water seen on the western side of two headlands might be localized coastal upwelling. In general, northern zones of the Strait are cooler than southern ones, probably due to increased vertical mixing away from the stratifying influence of the Fraser River.

1050–1230 (ED 106.1) — Thursday / Jeudi

SESSION 6A: EVAPORATION
SESSION 6A : ÉVAPORATION

AIRBORNE OBSERVATIONS OF REGIONAL EVAPORATION AND WATER-USE EFFICIENCY MEASUREMENTS

P.H. Schuepp, R.L. Desjardins, J.I. MacPherson, J. Boisvert and L. Austin

The development of rapid-response sensors for water vapour and CO_2 has made possible aircraft-based eddy-correlation measurements of evaporation and CO_2 exchange on a regional scale. Systematic tests of the technique against ground-based eddy-correlation observations over wheat fields in Manitoba, in 1985, will be reviewed. They showed that estimates of evaporation based on the average of 4 runs of at least 4 km in length differed from 1-h averages of ground observations above the same terrain by an average of 9%, with a 92% probability of agreement within 15%. Similar agreement was found for water-use efficiency estimates (CO_2 flux/vapour flux). On the other hand, analysis of the spatial resolution obtainable by grid flights showed that regional source and sink distributions of H_2O (CO_2) are not likely to be reproduced by single-transect grid patterns except for large-scale (>5 km) flux discrepancies.
Application of the airborne technique to the observation of evaporation from 8 test sites within the 500 km^2 area of a hydrological balance study in Québec, also in 1985, will be discussed. Integration of airborne observations with radar and satellite information is being explored as a possible test for regional water-balance models based on meteorological and pedological factors.

OPERATIONAL MEASUREMENTS OF EVAPOTRANSPIRATION FROM A BOREAL FOREST DRAINAGE BASIN USING AN ENERGY BALANCE/EDDY CORRELATION TECHNIQUE

B.D. Amiro

Meteorological techniques were applied in an operational role to measure evapotranspiration (ET) remotely at two sites in a boreal forest drainage basin located in southeastern Manitoba. An energy balance method was used where net radiation (Rn) and ground heat flux (G) were measured directly. Sensible heat flux (H) was measured by the eddy correlation technique using a propeller anemometer and a fine-wire thermocouple. The energy components were calculated hourly on-line and data were collected reliably over a five-month period.

The Rn and H instruments were mounted above the forest canopy and duplicate measurements at heights of 12 m and 6 m were in good agreement. Measurements at an open, bare rock site indicated that G could be a substantial fraction of the daily Rn at some locations, but over longer time periods, it was a smaller fraction and could be ignored.

The two measurement locations represented upland (open bedrock/jack pine forest) and lowland (aspen/willow forest) sites in the drainage basin. The daily value of Rn-H at the upland site was 0.57 times the value at the lowland location owing to differences in Rn, H and G. The mean ratio of daily H/Rn was 0.6 for the upland site and 0.4 for the lowland site. Seasonal variations in ET were caused by both energy limitations and water availability. A basin-wide ET was calculated by weighting the values for the two sites in proportion to their areas. The measured ET agreed well with precipitation minus runoff for the basin. Differences between these two quantities in summer and fall were attributed to water release and storage by the ground, respectively.

EDDY FLUXES OVER A DECIDUOUS FOREST IN SOUTHERN ONTARIO

H.H. Neumann and G. den Hartog

A 40-m tower for micrometeorological studies has been recently installed in a maple-aspen forest (tree height about 20 m) near Barrie, Ontario. The site has upwards of 2 km of essentially flat, forested fetch for the preferred wind direction (SSW). Measurements of the eddy fluxes of momentum, heat, water vapour and ozone were obtained in the late summer of 1985 using eddy correlation techniques. These are shown along with calculations of a stability-dependent drag coefficient. Power specta and cospectra are also given, illustrating the time-scales of turbulent transfer between the atmosphere and the forest, and the reduced time response requirement of sensors over the forest at our measuring height relative to those for typical studies over grass and agricultural crops. Data from the continuous monitoring of meteorological parameters, ozone, sulphur dioxide and particulate sulphate concentrations beginning in midsummer 1985 are presented along with estimated pollutant dry depositions.

TEMPORAL VARIABILITY OF RURAL-SUBURBAN BALANCES

H. Cleugh and T.R. Oke

Results of synchronous energy balance observations at quasi-rural and suburban sites in the Vancouver area are presented. They demonstrate, and allow quantification of, the effects of urbanization on energy partitioning at the surface under reasonably typical summer conditions for a mid-latitude city. One of the differences between the two environments is the greater temporal (especially day-to-day) variability in the partitioning of the turbulent sensible and latent heat fluxes at the urbanized site. It is hypothesized that this may be due to either or both of two causes. Firstly, it may be due to anthropogenic modification of water availability. Secondly, it may be an expression of the variability of larger (synoptic or meso-scale) influences on the state of the PBL, and the closer coupling of the surface to these conditions in the city where aerodynamic resistance is low.

THE CASP FIELD EXPERIMENT: A PRELIMINARY OVERVIEW OF THE METEOROLOGICAL COMPONENT

R.E. Stewart, R.W. Shaw and G.A. Isaac

The Canadian Atlantic Storms Program (CASP) field experiment was conducted from Janauary 15 to March 15, 1986. The principal objective of the meteorological component of CASP is to study and improve the prediction of the mesoscale structure of East Coast storms. Mesoscale features to be studied include: frontal characteristics, precipitation bands not related to frontal surface, freezing precipitation, rain/snow boundaries, and boundary-layer evolution across a land/ocean boundary. In cooperation with the U.S. GALE project, it is also anticipated that progress will be made in understanding the synoptic evolution of storms. Satellites, radar, aircraft, a radiometer, enhanced observations at regular surface and climate sites, a surface mesonetwork, offshore buoys, as well as special forecast workstations and numerical models were utilized during the field study.

The dates of occurrence and the types of storms and mesoscale features observed during the field study will be presented. A preliminary analysis of data from a small number of cases will be described. These examples will provide an indication of the type of research that will be conducted using CASP data. A complete description of these analysis plans will be briefly summarized.

STORM RESPONSE IN THE COASTAL OCEAN: PRELIMINARY RESULTS FROM THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)

Peter C. Smith and Carl Anderson

The oceanographic component of the CASP field experiment, conducted from November, 1985, through March, 1986, included:

a) current, temperature, salinity and bottom pressure measurements from an array of eleven moorings on the Scotian Shelf east of Halifax

b) sea-level measurements at seven sites along the Nova Scotia coastline

c) near-surface wind measurements at fixed locations from an array of up to six anemometer buoys

d) several surveys of the low-level [0(100 m)] wind field over the shelf using NAE Twin Otter and CCRS DC-3 aircraft

Preliminary analyses of these records will be used to discuss the character of the responses of current and subsurface pressure fields to atmospheric forcing (synoptic and mesoscale) by severe winter storms. In addition, the structure of the surface wind field near the coast will be examined and various measurements of marine winds will be intercompared.

OPERATIONAL EXPERIENCE WITH GRAPHICAL DISPLAY
STATIONS DURING THE CANADIAN ATLANTIC STORMS PROGRAM
J.D. Abraham and K.A. Macdonald

In support of the Canadian Atlantic Storms Program's (CASP) January 15 to March 15, 1986 field project, a dedicated forecast centre was established adjacent to the Maritimes Weather Centre in Bedford, N.S. This CASP Forecast Centre was staffed by operational meteorologists from several AES forecast offices. An important goal of the Forecast Centre was to assess the operational usefulness of a wide array of enhanced observational data, newly developed forecast guidance products and experimental graphics display equipment. The display equipment included a University of Wisconsin McIDAS workstation, the Canadian Meteorological Centre's RIDS (Remote Image Display System), the AES Aerospace Meteorology Division's RAINSAT system and the AES Forecast Research Division's PC-based display station. The capabilities of and products available through each of these systems will be outlined.

For most of the CASP forecasters, this was their first exposure to graphical display systems. Their feedback with respect to the usefulness of the various systems in their analysis, diagnosis and prognosis activities will be discussed. Also, we will look at the level of effort required to learn how to operate the systems and give the general consensus as to the positive and negative features of each. Based on this feedback, we hope to be able to give general specifications for a future graphics workstation which would best meet the needs perceived by operational meteorologists.

A CANADIAN PAM FACILITY AND ITS DEPLOYMENT IN CASP
Peter A. Taylor, James R. Salmon and Robert E. Mickle

The deployment of mesoscale networks of automated surface weather stations or "Mesonets" has been found to be extremely valuable in many U.S. mesoscale meteorological field studies. NCAR's PAM facility (Portable Automated Mesonet) has been developed to meet this need and was used extensively in GALE. As part of the Boundary Layer Research Division contribution to CASP we have developed, tested and deployed our own mesonets of surface stations, centred on the use of Campbell Scientific CR21X micro-loggers.

The present paper will describe the Canadian PAM facility of twenty-six stations developed for CASP and deployed in two separate

surface mesonets during the January - March 1986 field experiment. Nine of the stations were deployed in a linear meso-gamma scale array on Sable Island with a total length of approximately 35 km. The other seventeen stations formed a Halifax mesonet and were deployed in a 100-km triangular array to the north and east of the Halifax - Dartmouth area. Data from six of these stations were available on-line for forecasting purposes.

Preliminary analyses of selected data from these mesonets will be presented and the future development of this Canadian PAM facility will be discussed.

WAVE MODEL BUILDING FROM CASP
Fred Dobson and Will Perrie

As part of the Canadian Atlantic Storms Program, a large set of wave spectra was collected off the Nova Scotia coast. The wave array consisted of six non-directional "Waverider" buoys, three directional "Wavec" buoys, a meteorological "Minimet" buoy, and three underwater acoustic "WOTAN" wind meters, variously belonging to MEDS, BIO and Arctic Sciences Inc. under ESRF contract. They were deployed from 30 November 1985 to 15 April 1986, with gaps for service and repair. The spectra from a variety of gales and storms were archived via a unique autonomous logging system built around personal computers.

This is augmented by an enormous meteorological data set, including winds and soundings from Peter Taylor and Bob Mickle's mesonets on the Nova Scotia shore and Sable, which hopefully will give accurate mesoscale O(5-10 km) winds over the wave array, and boundary-layer modelling from Twin Otter and DC-3 data over the line. As well, the Atlantic Geoscience Centre and Dalhousie did bottom studies along the line, and C-CORE of Memorial did "CODAR" studies of surface currents in the area.
Modelling strives to verify the self-similar k-space "TMA" (Bouws et al. 1985, JGR 90, 975-986) shallow water wave spectra, and generalize directionally. It also studies the influence of bottom boundary layer, refraction and currents. Finally, it strives to infer the fetch and duration evolution of the spectrum when constrained by finite depth. This will be the preliminary report.

THE THREE-PEAK DISTRIBUTION IN EQUILIBRIUM RAIN

Roland List

Fifteen years of laboratory experiments by the University of Toronto Cloud Physics Group on the coalescence and breakup of drop pairs colliding at terminal fall speeds and moving close to vertical have allowed the parameterization of drop or fragment sizes after the interaction. These data are represented by a four-dimensional surface which allows an extension of experimental data into other drop combinations. When this information is now applied in the evolution of raindrop spectra during fall in a 1-dimensional shaft it can be shown that equilibrium spectra are evolving with peaks at diameters of 268 μm, 790 μm and 1760 μm. The position of these peaks is independent of rainfall rate. Rainfall only affects, in a proportional manner, the number concentration of raindrops. The equilibrium peak positions are independent of the original raindrop size distributions. Data will be given on the time evolution to equilibrium - which depends on rainfall rate, height of fall and initial distribution.

Examples will demonstrate that such distributions exist in nature. A first attempt at explaining the three peaks will also be made. This study is primarily aimed at the understanding of the formation of warm rain. Once the three-peak distribution is put on firmer ground by more measurements, deviations from equilibrium may be interpreted in terms of details of precipitation processes, mixing and other factors. Given the right circumstances the new distributions could also be representative for some cold rain situations.

THEORY OF UNDERWATER SOUND GENERATION BY RAIN

Jeffrey A. Nystuen

Underwater ambient noise measurements of the sound generated by rain striking the surface show promise as a means of measuring rainfall at sea. Recent measurements show a broad peak in the noise spectrum at roughly 15 kHz. This peak allows rain to be identified even when other noise sources, in particular, wind, are present. Numerical simulation of drop splashes show that the spectral signatures of different size drops are different. The spectral signature of the drop splashes depend on drop size, impact velocity and drop shape. Using measured drop size distributions, predictions for the underwater sound spectra are constructed from the spectral signatures of individual drops. These predictions are compared with the measured sound spectra.

THE RELATIONSHIP BETWEEN PRECIPITATION AND UNDERWATER SOUND
J.A. Scrimger and G.A. McBean

Measurements were made of underwater sound in a lake during the occurrence of rain, snow and hail. The noise spectra, for light winds (<1.2 m/s), have a sharp peak at 13.5 kHz with a sharp fall-off to lower frequencies and a more gradual fall-off to higher frequencies. The spectral level near the peak is related to the logarithm of the rain rate with wind speed as an additional parameter. At higher wind speeds the spectral peak is less sharp. The noise spectra for hail and snow show different characteristics. Correlation of the rain noise spectra with rain drop size distributions suggests that the high-frequency acoustic energy is due to small drops while the lower frequencies are generated by larger drops.

EVALUATION OF THE EFFECT OF CLOUD SEEDING ON RAINFALL IN SOUTH-WESTERN ALBERTA, 1977 AND 1980-1984
Keith D. Hage and Nacim Aktary

Cloud seeding by emission of silver iodide from ground-based generators was carried out for purposes of hail suppression and rainfall enhancement in southwestern Alberta in 1977 and 1980-1984. Rainfall data in the region of interest are examined using estimates of target rainfall, in the absence of seeding, based on (a) pre- and post-seeding target-to-control rainfall ratios, (b) rainfall averages from predictor stations selected by correlation analysis of a 34-year development data sample, and (c) averages of grid-point rainfall estimates interpolated from control rainfall stations by objective spatial analysis procedures. No evidence of a change in average rainfall attributable to cloud seeding by ground-based generators is found. The unseeded target-to-control rainfall ratios are found to be sensitive to different choices of unseeded periods in seeded and unseeded years. It is estimated from the statistics of the 57-year development and test sample used in correlation analysis that any change in average target rainfall in excess of 12 per cent in the 6 seeded years can be detected with 95 per cent confidence.

PRECIPITATION DEVELOPMENT IN NATURAL AND SEEDED CUMULUS CLOUDS IN SOUTHERN AFRICA
D.R. Hudak and Roland List

The processes leading to the development of precipitation in both natural and seeded cumulus clouds in southern Africa were examined, and an approach was established for an efficient rain enhancement experiment. Surface and upper-air data were used to describe the environmental conditions while aircraft and radar data were used to determine the ice water budget in the clouds. Twenty-three clouds, 12 unseeded and 11 seeded, from 11 days collected on the Bethlehem Precipitation Research Project provided the data source. Two

one-dimensional cloud models were used to help assess seedability. One model was steady-state with bulk microphysical parameterizations (Hirsch 1971), while the other was time-dependent with detailed microphysics (Nelson 1979).

The data were divided into 3 sets based on the main air masses affecting the area: maritime tropical (mT), continental tropical (cT), and maritime polar (mP). The smaller clouds on the mT days, with tops warmer than -20°C, were the most likely candidates for precipitation enhancement from both the microphysical and dynamic seeding viewpoints. There the Nelson model calculated a precipitation efficiency increase from 2% to 15% due to seeding. For clouds in the cT air the rapid natural onset of ice suggested that they were not seedable microphysically. Secondary ice production was identified as an integral part of the precipitation process in these clouds. Clouds in the mP air were determined to be not seedable because they were either very efficient microphysically or their lifetimes were too short. To verify these results in a statistically significant manner would require a much larger sample of cases.

1330–1510 (ED 1.11) **Thursday / Jeudi**

SESSION 7B: COASTAL OCEANOGRAPHY I
SESSION 7B : OCÉANOGRAPHIE CÔTIÈRE I

THE INFLUENCE OF WINTER COOLING ON FJORD DEEP WATER RENEWAL

Dario Stucchi

Water property and meteorological data collected over a two-year period in a northern British Columbia fjord system are examined. In Alice Arm, a shallow silled fjord, advective deep water renewals of varying extent occur annually during the winter months. In the winter of 1981-82 there was a complete renewal but the following winter the renewal was partial, extending down to 150 m. Winter cooling of the near-surface source waters in Observatory Inlet contribute substantially to the density increase. A winter heat budget calculation in Observatory Inlet shows that cooling occurs locally, primarily by sensible and latent heat transfers during outbreaks of Arctic air. The strong outflows of cold and dry Arctic air produce large (up to 700 W m^{-2}) fluxes of sensible and latent heat. The limited amount of data support the hypothesis that the inter-annual variability of the extent of deep water renewal is controlled by the amount of winter cooling. Thermal convection driven by the large surface heat losses is not a mechanism for deep water formation in Observatory Inlet. Wind stress is the dominant forcing of the mixed layer in Observatory Inlet as the calculated Monin-Obukhov length scale is larger than the observed mixed layer depth.

LOW-FREQUENCY CURRENT FLUCTUATIONS IN THE STRAIT OF GEORGIA, BRITISH COLUMBIA

Michael W. Stacey, Stephen Pond and Paul H. LeBlond

Velocity time series from an array including four cyclesonde moorings and five current-meter moorings, spanning the time interval from June 1984 until January 1985, have been analyzed to determine the forcing mechanisms and spatial structure of the low-frequency (> 5 days period) current fluctuations in the Strait of Georgia.

The nonlinear interaction of semidiurnal tidal constituents with bottom topography causes a near-bottom, low-frequency oscillation that is coherent over the span of the experimental array (≈ 11 km). The tidal subharmonics are important elsewhere in the water column too, and altogether account for about half of the low-frequency energy in the Strait.

There is evidence of significant wind forcing, and an empirical orthogonal function analysis of the vertical structure of the current fluctuations yields evidence for the existence of wind-forced Ekman spirals. The influence of the wind can be detected down to a depth of 300 m, the maximum depth to which measurements were made.

Longitudinal and transverse velocity correlations imply that at some depths the current fluctuations are very consistent with horizontally nondivergent, isotropic flow. They also suggest small spatial scales of less than 8 km.

THE VERTICAL STRUCTURE OF CURRENTS ON THE NORTHWEST SHELF OF AUSTRALIA AT SUBTIDAL FREQUENCIES

Ian Webster

An EOF analysis of current-meter data collected on the northwest shelf of Australia (NSW) suggested that the major part of the low-frequency (subinertial) circulation on the shelf was wind-forced. The circulation appeared to be dominantly barotropic, but significant variations in the flow with depth were observed.

In this paper, the vertical structure of the currents on the NWS is investigated using a rotary EOF analysis of the vertical gradients. The analysis is performed in the frequency domain over a frequency range of 0.03 to 0.78 cpd including the local inertial frequency of 0.69 cpd. The anticlockwise (cum sole) EOFs are found to be significantly coherent with the wind stress in the four frequency bands considered in the analysis, whereas significant coherences occurred in only two of the clockwise bands. To study the origin of the vertical structure in the currents, the observations are compared with the results of a model of the frictional boundary layers. The model incorporates surface and bottom boundary layers of relatively high eddy viscosity separated by a zone of relatively low eddy viscosity.

The parametrization of eddy viscosity as a function of depth requires specification of the rms wind stress, the rms bottom stress, and internal dissipation. With reasonable choices of these parameters, the model reproduces the vertical structures in the anticlockwise bands fairly well, but performs poorly in the clockwise bands. It is suggested that the source of much of the structure in the clockwise bands is due to baroclinicity in the flow.

THE ENERGY SOURCE FOR COASTAL TRAPPED WAVES ON THE NEW SOUTH WALES CONTINENTAL SHELF

Howard J. Freeland and John A. Church

The Australian Coastal Experiment, ACE, observed very large amplitude coastal trapped waves propagating northwards along the New South Wales continental shelf. We have analysed adjusted sea-level data from the ACE area, the coast of Tasmania, Bass Strait and the Great Australian Bight using spectral empirical orthogonal functions. These indicate that the ACE trapped wave field originates from Bass Strait. The Strait in turn is excited by coastal trapped waves that have been forced resonantly along the Great Australian Bight, impinge on the western entrance to Bass Strait and excite some form of sympathetic response within the Strait. At low frequencies a small fraction of the energy that originates in the Bight crosses the entrance to Bass Strait and passes around Tasmania.

Modelling studies indicate that a Bass Strait origin for the ACE wave field accounts for the energy distribution among the three dominant modes and their phase relations.

THE EFFECT OF A BAROCLINIC SHEAR CURRENT ON CONTINENTAL SHELF WAVES

David Holland and Ian Webster

A numerical model is used to investigate the modification of quasi-geostrophic continental shelf waves in the presence of a baroclinic shear current. The model solves the pertinent equations by reducing them into a two-dimensional eigenvalue problem. A coordinate transformation maps the shelf topography into a rectangular domain so that a finite-difference scheme may be applied. It is assumed that the ocean has a rigid lid and that the Boussinesq approximation is valid. The program calculates wavenumber and wavemode structure for arbitrary frequency, topography, stratification, and shear current using a shifted inverse power algorithm to solve the generalized complex eigenvalue problem. The real part of the eigenvalue describes phase propagation and the complex partsdescribes growth or decay of the wave. Results are obtained for the Labrador shelf.

A CLIMATOLOGY OF HAIL FOR THE SOUTHEASTERN PRAIRIES OF CANADA

S. LaDochy and A.H. Paul

Outside Alberta and southern Ontario, hail is a serious problem for Canadian agriculture only in the central and eastern Canadian Prairies, in Saskatchewan and Manitoba. This paper reports the first truly interprovincial study of hail climatology in Canada. It draws together a variety of information on hail in southeastern Saskatchewan and southern Manitoba to plug one of the glaring gaps in knowledge of North American hail climatology. LaDochy's ten-year study of Manitoba hail-insurance claims allied to Paul's data from a volunteer hail-observer network in southeastern Saskatchewan and studies of Saskatchewan hail-insurance data complement official meteorological records to provide the first comprehensive hail climatology in Canada beyond Alberta. The hail season in this region of the southeastern Canadian Prairies extends from early May to mid-September. Hail is most frequent in late afternoon and early evening. The hail season peaks in July, but August storms are especially damaging to the region's crops. Spatial variation in hail frequency and severity is not marked. Major hailstorms are of the travelling thunderstorm variety, occur on 10-20 days per summer, and are long-lived. Some cross the border from Saskatchewan into Manitoba. Implications of the results of the study for hail insurance and hail suppression are discussed.

AREA AND MAGNITUDE OF CONVECTIVE RAIN PATTERNS

H.C. Vaughan, J.T. Jensen and G.R. White

In an ongoing investigation of statewide monthly "dry" and "wet" areas, it was observed that single precipitation events show broad total area differences but their primary cell cores seldom varied in area by more than a factor of two. Three scales of differences in characteristics of precipitation areas have been examined using appropriate spatial and temporal scales. A one-minute rate observation within a 42 km^2 matrix composed of 25 equally spaced rain gauges, the total life of single summer rain observed across a portion of Iowa and Missouri, and monthly rainfall totals for all climatic rain gauge sites within Iowa during extreme dry and wet summer months were examined. Preliminary results show a very small range in primary core areas irrespective of core intensity. The total area or peripheral outline had little or no relationship whether high or low volume rain coverage occurred. The major components of precipitation events as defined here are: area coverage,which is a conservative component ranging in area by a factor of two or three resulting from upper-level winds, and rain intensity, a wide ranging dynamic parameter frequently having a swing of several orders of magnitude. The most disconcerting thing regarding this study was that during dry months single cell thunderstorms produced the majority of rain, frequently providing 100 per cent of the area normal rainfall during one event.

AN ANALYSIS OF 3- AND 7-DAY GROWING SEASON RAINFALL IN SOUTH-CENTRAL CANADA

Michael B. Richman and Peter J. Lamb

Results of a climatic pattern analysis of 3- and 7-day growing season rainfall in south-central Canada are presented. Principal component analysis (PCA) is applied to May through August 1949-1980 data for a network of 170 stations bounded by the Rocky Mountains on the west, the United States border on the south and east, and by the northern limit of agriculture (up to 55°N) on the north. The objectives of the study are to delineate the primary characteristic patterns of Canadian growing season rainfall, assess their reliability and validity, and to examine the sensitivity of the resulting patterns to varying the number of eigenfunctions retained.

The analyses utilize square-root transformed data, which are formed into station-versus-station correlation matrices containing the basic information on the variations of rainfall. The eigenanalyses of these matrices indicate that eight modes are significant by application of the scree test. However, the traditional use of unrotated PCs is not particularly useful in capturing the dominant modes and a Varimax orthogonally rotated solution is applied to resolve approximately 55 per cent of the total variation. These rotated patterns are coherent through all eight PCs and tend to have spatial scales of 800-1000 km within which the explained station variance rises to central values of 50 per cent.

The reliability of these patterns is assessed by independent analyses with spatial domain splits, temporal domain splits, comparison to another eigentechnique, comparison to an oblique solution and comparison to PCs drawn from the covariance matrix. Additionally, the validity of the presented solution to measure the modes of variability embedded within the correlation matrix is examined by comparison of the PC's loading morphologies to those of selected stations' point correlation patterns. All pattern verifications quantitatively establish the stability and validity of the eight modes of variation presented.

PATTERNS OF THE MESOSCALE CIRCULATION AND PRECIPITATION OVER THE GREAT LAKES

Andrej Saulesleja

A selection of seasonal and monthly maps was produced using weather observations from Voluntary Observing Ships (VOS) over the Great Lakes. These maps include the mean wind velocity and speed, cloudiness, visibility and frequency of precipitation. These maps and climatological summaries prepared for selected lake areas and land-based stations were compared. In the fall and winter seasons, a strong convergence of the vector mean wind was found over the lakes, and was most pronounced over the larger ones - Superior and Michigan. Although there is a possibility that these features could be produced through a "fair-weather" reporting bias, the mean wind structure seems consistent with patterns of increased cloudiness and more frequent precipitation

over the lakes in these seasons. Adjustments appear necessary to precipitation and evaporation estimates obtained from land-based measurements in order to take these patterns into account.

BUCKET SURVEYS REVIVED - THE SASKATCHEWAN EXPERIENCE

R.F. Hopkinson

Bucket surveys or supplemental precipitation surveys have been used by hydrologists and meteorologists to gather more precipitation data about significant storms than would generally be available from the climatological network. The data from such surveys are particularly useful for mesoscale events affecting areas less than 2500 km^2 but they also serve to provide information on storm maxima within larger area storms. Several bucket surveys were conducted in Saskatchewan by the Prairie Farm Rehabilitation Administration in the early 1960's. These storms are now documented in the Storm Rainfall in Canada (AES) publications. In the 1970's, Saskatchewan Environment carried out one bucket survey in northern Saskatchewan but until the early 1980's the bucket survey scene was relatively quiet, not necessarily because of a lack of storms. Late in 1981, Environment Canada's Inland Waters Directorate and Atmospheric Environment Service agreed that bucket surveys should be revived to hasten the flow of information for flood reports. The Regina offices of these two agencies developed an action plan over the following year. Several storms have since been investigated using these procedures including the phenomenal storm of August 3 to 4, 1985 near Parkman, Saskatchewan in which a 24-hour rainfall of 381 mm was documented.

The paper will describe the procedure used in Saskatchewan and subsequently adopted in Manitoba. The application of the bucket survey to the Parkman storm will be presented in some detail. Finally, the limitations and importance of data so derived will be discussed.

SNOW COVER DETERMINATION ON THE CANADIAN PRAIRIES USING MICROWAVE RADIOMETRY

B.E. Goodison, I. Rubinstein and F.W. Thirkettle

In 1982, a co-operative interagency remote-sensing experiment was conducted to assess snow cover measurement problems on the Canadian Prairies. One objective was to assess the use of passive microwave data for mapping the depth, water equivalent (SWE) and areal extent of snow cover. Extensive ground snow surveys designed for prairie snow cover conditions were supplemented by air-borne gamma-ray surveys over 1100 km of flight lines in southern Saskatchewan. These data provided the "ground truth" in the analysis of airborne and satellite microwave radiometer data (18 and 37 GHz). Airborne algorithms have been developed with best results being obtained for 25-km line segments. Vertically polarized brightness temperatures from the 37-GHz channel correlated with airborne gamma measurements of SWE in dry snow regions with an R^2 of 0.86. Vertical rather than horizontal polarization gave better results in this study.

These algorithms were tested on NIMBUS-7 SMMR data covering southern Saskatchewan for the February study period. Along the primary calibration line, satellite-derived SWE estimates were within 2-3 mm of gamma SWE measurements, although in other regions where the snowpack was icy and patchy, the estimates were 10-15 mm high. The spatial patterns of snow cover based on the satellite estimates compare well with ground and airborne variations. Regions of wet or melting snow are identifiable and the melt line was detectable from airborne and satellite microwave data. These algorithms are currently being tested for other periods in both Manitoba and Saskatchewan to assess their validity. Results to date of the algorithm development and testing will be presented. An initial assessment of the applicability of these methods for snow cover mapping will be provided.

1530–1730 (ED 1.11) **Thursday / Jeudi**

SESSION 8B: COASTAL OCEANOGRAPHY II
SESSION 8B : OCÉANOGRAPHIE COTIÈRE II

THE INFLUENCE OF BUOYANCY FLUX FROM INLETS ON CONTINENTAL SHELF CIRCULATION
Andrew J. Weaver and William W. Hsieh

The geostrophic adjustment of an initially motionless estuary is examined by means of four numerical experiments carried out using the Bryan-Cox ocean general circulation model (GCM). Less saline estuarine water was allowed to relax onto a continental shelf with and without a bottom canyon. The *reverse estuary*, with more saline inland water, is also studied in an attempt to elucidate the adjustment process.

In all cases a first mode baroclinic Kelvin wave is observed to propagate into the inlet. A barotropic eddy is also found to be trapped against the shelf break. In the presence of a canyon this eddy has very little Westward extent, unlike the eddy observed in the absence of a canyon. Conservation of potential vorticity is used to explain the existence of this eddy and why its sense is anticyclonic in the fresh estuary runs but cyclonic in the *reverse estuary* runs. Coastally trapped wave modes are also generated in the relaxation process. In the absence of a canyon, second and higher modes appear dominant, whereas in the presence of a canyon, the first mode appears dominant.

Recent results from the Australian Coastal Experiment (ACE) are examined and several problems are resolved by considering the Bass strait as a possible *reverse estuary* source for coastally trapped waves. A comparison between the model results and observed shelf-trapped eddies off the coast of British Columbia, is also presented.

OPEN BOUNDARY CONDITIONS IN COASTAL NUMERICAL MODELLING
Louise Royer

Problems in coastal numerical modelling arise from the necessity of restricting the computational area and then of having recourse to the the use of open boundary conditions. Chapman (1985, JPO 15, 1060-1075) compared different widely used boundary conditions and their effects on the solution. He omitted a new, potentially successful, condition proposed by Roed and Smedstad (1984, SIAM J. Sci. Comp. 5, 414-426) for forced motions at the boundary. The present study compares the latter boundary with a more standard radiation condition, based on the Sommerfeld equation, in the special cases of plane wave atmospheric forcing and forcing by an impulsive along-shelf wind field. A new modified version of the radiation condition used for the free-wave portion of the Roed's condition is proposed. This version, which is a combination of "Orlanski" and "Camerlengo-O'Brien" types of boundary condition, is tested in a simulation of shelf wave propagation. The whole exercise is part of a first phase in the task of numerically simulating the Labrador coastal waters.

ON THE SIGNIFICANCE OF NONLINEAR FRICTION IN TIDAL RECTIFICATION MODELS
Daniel G. Wright and John W. Loder

The influence of the representations of bottom and internal friction on the mean circulation associated with the topographic rectification of tidal currents in continental shelf regions is examined using idealized models. Two approaches are taken. An integral constraint on the fluid motion around closed geostrophic contours (Huthnance, J. Fluid Mech., 1981) is used to evaluate the along-isobath mean currents for various forms of the bottom stress law in the limit of depth-independence (i.e. no vertical structure in the horizontal currents). A second approach, which can be extended to the case of depth-dependence (i.e. including vertical structure in the horizontal currents), is developed by allowing the friction coefficients in the tidal equations to be complex-valued and linearizing the mean bottom stress law following Heaps (Deut. Hydrogr. Zeit., 1978). In the depth-independent limit, the two approaches yield consistent results which can be used to explain an apparent contradiction between the earlier results of Huthnance (1981) and Loder (J. Phys. Oceanogr., 1980) on the significance of nonlinear bottom friction. These results and the general influences of nonlinear friction are discussed in terms of the following factors: spatial and temporal variability in the friction coefficients; phase shifts and direction changes between the stress and velocity (or vertical shear) components at the tidal frequency; different values for the friction coefficients in the mean and tidal equations; and different directions of the mean bottom stress and mean bottom velocity.

LAGRANGIAN FLOWS IN DIXON ENTRANCE; EVIDENCE FOR TIDAL RECTIFICATION
Paul Greisman and W.R. Crawford

In order to measure near-surface currents, drifting buoys with on-board LORAN-C navigators and VHF radios were developed. The buoys have the

capability of transmitting their positions to a tending vessel 100 km distant and are tethered to "holey sock" drogues at 10 m-depth.

Drift tracks were measured in Dixon Entrance during June 1984. The buoy positions were transmitted and recorded every 30 minutes, which permitted the analyses of tidal oscillations as well as the determination of the mean flow. The presence of the cyclonic Rose Spit gyre was confirmed while an anticyclonic gyre around Learmonth Bank was revealed.

The drifter measurements are compared with moored current measurements made simultaneously. The two data sets are in substantial agreement both for the tidal oscillations and the mean flows.

The importance of tidal rectification relative to the wind stress and fresh water discharge is investigated. Fresh water runoff may be responsible for a net near-surface outflow exceeding 20 cm/s just after the freshet of the Nass and Skeena Rivers in June. The winds may be responsible for the fluctuations in the sub-tidal currents, but do not likely contribute to the average currents in Dixon Entrance. Although the depth in the region is typically 200 m, the presence of extremely steep submarine topography and strong tidal currents suggests that rectified tidal flows are about 20 cm/s eastward along the drop-off at the northern entrance to Hecate Strait and clockwise around Learmonth Bank.

LOCALIZED TIDAL STRESS: A GENERATING MECHANISM FOR MESOSCALE EDDIES IN WIDE, COASTAL SEA STRAITS

A. Visser, M. Bowman and W. Crawford

Under appropriate conditions, in shallow seas, tidal stresses can drive significant rectified currents whose scale can be much larger than the source region itself. An example is presented in Dixon Entrance, B.C., where the tidal stress acting along the steep ramp connecting shallow Hecate Strait to deep Dixon Entrance appears to drive a robust, surface intensified, basin wide (~50 km diameter), cyclonic eddy. We investigate this process with a non-linear, barotropic tidal model, to determine the effects of bathymetry and coastline on the location and scale of tidal residual eddies in eastern Dixon Entrance and northern Hecate Strait.

OCEANIC TURBULENCE ON THE CONTINENTAL SHELF

R.K. Dewey, W.R. Crawford, P.H. LeBlond and A.E. Gargett

A free-falling instrument, designed to profile in the ocean, has been modified to measure temperature, salinity and microstructure velocity gradients from the surface to within 15 cm of the bottom. A probe guard mounted at the lower end of the instrument protects the sensitive velocity and temperature sensors from damage at the bottom of each profile. Turbulent dissipation rates derived from these measurements have a noise level of 10^{-6} watts/m^3.

Measurements in Juan de Fuca Strait and on the west coast of Vancouver Island in 1985 show the variation of the thickness and turbulent

intensity in the bottom boundary layer to vary over a tidal cycle. Typical thicknesses of the turbulent bottom boundary layer are 10 m in the middle of the continental shelf and up to 50 m in Juan de Fuca Strait. Near shore in 50 m of water the boundary layer filled the entire water column.

STEADY WIND-DRIVEN UPWELLING IN THE PRESENCE OF A BAROCLINIC COASTALLY TRAPPED JET
A.E. Hay and E.D. Kinsella

The usual two-layer model for steady wind-driven upwelling along a uniform coastline is extended to incorporate the effects of an upper-layer jet trapped against the coast. The characteristic width of the jet is the internal deformation radius so the jet Rossby number in the governing equations for the upper layer is of order unity and the non-linear term involving cross-stream shear must be retained. It is shown, however, that the equations can be reduced to a manageable form when the upper-layer thickness and equilibrium displacement of the interface are both much less than the total depth. Explicit solutions are obtained for equilibrium jet profiles for which the interface is either exponential, which corresponds to a frictionless jet with uniform potential vorticity, or parabolic. It is also shown that solutions should be obtainable when the jet profile can be expressed as an arbitrary polynomial in the offshore coordinate. The principal differences between our results and the usual ones for the no jet case are that upwelling is reduced at the coast, and amplified offshore. The differences are due to a reduction in the divergence of the on-offshore velocities within an internal Rossby radius of the coast, and to increased divergence farther offshore. These changes in divergence are the result of the equilibrium displacement of the interface through the continuity equation and of advection of mean flow momentum by wind-induced offshore motion through the cross-stream shear.

0830–1030 (ED 106.1) **Friday / Vendredi**

SESSION 9A: GENERAL METEOROLOGY I
SESSION 9A : MÉTÉOROLOGIE GÉNÉRALE I

THE RAIN CHEMISTRY OF SASKATCHEWAN
S.R. Shewchuk

For several years the Saskatchewan Research Council has studied the rain chemistry of Saskatchewan. Two major networks have been set up in the northern and southern areas of the province. All rainfall was collected on an event basis.

A major thrust for this project was to provide the best possible quality assurance procedures for collection and analysis of the individual samples. All major ions and metals were considered in the samples. The wet deposited sulphur as rain ranged from 0.4 to 0.9 kg(S)/ha from the northern network and 0.9 to 3.0 kg(S)/ha from the southern network. There was a small increase in the alkaline earth structure of the rain in the southern part of the province.

MODEL SIMULATIONS OF THE CHEMISTRY OF A RAINBAND

H.G. Leighton, J. Pitre, A.-M. Valton and M.K. Yau

Two numerical models have been developed to investigate the effects of cloud microphysical, chemical and dynamical processes on the redistribution and transformation of pollutants in a rainband. The models are based on a two-dimensional dynamical cloud model in a stretched coordinate system with specified mesoscale forcing. The simpler of the two models incorporates into the dynamics model continuity equations for sulfur dioxide in air and sulfate aerosol in air, cloud and rain. Sulfur dioxide is treated as a passive tracer but the sulfate aerosol may enter the cloud water by nucleation and be subsequently transported into rain by microphysical processes or may enter rain directly by washout. The second, and more interesting model, contains much more complete chemistry. In addition to detailed solution chemistry of SO_2, HNO_3, NH_3, CO_2, O_3 and H_2O_2 gases, and the rainout and washout of $(NH_4)_2SO_4$ and H_2SO_4 aerosol, the model also includes oxidation of S(IV) to S(VI) by O_3 and H_2O_2.

The models have been applied to simulate a rainband which occurred on November 5, 1981 near London, Ontario for which measurements of the chemistry of the air and precipitation are available. Comparisons of the distributions of the pollutant species from the two models and of the model and observed distributions will be presented. Preliminary results show that the first model seriously underestimates the sulfate concentration in the rain.

RADIATIVE FEEDBACK DUE TO POLAR STRATOSPHERIC CLOUDS

Jean-Pierre Blanchet

Recent satellite observations of polar stratospheric clouds and the theoretical explanation of their formation brought up questions on the radiative effects of those thin clouds. The radiative heating resulting from PSCs has been examined by use of Mie calculations for spherical particles and a narrow-band radiation model. The spectral irradiance convergence is maximum in the wings of the 15-μm CO_2 band and covers mostly the region between 10 and 24 μm. The integrated results indicate heating rates of the order of ± 0.03 K/day for a case corresponding to the maximum extinction coefficients (at 1 μm) observable by SAM II. However, the theoretical development of PSCs results in potentially larger opacity. The predicted heating of a fully developed cloud is shown to exceed ± 1 K/day. The sign of the perturbation is essentially determined by the characteristic temperature of the upwelling thermal radiation. For an extremely cold, clear troposphere the radiative effect of PSCs is a positive feedback in agreement to results of Pollack and McKay (1985). However, due to the negative

correlation between stratospheric and tropospheric temperatures for the particular case investigated, the heating is expected to dominate in the denser PSC layer. Since this local heating rate is capable of balancing the cooling process that produces the PSC, it is possible that PSC development may be limited by radiative heating rather than by available water vapour. Thus a PSC would develop to the point where a thermal equilibrium is reached. The heating rate perturbation is most strongly affected by tropospheric cloud conditions. High-level cirrus result in maximum cooling (positive feedback) while low stratus lead to maximum heating (negative feedback). These results imply that the formation of PSCs can substantially affect the temperature of the lower stratosphere. Because of the radiative coupling between the troposphere and the stratosphere together with the high sensitivity of the feedback in the PSC formation process to the particular synoptic conditions, the large-scale effect of PSCs must be assessed from large-scale observational data or from GCM simulations. The above results are relevant to GCMs since those models often generate excessively low temperatures in the lower polar stratosphere causing strong stratospheric zonal circulation. A simple parameterization is suggested to include the effect of PSCs in broad-band radiation codes.

Reference

Pollack, J.B. and C.P. McKay, 1985: The impact of polar stratospheric clouds on the heating rates of the winter polar stratosphere. J. Atmos. Sci., 42, 245-262.

LOW-RELIEF TOPOGRAPHY AND APPARENT OROGRAPHIC ENHANCEMENT OF STORM RAINFALL TOTALS ALONG THE MANITOBA ESCARPMENT

R.A. McGinn and A.C. Giles

Synoptic-scale flow patterns associated with occluding baroclinic disturbances have been incorporated into a two-layer mesoscale model of orographic precipitation. This model postulates that condensation droplets formed in low-level orographic feeder clouds are washed out by raindrops falling from higher level seeder clouds. As a result, precipitation rates over low-relief topography can be significantly augmented.

The model has been applied to the low-relief topography of the Manitoba Escarpment and may account for the apparent enhancement of persistent (3-day) storm rainfall totals recorded in the region.

Severe flooding is sometimes a direct consequence of these storms and thus the annual floods which take place in this hydrological region can be generated by either a spring snowmelt or an orographically enhanced rainfall event. A brief analysis of the annual flood series suggests that the largest magnitude floods are, in fact, highly correlated to these rainfall events.

SUMMER OBSERVATIONS OF THE AIR TEMPERATURE DISTRIBUTION IN AN URBAN CANYON WITH AN ASPECT RATIO OF UNITY
Y. Nakamura

The air temperature distribution in a section of an urban canyon with an aspect ratio of 1 (height equals width) was observed at Kyoto, Japan on a hot summer day. The urban canyon is a street bounded by walls of buildings on both sides. The centre line of the street is oriented almost exactly east-west; the width of the street is 16 m; the height of the buildings on both the north and south sides is 17 m. Air temperatures were measured at 63 points (7 heights at each of 9 positions across the canyon). A special method to measure air temperature outdoors was devised in which fine thermocouples were used without radiation shields. Temperature errors due to solar radiation were calibrated in advance, and data measured at sunny points were corrected according to the calibration and the direct solar radiation observed at the same time.

The spatial variation of air temperature in the canyon was larger in the daytime than at night. Air temperatures near the sunny ground surface were greater than those in shade. This was most evident when the wind velocity was low, and was dependent on the wind direction at a height of 1 m above the ground. The increase of the local air temperature did not appear at points greater than 2 m above the ground. The distribution of the air temperatures at the upper points varied according to the wind direction. This was considered to be the result of a canyon vortex circulation. On the other hand, on some occasions the mean air temperatures in the canyon changed due to the advection of heat along the east-west direction.

0830–1030 (ED 1.11) **Friday / Vendredi**
SESSION 9B: CLIMATE
SESSION 9B : CLIMAT

TOGA - THE FIRST YEAR
Noel Boston

TOGA, the Tropical Ocean and Global Atmosphere program, is an international research program designed to improve the understanding of events in the tropical oceans and global atmosphere that significantly influence the predictability of seasonal to inter-annual variations. TOGA is part of the World Climate Research Program (WCRP).

To carry out the TOGA program, it is necessary to monitor the large-scale processes in the global atmosphere, in the upper tropical oceans and at the air-sea interface over a ten-year period. Further, it is necessary to assimilate the observations and incorporate them into coupled mathematical/physical computer models which will predict the climatic variability of the ocean-atmosphere system.

The large-scale atmospheric parameters will be provided by an augmented World Weather Watch (WWW) program of the WMO. The large-scale oceanic processes will be provided by observations from voluntary observing ships, research ships, drifting buoys, and satellites. The large-scale air-sea interface processes (fluxes) must be inferred from measurements provided by WWW, the Integrated Global Ocean Service System (IGOSS) of the Intergovernmental Oceanographic Commission (IOC), drifting buoys, voluntary observing ships, and satellites. Modelling will be carried out by individuals and groups coordinated by a Scientific Steering Group (SSG).

TOGA is a unique ten-year sustained effort which began on January 1, 1985. The first year of operation of the program has seen the establishment of the International TOGA Project Office in Boulder, Colorado, the completion of the International Implementation Plan, the establishment of a Global Sea Surface Temperature Centre, and the creation of an administrative structure.

The first year may be described as a build-up year in which specific roles and needs were identified and defined. These were presented to the 1986 spring meeting of the WCRP and commitments requested.

The program is described and the first year reviewed in terms of goals and accomplishments.

THE INFLUENCE OF HEAT TRANSFER FROM THE KUROSHIO REGION ON THE ATMOSPHERIC CIRCULATION

Y.P. Zhao and G.A. McBean

Correlations between the anomalies of monthly mean total heat transfer from the Kuroshio region of the ocean and the atmospheric circulation patterns have been investigated. It is found that the simultaneous correlations are only significant over the North Pacific Ocean. Regions of significant correlation are found over North America, Europe and Asia for lags of several months up to one year or more. Possible physical mechanisms for these correlations will be discussed.

AN EMPIRICAL STUDY OF THE TROPICAL MIDLATITUDE ATMOSPHERIC TELECONNECTION

Kevin Hamilton

Numerous observational and modelling studies have demonstrated that conditions in the tropical Pacific Ocean and overlying atmosphere can have significant impact on the circulation of the midlatitude atmosphere, particularly in winter. Notable is a clear tendency for an intensification of the climatological standing wave pattern over the North Pacific and North America during the warm tropical conditions associated with El Niño/ Southern Oscillation (ENSO) events. However, the actual midlatitude circulation anomalies do show a great deal of variability among individual ENSO years. The present investigation is attempting to determine how much of the variability of the midlatitude response to ENSO events can be attributed to differences in the details of the tropical anomalies from event to event. The study embraces the period 1875-1983 and is employing data relating to tropical sea surface temperatures (SSTs), tropical

precipitation, and midlatitude atmospheric surface pressures and temperatures. Preliminary results suggest that the midlatitude teleconnection pattern is less effectively excited by SST anomalies that extend fairly uniformly along the whole equatorial Pacific, than by SST anomalies that are more or less confined to the central and eastern Pacific.

CLIMATE IMPACT ASSESSMENTS OF THE GREENHOUSE EFFECT: FUTURE RESEARCH NEEDS IN THE GREAT LAKES REGION

Stewart J. Cohen

Any regional scale climate impact assessment of the "Greenhouse Effect" encounters a problem known as "mismatch of scales" in both temporal and spatial dimensions. Two examples are: 1) the separation of climate impacts from non-climate impacts (e.g. technological change), given that the latter will occur in some form over the next 50-100 years whether the climate changes or not, and 2) the separation of impacts due to events within the region from those caused by external factors.

The mismatch problem is discussed in light of recent studies on the impacts of CO_2-induced climatic change on the Great Lakes region. Significant changes are projected to occur to the region's hydrologic cycle, including a reduction in net basin supply, ice cover and lake levels. This could result in spinoff effects on transportation, hydroelectric power production, recreation, the consumption of water and energy, and the growth of crops. How might these changes affect the regional economy? Will there be local scale water supply problems that could lead to changes in the regional water distribution network? What are the most appropriate resource management strategies for the region under scenarios of economic and technological change, or status quo? In addition, what kind of information is needed from the meteorological and hydrological communities to improve the quality of impact assessment?

This paper lists a number of impacts, and considers several possible management scenarios, including 1) higher real prices for urban water users, 2) increased use of natural gas instead of electricity, 3) adjustments of lake-level regulation plans, 4) increased use of piped surface water by users dependent on ground water, and 5) changes in shipping season and ship design. Additional data which could improve regional impact studies include frequency distributions, variability, and extreme values.

THE RAGS OBSERVATORY FOR MONITORING OF GREENHOUSE CLIMATE CHANGE

W.F.J. Evans

Increases in the radiatively active gases (RAGS) in the atmosphere are predicted to have a major efect on the world climate by the year 2050. An observatory for measuring changes in the long-wave infrared radiation balance is being established at Asquith, Saskatchewan. It is to be part of a proposed world chain of advanced observatories designed to monitor the greenhouse effect. Test measurements with a computerised standard radiation station to evaluate the site began in January, 1986. Five levels of instrumentation are planned for the observatory, ranging from conventional radiation instrumenta-

tion in level 1 up to ultra-high resolution spectrometers in level 5. The level 1 instrumentation will provide Saskatchewan with the most advanced radiation station in Canada, and should be valuable for solar engineering applications and hydrology studies.

A STUDY OF DROUGHT ONSET DUE TO INTERACTIONS BETWEEN SOIL MOISTURE AND THE ATMOSPHERIC BOUNDARY LAYER
Trevor Scholtz, Kevin Walsh and Larry Mahrt

A two-layer soil model is combined with a model of the atmospheric boundary layer and a simple representation of the vegetation canopy. The model is used to study interactions between soil moisture, surface evaporation and boundary layer development. These interactions may lead to negative feedbacks which act to oppose further modification of the boundary layer-soil system, or, positive feedbacks which can encourage major changes in the moisture regime of the boundary layer-soil system. Systematic sensitivity tests are executed in order to estimate the nature and importance of these interactions. Emphasis is placed on the role of downward entrainment of dryer air. As the soil drying phase matures and surface evaporation decreases, the surface heating and subsequent buoyancy generation of turbulence increase. Resulting entrainment of dryer air may exceed the now reduced surface moisture flux leading to net drying of the boundary layer.

1050–1230 (ED 106.1) **Friday / Vendredi**

SESSION 10A: GENERAL METEOROLOGY II
SESSION 10A : MÉTÉOROLOGIE GÉNÉRALE II

THE PRESCRIBED FOREST BURN AT CHAPLEAU:
A FIELD EXPERIMENT FOR NUCLEAR WINTER STUDIES
W.F.J. Evans and L. Poulin

In August, 1985, the Ontario Ministry of Natural Resources conducted a controlled burn of 1500 hectares of forest near Chapleau which had been damaged by spruce budworm. This is part of a long-range strategy for reforestation and provides an excellent opportunity to study the fire, cloud and smoke processes involved in large forest fires such as are included in nuclear winter models, since a large amount of fuel is burned in a few hours. The burn produced a large smoke cloud which rose to over 14,000 feet and which was visible on GOES satellite imagery as a plume more than 100 km long. Extensive photographic coverage was taken to assist the design of field experiments in future summers. Meteorological data for the plume cloud will be presented. Preliminary optical-depth measurements on the smoke were made. Potential future field measurements will be described. Possible plans for field experiments in 1986 and 1987 at Chapleau or alternate sites will be discussed.

SIMULATION OF SOLAR TIDES IN THE CANADIAN CLIMATE CENTRE GENERAL CIRCULATION MODEL

Francis Zwiers and Kevin Hamilton

The results from two sixty-day simulations produced by the Canadian Climate Centre general circulation model (GCM) were analyzed to determine the solar diurnal and semidiurnal variations in the wind and pressure fields. In these simulations the radiative transfer calculations were performed every hour in order to adequately resolve the diurnal cycle. One simulation was for boreal summer and the other was for winter.

The simulated diurnal and semidiurnal surface pressure variations in the model were found to be quite realistic. Even some fairly subtle details of the geographical and seasonal variability were well simulated. The simulated tidal wind oscillation also appears to be reasonably consistent with the limited observations available.

Linear tidal theory calculations were performed with thermal forcings, vertical resolution and boundary conditions similar to those in the GCM. The results of these calculations can help to explain why the numerical limitations of the GCM have so little effect on the simulated tidal fields.

MONTHLY PREDICTION BY THE ANALOGUE METHOD

Amir Shabbar

In March 1985, the Atmospheric Environment Service of Canada undertook the issue of monthly and seasonal forecasts of temperature and precipitation anomalies. The methodology employs a number of techniques. One of them, involving the use of analogues, has been given a comprehensive investigation.

The analogue technique was used to select anomalies of 50-kPa height and 50-100 kPa thickness over a large portion of the Northern Hemisphere. A number of experiments were performed on the height anomalies of daily and 5-day average data. For the selection criterion, both root-mean-square and correlation techniques were investigated. Various weighting systems were applied to the target sequence, including the 4th power law. Among some of the promising results obtained from these experiments, we have found that the best analogue in the archive outscores persistence by a wide margin, and that given a set of objectively selected analogues, there exists, within that set, one member which significantly outscores persistence.

SIMULATING PRAIRIE WHEAT GROWTH WITH THE CERES MODEL

Earle A. Ripley

A computer model of wheat growth and development (CERES-WHEAT), has been adapted for microcomputer use and tested with data for a central Saskatchewan Crop District. The model operates on a daily time step and its weather data requirements are: precipitation, maximum and minimum screen temperatures, and incoming solar radiation. The crop is described by a number of genotype-

specific parameters that quantify the responses of growth, development, dry-matter partitioning, etc. to temperature, moisture and photoperiod variations, while the soil is described by its optical and hydraulic characteristics, and its water content at the start of the growing season.

Model simulations were run for the past 25-year period, using weather data from the Saskatoon-S.R.C. climate reference station. A correlation coefficient, between actual and simulated yields, of 0.70 was achieved after correction for an apparent "technology trend". Considerable improvement could likely be achieved if data from other weather stations were used, and if nitrogen fertilization response were incorporated into the model.

1050–1230 (ED 1.11) — Friday / Vendredi

SESSION 10B: SEA STATE AND SEA ICE
SESSION 10B : ÉTAT DE LA MER ET DES GLACES DE MER

SIMULATIONS OF FIRST-YEAR SEA-ICE CLIMATOLOGY AT THREE ARCTIC LOCATIONS
R. Gabison

A one-dimensional sea-ice thermodynamic model has been applied to three locations in the Arctic: Cambridge Bay, Frobisher Bay and Alert Inlet, to study the model's ability to simulate the annual cycle of first-year ice. The model results are compared with available climatological data and discussed in terms of the main thermodynamic processes, the combined effects of oceanic tides and of sea-ice deterioration by melting on the breakup of sea ice. A simple derivation of internal ice-melt is applied to find the changes in ice strength.

The impact of ocean swell and internal ice melt on the flexural failure of ice during melt season is studied. Ice strain is calculated from swell height and period. This is compared with the decrease in ice strength from internal melting to predict the date of flexural ice failure.

It is shown that the model is effective in simulating the climatology of the first-year ice thickness at the three Arctic locations. The study also suggests that improved model performance can be expected from additional research and application of flexural forcing of the ice by waves and tides and of deterioration of ice strength during the melting process.

A NOMOGRAM FOR PREDICTING THE MOVEMENT OF OIL SLICKS
V.R. Neralla

The Atmospheric Environment Service developed a computerized procedure for real-time forecasting of oil spill movement. The physical processes considered in the procedure are wind-driven surface currents which advect the oil parcel, spreading due to surface tension forces, dispersion due to turbulence, and weathering due to processes of evaporation and emulsification. In order

to obtain an initial guidance on oil spill movement, a simple manual procedure incorporating advection and spreading processes is devised. This manual procedure involves the construction of a nomogram based on simplified equations. Spill displacements through a given forecast period could be read easily from the nomogram. The nomogram technique is demonstrated using some real spill data.

OBSERVATION AND MODELLING OF ICEBERG DRIFT

Stuart D. Smith

During a series of three cruises of CSS Dawson, data have been collected to form a data base for the development and testing of dynamic models of iceberg drift. The tracks of 10 icebergs have been recorded by manually logging radar ranges and bearings at 10-minute intervals for periods of 1 to 3 days, along with LORAN C positioning of the ship. The mass and cross-sectional areas in air and water were estimated from photographs and sonar profiles. Currents were measured continuously using a Doppler acoustic profiler, with the ship holding station usually within 1 to 2 km range from the iceberg. An anemometer on a bow-mounted mast measured wind speed and direction. Data are being compiled at 10-minute intervals and with currents averaged over 10-m depth intervals.

A dynamic model has been developed to calculate iceberg tracks using wind and water drag forces derived from our data, and taking account of Coriolis and pressure-gradient forces. Examples of the data and of model results are shown.

A SECOND-GENERATION SHALLOW WATER RESIO WAVE MODEL

Will Perrie, Wolfgang Rosenthal and Bechara Toulany

The deep water discrete spectral wave model described in Resio, JPO 11: 510-525 (1981) is our starting point. As in Bouws et al., JGR 90: 975-986 (1985), the Phillips saturation range concepts for deep water wave conditions, as extended to finite depth by Kitaigorodskii et al., JPO 5: 410-420 (1975) are applied to the entire spectral range. This extends the self-similar deep water JONSWAP shape to finite water depth in general accordance with the shallow water "TMA" (TEXEL, MARSEN, ARSLOE) spectra. Thus, the deep water dispersion relation is replaced by the more general $\omega^2 = gk \tanh kH$, *and similarly for phase and group velocities. The so-called Kitaigorodskii factor:*

$$\phi_k(\omega_H) = \frac{k(\omega,H)^{-3}\ \partial k(\omega,H)/\partial f}{k(\omega,\infty)^{-3}\ \partial k(\omega,\infty)/\partial f}$$

where H is the depth, g is the gravitational acceleration, f the frequency, $\omega = 2\pi f$ *and* $\omega_H = 2\pi f\sqrt{H/g}$, *is applied to the spectral shape functions, for growth and saturation range, and therefore implicitly for swell and Phillips'* α *function.*

SWIM, QJRMS, in the press (1986) compares HYPAS, the finite depth version of the deep water hybrid parametric wave model developed at Hamburg with GONO, the hybrid parametric model developed at KNMI, and BMO the British Meteorological Office model. Each has a different approach to modelling shallow water waves, and responds differently to the SWIM tests. HYPAS has the same approach to accommodating finite depth as ours. The discrete spectral model considered here with its Kitaigorodskii factor - TMA spectra modifications is seen to behave strikingly like the hybrid parametric deep water model HYPA in the sloping and flat bottom SWIM tests. The more difficult North Sea SWIM test confirms the trend.

POSTERS / AFFICHAGE

ENVIRONMENT CANADA'S NATIONAL CLIMATE DATA ARCHIVE
Mike Webb and Frank Manning

The Canadian Climate Centre of DOE's Atmospheric Environment Service maintains an archive of climatological data in document, micrographic and digital form. This poster session will indicate service and product sources available from the Centre and how they can be obtained. Emphasis will be on recent publications, on digitized climate data and support software which output custom data displays and analyses, and on digitized marine weather data and exploitive software such as "MAST".

POTENTIAL ECONOMIC IMPACT ON PRAIRIE AGRICULTURE OF IMPROVEMENTS IN SHORT-RANGE CLIMATE PREDICTION AND MEDIUM-RANGE WEATHER FORECASTS, AND THE POSSIBLE INFLUENCE OF RADARSAT AND OTHER SPACEBORNE SENSOR DATA
A.K. McQuillan

Results are presented of benefits to prairie agriculture that could result from development of a useful short-range climate prediction capability and from improvements in medium-range weather forecasts. Assessments are made in the light of present concerns about land degradation, and trends to flexible cropping practices. Quantitative potential benefit estimates are given of improved decisions resulting from short-range climate prediction, including decisions on quantity of fertilizer to apply to crops, whether to recrop or summerfallow, type of crop to plant, and suitability of planting a fall crop. Improvements in medium-range weather forecasting are examined for the critical time windows at harvest and planting. Brief consideration is given to potentials of achieving these predictive capabilities within the next decade. Emphasis is placed on expected contributions from RADARSAT's synthetic aperture radar and scatterometer microwave sensors, including ocean surface wind stress information relevant to both atmospheric and oceanic circulation, and snow and soil moisture data believed to be important boundary forcings for short-range climate prediction.

NOTICE

The Newfoundland and Labrador Climate Advisory Committee is compiling an inventory of climate related data pertaining to Newfoundland and Labrador. The committee is interested in hearing from any person or organization that is aware of any such data that are not part of the regular meteorological archives. If you have any information please contact: Dr. Colin E. Banfield, Chairman NLCAC, c/o Dept. of Geography, Memorial University, St.John's, Newfoundland, A1B 3X9.

NOTES

"Conformément aux exigences relatives à l'immigration au Canada, cet emploi est offert aux citoyens canadiens et aux résidents permaments."

Au département de physique

AGENT DE RECHERCHE SOUS OCTROI DE SUBVENTION

Projet de recherche en sciences de l'atmosphère

Poste accessible aux femmes et aux hommes.

Sommaire de la fonction:
Dans le cadre du projet canadien d'études des tempêtes dans l'Atlantique, l'agent de recherche est chargé de l'analyse des données et du calcul du mouvement vertical pour les tempêtes en utilisant une technique qui combine et optimise les méthodes cinématique et adiabatique. Il assure également l'encadrement d'étudiants de 2e cycle en sciences de l'atmosphère.

Exigences:
- Diplôme universitaire de 3e cycle en sciences de l'atmosphère ou dans une discipline appropriée.
- Minimum de cinq (5) ans d'expérience dans l'utilisation des méthodes adiabatique et cinématique en calcul du mouvement vertical atmosphérique.
- Bonne connaissance de la combinaison et de l'optimisation des méthodes adiabetique et cinématique.

Traitement: Selon la politique institutionnelle en vigueur.

Durée de l'emploi: Un (1) an.

Les personnes intéressées doivent faire parvenir un curriculum vitae complet, en indiquant le numéro du concours, ***avant 17 heures, le vendredi 30 juin 1986,*** *à l'attention de:*

Madame Irène Lenoir, Agente de personnel, Service du personnel
Concours: 85-86-R08
UNIVERSITÉ DU QUÉBEC À MONTRÉAL, C.P. 8888, Succursale 'A'
Montréal (Québec) H3C 3P8

Université du Québec à Montréal

TWENTY-FIRST ANNUAL CONGRESS

The Newfoundland Centre of the Canadian Meteorological and Oceanographic Society and Memorial University of Newfoundland will host the Twenty-First Annual CMOS Congress, which will be held at Memorial University from June 16 to 19, 1987. The theme is PREDICTABILITY IN THE ATMOSPHERE AND THE OCEAN.

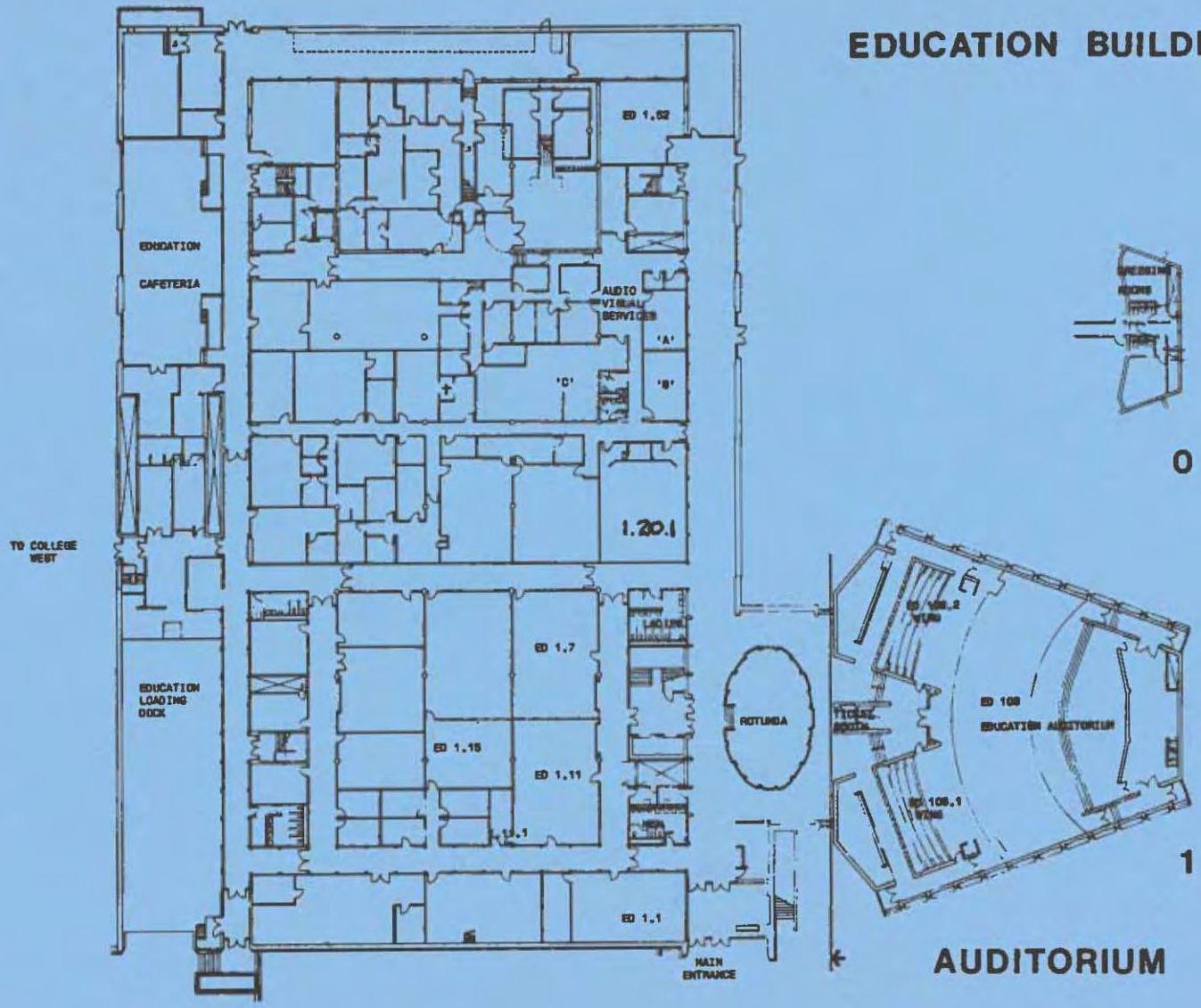
For further information, contact Dr. Alex Hay (Chairman, Scientific Program Committee) or Dr. Brian Sanderson (Chairman, Local Arrangements Committee), Department of Physics, Memorial University, St. John's, Nfld., Canada A1B 3X7. (Phone: (709) 737-8736).

VINGT ET UNIÈME CONGRÈS ANNUEL

Le Centre de Terre-Neuve de la Société canadienne de météorologie et d'océanographie et l'Université Memorial de Terre-Neuve seront les hôtes du vingt et unième congrès annuel de la SCMO, du 16 au 19 juin 1987, à cette université. Le thème en est : POSSIBILITÉ DE LA PRÉVISION ATMOSPHÉRIQUE ET OCÉANIQUE.

On peut obtenir d'autres renseignements auprès de M. Alex Hay (président, Comité du programme scientifique) ou M. Brian Sanderson (président, Comité organisateur), Département de physique, Memorial University, St. John's, Terre- Neuve, Canada A1B 3X7 (Téléphone : (709) 737-8736).

EDUCATION BUILDING 1



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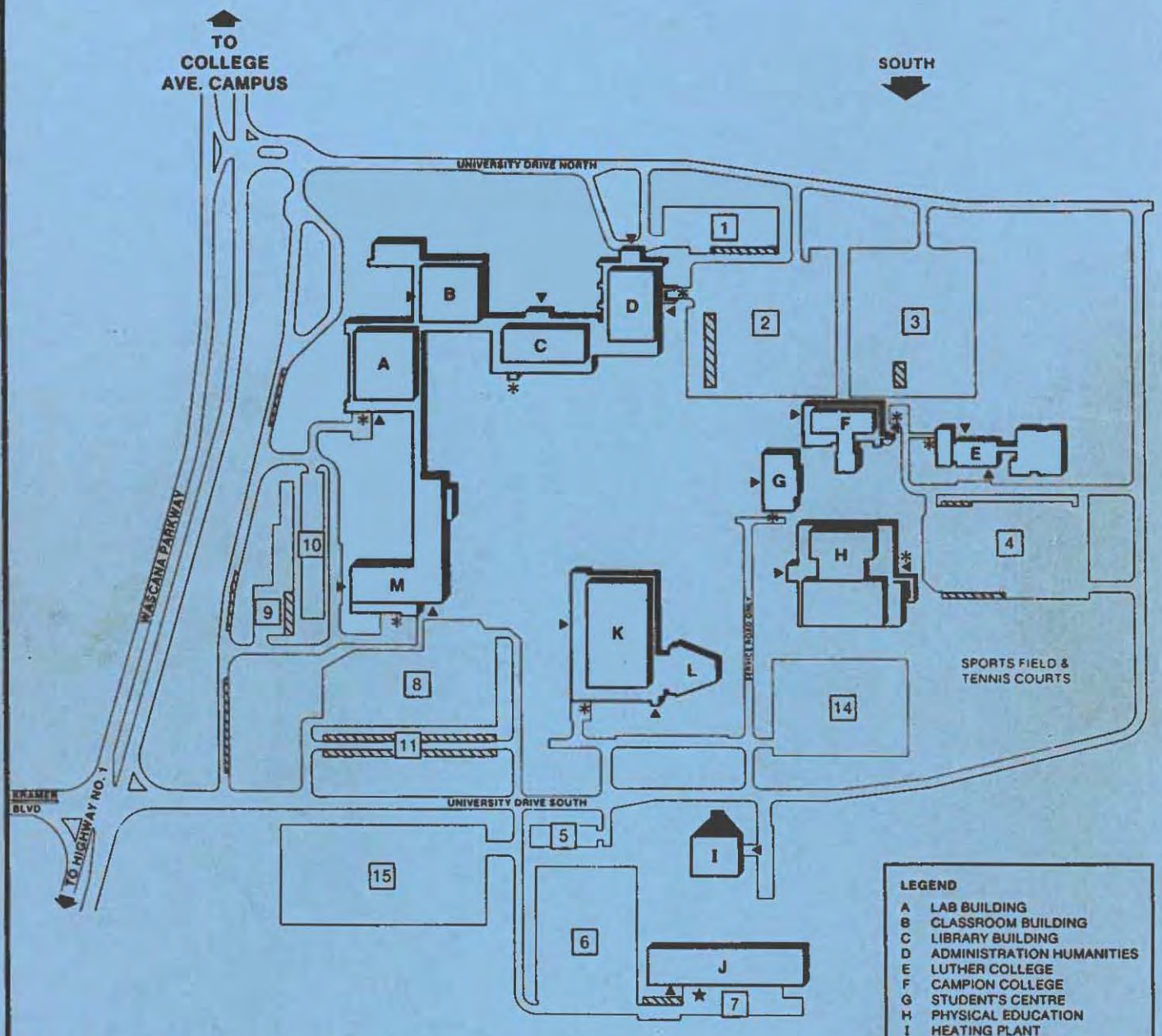
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TO HIGHWAY NO. 1
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C LIBRARY BUILDING
D ADMINISTRATION HUMANITIES
E LUTHER COLLEGE
F CAMPION COLLEGE
G STUDENT'S CENTRE
H PHYSICAL EDUCATION
I HEATING PLANT
J MAINTENANCE BLDG.
K EDUCATION BUILDING
L AUDITORIUM
M COLLEGE WEST
MAIN ENTRANCE
VISITOR PARKING
PARKING LOT NUMBER
SERVICE AREAS
CENTRAL RECEIVING

MAIN CAMPUS