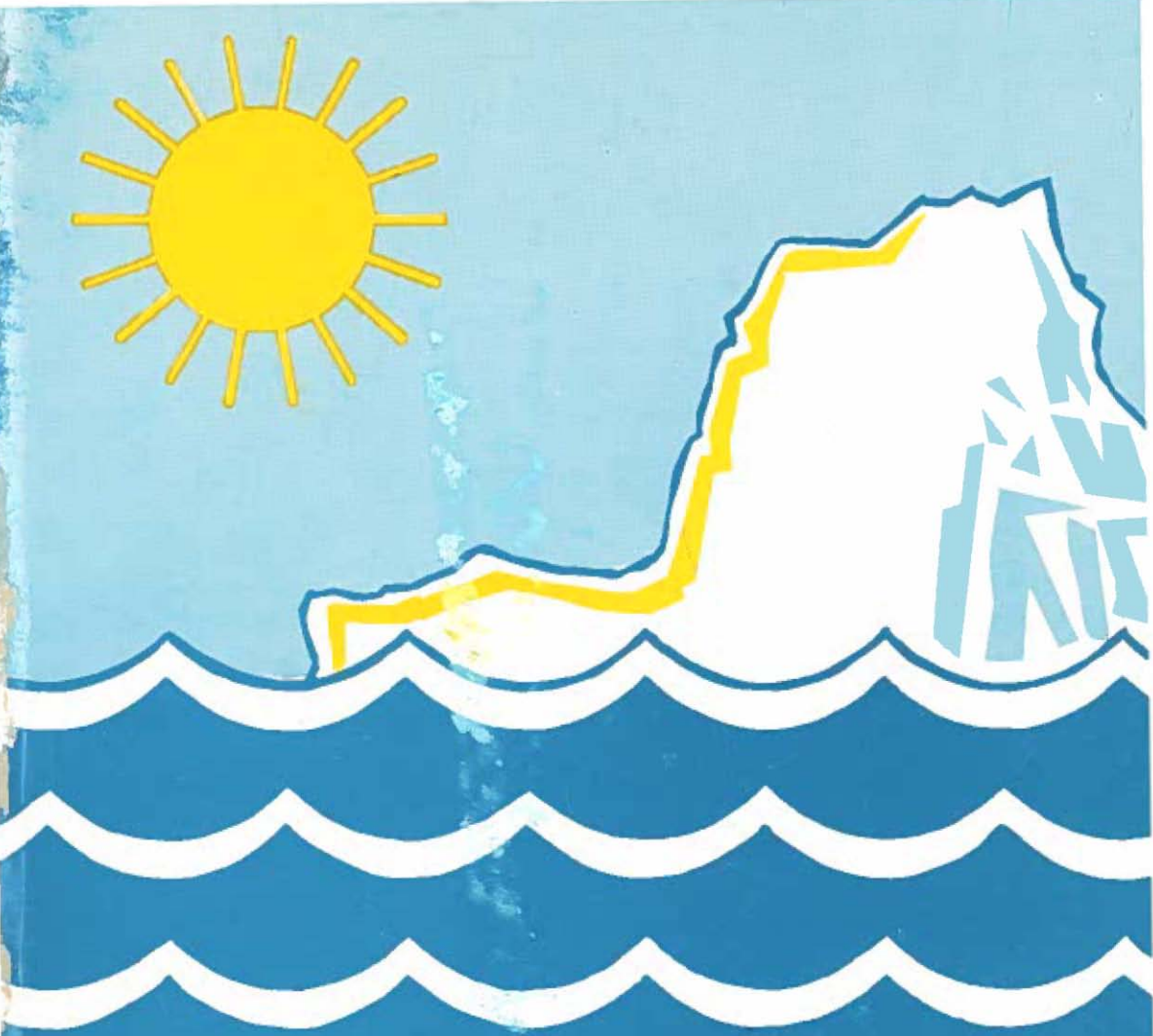

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Metéorologie et d'Océanographie

ST. JOHN'S 87

21st ANNUAL CONGRESS
21e CONGRÈS ANNUEL

June 16-19 Juin

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Programme with Abstracts
Programme avec Résumés

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

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TWENTYFIRST ANNUAL CONGRESS

CANADIAN METEOROLOGICAL AND OCEANOGRAPHIC SOCIETY

The Twentyfirst Annual Congress and Annual General Meeting of the Canadian Meteorological and Oceanographic Society will be held at Memorial University of Newfoundland, St. John's, Newfoundland, June 16-19, 1987. The scientific programme is integrated with the theme of the Congress: *Predictability in the Atmosphere and the Ocean*. The opening plenary sessions and a number of theme sessions will be of common interest to meteorologists and oceanographers. The other sessions comprise papers on topics of special interest announced in the Call for Papers, and on other topics in the fields of meteorology and oceanography.

The Scientific Programme and local arrangements for this meeting were organized by:

SCIENTIFIC PROGRAMME COMMITTEE

A. E. Hay, Chairman
J. Anderson
C. Banfield
M. Béland
R. Haedrich
S. Macko
I. Webster

LOCAL ARRANGEMENTS COMMITTEE

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D. Kinsella, Exhibits
S. Porter, Social
J. Richard, Registration
A. Walsh, Facilities

INVITED SPEAKERS

M. J. Bowman, State University of New York
K. Bryan, Princeton University
E. Lorenz, Massachusetts Institute of Technology
J. Lynch, Woods Hole Oceanographic Institution
J. Mauchline, Dunstaffnage Marine Research Laboratory
L. A. Mysak, McGill University
J. O. Nriagu, National Water Research Institute
A. R. Robinson, Harvard University
R. W. Stewart, Alberta Research Council

VINGT-ET-UNIÈME CONGRÈS ANNUEL

de la SOCIÉTÉ CANADIENNE de MÉTÉOROLOGIE et d'OCÉANOGRAPHIE

Le vingt-et-unième congrès annuel et l'assemblée générale annuelle de la Société de météorologie et d'océanographie auront lieu à Memorial University of Newfoundland, St-Jean, Terre Neuve, 16-19 juin, 1987. Le programme scientifique est intégré avec le thème du congrès: *Prévisibilité dans l'atmosphère et dans l'océan*. Les sessions plenières d'ouverture et un nombre de sessions thème seront d'interêt aussi bien pour les météorologistes que pour les océanographes. D'autres sessions seront comprises sur des sujets d'interêt particulier tel qu'annoncé dans la demande d'articles ainsi que des sujets portant sur le demaine de la météorologie et de l'océanographie.

Le programme scientifique et les arrangements locaux ont été organisés par:

LE COMITÉ DU PROGRAMME SCIENTIFIQUE

A. E. Hay, Président
J. Anderson
C. Banfield
M. Béland
R. Haedrich
S. Macko
I. Webster

LE COMITÉ DES ARRANGEMENTS LOCAUX

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J. Hellou, traduction
D. Kinsella, expositions
S. Porter, activities sociales
J. Richard, inscriptions
A. Walsh, location des lieux

CONFÉRENCIERS INVITÉS

M. J. Bowman, State University of New York
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A. R. Robinson, Harvard University
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SPONSORS

We gratefully acknowledge the following organizations for financial support and/or support in kind:

City of St. John's
Department of Physics, Memorial University of Newfoundland
Natural Science and Engineering Research Council (NSERC)
Newfoundland Institute for Cold Ocean Science (NICOS)
Northwest Atlantic Fisheries Centre
Province of Newfoundland and Labrador

COMMANDITAIRES

Nous aimerions remercier les commanditaires suivants pour leur aide financiaire et/ou aide en espèce:

Conseil de recherches en sciences naturelles et en génie (CRSNG)
Department of Physics, Memorial University of Newfoundland
Newfoundland Institute for Cold Ocean Science (NICOS)
Northwest Atlantic Fisheries Centre
Province of Newfoundland and Labrador
Ville de St-Jean

SESSION AND MEETING ROOM LOCATIONS

All sessions will be held in either the Music Building, or the Science Building. (see University map, back cover). Committee meetings will be held in the Science Building, the Chemistry/Physics Building and the Engineering (Carew) Building.

MUSIC BUILDING ROOMS

M1000 - Registration
M1045 - Plenary and A Sessions (except Wednesday PM)
M1032 - B Sessions
M2025 - C Sessions
M2017 - D Sessions
M1034 - Posters and Exhibits

SCIENCE BUILDING ROOMS

S2109 - Sessions 3A and 4A, (Wednesday, PM)
M1045 - Annual General Meeting
S2000 - Tuesday meetings
S2010 - Tuesday meetings
S2025 - Tuesday meetings
S2041 - Tuesday meetings
S2104 - Tuesday meetings
S3000 - Tuesday meetings

CHEMISTRY/PHYSICS BUILDING ROOM

C2049 - Tuesday meetings

ENGINEERING (CAREW) BUILDING ROOMS

X4002 - Tuesday meetings
X4003 - Tuesday meetings

SUMMARY OF SESSIONS

Monday, June 15		Room
1400 -	CNC/SCOR	S2041

Tuesday, June 16

0900 - 1200	Floating Ice SIG	C2049
0900 - 1200	Hydrology SIG	S2000
0900 - 1200	Education Committee on Meteorology	S2010
0900 - 1200	Education Committee on Oceanography	S2025
0900 - 1200	Mesoscale Subcommittees	S2041
0900 - 1200	Atmosphere-Ocean Editorial Committee	S2104
0900 - 1200	Climatological Bulletin Editorial Committee	S3000
0900 - 1200	CMOS Accreditation Committee (Session 1)	X4003
1300 - 1345	Chinook Editorial Committee	S2000
1300 - 1545	CMOS Scientific Committee	S2010
1300 - 1545	CMOS Centre Chairpersons	S2025
1300 - 1545	Agricultural and Forest Meteorology SIG	S2041
1300 - 1545	Operational Meteorology SIG	S2104
1300 - 1545	CMOS Accreditation Committee (Session 2)	X4003
1300 - 1600	Committee of Heads of Oceanography Groups in Canadian Universities	C2049
1300 - 1545	CMOS Professionalism Committee	S3000
1300 - 1710	Posters/Displays - Set Up Time	M1034
1445 - 1545	CMOS Publications Committee	S2000
1600 - 1730	CMOS National Council (Session 1)	X4002
1900 - 2100	ICE BREAKER RECEPTION	Junior Common Room
2000 - 2300	CMOS National Council (Session 2)	X4002

Wednesday, June 17

0800 - 1200	Registration and Information	M1000
0900 - 1030 1	*Plenary Theme Session I*	M1045
1050 - 1230 2	*Plenary Theme Session II*	M1045
1230 - 1330	Patterson Luncheon	Junior Common Room
1330 - 1710	Registration and Information	M1000
1330 - 1510 3A	*Dynamical Meteorology I*	S2109
1330 - 1510 3B	*Coastal and Shelf Oceanography I*	M1032
1330 - 1510 3C	*Marine Geochemistry and Paleo-Oceanography*	M2025
1330 - 1510 3D	*Applied Oceanography*	M2017

1530 - 1710	4A	*Dynamical Meteorology II*	S2109
1530 - 1710	4B	*Coastal and Shelf Oceanography II*	M1032
1530 - 1710	4C	*Marine Chemistry and Geochemical Processes*	M2025
1530 - 1710	4D	*Scientific and Funding Programs*	M2017
1730 - 1930		UBC Alumni Cocktails	Junior Common Room
1930 - 2230		CMOS Annual General Meeting	M1045

Thursday, June 18

0830 - 1030	5A	*Boundary Layers I. Winds Over Land and Sea*	M1045
0830 - 1030	5B	*Deep Sea Oceanography I: Theory*	M1032
0830 - 1030	5C	*Biological Oceanography I*	M2025
0830 - 1030	5D	*Chemistry of the Atmosphere and Ocean*	M2017
1050 - 1230	6A	*Boundary Layers II. Observations and Theory*	M1045
1050 - 1230	6B	*Deep Sea Oceanography II. Observations*	M1032
1050 - 1230	6C	*Biological Oceanography II*	M2025
1050 - 1230	6D	*Dispersal of Tracers*	M2017
1050 - 1230	6E	*Poster Session*	M1034
1330 - 1510	7A	*Atmosphere/Ocean Coupling I*	M1045
1330 - 1510	7B	*Operational Meteorology*	M1032
1330 - 1510	7C	*Biological/Physical Interactions in the Ocean*	M2025
1330 - 1510	7D	*Sea Ice and Icebergs I*	M2017
1530 - 1710	8A	*Atmosphere/Ocean Coupling II*	M1045
1530 - 1710	8B	*Labrador Current Oceanography*	M1032
1530 - 1710	8C	*Meteorological and Oceanographic Influences on Sockeye Tracks: MOIST*	M2025
1530 - 1710	8D	*Sea Ice and Icebergs II*	M2017
1800 - 1900		Cocktails	Junior Common Room
1900 -		CMOS Annual Banquet	Main Dining Hall

Friday, June 19

0830 - 1030	9A	*Numerical Weather Forecasting*	M1045
0830 - 1030	9B	*Canadian Atlantic Storms Program (CASP) I. Ocean*	M1032
0830 - 1030	9C	*Remote Sensing*	M2025
1050 - 1230	10A	*Climatology*	M1045
1050 - 1230	10B	*Canadian Atlantic Storms Program (CASP) II. Atmosphere*	M1032
1050 - 1230	10C	*Coastal and Shelf Oceanography III. Tides*	M2025
1050 - 1230	10D	*Waves*	M2017
1330 -		TOURS	

RÉSUMÉ DES SESSIONS

Lundi le 15 juin			Room
1400 -		CNC/SCOR	S2041

Mardi le 16 juin

0900 - 1200	GIS: Glace Flotante	C2049
0900 - 1200	GIS: Hydrologie	S2000
0900 - 1200	Comité d'éducation en météorologie	S2010
0900 - 1200	Comité d'éducation en océanographie	S2025
0900 - 1200	Sous-comité sur l'échelle moyenne	S2041
0900 - 1200	Conseil de rédaction d'ATMOSPHERE-OCEAN	S2104
0900 - 1200	Conseil de rédaction du Bulletin climatoloque	S3000
0900 - 1200	Comite d'accréditation de la SCMO (Session 1)	X4003
1300 - 1345	Conseil de rédaction du Chinook	S2000
1300 - 1545	Conseil scientifique de la SCMO	S2010
1300 - 1545	Comité des présidents des centres de la SCMO	S2025
1300 - 1545	GIS: météorologie agricole et forestière	S2041
1300 - 1545	GIS: météorologie opérationnelle	S2104
1300 - 1545	Comité sur le professionnalism de la SCMO	S3000
1300 - 1545	Comité d'accréditation de la SCMO (Session 2)	X4003
1300 - 1600	Comité des directeurs de groupes océanographiques des universités du Canada	C2049
1300 - 1710	Montage des expositions et des affiches	M1034
1445 - 1545	Comité de gestion des publications de la SCMO	S2000
1600 - 1730	Conseil national de la SCMO (Session 1)	X4002
1900 - 2100	BRISE-GLACE (RECEPTION)	Junior Common Room
2000 - 2300	Conseil national de la SCMO (Session 2)	X4002

Mercredi le 17 juin

0800 - 1200		Inscription et Information	M1000
0900 - 1030	1	*Session plenière thèmatique I*	M1045
1050 - 1230	2	*Session plenière thèmatique II*	M1045
1230 - 1330		Diner Patterson	Junior Common Room
1330 - 1710		Inscription et Information	M1000
1330 - 1510	3A	*Météorologie dynamique I*	S2109
1330 - 1510	3B	*Océanographie côtière et du plateau I*	M1032
1330 - 1510	3C	*Géochimie marine et paléo-océanographie*	M2025
1330 - 1510	3D	*Océanographie appliquée*	M2017

1530 - 1710 4A	*Météorologie dynamique II*	S2109
1530 - 1710 4B	*Océanographie côtière et du plateau II*	M1032
1530 - 1710 4C	*Chimie marine et processus géochimiques*	M2025
1530 - 1710 4D	*Programmes scientifiques et de subvention*	M2017
1730 - 1930	UBC Alumni Réception	Junior Common Room
1930 - 2230	Assemblée générale annuelle de la SCMO	S2109

Jeudi le 18 juin

0830 - 1030 5A	*La couche limite I. Le vent sur mer et terre*	M1045
0830 - 1030 5B	*Océanographie du fond des mers I: Théorie*	M1032
0830 - 1030 5C	*Océanographie biologique I*	M2025
0830 - 1030 5D	*Chimie de l'atmosphère et de l'océan*	M2017
1050 - 1230 6A	*La couche limite II. Observations et théorie*	M1045
1050 - 1230 6B	*Océanographie du fond des mers II. Observations*	M1032
1050 - 1230 6C	*Océanographie biologique II*	M2025
1050 - 1230 6D	*Dispersion des traceurs*	M2017
1050 - 1230 6E	*Affichage*	M1034
1330 - 1510 7A	*Couplage atmosphère/océan I*	M1045
1330 - 1510 7B	*Météorologie opérationnelle*	M1032
1330 - 1510 7C	*Prévision des systèmes biologiques marins*	M2025
1330 - 1510 7D	*Glace marine et icebergs II*	M2017
1530 - 1710 8A	*Couplage atmosphère/océan II*	M1045
1530 - 1710 8B	*Océanographie du courant du Labrador*	M1032
1530 - 1710 8C	*Couplage atmosphère/océan II*	M2025
1530 - 1710 8D	*Glace marine et icebergs II*	M2017
1800 - 1900	Réception	Junior Common Room
1900 -	Banquet de la SCMO	Main Dining Hall

Vendredi le 19 juin

0830 - 1030 9A	*Prévision météorologique numérique*	M1045
0830 - 1030 9B	*Le Programme canadien d'étude des tempêtes dans l'Atlantique (CASP) I. Océan*	M1032
0830 - 1030 9C	*Télédétection*	M2025
1050 - 1230 10A	*Climatologie*	M1045
1050 - 1230 10B	*Le Programme canadien d'étude des tempêtes dans l'Atlantique (CASP) II. Atmosphère*	M1032
1050 - 1230 10C	*Océanographie côtière et du plateau III. Le marée*	M2025
1050 - 1230 10D	*Ondes*	M2017
1330 -	TOURS	

WEDNESDAY	THURSDAY	FRIDAY
0900 – 1030	**0830 – 1030**	**0830 – 1030**
1 Plenary Session I M1045	5A Boundary Layers I M1045	9A Num. Weather Forecasting M1045
	5B Deep Sea Oceanography I M1032	9B CASP I: Ocean M1032
	5C Biological Oceanography I M2025	9C Remote Sensing M2025
	5D Chemistry Atmos. Ocean M2017	
Coffee 1030 – 1050		
1050 – 1230	**1050 – 1230**	**1050 – 1230**
2 Plenary Session II M1045	6A Boundary Layers II M1045	10A Climatology M1045
	6B Deep Sea Oceanography II M1032	10B CASP II: Atmosphere M1032
	6C Biological Oceanography II M2025	10C Coastal & Shelf Ocean.III M2025
	6D Dispersal of Tracers M2017	10D Waves M2017
	6E Posters M1034	
Lunch 1230 – 1330		
1330 – 1510	**1330 – 1510**	
3A Dynamical Meteorology I S2109	7A Atmos./Ocean Coupling I M1045	
3B Coastal & Shelf Ocean. I M1032	7B Operational Meteorology M1032	Tours
3C Mar. Geochem. & Paleo. M2025	7C Biol./Phys. Interactions M2025	
3D Applied Oceanography M2017	7D Sea Ice & Icebergs I M2017	
Coffee 1510 – 1530		
1530 – 1710	**1530 – 1710**	
4A Dynamical Meteorology II S2109	8A Atmos./Ocean Coupling II M1045	
4B Coastal & Shelf Ocean. II M1032	8B Labrador Current Oceanogr.M1032	Tours
4C Marine Chemistry M2025	8C MOIST M2025	
4D Programs M2017	8D Sea Ice & Icebergs II M2017	

WEDNESDAY MORNING

WELCOMING ADDRESS — Wed. 0900-0935

Chairperson B. G. Sanderson, Memorial University — Room M1045

0900 Dr. W. S. Appleby, President, CMOS
0910 His Honour James J. McGrath, Lieutenant-Governor, The Province of Newfoundland and Labrador
0920 Dr. L. Harris, President, Memorial University of Newfoundland

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SESSION 1 *PLENARY THEME SESSION I* — Wed. 0935-1030

Chairperson W. S. Appleby, President, CMOS — Room M1045

0935 PREDICTABLE WEATHER: FANTASY OR FACT?
Lorenz, E. N., Center for Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, MA

Coffee (1030-1050)

SESSION 2 *PLENARY THEME SESSION II* — Wed. 1050-1230

Chairperson A. E. Hay, Memorial University — Room M1045

1050 PREDICTABILITY, SENSITIVITY AND TRANSITIVITY IN THE COUPLED OCEAN ATMOSPHERE SYSTEM
Stewart, R. W., Alberta Research Council, Edmonton, AB

1140 PREDICTING OPEN OCEAN CURRENTS, FRONTS AND EDDIES: THE PROBLEM AND AN ONGOING SCHEME FOR THE GULF STREAM SYSTEM
Robinson, A. R., Division of Applied Sciences, Harvard University, Cambridge, MA

Lunch (1230-1330)

WEDNESDAY AFTERNOON

SESSION 3A *DYNAMICAL METEOROLOGY I* — Wed. 1330-1510

Chairperson T. Warn, McGill University — Room S2109

1330 ON THE GENESIS OF METEOROLOGICAL BOMBS
Moore, G. W. K. and W. R. Peltier, Department of Physics, University of Toronto, Toronto, ON

1345 CYCLONE SCALE BAROCLINIC INSTABILITY
Peltier, W. R. and G. W. K. Moore, Department of Physics, University of Toronto, Toronto, ON

1400 THE ROLE OF BAROCLINIC INSTABILITY IN THE PREDICTABILITY PROBLEM
Straus, D. M., Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD

1415 A STUDY OF WAVE-WAVE INTERACTIONS IN A STEADY-STATE STRATOSPHERIC MODEL
McLandress, C. and J. Derome, Department of Meteorology, McGill University, Montréal, PQ

1430 TOPOGRAPHIC WAVES IN A FORCED-DISSIPATED BAROTROPIC MODEL
Gravel, S. and J. Derome, Department of Meteorology, McGill University, Montréal, PQ

1445 THE STABILITY OF A FINITE-AMPLITUDE MOUNTAIN WAVE
Laprise, R. and W. R. Peltier, Department of Physics, University of Toronto, Toronto, ON

SESSION 3B *COASTAL AND SHELF OCEANOGRAPHY I* Wed. 1330-1515

Chairperson H. Freeland, Institute of Ocean Sciences Room M1032

1330 TIME DEPENDENT FORM OF THE ARRESTED TOPOGRAPHIC WAVE
Thompson, K. R., Department of Oceanography, Dalhousie University, Halifax, NS

1345 SUB-INERTIAL OSCILLATIONS ON A BAROCLINIC SHELF
Narayanan, S. and I. Webster, Department of Physics, Memorial University of Newfoundland, St. John's, NF

1400 SHELF WAVE SCATTERING DUE TO A LONGSHORE JUMP IN DEPTH
Middleton, J. F. and D.G. Wright, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, NS

1415 THE STABILITY AND THE VERTICAL STRUCTURE OF THE MEAN CURRENTS IN THE STRAIT OF GEORGIA
Stacey, M. W., S. Pond and P. H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, BC

1430 DEEP WATER REPLACEMENT IN THE STRAIT OF GEORGIA
Doherty, F. and P. H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, BC

1445 ANNUAL CYCLE OF TRANSPORT THROUGH HECATE STRAIT
Crawford, W. R., Institute of Ocean Sciences, Sidney, BC

1500 NET INFLOW AND OUTFLOW OBSERVATIONS DURING DEEPWATER RENEWAL IN TWO CLOSELY SPACED CHANNELS ON A SILL
Lee, W. G. and D. Nebert, Department of Oceanography, University of British Columbia, Vancouver, BC

SESSION 3C MARINE GEOCHEMISTRY AND PALEO-OCEANOGRAPHY Wed. 1330-1510

Chairperson S. Macko, Memorial University Room M2025

1330 Keynote Address:

BIOGENIC SULFUR FROM MARINE AND CONTINENTAL SOURCES
Nriagu, J., National Water Research Institute, Burlington, ON

1405 LATE QUATERNARY/HOLOCENE DEPOSITIONAL ENVIRONMENTS OF THE WESTERN CANADIAN ARCTIC ARCHIPELAGO
Pereira, C. P. G. and S. A. Macko, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland

1425 PRODUCTIVITY CYCLES IN THE EASTERN EQUATORIAL PACIFIC AND THE RESPONSE OF BENTHIC FORAMINIFERA
Pedersen, T. F.*, M. Pickering and N. J. Shackleton, *Department of Oceanography, University of British Columbia, Vancouver, BC

1445 ORIGIN OF THE HOLOCENE BLACK SEA SAPROPEL BY INCREASED PRIMARY PRODUCTION
Calvert, S. E.*, J. S. Vogel, J. R. Southon and M. R. Fontugne, *Department of Oceanography, University of British Columbia, Vancouver, BC

SESSION 3D APPLIED OCEANOGRAPHY Wed. 1330-1510

Chairperson L. Muir, COGLA Room M2017

1330 PHYSICAL OCEANOGRAPHIC PROCESSES RELEVANT TO WATER QUALITY MODELLING IN HALIFAX INLET
Hurlbut, S., ASA Consulting Limited, Dartmouth, NS

1345 METHODS OF CREATING AND PREDICTING INITIAL DILUTION FOR EFFLUENT DISPOSAL IN COASTAL WATERS
Sharp, J. J. and J. H. Allen, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NF

1400 SEDIMENTATION STUDIES FOR MARINE TERMINAL FACILITIES IN MUSQUASH HARBOUR, NEW BRUNSWICK
de Margerie, S., S. Davidson and S. Hurlbut, ASA Consulting Limited, Dartmouth, NS

1415 THE VARIABILITY OF ENVIRONMENTAL LOADS ON OFFSHORE STRUCTURES
Maes, M. A.*, L. R. Muir and V. Swail, *Det Norske Veritas (Canada) Limited, Calgary, AB

1430 ON WAVE-CURRENT-STRUCTURE INTERACTION
Baddour, E. and S. Shaowen, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NF

1445 ON THE USE OF THERMITE FOR THE FRACTURING OF ICEBERGS
Lewis, J. C.* and P. H. Gammon, *Department of Physics, Memorial University of Newfoundland, St. John's, NF

Coffee (1510-1530)

SESSION 4A *DYNAMICAL METEOROLOGY II* Wed. 1530-1710

Chairperson M. Béland, AES Dorval Room S2109

1530 PRELIMINARY EXPERIMENTS WITH A ONE-DIMENSIONAL TURBULENCE MODEL; ENSTROPHY CASCADES AND INTERMITTENCY
Bartello, P. and T. Warn, Department of Meteorology, McGill University, Montréal, PQ

1545 A DIAGNOSTIC VORTICITY ANALYSIS OF BLOCKING USING DATA FROM THE CANADIAN CLIMATE CENTRE GENERAL CIRCULATION MODEL
Lin, C. A. and W. A. Gough, Department of Meteorology, McGill University, Montréal, PQ

1600 BAROTROPIC MODON PROPAGATION OVER SLOWLY VARYING TOPOGRAPHY
Swaters, G. E., Department of Mathematics, University of Alberta, Edmonton, AB

1615 STABILITY CONDITIONS AND A PRIORI ESTIMATES FOR EQUIVALENT-BAROTROPIC MODONS
Swaters, G. E., Department of Mathematics, University of Alberta, Edmonton, AB

SESSION 4B *COASTAL AND SHELF OCEANOGRAPHY II* Wed. 1530-1710

Chairperson Y. Gratton, Université du Québec à Rimouski Room M1032

1530 LOW FREQUENCY VARIABILITY IN THE DEEPER WATERS OF THE GULF OF ST. LAWRENCE
Bugden, G. L., Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

1545 ON THE VARIABILITY AND VERTICAL STRUCTURE OF LONGSHORE CURRENTS IN THE JACQUES CARTIER STRAIT, SUMMER 1986
Koutitonsky, V. G., D. Lefaivre, D. Haines and P. Ouellet, INRS-Océanologie, Institut national de la recherche scientifique, Rimouski, PQ

1600 NUMERICAL SIMULATION OF ATMOSPHERICALLY-FORCED CIRCULATION IN THE SOUTHERN BEAUFORT SEA
Budgell, W. P., Institute of Ocean Sciences, Sidney, BC

1615 LABORATORY EXPERIMENTS: SLOPE FLOW INDUCED BY SURFACE SALT FLUX
van Hardenberg, B. J.*, D. R. Topham and P. H. LeBlond, *Ocean Physics Group, Institute of Ocean Sciences, Sidney, BC

1630 SEDIMENT TRANSPORT PROCESSES IN THE MACKENZIE RIVER PLUME
Davidson, S., S. de Margerie and P. Hill, ASA Consulting Limited, Dartmouth, NS

SESSION 4C MARINE CHEMISTRY AND GEOCHEMICAL PROCESSES

Wed. 1530-1710

Chairperson J. Welhan, Memorial University Room M2025

1530 ORGANIC GEOCHEMICAL COMPARISONS OF FORTUNE BAY AND BAY D'ESPOIR, NEWFOUNDLAND
Pulchan, K. and S. A. Macko, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF

1550 CHARACTERIZATION OF SELECTED ORGANICS ON PARTICLES AND SEDIMENTS IN THE ST. LAWRENCE ESTUARY
Tronczynski, J., J. N. Gearing and S. Macko, Fisheries and Oceans, Maurice-Lamontagne Institute, Mont-Joli, PQ

1610 ORGANIC GEOCHEMISTRY OF SEDIMENT CORES FROM THREE NEWFOUNDLAND BAYS
Ostrom, N. E., C. G. Troke and S. A. Macko, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF

1630 SEDIMENTARY GEOCHEMISTRY OF TWO ABYSSAL PLAINS IN THE NORTH ATLANTIC
Buckley, D. E., Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, NS

1650 STABLE ISOTOPIC COMPOSITION OF PLANT PIGMENTS
Bidigare, R. R., M. C. Kennicutt II and S. Macko, Department of Oceanography, Texas A & M University, College Station, TX

SESSION 4D SCIENTIFIC AND FUNDING PROGRAMS Wed. 1530-1710

Chairperson B. Ruddick, Dalhousie University Room M2017

1530 ERICA: PLANNING AND PROGRESS
Hadlock, R., C. W. Kreitzberg and R. F. Abbey, Jr., Battelle Memorial Institute, Richland, MA

1555 THE WORLD CLIMATE RESEARCH PROGRAMME: RATIONALE AND PROJECTS
McBean, G. A., Canadian Climate Centre, Institute of Ocean Sciences, Sidney, BC

1620 THE ONR PROGRAM IN OCEAN AND ATMOSPHERIC SCIENCE
Weinstein, A. I., Ocean Sciences Division, Department of the Navy, Arlington, VA

1645 LOOKING FAR DOWNSTREAM; CMOS IN 2087
LeBlond, P. H., Department of Oceanography, University of British Columbia, Vancouver, BC

UBC Alumni Cocktails Wed. 1730-1930
Junior Common Room

CMOS Annual General Meeting Wed. 1930-2230
Room M1045

THURSDAY MORNING

SESSION 5A BOUNDARY LAYERS I: WINDS OVER LAND AND SEA

Thurs. 0830-1030

Chairperson G. Strong, Alberta Research Council Room M1045

0830 THE ASKERVEIN HILL PROJECT: VERTICAL PROFILES ABOVE THE HILLTOP
Mickle, R. E., P. A. Taylor and H. W. Teunissen, Boundary-Layer Research Division, Atmospheric Environment Service, Downsview, ON

0845 THE ASKERVEIN HILL PROJECT: MEAN WIND VARIATIONS AT FIXED HEIGHTS ABOVE THE GROUND
Taylor, P. A. and J. R. Salmon, Boundary-Layer Research Division, Atmospheric Environment Service,Downsview, ON

0900 A COMPARISON OF SHORE AND NEARBY SHIP WIND REPORTS ALONG THE B.C. COAST
Anderson, J., Pacific Weather Centre, Vancouver, BC

0915 THEORETICAL WIND SPEED PROFILES OVER THE SEA WITH APPLICATION TO DATA FROM SABLE ISLAND
Walmsley, J. L., Boundary-Layer Research Division, Atmospheric Environment Service, Downsview, ON

0930 CLIMATOLOGICAL ESTIMATES OF LAND-SEA WIND-SPEED RATIOS IN THE VICINITY OF SABLE ISLAND
Walmsley, J. L., P. A. Taylor and V. Swail, Boundary-Layer Research Division, Atmospheric Environment Service, Downsview, ON

0945 THE SPATIAL COHERENCE OF MARINE WIND OBSERVATIONS
Brown, R. D. and V. R. Swail, Hydrometeorology and Marine Division, Canadian Climate Centre,Downsview, ON

1000 ISALLOBARIC CONTRIBUTIONS TO THE REAL WIND: A CASE STUDY, JANUARY 14TH, 1986
Earle, A. G. and D. E. Steeves, Newfoundland Weather Centre, Gander, NF

SESSION 5B DEEP SEA OCEANOGRAPHY I: THEORY Thurs. 0830-1030

Chairperson J. Lazier, Bedford Institute Room M1032

0830 THE INERTIAL SUBGYRES FOUND IN NUMERICAL OCEAN MODELS
Greatbatch, R. J., Department of Physics, Memorial University of Newfoundland, St. John's, NF

0845 THE INFLUENCE OF TOPOGRAPHY ON THE STRUCTURE OF WESTERN BOUNDARY CURRENTS
Greatbatch, R. J. and D. M. Holland, Department of Physics, Memorial University of Newfoundland, St. John's, NF

0900 GENERATION OF ANNUAL PERIOD ROSSBY WAVES IN THE SOUTH ATLANTIC OCEAN BY THE WIND STRESS CURL
Reason, C. J. C. and L. A. Mysak, Department of Meteorology, McGill University, Montréal, PQ

0915 TRAPPING OF NEAR-INERTIAL FRONTAL-VORTICITY WAVES DUE TO CRITICAL LAYER ABSORPTION, WITH APPLICATION TO THE NORTH PACIFIC SUBTROPICAL FRONT
Swaters, G. E., Department of Mathematics, University of Alberta, Edmonton, AB

0930 ISOLATED BAROCLINIC EDDY IN A SHEAR OR STRAIN FLOW: THEORY
Ruddick, B., Department of Oceanography, Dalhousie University, Halifax, NS

0945 ISOLATED BAROCLINIC EDDY IN A SHEAR OR STRAIN FLOW: EXPERIMENT
Brickman, D., Department of Oceanography, Dalhousie University, Halifax, NS

SESSION 5C *BIOLOGICAL OCEANOGRAPHY I* Thurs, 0830-1030

Chairperson R. Haedrich, Memorial University Room M2025

0830 Keynote Address:

PHYSICAL AND BIOLOGICAL STUDIES IN THE ROCKALL TROUGH, NORTHEAST ATLANTIC
J. Mauchline, Scottish Marine Biological Association, Dunstaffnage Marine Laboratory, P. O. Box 3, Oban, Argyll, Scotland, U.K.

0900 MARINE BIOTIC AND ENVIRONMENTAL CYCLES
Dunbar, M. J., Institute of Oceanography, McGill University, Montréal, PQ

0915 VARIABILITY IN THE HYDROTHERMAL VENT ENVIRONMENT: FROM SECONDS TO CENTURIES
Tunnicliffe, V., Biology Department, University of Victoria, Victoria, BC

0930 SEASONAL PATTERNS IN OCEANOGRAPHIC AND BIOLOGICAL EVENTS IN A FJORD, BONNE BAY, NEWFOUNDLAND
Hooper, R. G., Department of Biology/NICOS, Memorial University of Newfoundland, St. John's, NF

0945 PREDICTING GUANO PRODUCTION FROM EL NINO EVENTS
Schneider, D., Newfoundand Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, NF

1000 THE RELATIVE IMPORTANCE OF BIOLOGICAL AND PHYSICAL PROCESSES IN STRUCTURING THE FAUNAL ASSEMBLAGES OF TWO NEWFOUNDLAND FJORDS
Richard, J. M., Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, NF

1015 OCEANOGRAPHY AND LIMNOLOGY: CONSTRAINT AND PREDICTABILITY IN THE FISH PRODUCTION SYSTEMS
Johnson, L., Freshwater Institute, Winnipeg, MB

SESSION 5D CHEMISTRY OF THE ATMOSPHERE AND OCEAN Thurs. 0830-1030

Chairperson T. Pedersen, University of British Columbia Room M2017

0830 AN UNDERWATER MOVIE: HYDROTHERMAL VENT ORGANISMS NEAR A NATURAL GAS AND OIL SEEP IN GREEN CANYON, GULF OF MEXICO
Kennicutt II, M. C., Department of Oceanography, Texas A & M University, College Station, TX

0850 THE NATURAL SEEPAGE OF PETROLEUM ON THE GULF OF MEXICO CONTINENTAL SLOPE
Kennicutt II, M. C. and J. M. Brooks, Department of Oceanography, Texas A & M University, College Station, TX

0910 THE ROLE OF MID-OCEAN RIDGE HYDROTHERMAL PROCESSES IN THE CYCLING OF CARBON IN THE OCEANS
Welhan, J. and H. Craig, Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF

0930 INTERACTIONS ENTRE LE FER ET L'ARSENIC DANS LES SÉDIMENTS DU SAINT-LAURENT
Belzile, N. and J. Lebel, Département d'Océanographie, Université du Québèc à Rimouski, Rimouski, PQ

0950 MASS TRANSPORT CONSTRAINTS ON THE GROWTH OF FERRO-MANGANESE NODULES
Boudreau, B. P., Department of Oceanography, University of British Columbia, Vancouver, BC

1010 THE INFLUENCE OF THE ICE PHASE ON THE CHEMISTRY OF A RAINBAND
Leighton, H. G., A. Giles and M. K. Yau, Department of Meteorology, McGill University, Montréal, PQ

Coffee (1030-1050)

SESSION 6A BOUNDARY LAYERS II: OBSERVATIONS AND THEORY

Thurs. 1050-1230

Chairperson P. Taylor, AES Downsview Room 1045

1050 MEASUREMENTS OF THE WIND STRESS, HEAT FLUX, AND TURBULENCE INTENSITY DURING STORM CONDITIONS OVER THE NORTH SEA
Geernaert, G. L. and S. E. Larsen, Navy Center for Space Technology, Naval Research Laboratory, Washington, DC

1105 PRELIMINARY RESULTS OF THE HUMIDITY EXCHANGE MAIN EXPERIMENT (HEXMAX)
Smith, S. D., Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

1120 A PARAMETERIZATION OF THE STABLE ATMOSPHERIC BOUNDARY LAYER
Delage, Y., Recherche en prévision numérique, Service de l'environnement atmosphèrique, Dorval, PQ

1135 INFLUENCE OF THE EARTH'S ROTATION ON THE TURBULENT STRUCTURE OF THE NEUTRAL PLANETARY BOUNDARY LAYER
Riopelle, G. and G. D. Stubley, Department of Mechanical Engineering, University of Waterloo, Waterloo, ON

1150 ON EFFECTIVE ROUGHNESS LENGTHS OF HETEROGENEOUS TERRAIN FOR USE IN LARGE SCALE MODELS
Taylor, P. A., Boundary-Layer Research Division, Atmospheric Environment Service, Downsview, ON

1205 VERTICALLY INTEGRATED MODELS OF BOTTOM MIXED LAYER GROWTH IN THE OCEAN
Jin, Y. H. and A. E. Hay, Department of Physics, Memorial University of Newfoundland, St. John's, NF

SESSION 6B DEEP SEA OCEANOGRAPHY II. OBSERVATIONS.

Thurs. 1050-1230

Chairperson L. Mysak, McGill University Room M1032

1050 THE MIXING OF MEDDY "SHARON"
Ruddick, B. and D. Hebert, Department of Oceanography, Dalhousie University, Halifax, NS

1105 POSSIBLE INSTRUMENTAL EFFECTS CONTAMINATING INTERDECADAL TRENDS IN SHIP-BASED SST OBSERVATIONS
Allingham, M., L. A. Mysak and K. Hamilton, Department of Meteorology, McGill University, Montréal, PQ

1120 T/S PROPERTIES OF THE ARCTIC OCEAN NEAR THE ALPHA RIDGE
Perkin, R. G., and E. L. Lewis, Institute of Ocean Science, Sidney, BC

SESSION 6C *BIOLOGICAL OCEANOGRAPHY II* Thurs. 1050-1230

Chairperson J. Anderson, Northwest Atlantic Fisheries Centre
Room M2025

1050 THE IMPORTANCE OF SPATIAL SCALE IN CHARACTERIZING BENTHIC COMMUNITY COMPOSITION AND ITS RELATION TO THE SUBSTRATUM
Gagnon, J. M., Department of Biology, Memorial University of Newfoundland, St. John's, NF

1105 LOCATION, DEMOGRAPHY AND MICRODISTRIBUTION OF 'COLD SEEP' BENTHIC COMMUNITIES IN THE JAPAN TRENCH SYSTEM: BIOLOGICAL REFLECTION OF GEOLOGICAL PROCESSES
Juniper, S. K., Department of Biology, University of Victoria, Victoria, BC

1120 THE GEOGRAPHICAL DISTRIBUTION AND LIFE HISTORY OF BOREOMYSIS NOBILIS G. O. SARS 1879 IN COASTAL NEWFOUNDLAND FJORDS
Munro, K. and J. M. Richard, Department of Biology, Memorial University of Newfoundland, St. John's, NF

1135 STUDIES ON THE AUTECOLOGY OF SAGITTA SINICA, N. SP. (CHAETOGNATHA) AND OF ALLIED SPECIES FROM THE EAST CHINA SEA
Yichang, X., Institute of Oceanology, Academia Sinica, Tsingtao, People's Republic of China

1150 PREDICTABILITY OF COMMUNITY COMPOSITION IN DEEP-LIVING DEMERSAL FISHES
Haedrich, R. L.* and N. R. Merrit, *Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, NF

SESSION 6D *DISPERSAL OF TRACERS IN THE ATMOSPHERE AND OCEAN*
Thurs. 1050-1235

Chairperson V. Koutitonsky, INRS Rimouski Room M2017

1050 COMMENTS ON DIFFUSION IN THE LAGRANGIAN FRAMEWORK
Sanderson, B. G., Department of Physics, Memorial University of Newfoundland, St. John's, NF

1105 RANDOM WALKS IN NONHOMOGENEOUS TURBULENCE
Bennett, A. F., Institute of Ocean Sciences, Sidney, BC

1120 SIMULATED FLOAT STATISTICS OFF VANCOUVER ISLAND
Freeland, H. J. and W. R. Crawford, Institute of Ocean Sciences, Sidney, BC

1135 VELOCITIES RELATIVE TO THE CENTROID OF A CLUSTER OF DRIFTERS
Pal, B. K. and B. G. Sanderson, Department of Physics, Memorial University of Newfoundland, St. John's, NF

1150 INTERANNUAL VARIABILITY OF TRANSBOUNDARY SULFUR MASS FLUX
Olson, M. P. and K. K. Oikawa, Air Quality and Inter-Environmental Research Branch, Atmospheric Environment Service, Downsview, ON

1205 CROSS-FRONTAL FLUXES OF HEAT AND NITRATE ON GEORGES BANK
Loder, J. W., E. P. W. Horne and O. Ulloa, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

1220 HORIZONTAL MIXING OF PLANKTON BY INTERNAL WAVES, SURFACE WAVES AND SMALLER SCALE TURBULENT MOTION
Sanderson, B. G., B. K. Pal and A. Goulding, Department of Physics, Memorial University of Newfoundland, St. John's, NF

SESSION 6E: POSTERS Thurs. 1050-1230

Room M1034

1 SATELLITE SCATTEROMETER APPLICATIONS FOR ARCTIC ICE/WATER BOUNDARY IDENTIFICATION
Peteherych, S., Atmospheric Environment Service, Downsview, ON

2 THE LIGHT ENVIRONMENT OF GREENHOUSE-GROWN CONIFER SEEDLINGS
Tuller, S. E. and M. J. Peterson, Department of Geography, University of Victoria, Victoria, BC

3 TEMPERATURE ANALYSES FROM NEAR REAL-TIME OCEANOGRAPHIC OBSERVATIONS
Gagnon, J. J., J. R. Keeley and P. A. Bolduc, Marine Environmental Data Service, Department of Fisheries and Oceans, Ottawa, ON

4 REAL-TIME AND NEAR REAL-TIME DATA AND DATA PRODUCTS AVAILABLE FROM MEDS
Gagnon, J. J., P. A. Bolduc and J. R. Keeley, Marine Environmental Data Service, Department of Fisheries and Oceans, Ottawa, ON

5 ENVIRONMENT CANADA NATIONAL CLIMATE DATE ARCHIVE
Webb, M., Canadian Climate Centre, Atmospheric Environment Service, Downsview, ON

6 COLD OCEAN PRODUCTIVITY EXPERIMENT (COPE 86); PARTICLE FLUX, NUTRIENT, AND SESTON CHARACTERISTICS
Thompson, R. J., D. Deibel, L. R. Pomeroy, D. J. Douglas and P. C. Griffith, Marine Sciences Research Laboratory, Memorial University of Newfoundland, St. John's, NF

7 COPE-86: RESPONSE OF HETEROTROPHIC BACTERIA AT LOW TEMPERATURE TO VARIED SUBSTRATE CONCENTRATIONS
Pomeroy, L. R., D. Deibel, R. J. Thompson, D. J. Douglas and P. Griffith, Institute of Ecology, University of Georgia, Athens, GA

8 COPE-86: SHORT-TERM TEMPERATURE RESPONSE OF HETEROTROPHIC AND PHOTOSYNTHETIC COLD OCEAN MICROPLANKTON
Douglas, D. J., D. Deibel, R. J. Thompson, P. C. Griffith and L. R. Pomeroy, Institute of Ecology, University of Georgia, Athens, GA

9 OBSERVATIONS OF AND FORECASTS FOR ROAD, BRIDGE, AND RUNWAY SURFACES
Kelley, J. R., D. C. Trask and O. M. Hunt, Surface Systems Incorporated, St. Louis, MO

10 DEEPSEA WAVE HINDCASTS IN THE NORTH PACIFIC
Helbig, J. A. and J. A. Stronach, Pacific Ocean Sciences Ltd., Burnaby, BC

11 A CASE STUDY OF SOME AGEOSTROPHIC WIND EFFECTS ASSOCIATED WITH A MODERATELY DEEPENING AND FAST MOVING LOW
Kirkwood, K. H., Newfoundland Weather Centre, Gander, NF

12 DOPPLER RADAR OBSERVATIONS OF A MESOSCALE CONVECTIVE COMPLEX IN SOUTHERN ONTARIO
Joe, P. I. and C. L. Crozier, ARPP, Atmospheric Environment Service, Downsview, ON

Lunch (1230-1330)

THURSDAY AFTERNOON

SESSION 7A *ATMOSPHERE/OCEAN COUPLING I* Thurs. 1330-1510

Chairperson R. Greatbatch, Memorial University Room M1045

1330 Keynote Address:

MODELLING THE RESPONSE OF THE OCEAN TO ATMOSPHERIC CARBON DIOXIDE INCREASE
Bryan, K., Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, NJ

1400 AN EXTENDED FORECAST EXPERIMENT FOR JANUARY 1983
Boer, G. J. and E. Chan, Canadian Climate Centre, Atmospheric Environment Service, Downsview, ON

1415 THE EFFECT OF NORTH PACIFIC SEA SURFACE TEMPERATURE ANOMALIES ON THE JANUARY CLIMATE OF A GENERAL CIRCULATION MODEL
Pitcher, E. J., School of Marine and Atmospheric Science, University of Miami, Miami, FL

1430 A SIMPLE MOIST MODEL RELEVANT TO THE ORIGIN OF INTRASEASONAL DISTURBANCES IN THE TROPICS
Yamagata, T., Research Institute for Applied Mechanics, Kyushu University 87, Kasuga, Japan

1445 THE ANOMALIES OF THE NORTH PACIFIC SEA SURFACE TEMPERATURE AND THEIR ROLE IN MID-LATITUDE AIR-SEA INTERACTION
McBean, G. A. and Y. P. Zhao, Canadian Climate Centre, Institute of Ocean Sciences, Sidney, BC

SESSION 7B *OPERATIONAL METEOROLOGY* Thurs. 1330-1515

Chairperson W. S. Appleby, AES Halifax Room M1032

1330 AN OPERATIONAL CHECKLIST FOR FORECASTING EXPLOSIVE CYCLOGENESIS OVER THE EASTERN PACIFIC
McLennan, N. and L. Neil, Pacific Weather Centre, Vancouver, BC

1345 THE IMPORTANCE OF THE LOWER LEVEL WIND PROFILE IN TORNADO PREDICTION
Patrick, D. and A. J. Keck, Prairie Weather Centre, Winnipeg, MB

1400 FREEZING RAIN EVENT AT ST. JOHN'S, NEWFOUNDLAND ON MARCH 2ND, 1986
Earle, A. G. and D. E. Steeves, Newfoundland Weather Centre, Gander, NF

1415 DOPPLER RADAR DETECTION OF SEVERE WEATHER IN SOUTHERN ONTARIO
Joe, P. I. and C. L. Crozier, ARPP, Atmospheric Environment Service, Downsview, ON

1430 THE CO-EXISTENCE OF SPONGY AND GLAZE ICE ON HEAT CONDUCTING OBJECTS
Szilder, K. and E. P. Lozowski, Department of Geography, University of Alberta, Edmonton, AB

1445 A RATIONAL APPROACH TO EVAPORATION PAN OPERATION IN CANADA AND OTHER COLD CLIMATES
Hopkinson, R. F., Scientific Services Division, Atmospheric Environment Service, Regina, SK

1500 PREDICTION OF SURFACE WETNESS DURATION FROM OPERATIONAL METEOROLOGICAL DATA
Gillespie, T. J., Agrometeorology, University of Guelph, Guelph, ON

SESSION 7C *BIOLOGICAL/PHYSICAL INTERACTIONS IN THE OCEAN* Thurs. 1330-1515

Chairperson G. Evans, Northwest Atlantic Fisheries Centre Rm M2025

1330 Keynote Address:

TIME SCALES, SPACE SCALES AND FISH SCALES: VISCOUS VORTICES AND VOLUTED VIVARIA.
Bowman, M. J., Marine Sciences Research Center, State University of New York

1400 ASSOCIATION OF PRIMARY PRODUCTION AND RECRUITMENT IN SUBARCTIC ECOSYSTEMS: THE APPRISE PROGRAM
Bienfang, P. K., Oceanic Institute, Makapuu Point, Waimanalo, HI

1415 VARIABILITY IN ICHTHYOPLANKTON ABUNDANCE SAMPLED DURING 24 H AND ERROR ESTIMATES ASSOCIATED WITH THEIR NON-CONSTANT DEPTH DISTRIBUTION
Anderson, J. T.* and I. Webster, *Department of Fisheries and Oceans, St. John's, NF

1430 CAN INTERANNUAL VARIATION IN PLANKTON ABUNDANCE BE PREDICTED FROM OBSERVATIONS OF MIXED LAYER DEPTH?
Evans, G. T. and P. Pepin, Science Branch, Fisheries and Oceans, St. John's, NF

1445 PREDICTING THE PRODUCTIVITY OF TIDALLY-DOMINATED ESTUARIES AND COASTAL WATERS
Daborn, G. R., D. L. DeWolfe and M. Brylinsky, Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS

1500 THE EFFECTS OF ENTRAINMENT OF SHELF WATER BY WARM CORE RINGS ON NORTHWEST ATLANTIC FISH RECRUITMENTS
Myers, R. A.* and K. Drinkwater, *Fisheries Research Branch, Department of Fisheries and Oceans, St. John's, NF

SESSION 7D *SEA ICE AND ICEBERGS I* Thurs. 1330-1510

Chairperson J. Lewis, Memorial University Room M2017

1330 THE CALCULATION OF WATER CURRENTS APPLICABLE TO MODELS OF SEA-ICE DYNAMICS
Neralla, V. R. and M. L. Khandekar, Atmospheric Environment Service, Downsview, ON

1345 PREDICTION OF SHORT TERM-ICE EDGE DRIFT
El-Tahan, M.* and G. Warbanski, *Fenco Newfoundland Limited, St. John's, NF

1400 DYNAMIC MODELLING OF ICEBERG DRIFT USING CURRENT PROFILES
Smith, S. D. and N. R. Donaldson, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

1415 SHORT TERM PREDICTABILITY OF ICEBERG PATHS
de Margerie, S., ASA Consulting Limited, Dartmouth, NS

1430 A PROBABILISTIC ICE CLIMATOLOGY FOR CANADIAN WATERWAYS
Perchanok, M., C. Ferregut, C. Daley and R. Brown, Artec Canada Limited, Kanata, ON

1445 PREDICTING SEVERE ICEBERG SEASONS ON THE GRAND BANKS OF NEWFOUNDLAND
Davidson, L. W., Seaconsult Limited, St. John's, NF

Coffee (1510-1530)

SESSION 8A *ATMOSPHERE/OCEAN COUPLING II* Thurs. 1530-1710

Chairperson K. Bryan, Princeton University Room M1045

1530 THE STEADY STATE RESPONSE OF THE ATMOSPHERE TO MIDLATITUDE HEATING WITH VARIOUS ZONAL STRUCTURES
Weaver, A. J.*, L. A. Mysak and A. F. Bennett, *Department of Mathematics, University of British Columbia, Vancouver, BC

1545 THE RELATIONSHIP BETWEEN SUB-SAHARAN RAINFALL AND GLOBAL SEA SURFACE TEMPERATURES
Semazzi, F. H. M., V. Metha and Y. C. Sud, Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD

1600 PACIFIC OCEAN SST AND INDIAN MONSOON RAINFALL
Parthasarathy, B., J. K. Eischeid and H. F. Diaz, University of Colorado, CIRES, Boulder, CO

SESSION 8B *LABRADOR CURRENT OCEANOGRAPHY* Thurs. 1530-1715

Chairperson S. Narayanan, Memorial University Room M1032

1530 THE BAROCLINIC CIRCULATION IN HUDSON STRAIT
LeBlond, P. H.* and J. Cherniawsky, *Department of Oceanography, University of British Columbia, Vancouver, BC

1545 LOW-FREQUENCY CURRENT VARIABILITY ON THE LABRADOR SHELF
Webster, I., S. Narayanan and D. Holland, Department of Physics, Memorial University of Newfoundland, St. John's, NF

1600 THE INTERACTION OF TOPOGRAPHY WITH THE BAROTROPIC AND BAROCLINIC LABRADOR CURRENT
Greenberg, D., B. Petrie and D. Wright, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

1615 RENEWAL OF DEEP WATER OVER THE LABRADOR SHELF
Lazier, J. R. N., Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, NS

1630 CURRENT METER OBSERVATIONS FROM THE NORTHERN GRAND BANKS, 1986
de Young, B. and C. L. Tang, Atlantic Oceanography Laboratory, Bedford Institute of Oceanography, Dartmouth, NS

1645 OBSERVATIONS OF AN OCEAN FRONT SOUTH OF FLEMISH PASS
Murphy, D. L., I. Anderson and N. B. Thayer, United States Coast Guard, International Ice Patrol, Groton, CT

1700 ON THE EFFECTS OF FRICTIONAL TORQUE ON THE DOWNSTREAM EVOLUTION OF A WEAKLY NON-LINEAR LABRADOR CURRENT
Hay, A. E., Department of Physics, Memorial University of Newfoundland

SESSION 8C *METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS: MOIST* Thurs. 1530-1710

Chairperson R. Hooper, Memorial University M2025

1530 Keynote Address:

OVERVIEW OF PROJECT MOIST: METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE TRACKS
Mysak, L. A., Department of Meteorology, McGill University, Montreal, PQ

1600 ON THE PHYSICAL OCEANOGRAPHY OF BRITISH COLUMBIA'S "INSIDE PASSAGE"
terHart, B. A.* and K. A. Thomson, *Department of Oceanography, University of British Columbia, Vancouver, BC

1615 OCEANOGRAPHIC INFLUENCES ON SOCKEYE SALMON MIGRATIONS: TELEMETRY RESULTS
Quinn, T.* and B. terHart, *School of Fisheries, University of Washington, Seattle, WA

1630 TEMPERATURE AND SALINITY INFLUENCES ON SOCKEYE SALMON COASTAL MIGRATIONS (MOIST 85 AND 86)
Thomson, K. A.* and B. A. terHart, *Dobrocky Seatech Limited, Sidney, BC

1645 NUMERICALLY MODELLING THE INTERNAL VARIABILITY OF THE NORTHEAST PACIFIC OCEAN
Hsieh, W. W. and W. G. Lee, Department of Oceanography, University of British Columbia, Vancouver, BC

SESSION 8D *SEA ICE AND ICEBERGS II* Thurs. 1530-1710

Chairperson G. Warbanski, Husky Bow Valley Room M2017

1530 SEA ICE DIVERGENCE AND BANDING IN THE MARGINAL ICE ZONE: NUMERICAL EXPERIMENTS
Steele, M., Geophysical Fluid Dynamics Program, Princeton University, Princeton, NJ

1545 INTERMITTENT MOMENTUM TRANSPORT IN THE VISCOUS SUBLAYER AND BUFFER LAYER UNDER SMOOTH SEA ICE - RESOLUTE, N.W.T.
Chriss, T. M.* and E. P. W. Horne, *Department of Earth and Environmental Sciences, Wesleyan University, Middletown, CT

1600 INVESTIGATIONS INTO THE WAVE-INDUCED MOTION OF SMALL GLACIAL ICE MASSES
Lever, J. H., Faculty of Engineering/C-CORE, Memorial University of Newfoundland, St. John's, NF

1615 METHODS FOR THE FRACTURING OF ICEBERGS
Gammon, P. H.*, J. C. Lewis and L. R. Muir, *Consolidated Technologies Limited, St. John's, NF

1630 THE DEGRADATION AND INFILLING OF ICEBERG SCOURS
Davidson, S. H.*, J. V. Barrie and C. F. M. Lewis, *ASA Consulting Limited, Dartmouth, NS

Cocktail Hour Thurs. 1800-1900

Junior Common Room

Annual Banquet Thurs. 1900-

Main Dining Hall

FRIDAY MORNING

SESSION 9A *NUMERICAL WEATHER FORECASTING* Fri. 0830-1030

Chairperson A. N. Staniforth, AES Dorval Room M1045

0830 EXTENDED PREDICTABILITY DUE TO INTERNAL DYNAMICAL MECHANISMS
Boer, G. J. and F. W. Zwiers, Canadian Climate Centre, Atmospheric Environment Service, Downsview, ON

0845 POSITION AND DEPTH OF LOWS IN THE EASTERN PACIFIC: A COMPARISON OF THREE NUMERICAL MODELS
Anderson, J., Pacific Weather Centre, Vancouver, BC

0900 APPLICATION OF THE SEMI-LAGRANGIAN METHOD TO A SPECTRAL MODEL OF THE SHALLOW WATER EQUATIONS
Ritchie, H., Recherche en prévision numérique, Dorval, PQ

0915 APPLICATION OF A TWO-TIME-LEVEL SEMI-LAGRANGIAN METHOD TO A SPECTRAL MODEL OF THE SHALLOW-WATER EQUATIONS
Côté, J., Recherche en prévision numérique, Service de l'environnement atmosphèrique, Dorval, PQ

0930 SENSITIVITY EXPERIMENTS TO SOUTHERN HEMISPHERIC INITIAL DATA ON NORTHERN HEMISPHERIC MEDIUM RANGE FORECASTS
Yakimiw, E., Recherche en prévision numérique, Service de l'environnement atmosphèrique, Dorval, PQ

0945 COMPARISON OF MOS AND PERFECT PROG SYSTEMS IN PRODUCING NUMERICAL WEATHER ELEMENT FORECASTS
Brunet, N., R. Verret and N. Yacowar, Techniques Development Section, Canadian Meteorological Centre, Dorval, PQ

1000 COMPARISON OF AUTOMATED WEATHER ELEMENT FORECASTS WITH FORECASTS ISSUED BY THE WEATHER CENTERS AND WITH DIRECT MODEL OUTPUT
Brunet, N., R. Verret and N. Yacowar, Techniques Development Section, Canadian Meteorological Centre, Dorval, PQ

SESSION 9B *CANADIAN ATLANTIC STORMS PROGRAM (CASP) I: OCEAN* Fri. 0830-1030

Chairperson P. C. Smith, Bedford Institute of Oceanography Room M1032

0830 OCEANIC VARIABILITY DURING THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)
Anderson, C. and P. C. Smith, Physical and Chemical Sciences Division, Bedford Institute of Oceanography, Dartmouth, NS

0845 INERTIAL OSCILLATIONS NEAR THE COAST OF NOVA SCOTIA DURING CASP
Smith, P. C., Physical and Chemical Sciences Division, Bedford Institute of Oceanography, Dartmouth, NS

0900 RESPONSE OF THE SCOTIAN SHELF TO LOCAL METEOROLOGICAL FORCING-PRELIMINARY OBSERVATIONS FROM CASP
Schwing, F. B.* and C. Anderson, Department of Oceanography, *Dalhousie University, Halifax, NS

0915 LAGRANGIAN DRIFTER DEPLOYMENT DURING CASP
Dempsey, R. I.* and D. J. Lawrence, *Seimac Limited, Bedford, NS

0930 MODELLING THE CANADIAN ATLANTIC STORMS PROGRAM WAVE DATASET
Perrie, W. and B. Toulany, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS

0945 AN INTERCOMPARISON STUDY OF OCEAN WAVE MODELS DURING THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)
Khandekar, M. L. and B. M. Eid, Atmospheric Environment Service, Downsview, ON

1000 ANALYSIS METHODS FOR THE ESTIMATION OF OCEAN SURFACE PARAMETERS FROM GROUND WAVE RADAR DATA
Howell, R., S. K. Srivastava and J. Walsh, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NF

SESSION 9C *REMOTE SENSING* Fri. 0830-1030

Chairperson J. Walsh, Memorial University Room M2025

1830 Keynote Address:

OCEAN ACOUSTIC TOMOGRAPHY - ITS ADVANTAGES, DISADVANTAGES, AND INTEGRATION WITH OTHER REMOTE SENSING SYSTEMS
Lynch, J., Woods Hole Oceanographic Institution, Woods Hole, MA

0900 MATCHED FIELD ESTIMATION OF ENVIRONMENTAL PARAMETERS
Tolstoy, A., Naval Research Laboratory, Washington, DC

0915 EXPLICIT POINT-TO-POINT RAYPATHS FOR VELOCITY PROFILES WITH RAMP SEGMENTS AND GRADIENT REVERSALS
Vetter, W. J., Faculty of Engineering, Memorial University of Newfoundland, St. John's, NF

0930 COMPARISONS OF NUMERICAL MODEL RESULTS AND ACOUSTIC BACKSCATTER OBSERVATIONS OF A SUBMARINE SPRING PLUME
Colbourne, E. B. and A. E. Hay, Department of Physics, Memorial University of Newfoundland, St. John's, NF

0945 CONTRIBUTION OF OFF-PATCH SCATTER IN RADAR RETURN FROM THE OCEAN SURFACE
Srivastava, R. S., S. K. Srivastava and J. Walsh, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, NF

1000 THE KING CITY DOPPLER RADAR
Crozier, C. L. and P. I. Joe, ARPP, Atmospheric Environment Service, Toronto, ON

1015 SIMULTANEOUS PHYSICAL RETRIEVAL OF TEMPERATURE AND RELATIVE HUMIDITY FROM THE TIROS-N OPERATIONAL VERTICAL SOUNDER (TOVS)
Steenbergen, J. D., B. T. Greaves and T. C. Yip, Atmospheric Environment Service, Downsview, ON

Coffee (1030-1050)

SESSION 10A *CLIMATOLOGY* Fri. 1050-1230

Chairperson C. Banfield, Memorial University Room M1045

1050 ALPINE CLIMATES AND SUMMER GROUND TEMPERATURES, GASPE, QUEBEC
Schmidlin, T. W., Geography Department, Kent State University, Kent, OH

1105 AES EXPERIMENTAL MONTHLY AND SEASONAL FORECASTS
Scholefield, P., A. Shabbar and A. Caillet, Canadian Climate Centre/CCRM, Atmospheric Environment Service, Downsview, ON

1120 A WINTER CYCLONE CLIMATOLOGY OF THE CCC GENERAL CIRCULATION MODEL
Lambert, S. J., Numerical Modelling Division, Atmospheric Environment Service, Downsview, ON

1135 THE STRUCTURE AND DISTRIBUTION OF PERSISTENT CIRCULATION ANOMALIES IN A GENERAL CIRCULATION MODEL
Dugas, B. and J. Derome, Department of Meteorology, McGill University, Montréal, PQ

1150 VARIATION OF NORTHERN HEMISPHERE 50 KPA HEIGHT 1946-1985
Knox, J. L.*, K. Higuchi, A. Shabbar and N. E. Sargent, *285 Deloraine Avenue, Toronto, ON

1205 THE COUPLED EFFECTS OF INCREASED TRACE GAS EMISSIONS AND VOLCANIC AEROSOLS ON ATMOSPHERIC CHEMICAL AND THERMAL STRUCTURE AND SURFACE CLIMATE
Vupputuri, R. K. R., Numerical Modelling Division, Atmospheric Environment Service, Downsview, ON

1220 ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE ON ENERGY, FORESTRY AND AGRICULTURE IN QUEBEC
Singh, B., Department of Geography, Université de Montreal, Montréal, PQ

SESSION 10B CANADIAN ATLANTIC STORMS PROGRAM (CASP) II: ATMOSPHERE Fri. 1050-1230

Chairperson R. E. Stewart, AES Downsview Room M1032

1050 RAIN/SNOW BOUNDARIES AND FREEZING PRECIPITATION IN CANADIAN EAST COAST WINTER STORMS
Stewart, R. E., Cloud Physics Research Division, Atmospheric Environment Service, Downsview, ON

1105 SYNOPTIC ANALYSIS OF CASP IOP 14
Jean, M. and M. K. Yau, Department of Meteorology, McGill University, Montréal, PQ

1120 UPDRAFTS WITHIN A CASP STORM
Frigon, A. and I. Zawadzki, Département de Physique, Université du Québec à Montréal, Montréal, PQ

1135 VERIFICATION OF SOME STATISTICAL WEATHER ELEMENT FORECASTS FROM THE CASP PERIOD
Sarrazin, R., Forecast Research Division, Atmospheric Environment Service, Downsview, ON

1150 PROCESSING AND QUALITY CONTROL OF THE CASP SOUNDING DATA
Strong, G. S., Atmospheric Sciences Department, Alberta Research Council, Red Deer, AB

SESSION 10C COASTAL AND SHELF OCEANOGRAPHY III: TIDES Fri. 1050-1230

Chairperson I. Webster, Memorial University Room M2025

1050 REAL-TIME CURRENT AND TIDE MEASUREMENTS IN NUMERICAL MODELLING AND PREDICTION
Hayes, J. G., National Oceanic and Atmospheric Administration, United States Department of Commerce, Rockville, MD

1105 3-D TIDAL MODELLING OF CUMBERLAND BASIN
de Margerie, S. and D. DeWolfe, ASA Consulting Limited, Dartmouth, NS

1120 INTERNAL TIDE GENERATION AT THE HEAD OF THE LAURENTIAN CHANNEL
Gratton, Y. and F. Saucier, Département d'Océanographie, Université du Québec à Rimouski, Rimouski, PQ

1135 TIDAL STRESS: A GENERATING MECHANISM FOR MESO-SCALE EDDIES IN DIXON ENTRANCE
Visser, A. W. and M. J. Bowman, Marine Sciences Research Center, State University of New York at Stony Brook, Stony Brook, NY

1150 ON TOPOGRAPHIC RECTIFICATION OF TIDAL CURRENTS NEAR THE ENTRANCE OF THE ST. LAWRENCE ESTUARY
Koutitonsky, V. G.* and R. E. Wilson, *INRS-Océanologie, Institut national de la recherche scientifique, Rimouski, PQ

SESSION 10D WAVES Fri. 1050-1230

Chairperson P. H. LeBlond, University of British Columbia Rm M2017

1050 NEW MEASUREMENTS OF WAVES AND SUB-BOTTOM POREWATER PRESSURES IN THE BEAUFORT SEA
Hodgins, D. O., Seaconsult Marine Research Limited, Vancouver, BC

1105 WAVE GROWTH IN SCATTERED SEA-ICE
Masson, D. and P. H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, BC

1120 WAVE-CURRENT INTERACTION IN THE QUEEN CHARLOTTES
Stronach, J. A. and J. A. Helbig, Pacific Ocean Sciences Ltd., Burnaby, BC

1135 KINEMATIC INTERPRETATION OF WAVE-CURRENT INTERACTION
Helbig, J. A., Pacific Ocean Sciences Ltd., Burnaby, BC

1150 ON THE IMPACT OF OFFSHORE WAVE MONITORING BUOYS ON SEVERE SEA STATE FORECASTS IN B.C. COASTAL WATERS
Hodgins, D. O., Seaconsult Marine Research Limited, Vancouver, BC

1205 RECENT DEVELOPMENTS IN WAVE DATA SYNTHESIS, ANALYSIS AND PREDICTION APPLIED TO THE CANADIAN OFFSHORE
McClintock, J. D., Seaconsult Limited, St. John's, NF

Lunch (1230-1330)

Tours

SESSION 1 PLENARY THEME SESSION I Wed. 0935-1030

Chairperson W. S. Appleby, President, CMOS Room M1045

PREDICTABLE WEATHER: FANTASY OR FACT?

Edward N. Lorenz, Center for Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A.

We compare weather forecasting with the prediction of other natural phenomena such as oceanic tides. We examine the possibility that a forecast may fail because it depends upon something which has not been detected or has not even occurred. We show theoretically that the accuracy of predictions of irregularly varying natural phenomena must decay as the range of prediction increases, becoming in the limit no better than guesswork. Mathematical models of the atmosphere suggest that day-to-day weather changes are not predictable more than a few weeks ahead. Quantities such as monthly averages may entail less severe limitations.

We can nevertheless identify certain features whose predictability at long range is assured by past experience in predicting them. The quasi-biennial oscillation allows us to predict the equatorial stratospheric winds a year ahead with fair accuracy. The course of an El Nino event, once it becomes established, is reasonably predictable for a few months. Of special theoretical interest are various "coherent structures", which are supposed to be nearly immune to perturbing influences. We examine the case for regarding tropical cyclones as coherent structures, even though their paths are notoriously unpredictable.

We consider the possible role of slowly varying boundary conditions in extending the range of predictability. Sea-surface temperature fields offer the most frequently cited example.

Our overall conclusions sound like those of a generation ago: there will always be limitations, but significant improvements are both possible and likely. Perhaps more progress has been made in prediction than in understanding predictability.

SESSION 2 PLENARY THEME SESSION II Wed. 1050-1230

Chairperson A. E. Hay, Memorial University Room M1045

PREDICTABILITY, SENSITIVITY AND TRANSITIVITY IN THE COUPLED OCEAN ATMOSPHERE SYSTEM

R. W. Stewart, Alberta Research Council, P. O. Box 8330, Postal Station F, Edmonton, AB, T6H 5X2

The word "predictability" may usefully be restricted to meanings close to

ordinary weather forecasting: the ability to predict the evolution of a system given information on its prior state. "Sensitivity" can be used for "prediction of the second kind", a typical example of which is prediction of the statistical behaviour of the atmosphere (i.e., climate) for a particular distribution of sea surface temperature, sea ice, radiatively active gases, etc.

The behaviour of the ocean is determined by the atmosphere: wind stress and radiation balance at the surface. For the major mid-latitude circulations, the time constants in the ocean are so much longer than those in the atmosphere, that atmospheric climate is probably sufficient to determine the behaviour of the ocean, although the ocean has some random features which degrade the ability to predict. However, the behaviour of the upper tens of metres of the ocean, and some tropical circulations respond much more quickly so that they are significantly influenced by weather, not just climate. In this, we are looking at the sensitivity of the ocean to atmospheric forcing.

It seems that there is some predictability in the ocean. Models of the upper Tropical Ocean, when driven by information about atmospheric driving, give promise of predictability. The hypothesis that drives TOGA is that the sensitivity of the atmosphere to these oceanic changes can be understood, permitting forecasts of climate. A great project within the World Climate Research Program is an attempt to determine the sensitivity of the combined ocean atmosphere system to variations in the composition of the atmosphere, notably the increase in radioactive gases. Before we can solve this problem we need a great increase both in our knowledge of and our capability to model the ocean. This is being addressed in WOCE.

However, when we do have this improved ocean model, permitting genuinely coupled ocean-atmosphere modelling, we will be faced with Lorentz's "transitivity": given the composition of the atmosphere, the distribution of continents, and the amount of water in the ocean and the insolation, is there only one climate about which weather will fluctuate -- or could there be many different climates, each with quasi stability? I regard this as an unresolved problem. Its resolution will have important implications for climate research.

PREDICTING OPEN OCEAN CURRENTS, FRONTS AND EDDIES: THE PROBLEM AND AN ONGOING SCHEME FOR THE GULF STREAM SYSTEM

Robinson, Allan R., Division of Applied Sciences, Harvard University, Cambridge, MA 02138

The concept of ocean prediction science, related to the forecasting of the "internal weather of the sea" is introduced as important for ocean scientific research generally and for practical application in the areas of marine operations and planetary environmental management. Systematic field estimation, melding observations obtained by remotely located and *in situ* sensors with dynamical model forecasts (4-dimensional data assimilation) is advocated. The characteristics of the oceanic mesoscale (analogous to the atmospheric synoptic scale) are reviewed. Forecasting the mesoscale (O(10-10 squared km) and O(10-10 squared days) is feasible and has been initiated, but a regional approach is now necessary. Examples of recent progress in mesoscale prediction research are presented. An ongoing forecast system which is nowcasting and forecasting in the Gulf-Stream region (Gulfcasting) is presented which consists of satellite IR and critically located *in situ* AXBT observations used to initialize and update the Harvard Open Ocean Dynamical model in real time.

SESSION 3A DYNAMICAL METEOROLOGY I Wed. 1330-1510

Chairperson T. Warn, McGill University Room S2109

ON THE GENESIS OF METEOROLOGICAL BOMBS

G. W. Kent Moore*, and W. R. Peltier, *Department of Physics, University of Toronto, Toronto, Ontario, M5S 1A7

We consider the problem of identifying the dynamical processes which are responsible for the development of meteorological bombs, those relatively short wavelength cyclones which are observed to deepen "explosively". The basis of the explanation which we have developed for this phenomenon is the new a-geostrophic cyclone mode of baroclinic instability that we have shown to be a prominent characteristic of the instability spectrum of realistic atmospheric frontal zones. The existence of this cyclone is not explicable in terms of quasi-geostrophic theory. We show that the incorporation of a parameterization of the latent heat released by the ascent of moist boundary-layer air through the nascent cyclone results in a dramatic reduction of the e-folding time of the disturbance. This rapid increase of the growth rate is the result of a co-operative interaction between the process responsible for the existence of the cyclone and that responsible for the latent heat release. When a conventional Charney-Eady mode of baroclinic instability is analyzed in the same way it shows no similar sensitivity to moist processes.

CYCLONE SCALE BAROCLINIC INSTABILITY

W. R. Peltier*, and G. W. Kent Moore, *Department of Physics, University of Toronto, Toronto, Ontario, M5S 1A7

We address the issue of the stability of realistic frontal structures to arbitrary three dimensional perturbations which do not satisfy the constraints of quasi-geostrophy. The resulting non-separable baroclinic instability problem is analyzed using the full primitive equations employing a variant of the Galerkin method which was originally developed to investigate the stability of nonlinear Kelvin-Helmholtz waves. This analysis demonstrates that realistic frontal zones, such as those generated by the semi-geostrophic theory of Hoskins and Bretherton, are susceptible to baroclinic instability not only via the well known Charney-Eady mode, which is a deep troposphere filling structure, but also via a new boundary confined mode which is not predicted at all by quasi-geostrophic theory. The fastest growing mode in this new branch of the instability spectrum has a horizontal wavelength of 1000 km and apparently provides the long sought explanation of mid-latitude frontal "cyclones" which are to be understood as fundamentally different from the "long waves" of Charney and Eady. Of particular interest is the fact that this new cyclone scale mode of baroclinic instability is extremely sensitive to the influence of latent heat release in the region of ascending air. The mode appears to provide a viable explanation of phenomena as diverse as the polar-front cyclones of mid-latitudes, and Baiu-front cyclones of the far east, and both polar lows and comma clouds. The companion paper describes the application of this new theory to the understanding of "meteorological bombs" while the present paper focuses on the fundamentals of the new instability mechanism.

THE ROLE OF BAROCLINIC INSTABILITY IN THE PREDICTABILITY PROBLEM

David M. Straus, Laboratory for Atmospheres, Code 611, NASA/Goddard Space Flight Center, Greenbelt, MD, 20771

The predictability problem (i.e. growth of initially small errors) is studied within the context of two-layer quasigeostrophic channel flow. In contrast to earlier work on this subject, the zonal flow, which is forced by relaxation towards a radiative equilibrium, responds to the eddy potential vorticity flux. The role of baroclinic instability (interactions of the eddies with the zonal flow) in the growth errors is compared to the role of the nonlinear (wave-wave) interactions. This is accomplished both diagnostically, using a large number of numerical runs, and by suppressing the wave-wave interactions during the numerical integration itself.

Implications for the relevance of the "classical" theory of predictability due to Lorenz (in which only wave-wave interactions are accounted for) to the real atmosphere are discussed. Generalizations of the current model to include an orographically forced stationary wave are pursued.

A STUDY OF WAVE-WAVE INTERACTIONS IN A STEADY-STATE STRATOSPHERIC MODEL

C. McLandress and J. Derome
Department of Meteorology
McGill University
805 Sherbrooke St. W.
Montreal, Que.
H3A 2K6

The role of wave-wave interactions in determining the structure of stationary planetary waves in the statosphere is investigated using a hemispheric quasi-geostrophic steady-state model. Expanding the perturbation streamfunction as a sum of zonal harmonics leads to a set of coupled nonlinear partial differential equations. Solutions to the equations are obtained by the Newton-Raphson method. The model is forced at the lower boundary by specifying the streamfunction. Realistic values are used for both the lower boundary condition and the mean zonal wind. The zonal truncation is varied from two to five waves. There is a notable increase at 20 kms in the amplitude of wavenumber one as compared to the linear case. Similiar but smaller increases occur for the other zonal waves. At higher levels an eastward phase shift of wavenumber one is found.

TOPOGRAPHIC WAVES IN A FORCED-DISSIPATED BAROTROPIC MODEL

Sylvie Gravel and Jacques Derome
Department of Meteorology
McGill University
Montreal, Que.
H3A 2K6

Charney and DeVore (1979) have proposed an explanation for the bimodal distribution of the large scale weather regimes. They suggested that the zonal and blocked states are both equilibrium solutions to the governing equations of the atmosphere. Their results were obtained with a highly truncated barotropic beta-plane model. Other results which have appeared in

the literature suggest that the presence of multiple equilibria is strongly dependent on a series of parameters.

To study this dependence, we used the pseudo-arclength method that allows us to follow stationary solution curves in parameter space. Our model is a barotropic quasi-geostrophic beta-plane model with topography, dissipation and an externally defined forcing.

We were able to see how varying the amplitude of the toporgraphy, the type of external forcing, the intensity of the dissipation, the geometry of our beta-plane channel or the truncation of the spectral representation affects the solution curves. Those changes are particularly important in the region where the linear resonance of the inviscid equivalent to our model occurs. The changes lead to the appearance or disappearance of the multiple equilibria.

THE STABILITY OF A FINITE-AMPLITUDE MOUNTAIN WAVE

R. Laprise and W.R. Peltier
Dept. of Physics
University of Toronto
Toronto, Ontario
M5G 1A7

Long's steady-state solution (Tellus, 1953) for the flow of fluid of constant velocity and static stability over an isolated obstacle of finite height is subjected to a linear stability analysis. Unstable normal modes of the system are shown to exist when the Froude number (Nh/U) exceeds a critical value which is precisely that for which streamlines locally overturn. This implies the existence of a locally superadiabatic lapse-rate and hence wave breaking. Our analysis reveals that, in addition to an obvious convective mode which should exist on the basis of intuitive considerations, there also exists a trapped mode which is confined to the cavity between the region of supercritically steepened streamlines and the ground. This trapped mode appears to be instrumental in the transition from a freely propagating internal wave dominated flow to one resembling supercritical flows in hydraulics, such as are observed to occur in association with severe downslope windstorms.

SESSION 3B COASTAL AND SHELF OCEANOGRAPHY I Wed. 1330-1515

Chairperson H. Freeland, Institute of Ocean Sciences Room M1032

TIME DEPENDENT FORM OF THE ARRESTED TOPOGRAPHIC WAVE

Keith R. Thompson, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1 Canada

The response of an idealised wedge shelf sea to wind forcing is examined. The wind forcing is assumed to be periodic in both time and the alongshelf direction. Simple analytical solutions are obtained and then used to determine those frequencies at which the arrested topographic wave (ATW) solution of Csanady pertains. A simple physical interpretation of the circulation is given in terms of a linear combination of the ATW and a sum of frictional

shelf waves. This simple model is finally applied to bottom pressure and sea level data recorded on the Scotian Shelf during August–December, 1984.

SUB-INERTIAL OSCILLATIONS ON A BAROCLINIC SHELF

Savithri Narayanan and Ian Webster
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Memorial University
St. John's, NFLD.
Canada, A1B 3X7

The sub-inertial oscillations on a continental shelf with a shelf edge density front separating two homogeneous fluids are analysed using linearised perturbation equations. Since, in applications of this model, the forcing functions such as the wind stress would be defined at real frequencies, the spatial problem with real frequency and complex wavenumber is examined. The shelf edge current is assumed to be in the same direction as the direction of the phase propagation of the topographic shelf waves for applications to the Labrador Shelf. In the case of a barotropic shelf edge current (very low stratification), the sub-inertial oscillations consist of propagating shelf and shear wavemodes, shelf/shear wave hybrids and (non-energy transporting) coalescent modes at complex wavenumbers which decay away from any source of energy. As the Rossby number of the shear flow is increased, the dispersion characteristics of these modes undergo major qualitative changes. The presence of the front allows the existence of unstable modes in addition to the neutral shelf wave modes. Hence the manner in which energy is transported along a continental shelf can be fundamentally altered by the presecne of a mean current.

SHELF WAVE SCATTERING DUE TO A LONGSHORE JUMP IN DEPTH

John F. Middleton and Daniel G. Wright, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada B2Y 4A2

The scattering of barotropic shelf waves by an abrupt jump in longshore topography is examined for unbounded and bounded exponential shelves by matching modal representations for longshore transport and sea level. For unbounded shelves a simple analytical expression for the ratio of transmitted to incident energy flux, F_T/F_I, is derived and used to show that (a) transmission decreases with increasing jump size, (b) a topographic jump acts to pass (retard) incident modes which have cross shelf scales that are larger (smaller) than that of the topography, (c) F_T/F_I is a maximum and essentially constant at frequencies below 1/3 of that of the zero in incident wave group speed, ω_z, and (d) that F_T/F_I monotonically decreases to zero as frequency approaches ω_z. Estimates of F_T/F_I are also obtained for bounded shelves where the effects of a wall, flat and infinitely deep ocean at the shelf break are investigated. Results are determined from an asymptotically exact first order differential equation for stream function that is derived from the matching conditions assuming $\omega^2/\omega^2_z << 1$. The estimates of F_T/F_I for each shelf break condition are similar and with results obtained at high frequencies

qualitatively summarized by those for an unbounded shelf. In addition, at low frequencies, low mode waves exhibit a strong tendency to propagate along f/h contours even as the jump is crossed and scattered energy is found to reside mainly in the gravest reflected and transmitted modes. The analysis also suggests that results may be applicable to scattering by smooth jumps provided the longshore topographic scale is less than half the shelf width.

THE STABILITY AND THE VERTICAL STRUCTURE OF THE MEAN CURRENTS IN THE STRAIT OF GEORGIA.

Michael W. Stacey, Stephen Pond, and Paul H. LeBlond, Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5

The balance of forces responsible for the vertical structure of the mean currents in the Strait of Georgia has been examined using data collected from four cyclesonde moorings. A geostrophic calculation shows that over much of the water column the vertical shear in the horizontal velocity is explained by the thermal wind equations, i.e., the currents are in approximate geostrophic balance. In the upper 60 m of the water column in particular, however, the observed velocity shear can be much larger than that predicted by the observed isopycnal slope. In this region the relevant dynamical balance is between the Coriolis force and the force arising from the vertical diffusion of horizontal momentum. A vertical eddy viscosity of the order of 0.5 m^2/s is deduced from the velocity profile at one cyclesonde mooring. Simple models of barotropic and baroclinic instability suggest that such instabilities can occur in the strait in the presence of diffusive effects, but that the diffusive effects may significantly reduce the growth rates of the fastest growing waves, and may in certain circumstances suppress instability completely.

DEEP WATER REPLACEMENT IN THE STRAIT OF GEORGIA

Ford Doherty and Paul LeBlond. Department of Oceanography, University of British Columbia, Vancouver, B.C., V6T 1W5.

Hydrographic data from a year of monthly cruises in the Strait of Georgia have been examined, with particulr attention to deep water replacement. The signature of winter and summer replacement events is clearly recognizable in the temporal variation of properties along the strait. The northward horizontal speed of property changes is determined and found to vary across the strait, being greatest on the eastern side. The replacement of deep and intermediate waters is also examined through volumetric analysis. Interannual variability at a central station is examined and related, in part, to atmospheric winter cooling conditions.

ANNUAL CYCLE OF TRANSPORT THROUGH HECATE STRAIT

Crawford, William R., Institute of Ocean Sciences, Sidney, BC

Three lines of current meter moorings were maintained in Hecate Strait for 11 months in 1983 to 1984, together with subsurface pressure gauges and anemometers. Currents across each line are used to compute water transport through Hecate Strait. In all seasons, fluctuations in the transport are wind driven. A fall transition in October marks the change from summer to winter regimes. Currents preceding this transition are weak and variable. Autumn storms with

strong winds from the Southeast set up the winter circulation in a period of a few days. A cyclonic eddy is spun up in the southern end of Hecate Strait, such that currents flow northward with the wind along the eastern shore and southward over the 200 metre contour on the western side of the strait. Flow in this eddy exceeds the net, northward, winter transport through the strait of 1±1 Sv, as measured by the two lines of current meters situated to the north of the eddy. Although the transport is wind driven, sea-level differences across the strait are better indicators of the transport than any one of four wind records from nearby, well-exposed anemometers.

NET INFLOW AND OUTFLOW OBSERVATIONS DURING DEEPWATER RENEWAL IN TWO CLOSELY SPACED CHANNELS ON A SILL

Warren G. Lee and Dave Nebert
Department of Oceanography,
University of British Columbia,
Vancouver B.C. V6T 1W5.

During the deepwater renewal period of July through September 1982, 6 current meters (of the 25 total) were deployed at the Kite Island sill in Boca de Quadra. The Kite Island sill is approximately 100m deep and separates two 400m deep basins. The topography of this area is complicated by right-angle bends and by the location of Kite Island right in the middle of the sill. In the northern "A" channel, 2 meters were deployed at 18m and 104m depth. In the southern "B" channel, 4 meters were deployed at depths of 20m, 34m, 99m and 111m. Vector averaged velocities were calculated over two week time intervals and show distinct differences between the deep flow of the two channels. The 104m deep meter in the "A" channel shows a net inflow of about 26 cm/s and the 99m and 111m deep meters in the "B" channel show net outflows of about 15 cm/s for 4 two week periods. Analysis of temperature and salinity records suggest that during deepwater renewal, more dense water enters the central basin through the "A" channel side and less dense water is removed through the "B" channel side.

SESSION 3C MARINE GEOCHEMISTRY AND PALEO-OCEANOGRAPHY
Wed. 1330-1510

Chairperson S. Macko, Memorial University Room M2025

BIOGENIC SULFUR FROM MARINE AND CONTINENTAL SOURCES

Jerome O. Nriagu, National Water Research Institute, Burlington, Ontario

Reduced sulfur compounds (including dimethyl sulfide or DMS, hydrogen sulfide and carbon disulfide) emitted from marine and continental ecosystems are readily oxidized in the atmosphere and hence contribute to the acidity of

rainfall. The DMS flux out of the ocean is now generally accepted to be about 40 Tg/a (million tonnes per year), and accounts for a significant fraction of the SO_2 concentration in the marine atmosphere. Estimates of the biogenic S release from soils and wetlands are still very tentative, being in the range of 10 to 30 Tg/a. In Canada, soils and wetlands account for 20-30% of the total annual S emission; the James Bay lowlands are believed to be the major source of biogenic sulfur which may be responsible for the acidity of rainfall at remote locations in the country. Because of the considerable geochemical and ecological importance of biogenic sulfur, a number of recent studies have looked at the production, reaction rates and fate of these compounds in different ecosystems. These data will be reviewed in terms of what they can tell us about the natural sulfur cycle and the influence of current human activities on it.

LATE QUATERNARY/HOLOCENE DEPOSITIONAL ENVIRONMENTS OF THE WESTERN CANADIAN ARCTIC ARCHIPELAGO

Pereira, C.P.G. and S.A. Macko
Dept. of Earth Sciences, Memorial University of Newfoundland, St. John's, NF A1B 3X5.

Sedimentological mineralogical and geochemical analyses of subsurface and surface sediments from the western Canadian archipelago in the inter-island channels and deep-water basins east of Melville Island describe two discrete, depth-related environments with numerous small scale variations in the geochemical and sedimentological inputs. These input variabilities are discussed in terms of the related geological and oceanographical databases.

The inter-island channels and basins appear to have a classical deep-water sediment component, dominated by clay (85-100%). Coarse silt and fine sand generally dominate the sediment in the nearshore in sublittoral environments and are associated with a significant ice-rafted component (<43%). Chlorite (43-68%) and illite (26-43%) clay minerals are regionally dominant with montmorillonite (4-43%) being a major clay constituent of the nearshore and sublittoral zones. The distribution of stable carbon and nitrogen isotopes indicate three independent sources of organics, including a) marine plankton production, b) terri- genous inputs and c) macrophytic algae. The macrophytes are considered to have caused the highest values in $\delta^{15}N$(+6.8 o/oo) and $\delta^{13}C$(-21.0 o/oo). These samples are generally located in narrow, isolated channels. Terrigenous isotopic compositions (+3.1 o/oo $\delta^{15}N$; -25.2 o/oo $\delta^{13}C$) tend to be associated with organic rich sediments and may be the result of concentration of old organic rich deposits by ice scour.

Synthesis of the data, identifies a regional depositional model and demonstrates the existence of a nearshore shallow water region and an offshore deep-water environment. The data also show the existence of local perturbations to this regional model, which are probably controlled by very localized conditions such as, proximity of land, algae blooms, ocean currents, underwater topography, spring/summer melt-water run-off and seasonal ice-cover. An insight is given in assessing data from a high latitude predominantly ice covered marine environment.

PRODUCTIVITY CYCLES IN THE EASTERN EQUATORIAL PACIFIC AND THE RESPONSE OF BENTHIC FORAMINIFERA

Thomas F. Pedersen*, Mark Pickering and Nicholas J. Shackleton

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A pronounced enrichment of the organic carbon concentration in late Stage II is ubiquitous in eastern equatorial Pacific sediments, as demonstrated by three cores from the Panama Basin area, and reflects enhanced upwelling along the equatorial divergence during glacial periods. An approximately 200 kyr record of [Corg] in the central Panama Basin suggests that previous glacial stages (certainly Stage 6) are associated with similar carbon pulses. Iodine:Corg ratio profiles for all three cores show approximate first-order decreases with depth; there are no deviations from the first-order curves through the Corg maxima. Similarly, there is no significant increase in the Mo concentration in the sediments in the Corg-rich horizons. These data indicate that despite a major increase in the Corg accumulation rate during Stages 2 and 6, pore waters in the upper portion of the sediment column remain oxygen replete. Otherwise the I:Corg ratio would show a decrease and the Mo concentration an increase in association with the carbon peaks. Further evidence to support this conclusion is provided by benthic foram size and population data. Both the size and numbers of Uvigerina spp., for example, increase in the Stage 2 maximum. Because Uvigerina grow in the top cm (B. Corliss, pers. comm.) and because the larger the organism, the more oxygen is required for respiration, it is clear that that oxygen-replete conditions prevailed in at least the top cm during the period of high Corg accumulation. These geochemical and faunal observations constrain the estimation of oxygen paleo-concentrations in sediments subjected to large temporal changes in the input flux of organic matter.

ORIGIN OF THE HOLOCENE BLACK SEA SAPROPEL BY INCREASED PRIMARY PRODUCTION

S.E. Calvert, J.S. Vogel, J.R. Southon and M.R. Fontugne: Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5

High-resolution profiles of del 13C and tandem accelerator radiocarbon ages of organic matter have been obtained in two Black Sea cores (906 and 2248m) collected in 1969 by ATLANTIS. The sapropel is distinguished by del 13C values similar to those of the modern Black Sea plankton (-23‰), whereas the associated facies contain variable mixtures of planktonic and terrestrial (-27‰) organic matter. The radiocarbon ages of the organic matter in the sapropels are 1600-4000 and 4000-6000 years B.P., the deep-water core

containing the younger sapropel. The carbon accumulation rates are similar in the sapropel and the modern facies at the shallow-water site but higher by a factor of two in the sapropel in the deep-water site.
The stable isotope, chronological and accumulation rate information show that the sapropel formed as a result of increased plankton production during the evolution of the Black Sea from the Pleistocene lake to the modern marine phase and that a sapropel is not presently forming because production has decreased during the past 1000 years.

SESSION 3D APPLIED OCEANOGRAPHY Wed. 1330-1510

Chairperson L. Muir, COGLA Room M2017

PHYSICAL OCEANOGRAPHIC PROCESSES RELEVANT TO WATER QUALITY MODELLING IN HALIFAX INLET

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A numerical water quality model of Halifax Inlet has been developed in order to assess the water quality impacts of various municipal sewage treatment options. The model includes three components: a sewage load model, which quantifies sewage loads based on population and land use distributions, a hydrodynamic component which represents the mixing and flushing characteristics of the Inlet and a constituent transport/fate component which models the spatial and temporal distribution of the water quality indicators.

The hydrodynamic component consists of a two dimensional vertically averaged tidal model with parameterizations for mixing due to processes not explicitly considered in the model. As part of the model development, a study of the flushing characteristics of the inlet has quantified the major oceanographic processes. Of particular interest is Bedford Basin, a relatively broad fjord-like basin at the landward end of the Inlet. The surface waters of Bedford Basin are flushed primarily by tides, winds and river flow while the deep waters are flushed almost exclusively by periodic intrusions of dense continental shelf bottom water. Due to the relatively long residence times this bottom water is potentially sensitive to impacts by sewage input.

METHODS OF CREATING AND PREDICTING INITIAL DILUTION FOR EFFLUENT DISPOSAL IN COASTAL WATERS

J.J. Sharp*, and J.H. Allen, *Ocean Engineering Group, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland

The paper describes different techniques used in the Engineering design of coastal outfalls to obtain a desired initial dilution. The various stages of the dilution process will be described and methods of calculation outlined. The analysis will include both buoyant and non buoyant effluents.

SEDIMENTATION STUDIES FOR MARINE TERMINAL FACILITIES IN MUSQUASH HARBOUR, NEW BRUNSWICK

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The New Brunswick Electric Power Commission, together with Ports Canada, is planning to develop marine terminal facilities in Musquash Harbour, New Brunswick. The purpose of the proposed marine terminal is to provide an off-loading site for coal to supply the Coleson Cove Power Plant once the plant is converted from oil to coal burning operation. Extensive dredging of the harbour bottom may be required in order to provide adequate draft for the ships using the facility; this dredging may significantly alter the natural bathymetry, and thus the sedimentation patterns, within the harbour. The purpose of the described studies was to estimate the impact of marine terminal construction on the sedimentation patterns within Musquash Harbour, with particular emphasis on the expected maintenance dredging requirements. Several construction alternatives were considered.

The hydrodynamics of Musquash Harbour are dominated by tidal currents generated by the high tides in the Bay of Fundy combined with the effects of storm-generated waves. A three-dimensional numerical tidal model, specially adapted for large amplitude tidal environments, was applied to the Harbour, considering both pre- and post-dredging bathymetries. A wave propagation model including wave refraction, shoaling, breaking and energy dissipation due to bottom friction was also applied. The results of each of these models were combined to yield the rate of energy dissipation at each grid location in the Harbour, for pre-construction conditions and for each construction alternative. These results were then input into erosion/sedimentation formulations which yielded the expected siltation rates for each construction alternative, allowing the most advantageous construction alternative to be chosen.

THE VARIABILITY OF ENVIRONMENTAL LOADS ON OFFSHORE STRUCTURES

Marc A. Maes, Langley R. Muir, Val Swail

Det Norske Veritas (Canada) Ltd., 1110-10201 Southport Road S.W., Calgary, JZW 4X9

Over the past three years, a team under the auspices of the Canadian Standards Association has been writing a "Building Code" in anticipation of the use of large, engineered structures for Oil and Gas production on the Canadian offshore. This limit-states Code will be state-of-the-art and, while not imposing an unacceptable economic burden on the designer, will ensure the safety of both personnel and the environment.

Of central importance in this Code will be the assessment of risk and the selection of appropriate safety factors for each design element. The most contentious loads that designers must deal with are the environmental loads due to winds, waves and currents. A critical parameter which is important for the calculation of design risks is the coefficient of variation of the loads. The oceanographic and meteorological data bases presently available at the Canadian Climate Centre, Environment Canada, are used to produce plots for the coefficient of variation of annual and monthly environmental loads. Extreme loads due to winds and waves induced by both inertia and drag are examined for the East Coast, West Coast and the Beaufort Sea. Important data gaps are identified.

ON WAVE-CURRENT-STRUCTURE INTERACTION

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A1B 3X5

A major component of hydrodynamic loading in an offshore environment is due to ocean waves. However, currents appreciably may change the wave conditions, altering the wavelength, amplitude, steepness, direction of propagation. The interaction of waves with currents is an important parameter which should be considered in ocean engineering structure design and wave forecast. In this paper a review and classification of currently available theories on wave-current- structure interaction are presented. In this field of research investigators either study the changes in the waves after interacting with a current or the characteristics of a wave-current field, without the presence of an obstacle. Others would consider the perturbation to a wave-current field and its interaction with slender or large bodies. The influence of currents on the wave loading is usually based on the assumption that the size of structure is small compared to incident wave. However for large bodies, this assumption might not be valid. Topics for further research are identified and discussed.

ON THE USE OF THERMITE FOR THE FRACTURING OF ICEBERGS

John Courtenay Lewis* and P.H. Gammon, *Physics Department, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X7

The use of thermite has been proposed as a method for the destruction of icebergs. We review the field trials that have been carried out with the material. We argue that there is no reason whatever to expect the method to be feasible with such quantities of thermite as can reasonably be deployed

from a marine platform. This, together with the well-known hazardous nature of its reaction with ice, implies that further investigation of thermite destruction as a method for iceberg management is likely to prove sterile.

SESSION 4A DYNAMICAL METEOROLOGY II Wed. 1530-1710

Chairperson M. Béland, AES Dorval Room S2109

PRELIMINARY EXPERIMENTS WITH A ONE-DIMENSIONAL TURBULENCE MODEL; ENSTROPHY CASCADES AND INTERMITTENCY

P. Bartello*, and T. Warn, *Meteorology Dep't, McGill University, 805 Sherbrooke St. W., Montreal, PQ, H3A 2K6

Severe unidirectional Fourier truncation of the equations for 2-D incompressible flow leads to a system of three coupled PDE's in 1 space dimension with the same quadratic invariants as the original set (i.e., energy and enstrophy). Numerically generated equilibria for inviscid, truncated versions of the reduced system seem consistent with Kraichnan's energy-enstrophy equipartition spectra. Preliminary viscous calculations for decaying turbulence at moderate resolution (1024 degrees of freedom) also appear to be consistent with a direct, K^{-3}, enstrophy cascading inertial range for small dissipation. The enstrophy dissipation is found to exhibit a high degree of spatial intermittency, with occasional strong bursts producing linear phase locking.

A DIAGNOSTIC VORTICITY ANALYSIS OF BLOCKING USING DATA FROM THE CANADIAN CLIMATE CENTRE GENERAL CIRCULATION MODEL

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A diagnostic analysis of global atmospheric blocking is performed using data from the Canadian Climate Centre general circulation model. The data set consists of seven months of daily 500mb and 1000mb Northern Hemisphere charts. Two methods of block identification, using visual identification and anomalous heights, are used and compared. The frequency, latitudinal and longitudinal distributions of the fourteen model blocks found all compare well with climatology; they are however of shorter duration.

The advections of relative and planetary vorticity are evaluated at the 500mb level. For winter climatology, the spatial longitude-latitude distributions of the two advections are highly negatively correlated, with their amplitudes being almost equal. The spatial distributions are also evaluated for the model blocks. A negative correlation of the two vorticity advections, averaged over the duration of the block, is still found. However, the magnitude of the relative vorticity

advection exceeds that of the planetary vorticity advection, especially near the block location. The results are interpreted in terms of the barotropic vorticity equation for the time-mean state, in the presence of eddy forcing and dissipation. The results suggest that the latter two quantities are both small compared to the two vorticity advections for the winter mean state, but both eddy forcing and dissipation are likely to be important for blocking episodes.

BAROTROPIC MODON PROPAGATION OVER SLOWLY VARYING TOPOGRAPHY

Gordon E. Swaters, Department of Mathematics, University of Alberta, Edmonton, Alberta, Canada, T6G 2G1

A perturbation theory is developed to describe modon propagation over slowly varying topography. The theory is developed from the rigid-lid shallow-water equations on an infinite β-plane. Nonlinear hyperbolic equations are derived, based on the conservation of energy, enstrophy and vorticity, to describe the evolution of the slowly varying modon radius, translation speed and wavenumber for arbitrary finite-amplitude topography. To leading order, the modon is unaffected by meridional gradients in topography. Analytical perturbation solutions for the modon radius, translation speed and wavenumber are obtained for small-amplitude topography. The perturbations take the form of hyperbolic transients and a stationary component proportional to the topography. The solution predicts that as the modon moves into a region of shallower (deeper) fluid the modon radius increases (decreases), the translation speed decreases (increases) and the modon wavenumber decreases (increases). In addition, as the modon propagates into a region of shallower (deeper) fluid there is an amplification (diminishing) of the extrema in the streamfunction and vorticity fields. These properties suggest that the modon may be able to be topographically-captured and amplified, and thus may have application to the onset of atmospheric blocking. The general solution is applied to mid-latitude scales and a ridge-like topographic feature.

STABILITY CONDITIONS AND A PRIORI ESTIMATES FOR EQUIVALENT-BAROTROPIC MODONS

Gordon E. Swaters, Department of Mathematics, University of Alberta, Edmonton, Alberta, Canada, T6G 2G1

Linear Liapunov stability conditions are obtained for all classes of equivalent-barotropic modons. The stability conditions are stated in terms of a parameter η called the "generalized disturbance wavenumber" related to the ratio of the initial values of disturbance enstrophy to energy. It is shown that $c > 0$ modons (c is the drift speed, nondimensionalized by the long wave speed) are stable when $\eta \geq k$ (k is the modon wavenumber), and that $c < -1$ modons are stable when $\eta \geq k$. This dependency of the stability on the initial spectral structure of the disturbance is observed in numerical calculations. A priori L^2-type estimates bounding the growth of perturbations are derived. The instability mechanism is interpreted in terms of Fjortoft's energy cascade theorem.

SESSION 4B COASTAL AND SHELF OCEANOGRAPHY II Wed. 1530-1710

Chairperson Y. Gratton, Université du Québec à Rimouski Room M1032

LOW FREQUENCY VARIABILITY IN THE DEEPER WATERS OF THE GULF OF ST. LAWRENCE

Gary L. Bugden, Department of Fisheries and Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2

Variations of several degrees in the temperature of the deeper waters of the Gulf of St. Lawrence over the last several decades are examined. The variations are very coherent along the Laurentian Channel from the Gulf entrance at Cabot Strait to the St. Lawrence Estuary, a distance of over 1000 km. Along channel phase lags and temperature reductions are consistent with a slow advection from the edge of the continental shelf coupled with reasonable values for horizontal and vertical diffusion. Comparison of the temperature variations with data from the Slope Water region east of the Scotian Shelf seems to indicate that they are related to the position of the Shelf-Slope Water boundary. However, a strong relationship also appears to exist between the variations and the fresh water discharge from the St. Lawrence River System. The role of each of these driving mechanisms is evaluated.

ON THE VARIABILITY AND VERTICAL STRUCTURE OF LONGSHORE CURRENTS IN THE JACQUES CARTIER STRAIT, SUMMER 1986

V.G. KOUTITONSKY, D. LEFAIVRE, D. HAINES, AND P. OUELLET
INRS-Océanologie, 310 avenue des Ursulines, Rimouski, (Québec), G5L 3A1

The analysis of a current meter data set, gathered from three stations along the northern shore of the Gulf of St. Lawrence as part of the COHJAC (Circulation, Oceanography, and Hydrography of the Jacques Cartier Strait) project is presented. In particular, frequency domain analysis is used to describe the vertical structure and the variability of long shore low frequency fluctuations, in relation to meteorological forcing. On going COHJAC sea level and current measurements are discussed.

NUMERICAL SIMULATION OF ATMOSPHERICALLY-FORCED CIRCULATION IN THE SOUTHERN BEAUFORT SEA

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

A potential enstrophy conserving numerical approximation to the shallow water equations is used to investigate the homogeneous shelf sea response to atmospheric forcing in the southern Beaufort Sea. It is shown that atmospheric pressure

gradient forcing is particularly efficient in generating along-shelf currents in the vicinity of the shelf break and along canyon walls. The atmospheric pressure gradient appears to be the predominant forcing mechanism for shelf circulation under conditions of consolidated pack ice cover. The influence of wind stress forcing tends to be fetch-limited by the location of the ice edge during open water conditions.

It is found that during storm events the major features of the nearly steady shelf circulation can well represented by a simple analytic model. During the relaxation phase occurring after the storm has passed, the shelf response is considerably more complex. Trains of continental shelf waves emanating from the Barrow Canyon region of the Alaskan shelf propagate down the North Slope shelf to Herschel Canyon in the Canadian Beaufort where abrupt changes in shelf topography cause scattering into smaller scale (< 80 km) features which persist for 1-3 days.

Simulated drifter tracks indicate that during storm events the motion of isolated ice floes should be reasonably predictable since Lagrangian autocorrelation length scales in the along-isobath direction are on the order of 600 km or more. Between storm events the simulated drifter motions take on a quasi-random character with Lagrangian autocorrelation length scales on the order of 60 km or less. Under these conditions stochastic (e.g., Markov, autoregressive-moving average, Kalman filter) models should probably be employed to forecast ice motion.

LABORATORY EXPERIMENTS: SLOPE FLOW INDUCED BY SURFACE SALT FLUX

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In shallow shelf regions of the Beaufort Sea in the Canadian Arctic, the convectively mixed layer which forms due to salt expulsion as sea water freezes, extends to the bottom. Bottom currents may be caused when horizontal gradients are created by non-uniform buoyancy flux or by a bottom slope. A surface salt flux over a region of non-uniform depth was simulated in a laboratory model by a percolation of saline water through a porous membrane into a tank with fluid of lower salinity. In a series of experiments with bottom angles set between 2 and 6 degrees, shadowgraph images show that a bottom slope flow was induced under the convectively mixed layer. For a range of salt fluxes, maximum velocities of 0.08-0.56 cm/s were measured in the slope flow at 0.4-0.6 cm above the bottom. Profiles of the salinity and density in the mixed layer and in the slope flow, obtained from conductivity micro-cells and thermistors, show that the salinities in the bottom flow rose 0.3 to 0.9 ppt above those in the mixed layer. In several of the experiments, the bottom flow was seen to start at some distance from the shallow end of the tank, and a counter-rotating flow cell formed uphill from this point, but disappeared as the starting point gradually moved toward the shallow end. The slope flow is considered as a gravity driven current modified by a turbulent environment.

SEDIMENT TRANSPORT PROCESSES IN THE MACKENZIE RIVER PLUME
Susan Davidson, Sylvain de Margerie and Dr. Philip Hill
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The Mackenzie River is the major source of new sediment to the Beaufort Shelf. The suspended material carried by the river plume is eventually deposited on the seabed, however, significant sediment reworking can occur prior to final deposition. Previous studies have indicated that surficial sediment reworking is at a maximum at approximately the 5 m isobath on the Mackenzie River delta. These conclusions have been based on examination of sedimentary facies together with suspended sediment measurements.

Sediment reworking occurs when the near-bed currents induce bottom shear stresses larger than the critical values for the erosion of the seabed sediments. This paper considers sediment reworking from an oceanographic perspective through consideration of the driving forces behind sediment resuspension. The major oceanographic processes responsible for near-bed currents on the inner Beaufort Shelf are described and quantified. These processes include wind waves, wind driven bottom currents, tidal currents and currents resulting from the estuarine circulation. This work has been based on the analyses of time series measurements during the 1984, 1985 and 1986 open water seasons combined with theoretical considerations of the relevant oceanographic processes.

SESSION 4C MARINE CHEMISTRY AND GEOCHEMICAL PROCESSES

Wed. 1530-1710

Chairperson J. Welhan, Memorial University Room M2025

ORGANIC GEOCHEMICAL COMPARISONS OF FORTUNE BAY AND BAY D'ESPOIR, NEWFOUNDLAND
K. Pulchan and S.A. Macko, Department of Earth Science, Memorial University of Newfoundland, St. John's, Newfoundland

Fortune Bay and Bay D'Espoir are two fjords in close proximity, yet with contrasting internal properties and processes. Samples from six cores from Bay D'Espoir and five cores from Bay D'Espoir were analysed for organic carbon and nitrogen content, $\delta^{13}C$, $\delta^{15}N$, and total individual amino acids. $\delta^{13}C$ values for Bay D'Espoir samples were relatively lower than those for Fortune Bay, indicating a stronger influence of a terrigenous source in Bay D'Espoir. $\delta^{15}N$ values were constant (7-8°/oo) for all cores

(except for 2 cores from Bay D'Espoir). Productivity levels were reflected in the organic content and total amino acid abundances which were relatively higher in Fortune Bay samples than those in Bay D'Espoir samples. There is a general decrease in organic content and total amino acids with depth. The magnitude of this trend varies with core. In two cores from Fortune Bay these changes may be related to a change from marine sedimentation to glaciofluvial sedimentation. The change in sedimentation pattern is also reflected in the grain-size fraction greater than 63 μ, foraminferal counts and $\delta^{18}O$ of the foraminiferal carbonate tests.

CHARACTERIZATION OF SELECTED ORGANICS ON PARTICLES AND SEDIMENTS IN THE ST. LAWRENCE ESTUARY

J. Tronczynski, J.N. Gearing, and S. Macko. Fisheries and Oceans, Maurice-Lamontagne Institute, C.P. 1000, Mont-Joli, Québec.

Samples of particulate matter were collected between Québec City and Pointe des Monts; sediment cores were taken off Rimouski. Stable carbon and nitrogen isotope ratios provided information on the bulk organic material and some lipid fractions. Individual hydrocarbons and fatty acids traced carbon from algae, bacteria, terrigenous plants, and anthropogenic pollutants such as sewage, petroleum, and combustion-derived polycyclic aromatic hydrocarbons.

In the upper estuary near Québec City, particulates contain significant contributions from algal fatty acids and from degraded anthropogenic hydrocarbons. Within the zone of high turbidity, loss of the more labile fatty acids indicates a long residence time for the suspended particles and/or high bacterial activity. In the lower estuary, the particulates have isotope ratios typical of open marine systems (del C-13 = -21.9 and del N-15 = +7.6). The concentration of aliphatic hydrocarbons (1.3 ug/l) is equivalent to those reported from George's Bank and the western Atlantic, however over 90% of the particulate hydrocarbons in the lower St. Lawrence exhibit patterns typical of anthropogenic pollutants.

Surface sediments in the lower estuary have isotope ratios (-23.7 and +5.1) significantly different from those of the particulates. Their levels of total hydrocarbons (around 120 ug/g) are higher than those reported for unpolluted marine sediments (1-50ug/g) but lower than levels considered dangerous (around 500ug/g). Near the bottom of the core (approximately 100 years ago) there are only 30ug/g hydrocarbons, with the difference arising from a change in anthropogenic components. The levels of hydrocarbons from terrestrial plants and from combustion products do not change significantly over time.

ORGANIC GEOCHEMISTRY OF SEDIMENT CORES FROM THREE NEWFOUNDLAND BAYS

Ostrom, N.E., C.G. Troke and S.A. Macko, Dept. of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X5.

Sediment cores and water samples from three Newfoundland Bays were studied to gain a better understanding of sources, recycling, and preservation of organic matter in these systems. Stable isotopes of carbon and nitrogen reveal predominantly marine organic matter sources throughout the Holocene, with values ranging from 6.1 to 7.8 o/oo for $\delta^{15}N$ and -22.5 to -20.8 o/oo for $\delta^{13}C$. Carbon and nitrogen content decreased with depth in the sediment, with nitrogen being lost more rapidly. These changes correlate with decreased amino acid concentrations with depth, possibly indicating microbial utilization of organic material. Microbial activity has been associated with isotopic fractionations in sediments and may be present in some but not all sediment cores studied.

SEDIMENTARY GEOCHEMISTRY OF TWO ABYSSAL PLAINS IN THE NORTH ATLANTIC

Dale E. Buckley, Geological Survey of Canada, Atlantic Geoscience Centre, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, Canada, B2Y 4A2

Turbidite deposits dominate the sediments accumulating on the Madeira Abyssal Plain (MAP) and the Southern Nares Abyssal Plain in the North Atlantic Ocean. Thick carbonate-rich turbidites in the MAP can be correlated over distances as great as 100 km and appear to be derived from upper slope regions along the continental margin of Southern Europe and North Africa. Variations in organic carbon content and concentrations as high as 1.7% are preserved in some of these turbidites as a result of rapid burial and limited post depositional oxidation. Turbidites in SNAP are generally thin and highly variable with little correlation over distances as little as one km. These siliceous clay turbidites appear to be derived from the continental margin of eastern North America and contain relatively low concentrations of preserved organic carbon (generally less than 0.5%). Early stages of organic matter decomposition can be recognized in the upper layers of sediments from both areas. Oxidation and denitrification processes are depicted in profiles of NO_3^-, NO_2^-, and NH_4^+ in pore waters. As a result of chemical reduction with depth, Mn^{2+} is mobilized in the pore water. Early stages of mineral authigenesis are also indicated by depletion of Si and K in pore waters below about 2 m depth in the sediments.

STABLE ISOTOPIC COMPOSITION OF PLANT PIGMENTS

Bidigare, R.R.[1], M.C. Kennicutt II[1] and S. Macko[1]
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The study of the distribution of stable carbon and nitrogen isotopes in marine organic matter has been limited by the fact that it is extremely difficult, if not impossible, to separate the complex suite of suspended particulates into its major components, detritus, bacteria, phytoplankton and microzooplankton. Knowledge of the isotopic composition of these individual pools can potentially be useful for (1) sourcing organic matter, (2) delineating genetic relationships between transformed products and their biological precursors, and (3) investigating the cycling of organic matter in the upper ocean. We have combined the techniques of source-specific molecular isolations and stable nitrogen/carbon isotopic compositions to better define the sources, transformation and transport of organic matter. Preliminary data are presented for chlorophyll and carotenoid pigments isolated from several sources and results are discussed in relation to intermediary metabolism in photosynthetic autotrophs.

SESSION 4D SCIENTIFIC AND FUNDING PROGRAMS Wed. 1530-1710

Chairperson B. Ruddick, Dalhousie University Room M2017

ERICA: PLANNING AND PROGRESS

Ron Hadlock, Carl W. Kreitzberg and Robert F. Abbey, Jr.
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Scientific hypotheses for explosively-developing winter storms at sea will be tested by the field phase of the Office of Naval Research's basic research program Experiment on Rapidly Intensifying Cyclones over the Atlantic. Needed data will be obtained on the atmospheric synoptic, meso-, and boundary-layer scales and at the air-sea interface, including ocean surface properties. The overall ERICA objectives are to: (1) develop an understanding of the fundamental physical processes that lead to explosive atmospheric cyclogenesis at sea, (2) identify measurable precursors that can be used for accurate operational dynamical meteorological forecast model predictions, and (3) determine the minimum set of these observables that is necessary for accurate forecasts of intense cyclogenesis at sea. Hypothesis testing will involve the numerical modeling research component of ERICA; development of improved operational forecasting methods will come after ERICA determines the necessary and sufficient physical processes

and their unique interactions. The measurements are scheduled for Winter 1988-1989 over the region of the northwestern Atlantic Ocean, generally from Cape Hatteras to Newfoundland. Much of the needed data will be acquired by use of satellites, aircraft, soundings, buoys, and radars. ERICA, a partnership in research among ONR and its contractors, other agencies, and universities, will benefit from the experience gained in the CASP and GALE experimental programs and the lessons learned therefrom. The ERICA Steering Committee and the many participants in the September 1986 ERICA Workshop at Drexel University, have made progress on an inclusive set of testable scientific hypotheses, definition of needed and desired data types and instrumentation systems, and field deployment strategies. This progress, at approximately seventeen months prior to experiment start-up, will be described and discussed.

THE WORLD CLIMATE RESEARCH PROGRAMME: RATIONALE AND PROJECTS

G.A. McBean, Canadian Climate Centre, Institute of Ocean Sciences, Sidney, B.C., V8L 4B2

The World Climate Research Programme is aimed at determining to what extent climate can be predicted and the extent of man's influence on climate. The background and the scientific rationale of the WCRP will be described. The WCRP presently consists of several major projects, such as TOGA and WOCE. The way in which these projects will contribute to the overall WCRP objectives will be discussed. The presentation will include a description of present Canadian participation in the WCRP and some suggestions for future involvement.

THE ONR PROGRAM IN OCEAN AND ATMOSPHERIC SCIENCE

Alan I. Weinstein, Office of Naval Research (Code 1122), Arlington, VA 22217 USA

The Office of Naval Research sponsors a broad based fundamental research program in Ocean and Atmospheric Science that includes research in open ocean and coastal physical oceanography, oceanic biology, oceanic chemistry and marine meteorology. The funding level is approximately $35 Million.

The objective of the research is to understand that basic process in, on and over the world's oceans. The approach incorporates a combination of specialized observational instrumentation, detailed field studies and theoretical investigations all leading to the development, verification, and improvement of hypotheses to explain the evolution of the world's oceans and the atmosphere above them. In time, these hypotheses will be turned into predictive models for use by operational Navy forecasters on land and at sea.

The program is primarily rooted in the academic community, but makes use of private contractors and laboratories when specific requirements dictate.

LOOKING FAR DOWNSTREAM; CMOS IN 2087

Paul H. LeBlond. Department of Oceanography, University of British Columbia, B.C. V6T 1W5. Director of Research, Science for Peace.

Current trends in Earth Sciences will be reviewed and analyzed, with particular emphasis on the fluid environment. The expected effects of the continuation of these trends for a century will be examined with regards to their impact on the role and status of the Earth Sciences in the world of 2087. More specifically, the projected role and status of CMOS and Canadian meteorology and oceanography will be discussed. Finally, the conditions under which the extrapolation is valid will be examined and contemporary action by individuals and organisations towards fulfillment of these conditions will be suggested.

SESSION 5A BOUNDARY LAYERS I: WINDS OVER LAND AND SEA

Thurs. 0830-1030

Chairperson G. Strong, Alberta Research Council Room M1045

THE ASKERVEIN HILL PROJECT: VERTICAL PROFILES ABOVE THE HILLTOP

R. E. Mickle*, P. A. Taylor and H. W. Teunissen, *Boundary-Layer Research Division, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4

Askervein is a 126m high, grass and heather covered hill on the west coast of the island of South Uist in the Outer Hebrides of Scotland. As a part of an International Energy Agency coordinated study, wind speed and turbulence profiles were measured on 50m towers and with TALA kites at the hilltop and an upwind reference location during field experiments in 1982 and 1983.

Preliminary results were presented at the 1984 congress. In the present paper we will review and summarize the hilltop profile data for a wide range of upstream flow directions. These data clearly show the influence of the hill's asymmetric shape, the very shallow depth of the inner layer within which turbulence has a significant effect on the dynamics, and the virtual absence for practical purposes of a near surface equilibrium layer in the flow above the hilltop. The data will be compared against numerical and wind tunnel flow simulations.

THE ASKERVEIN HILL PROJECT: MEAN WIND VARIATIONS AT FIXED HEIGHTS ABOVE THE GROUND

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In addition to the 50m towers at hilltop and upwind reference sites discussed in the preceding paper by Mickle et al, 35 posts measuring mean wind speed at 10m or, if lowered, at 3m, were deployed during the Askervein '82 and '83 experiments. Data from these, and an additional 15 ten metre towers instrumented with Gill UVW anemometers deployed during Askervein '83, provide an excellent and extensive data set on the spatial variations in mean wind speed along three lines across the hill. Data for different wind directions clearly illustrate the effect of hill shape on near surface flow variations. Comparisons between the field data and model predictions will be used to illustrate the strengths and weaknesses of various models and of simple guidelines for boundary layer flow over hills.

A COMPARISON OF SHORE AND NEARBY SHIP WIND REPORTS ALONG THE B.C. COAST

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The substantial topography along the British Columbia coast severely distorts the surface wind flow, and the marine community is compelled to make subjective adjustments to land-based station reports for use over water. In many cases these corrections are substantial, both in direction and speed.

From March to December 1986, wind reports from lighthouses, automatic stations, AES synoptic stations and selected offshore buoys along the outer B.C. coast were compared to reports from ships-of-opportunity within 1 degree latitude (60 nautical miles). Mean direction and speed errors for a number of wind regimes were calculated, and correction factors (where applicable) were tabulated. No correction was applied to ship winds as these are the values seen and used by the marine forecasters and the community.

As expected, those stations with the best exposure proved to be most representative of conditions over water. Most shore stations reported winds which were too light, but a few measured winds which were in excess of the ship reports. At least one synoptic situation, where winds were "turned" 180 degrees between ship and station, was noted.

THEORETICAL WIND SPEED PROFILES OVER THE SEA WITH APPLICATION TO DATA FROM SABLE ISLAND

John L. Walmsley, Boundary-Layer Research Division, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4

In October 1985, the Boundary-Layer Research Division conducted an experiment on Sable Island, Nova Scotia in which 10-m wind measurements were made at a number of locations. Wind data were also collected at 4 levels on one of the 10-m masts and at 6 levels on a 26-m mast, both located on the South Beach. Other data used in the present study consisted of air temperature measured at 9 m and sea temperature measured at the beach.

The theory for wind speed and temperature profiles over the sea will be reviewed and a method of deriving over-sea parameters (u^*, t^*, z_o, L) from wind data at one level and air-sea temperature difference will be described. The method will then be applied to data collected at beach sites in onshore flow during the October 1985 experiment.

Once the above parameters are obtained, theoretical wind profiles may be computed with observed profiles. In order to make a proper comparison it is essential to account for internal boundary layers generated at the shoreline by the step-change in surface roughness. Only the data measured above the internal boundary layer are representative of over-sea conditions and may, therefore, be used for verifying the theoretical profiles. Agreement between calculated and measured data is generally very good. A complicating factor, however, is a slight upstream-blockage effect due to a 7-m high dune located about 140 m downwind of the 26-m mast. Estimates of the magnitude of this effect partially account for small discrepancies in measurements at the 26-m and 10-m mast locations.

CLIMATOLOGICAL ESTIMATES OF LAND-SEA WIND-SPEED RATIOS IN THE VICINITY OF SABLE ISLAND

John L. Walmsley*, Peter A. Taylor and Val Swail, *Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4

Monthly climatological wind data, stratified by wind direction and averaged over several years, were obtained from the Sable Island, Nova Scotia weather station and from ships and drilling rigs in the immediate vicinity. The over-sea data were adjusted to a height of 10 m using theoretical profile formulae which incorporated monthly climatological averages of air-sea temperature difference for the same periods. Land-sea ratios of 10-m wind speeds were then computed for each of the 8 principal wind directions.

The "guidelines" method of Taylor and Lee (1984) was used to obtain estimates of land-sea wind speed ratios at 10-m at the location of the AES U2A anemometer. This method requires as input the type of terrain feature (e.g., two-dimensional ridge, escarpment, three-dimensional hill), the hill height (or valley depth) with respect to surrounding flat terrain, a measure of the horizontal scale of the terrain feature, the local surface roughness, the upstream roughness and the distance in the upstream direction to a step-change in roughness. These estimates were made for each of the 8 principal wind directions.

A comparison was made between the "guidelines" estimates and the land-sea wind speed ratio derived from the climatological data. The agreement was good and suggests that island or coastal data may be used to estimate over-sea wind speeds at various heights in the vicinity provided information on the local terrain needed to compute the "guidelines" estimated and information on air-sea temperature difference needed to adjust to the desired height are available.

Taylor, P. A. and R. J. Lee, 1984: Simple Guidelines for Estimating Wind Speed Variations Due to Small Scale Topographic Features. Climatol. Bul., 18 (2),. 3-32.

THE SPATIAL COHERENCE OF MARINE WIND OBSERVATIONS

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The spatial coherence of winds from ships, oil rigs and the SEASAT-A Scatterometer (SASS) were investigated through correlation analysis. Values of the spatial correlation coefficient in minimum separation classes revealed that SASS winds were the most consistent, followed by rig winds, estimated ship winds and measured ship winds: the variance explained by adjacent observations was found to be 86%, 76%, 55% and 48% respectively. Comparison of spatial correlations for ship wind speed reports made during daylight and darkness hours showed significantly lower consistency in nighttime reports. This was a feature of both estimated and measured ship winds. Correlation models consistent with the assumptions of homogeneity and isotropy were found to provide a reasonable fit to ship wind

spatial correlation results while contour plots of r_s, r_u and r_v about OWS DELTA were consistent with the theoretical results of Buell(1960).

ISALLOBARIC CONTRIBUTION TO THE REAL WIND: A CASE STUDY, JANUARY 14TH, 1986
A.G. Earle and D.E. Steeves

On January 14th, 1986 a rapidly deepening and fast moving low pressure centre moved from south of Nova Scotia to southeastern Labrador. Pressure falls of 13 millibars/3 hours and rises of 17 millibars/3 hours were analyzed with this low which deepened some 36 millibars in an 18 hour period. With the passage of this system the Canadian Coast Guard ship 'Sir William Alexander' in the northeast Gulf of St. Lawrence reported winds increasing from south at 70 knots gusting to 80 to southwest 80 gusting in excess of 100 in a space of 30 minutes and then dropped to southwest 60 and gusting 30 minutes later. The ship also experienced a pressure fall of 13 millibars in 2 hours.

An analysis and discussion of surface and upper air characteristics is presented. The wind observations from the ship are analyzed and found to be compatible with those from adjacent land stations. It is then shown that the isallobaric wind component is a very significant contribution to the real wind experienced by the ship.

SESSION 5B DEEP SEA OCEANOGRAPHY I: THEORY Thurs. 0830-1030

Chairperson J. Lazier, Bedford Institute Room M1032

THE INERTIAL SUBGYRES FOUND IN NUMERICAL OCEAN MODELS
R. J. Greatbatch, Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7

It is shown that the inertial recirculating subgyres found recently by Boning (1986) in a steady, barotropic ocean model with lateral friction are similar in character to the barotropic modon solution of Stern (1975). This means that their zonal and meridional scales are strongly influenced by the inertial length scale $\lambda_I = (U/\beta)^{1/2}$, as is demonstrated. This contrasts with the situation found in multi-level, eddy-resolving general circulation models (EGCM's) where the inertial recirculating subgyres have a character similar to Fofonoff's (1954) solution. It is shown that the zonal penetration scale in these cases is independent of λ_I. As discussed by Holland and Schmitz (1985) it is set instead by a balance between instability processes that tend to confine the inertial subgyres near to the western boundary and inertial processes that try to extend them all the way to the eastern boundary. This suggests that a barotropic model with lateral friction is inappropriate for mimicking this feature of the time-mean circulation in EGCM's.

THE INFLUENCE OF TOPOGRAPHY ON THE STRUCTURE OF WESTERN BOUNDARY CURRENTS
R. J. Greatbatch* and D. M. Holland, *Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7

The influence of topography on the structure of steady-state western boundary currents is examined using a barotropic model. In a linear model with bottom friction, the offshore pressure gradient diffuses equatorward as predicted by Csanady's arrested topographic wave theory. In the highly non-linear, potential vorticity conserving limit, the flow turns equatorward ahead of the shelf in both subpolar and subtropical gyre cases, the dynamics being the same as that for the passage of a westward flow of air over a mountain range. Possible consequences for the Gulf Stream and Labrador current system are discussed.

GENERATION OF ANNUAL PERIOD ROSSBY WAVES IN THE SOUTH ATLANTIC OCEAN BY THE WIND STRESS CURL,
C.J.C. Reason, L.A. Mysak, Climate Research Group, Department of Meteorology, McGill University, 805 Sherbrooke St. W., Montreal, Quebec, H3A 2K6, and P.F. Cummins.
The properties of first mode annual period baroclinic Rossby waves generated by the observed wind stress curl in the South Atlantic and South West Indian Oceans are presented. The forcing wind field for the area 15 S to 51S, 45 W to 41 E was obtained from an harmonic analysis at the annual period of the monthly mean wind stress curl values derived from Hellerman and Rosenstein's data, and was used to drive a linear, reduced gravity model of the South Atlantic and South West Indian Oceans bounded by the latitudes 15 S and 51 S and by longitudes 46 W and 50 E. Boundary geometries and oceans are represented to 1.0 and 0.2 degree accuracy, respectively, by a finite difference grid in spherical polar co-ordinates.
In the South Atlantic Ocean, the response consists of long Rossby waves which generally propagate their phase southwestwards across the ocean and which exhibit refraction of wave energy towards the equator. Short Rossby waves with eastward energy propagation are generated in the small area of the Indian Ocean included in the model domain. Medium to long waves generated to the south east of Africa reflect their energy off this landmass into the Indian Ocean.
Slowness curve theory and wavenumber computations along wave rays in the South Atlantic are applied to match the model wave trains with probable sources. It is found that wind stress curl maxima off the Namibian coast near 25 S,10 E, near the Agulhas Plateau at 38 S,25 E and in the South Atlantic Ocean interior near 38 S,10W are the most efficient wave generators.

TRAPPING OF NEAR-INERTIAL FRONTAL-VORTICITY WAVES DUE TO CRITICAL LAYER ABSORPTION, WITH APPLICATION TO THE NORTH PACIFIC SUBTROPICAL FRONT
Gordon E. Swaters, Department of Mathematics, University of Alberta, Edmonton, Alberta, Canada, T6G 2G1

A theory is presented which describes stable large wavenumber small amplitude baroclinic vorticity wave perturbations of geostrophic fronts which use the transverse frontal vorticity gradient as a pseudo-β effect. The waves, which propagate downstream in the along-front direction, are transversely trapped

due to critical layer absorption. The wave streamfunction is obtained by asymptotically matching a WKB solution valid in the exterior of the critical layers to a Frobenius solution valid for the leading order critical layer interiors. The theory is applied to the North Pacific Subtropical Front in an attempt to provide an explanation for an anomalous cross-front XBT temperature section observed during the FRONTS '80 experimental program. The theory is able to describe many of the observed features of the temperature section.

ISOLATED BAROCLINIC EDDY IN A SHEAR OR STRAIN FLOW: THEORY

Barry Ruddick

Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, B3H 4J1 Canada

A three layer model is used to study the effects of pure strain flow and simple shearing flow on isolated, anticyclonic, baroclinic vortices such as Mediterranean salt lenses. Exact steady solutions are found representing elliptical vortices with uniform interior vorticity. These solutions become increasingly elliptical with increasing strain or shear, with the major axis always 45° clockwise from the principal (outflow) axis of the strain field. This is shown to be necessary so that the mean flow not exchange energy with the lens. At some critical value of strain or shear, these solutions cease to exist. The results suggest that for a lens of a given Rossby number, there is a maximum large-scale strain beyond which the lens must undergo drastic changes in order to survive.

ISOLATED BAROCLINIC EDDY IN A SHEAR OR STRAIN FLOW: EXPERIMENT

David Brickman

Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, B3H 4J1 Canada

To date, most of the work on coherent vortices in the ocean has concentrated on their properties and behavior in isolation from the fluid that surrounds them. However, as these structures move through the real ocean they encounter regions of strain and shear that may effect their evolution and stability. If the external flow field destabilizes lenses, then this must be taken into consideration when constructing scenarios of ocean mixing. What is the effect of a large scale strain field on a coherent vortex, and what value of strain can such elements withstand before breaking apart?

This problem is being investigated in the rotating table laboratory at Dalhousie University. Coherent vortices of known stability are created using a constant flux source of less dense water. The external flow field is generated by combinations of sources and sinks of fluid. In practice, one first creates the vortex, then turns on the external field and observes the effect on the lens.

The details of the lab experiment will be presented and the theory of the behavior of a C-V in an external strain field will be disussed. The theory is supported using laboratory results shown on video cassette tape.

SESSION 5C BIOLOGICAL OCEANOGRAPHY I Thurs. 0830-1030

Chairperson R. Haedrich, Memorial University Room M2025

PHYSICAL AND BIOLOGICAL STUDIES IN THE ROCKALL TROUGH, NORTHEAST ATLANTIC
J. Mauchline, Scottish Marine Biological Association, Dunstaffnage Marine Laboratory, P. O. Box 3, Oban, Argyll, Scotland, U.K.

The Rockall Trough is a finger-like extension of the Northeast Atlantic deep water. Time series data have been obtained for the physical parameters of the water masses, the pelagic and benthic faunas, and the demersal fish. These data infer half-life residence times of water masses in the trough of the order of months. Several species, with more or less continuous geographical distributions in the Northeast Atlantic, form reproductive nodes within the trough. Carriage of larvae and juveniles from these nodes aids recruitment and maintenance of these species outside the trough.

MARINE BIOTIC AND ENVIRONMENTAL CYCLES
M.J. Dunbar, Institute of Oceanography, McGill University

There is increasing evidence of cycles, in the period of 50-75 years approximately, in marine biota and in climatic or other environmental factors. This paper reviews some of the evidence and addresses the problem of coming to some understanding of their interrelation. The cycles are not synchronous, nor would they be expected to be, since they must be dependent upon a complex pattern of relationship or causation within a complex ecosystem. Since such cycles form a natural background to population fluctuations that may be in part due to the activities of mankind, it is important to understand them in the interests of rational management and conservation.

VARIABILITY IN THE HYDROTHERMAL VENT ENVIRONMENT: FROM SECONDS TO CENTURIES
Tunnicliffe, Verena, Biology Department, University of Victoria, Victoria, BC

The physical, chemical, and geological characteristics of the hydrothermal vent environment impose a high degree of variability that tends to be unpredictable from the perspective of vent organisms. From our work on the Juan de Fuca and Explorer Ridges, and from a review of East Pacific Rise and Galapagos studies, effects of temporal variability emerge on a number of different time scales:

1. Seconds - Turbulence and eddying around high temperature plumes result in variable mixing of vent and normal sea water thereby affecting metabolism and respiration in nearby animals.
2. Hours - Evidence from flow meters, thermistor, and turbidity plumes indicates fluctuating vent flows responding to a diurnal tidal cycle. Animals show a corresponding behavioural response.
3. Days - Anhydrite chimney accumulations at 2 to 20 $cm.da^{-1}$ result in continual structural collapses deleterious to surrounding animals.
4. Weeks - Conduit shifts and clogging alter vent flows and animal recruitment may occur in response. Induration of sulphides tends to stabilize the accumulating structures.

5. Years - Three different cruises have revisited vent sites to find major community shifts in response to alteration of both high and low temperature flows. Some areas have died entirely.
6. Centuries - Frequent tectonic and volcanic events on ridges must be catastrophic to organisms; segment jumping and changes in spreading rates would be reflected in such event. Population isolation can result in speciation or extinction.

In response to such wide ranges in habitat predictability, certain strategies might be expected in these organisms. These include flexible physiological and metabolic processes, wide niches within the vent habitat, continual reproduction, and wide-ranging populations. Some of these features are now known to exist.

SEASONAL PATTERNS IN OCEANOGRAPHIC AND BIOLOGICAL EVENTS IN A FJORD, BONNE BAY, NEWFOUNDLAND

Robert G. Hooper, Biology/N.I.C.O.S., Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7

The water masses of Bonne Bay show a seasonal warming and cooling cycle that results in consistent stratification patterns during each summer. This temperature and salinity stratification correlates well with sessile biological zonation patterns. The distribution of mobile organisms also changes seasonally corresponding to the pycnocline depths associated with specific water masses. Low salinity controlled stability of the inner basin of Bonne Bay impedes mixing and as a result stratification is more compressed than outside the shallow sill. In the fall reverse thermoclines associated with cold low surface salinity water develop, sometimes entrapping warm water fish, which normally migrate south. When the stability is lost, due to freezing, the resultant turnover results in sudden mass mortality. Mackeral, Atlantic sauries, dogfish and squid are the most frequent victims of this phenomenon.

PREDICTING GUANO PRODUCTION FROM EL NINO EVENTS.

David Schneider (Newfoundland Institute for Cold Ocean Science, Memorial University, St. John's, Canada) David Cameron Duffy (Universidad Nacional, Hereida, Costa Rica)

The 1982-83 El Nino event was unusual in its duration, intensity, and seasonal timing; it was followed by analogous shifts in zonal and meridional atmospheric circulation in the Atlantic. The 1982-83 event caused distributional and demographic changes in upper trophic level marine organisms in the Pacific; it has been linked to changes in marine populations elsewhere in the world. We investigated the predictability of guano production in the eastern tropical Pacific and eastern tropical Atlantic in relation to El Nino events from 1908 to 1960. The frequency of El Nino events at a time scale of 4.7 years explained 80% of variation in guano production. Single events explained only 8% of the annual variation in guano production in Peru. Guano production in the southern Atlantic was unrelated to El Nino events in the Pacific. Contrary to expectation, decreases in Peruvian production were followed by significant increases in Benguela production at a lag of 1 year.

THE RELATIVE IMPORTANCE OF BIOLOGICAL AND PHYSICAL PROCESSES IN STRUCTURING THE FAUNAL ASSEMBLAGES OF TWO NEWFOUNDLAND FJORDS

Richard, J.M. Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X7

The pelagic fish and macrozooplankton faunas of two Newfoundland fjords, Bay d'Espoir and Fortune Bay, were examined in May 1982 and June 1983. The fjords are known to contain predominantly different deep water masses and to differ in the nature and frequency of deep water exchange. Bay d'Espoir is a stable environment; Fortune Bay is dynamic. To assess the relative importance of physical and biological processes as regulatory mechanisms of the fjord faunas, I examined the spatial and temporal variability in species composition, species rank order of abundances and biomass of the fish and macrozooplankton faunas. The results suggested that the structure and persistence of the fish faunas were related to environmental stability. In Bay d'Espoir, six of thirteen (46 %) species were collected in both years compared to two of eleven (18 %) species in Fortune Bay. Percentage similarity between years was high in Bay d'Espoir (91.5 %) and low in Fortune Bay (43.6 %). Species composition and rank order of abundances within and between years were less variable in Bay d'Espoir than in Fortune Bay, as were catch rates for the dominant species. These results suggest that the fish fauna in Bay d'Espoir was regulated primarily by in situ biological processes while advective processes were more important in Fortune Bay. Similar results were not obtained for the macrozooplankton faunas which were thought to respond primarily to more short-term or seasonal changes in environmental conditions.

OCEANOGRAPHY AND LIMNOLOGY: CONSTRAINT AND PREDICTABILITY IN THE FISH PRODUCTION SYSTEMS

Lionel Johnson, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6

The greater the complex of constraints on a system the greater is its predictability. In systems of low constraint such as the atmosphere and the oceans we can only expect a very low level of predictability. It is therefore necessary to start with global generalities, then work down to specifics as may be possible in individual cases. From an oceanographic standpoint, lakes may be regarded as small oceans, each with a set of constraints appropriate to the latitude. They thus provide "cross-sections" or "stills" of the ocean at each latitude. The inherent possibilities of this approach are apparent if we consider the fish populations in lakes. Fish, being terminal in the food-web, are the great integrators of environmental conditions. The pristine fish population of a lake, existing within an essentially closed thermodynamic system, therefore provides information on the effect of the local environment without excessive noise being introduced from neighboring systems. These effects are illustrated by a brief survey of the characteristics of lake populations across the world, compared with selected ocean populations.

SESSION 5D CHEMISTRY OF THE ATMOSPHERE AND OCEAN Thurs. 0830-1030

Chairperson T. Pedersen, University of British Columbia Room M2017

AN UNDERWATER MOVIE: HYDROTHERMAL VENT ORGANISMS NEAR A NATURAL GAS AND OIL SEEP IN GREEN CANYON, GULF OF MEXICO

Kennicutt II, M. C., Department of Oceanography, Texas A & M University, College Station, TX

A short film is to be shown of a recent Johnson sealink dive to a natural gas/oil vent discovered in the Green Canyon, Gulf of Mexico. Assemblages of organisms analogous to those observed at hydrothermal vents have been documented. Symbiotic methane utilizing bacteria appear to support the foodweb in this type of vent.

THE NATURAL SEEPAGE OF PETROLEUM ON THE GULF OF MEXICO CONTINENTAL SLOPE

Mahlon C. Kennicutt II and James M. Brooks
Department of Oceanography, Texas A & M University, College Station, TX 77843

It has long been speculated that natural petroleum seepage is a significant contribution of hydrocarbons to the marine environment. However, direct observations of oil seepage in a strictly marine setting are limited. Recent findings in the deep (> 300 m) Gulf of Mexico suggest that natural seepage may be a widespread phenomena. Massive petroleum seepage in the Green Canyon Lease Area has been compared with the oil and gas reservoired in the deep subsurface (2000-3000 m) and is very similar. Parameters compared include molecular and isotopic distributions of both gases and liquids. The presence of significant amounts of dibenzothiophenes (DBTs) has also been documented at many slope sites and the molecular composition of the DBTs is similar to reservoired Gulf oils. The seepage at the slope sites appears to be massive and often occurs as a separate phase. In contrast to this, results from DSDP Leg 96 suggest that low-level thermogenic hydrocarbons are permeating a large area of fan sediments in a much more diffuse manner than on the slope. Regional evaluations of the norther Gulf of Mexico with more than 2000 piston cores suggest that these phenomena are widespread. All of the above studies will be reviewed and the regional evaluations presented.

THE ROLE OF MID-OCEAN RIDGE HYDROTHERMAL PROCESSES IN THE CYCLING OF CARBON IN THE OCEANS

J. Welhan[1] and H. Craig[2],
1.Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NF A1B 3X5
2.Isotope Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093

Mid-ocean ridge (MOR) hydrothermal processes exert an important influence on the carbon balance in the oceans and on the global

oceanic carbon cycle. Relative to juvenile helium, whose flux from the mantle to the hydrosphere via MOR hydrothermal circulation is relatively well known, total carbon input to the oceans from high-T weathering of MOR basalts is of the order of 10^{12} moles/y. Of this, about 1% is in the form of CH_4, the remainder being dissolved inorganic carbon (DIC) as CO_2. If high-T hydrothermal metamorphism of sedimentary organic carbon in sedimented rifts and back-arc basins is important on a global scale, then a much higher proportion of reduced carbon gases may be injected. However, MOR-injected methane is rapidly consumed (probably biologically) in the water column, so its impact on the global hydrocarbon cycle appears to be negligible.
Isotopic data on MOR-injected CO_2 is consistent with published thermodynamic solution models which suggest that seawater DIC could be precipitated within the oceanic crust as hydrothermal carbonates. Carbon isotope data on high-T hydrothermal CO_2 is consistent with near-quantitative precipitation of DIC from recharging seawater, suggesting that the bulk of the CO_2 injected into the oceans at MOR's is basalt-derived.
The MOR carbon flux represents of the order of 2 - 25 % of the river input of DIC, so that it is a significant term in the global carbon balance of the oceans. Data on altered basalts suggest that DIC uptake by hydrothermally altered oceanic crust is of the same order of magnitude as the basalt injection rate, raising the possibility of MOR hydrothermal processes also playing a significant role in closing the DIC weathering cycle.

INTERACTIONS ENTRE LE FER ET L'ARSENIC DANS LES SÉDIMENTS DU SAINT-LAURENT

BELZILE, Nelson et LEBEL, Jean, Département d'océanographie, Université du Québec à Rimouski, 310 ave des Ursulines, Rimouski (Québec) G5L 3A1.

Une étude effectuée sur les sédiments et les eaux interstitielles du chenal Laurentien a permis d'établir une relation étroite entre la géochimie de l'arsenic et celle du fer. Nous obtenons d'abord, par le biais d'extractions chimiques sur la phase solide du sédiment, des résultats qui montrent une forte affinité de l'arsenic pour les hydroxydes de fer concentrés dans la couche oxydée du sédiment. Ces hydroxydes de fer sont réduits en profondeur ce qui entraîne la libération simultanée des formes dissoutes du fer et de l'arsenic observée dans l'eau interstitielle. Nous avons confirmé ces observations par des expériences en laboratoire reproduisant les conditions du milieu. Dans les sédiments plus profonds (>20 cm), des conditions favorisent la formation de pyrite (FeS_2) diagénétique, laquelle peut incorporer l'arsenic dans sa structure cristalline et contrôler alors la distribution de l'arsenic à ces profondeurs. À partir de ces résultats, nous avons élaboré un modèle simple pour décrire l'ensemble de ces processus; ce modèle permet d'expliquer aussi les différences qui sont observées entre les stations en fonction de la qualité et de la quantité de matériel qui sédimente au fond du chenal.

MASS TRANSPORT CONSTRAINTS ON THE GROWTH OF FERRO-MANGANESE NODULES

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A successful theory for the genesis of manganese nodules must predict their observed growth-rates and account for their general morphological features. If the Mn(II) oxidation reaction is relatively rapid, then the transport of dissolved metals to a nodule surface controls the accretion rate and shape. This transport process can be described using diffusion-advection models and boundary-layer theory.

The discoidal shape of many shallow-water ferro-manganese nodules is thought to reflect a strong underlying diagenetic source for the accreting metals. However, the coarse-grained sediments found usually beneath these nodules are unlikely to support substantial fluxes of dissolved metals. Lateral movement of metal-enriched bottom waters over these oxidized sediments are a more likely source. Assuming a lateral source and that the sediment-water interface is relatively inert to dissolved metals, a boundary-layer transport model can reproduce the discoidal morphology. When applied to the environmental conditions of Lake Charlotte (N.S.) and Jervis Inlet (B.C.), the model-predicted growth-rates are in good agreement with other independent estimates for the nodules found at these two locations.

The identification of an underlying sediment source of metals for deep-sea nodules on highly oxidized sediments has proven to be elusive. On the other hand, seawater presents a readily available supply, at least to the top surface of nodules. Assuming that nodules and oxidized red-clays are equally reactive to dissolved metals, then the predicted flux of dissolved Mn through the benthic-boundary-layer to the nodules matches the measured radiometric rates. The formation of more spherical nodules can also be expected.

THE INFLUENCE OF THE ICE PHASE ON THE CHEMISTRY OF A RAINBAND

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Previously we have reported on simulations of a rainband with a combination of a two-dimensional dynamical cloud model and a cloud chemistry model. The simulations were compared with observations of the air, cloud and rain chemistry of the rainband and although in some aspects there was good agreement between the observations and simulations, in others there were significant discrepencies. In particular, the simulated concentration of sulphate in the air within the cloud appeares to be too high and the

concentration within the rain too low. One of the limitations of the original simulations was the absence of the ice phase. The goal of the work reported here is to determine to what extent the inclusion of ice and snow in the models influences the results of the simulations, and in particular whether this produces better agreement with the observations.

Ice within the model is treated in the manner described by Yau (1981). In this parameterization ice may exist at a particular grid point in one of two forms, crystals or snowflakes, depending on the size of the ice particles. Although the chemistry model includes sulphur dioxide, ammonia, nitric acid, ozone, hydrogen peroxide, and an aerosol consisting of ammonium sulphate and sulphuric acid, it is believed that the main influence of the ice will be on the scavenging of sulphate. Thus ice of either form may collect the sulphate aerosol directly or it may collect droplets by riming and incorporate the dissolved sulphate into the rimed ice particle. Preliminary results show that the inclusion of the ice phase modifies the cloud dynamics which may complicate the interpretation of the differences in the results of the simulations with and without ice.

SESSION 6A BOUNDARY LAYERS II: OBSERVATIONS AND THEORY
Thurs. 1050-1230

Chairperson P. Taylor, AES Downsview Room 1045

MEASUREMENTS OF THE WIND STRESS, HEAT FLUX, AND TURBULENCE INTENSITY DURING STORM CONDITIONS OVER THE NORTH SEA

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During the first two weeks of December, 1985, measurements of the wind stress, heat flux, and windspeed variance statistics were collected from a research platform in the North Sea. Using a sonic anemometer, the turbulence data represent windspeeds up to 30 m/sec, and the encountered air-sea temperature difference spanned from -3^{o} to $+3^{o}$C. The data were collected from a boom extending 17 meters to the west of the North Sea Platform at the 33 meter level above the water surface.

Based on 116 records of data (with an average duration of 30 minutes each), the neutral drag coefficient was found to exhibit a windspeed dependence that is described by $10^{3}CDN = .084\ U_{10} + .58$, where the subscript indicates the 10 meter height above the surface. There were scanty heat flux data available for unstable conditions; however, for stable stratifications, we found a mean Stanton number, CH, to be 0.75×10^{-3}. The mean values for σ_u/u_*, σ_v/u_*, and σ_w/u_*, were found to be 2.25, 1.94, and 1.27, respectively.

We additionally examined the direction of the stress vector relative to the direction of the mean wind. It was found that the sign of this difference (and its magnitude) depends to a large degree on the thermal wind, which in turn is related to the heat flux.

PRELIMINARY RESULTS OF THE HUMIDITY EXCHANGE MAIN EXPERIMENT (HEXMAX)

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HEXMAX is the culmination of the Humidity Exchange over the Sea (HEXOS) programme to investigate evaporation at the sea surface and associated phenomena. The 8 week experiment took place in the North Sea at and around "Meetpost Noordwijk", a research and meteorological platform 10 km off the Dutch coast during October and November of 1986. Participants were from Canada, Denmark, France, Great Britain, the Netherlands, the USA, and W. Germany. Eddy correlation measurements of evaporation, sensible heat flux and wind stress were made at a 20 m boom extending to the west of the platform. A video camera observed wave breaking. The size distribution and composition of aerosol droplets were sampled. Sodar monitored inversion height and atmospheric boundary layer structure. Wind speed and direction, humidity, air and water temperatures, short- and long-wave radiation and the wave spectrum were monitored on a routine basis.

Spatial coverage was extended by a British vessel, RRS Frederick Russell carrying out oceanographic, micrometeorological, meteorological and radiosonde measurements, and a shore-based tethersonde and radiosonde station was established to obtain regular atmospheric soundings. A Hercules aircraft equipped for boundary layer research with gust probes, aerosol samplers and other specialized instruments, flew patterns over the experimental area on several days.

Weather conditions contributed to the success of the experiment. Fine and calm weather during the initial week, which facilitated installation of the sensors, was followed by persistent westerly winds during most of the remaining 7 weeks. A large collection of eddy flux, aerosol and supporting data has been obtained at wind speeds up to 25 m/s and in a range of sea states and atmospheric stability conditions. We are confident that analysis of these data will allow us to develop an improved evaporation formula for use in atmospheric and oceanic models.

A PARAMETERIZATION OF THE STABLE ATMOSPHERIC BOUNDARY LAYER

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Developers of forecast models and GCMs are still looking for an efficient and correct parameterization of the boundary layer. The two formulations proposed here are extensions into the Ekman layer of the well accepted surface layer expressions for the stable case. In one formulation, the diffusion coefficient is a diagnostic function of the wind shear and Richardson number while, in the other, it is expressed using the prognostically determined turbulent kinetic energy. The parameterization is tested in a one-dimensional model simulating the evolution of the nocturnal boundary layer (NBL) with and without radiative cooling. The two formulations give very similar results

except near the top of the NBL, where the turbulent energy vanishes while the diagnostic formulation allows some vertical transfer.

The distinctive feature of the parameterization, which makes it interesting for weather forecasts or climate models, is that it conserves its simulating skill when vertical resolution is reduced. Typically, the difference in the calculated wind speed at 10 m or in surface fluxes between the high resolution runs and the low resolution runs is only a few percent. By low resolution, we mean a grid spacing of the order of the height of the NBL (150-400 m), the first level being at a height corresponding to half the grid spacing. This performance is maintained for inversion amplitude up to 40°C and for roughness lengths ranging form .0001 to 10 m.

The choice of one or the other formulation is a question of taste or conformity with the formulation for the unstable case (to be studied next). It appears, however, that there is no significant advantage in using the more complex turbulent kinetic energy formulation for the stable case.

INFLUENCE OF THE EARTH'S ROTATION ON THE TURBULENT STRUCTURE OF THE NEUTRAL PLANETARY BOUNDARY LAYER

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Although the neutral planetary boundary layer (p.b.l.) has been the subject of a large number of studies, its turbulent structure is not yet fully understood.
Neutral p.b.l. models using an empirical formulation for the turbulent mixing length generally yield good agreement with observational evidence. However the standard turbulent kinetic energy-dissipation rate k-ϵ model, which has stronger physical foundations, overpredicts the depth of the neutral p.b.l. and gives poor agreement with the observations. Earlier workers have postulated that this discrepancy may be due to the fact that rotational effects are not included in the k-ϵ model.
With the use of an algebraic stress model, which directly accounts for rotation, the influence of the earth's rotation on the turbulent stresses has been investigated. The effect of rotation on the dissipation process has also been examined.
It will be shown that although rotation does affect the turbulent structure of the neutral p.b.l., this influence is not large enough to explain the discrepancy between experimental data and earlier numerical k-ϵ model results. The causes of this discrepancy are thought to lie elsewhere than in rotational effects.

ON EFFECTIVE ROUGHNESS LENGTHS OF HETEROGENEOUS TERRAIN FOR USE IN LARGE SCALE MODELS

Peter A. Taylor, Boundary-Layer Research Division, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4

Simple calculations of a really averaged flow over flat but heterogeneous terrain are presented. These suggest a definition of an effective roughness length, z^{eff}_o, which could be used in large scale models. Comparisons are made between several alternative definitions and the possible use of global land cover archives to determine roughness length fields for large scale models is discussed. The effect of flow transition zones between areas of different

roughness is assessed with boundary-layer models. As a first step we believe that these can be neglected and that $\ln z^{eff}_o = < \ln z_o >$, where $< >$ indicates an areal average and z_o is the local micrometeorological roughness length, provides a reasonable approximation.

VERTICALLY INTEGRATED MODELS OF BOTTOM MIXED LAYER GROWTH IN THE OCEAN
You-Huang Jin* and Alex E. Hay, *Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7

A model for the growth of bottom mixed layers in the ocean is developed using the vertically integrated equations of motion. The vertical variation of mean speed with height is retained in the integration, and appears explicitly in the expression for the vertical integral of the mean kinetic energy. Balancing the time rate of the change of mean kinetic energy and potential energy against the work done by the pressure gradient associated with the interior geostrophic flow and the work done against friction yields a modified form of the Richardson number closure scheme used by Pollard et al. (1973) and Thompson (1973). The resulting equations are solved analytically for the case of stably stratified flow over a horizontal flat bottom. An expression is derived for mixed layer thickness which is similar in form to that obtained by Weatherly and Martin (1978) using the Mellor and Yamada (1974) level two turbulent closure scheme. For the sloping flat bottom case the problem is solved numerically, and the results are also consistent with those given by Weatherly and Martin (1978).

SESSION 6B DEEP SEA OCEANOGRAPHY II. OBSERVATIONS.
Thurs. 1050-1230

Chairperson L. Mysak, McGill University Room M1032

THE MIXING OF MEDDY "SHARON"
Barry Ruddick* and Dave Hebert, *Dept. of Oceanography, Dalhousie University, Halifax, N.S.

Most people are motivated to study Submesoscale Coherent Vortices (SCV's) because they are fun; they are concrete and intriguing objects which are not properly accounted for in spectral models of ocean turbulence. One of the "name-brand" SCV's, the Mediterranean EDDY, may account for a significant fraction of the lateral heat and salt transported across the Eastern North Atlantic. Some of them even make their way across to the Western North Atlantic intact. Meddies must eventually either break apart or mix with the surrounding ocean waters. How, how rapidly, and when they do this will affect the probability of finding patches of anomalous water or intense vorticity, and will affect the details of the dispersion of the water properties by the mesoscale eddy field. Thus the manner and rate with which these lenses mix with the surrounding waters is important to know.

A lens of anomalously salty Mediterranean outflow water in the Canary Basin has been tracked by means of SOFAR floats from October 1984 to October 1986 by L. Armi and T. Rossby (pers. comm.). In June 1985, we were able to find the lens and survey it with CTD, current measuring, and microstructure instruments. We found that the lens was being eaten away at the edges by intrusive layers about 30 m thick, in a region a few kilometers wide. Later surveys showed that the intrusions worked their way to the centre, causing the core to mix completely with the surrounding water. We discuss the signatures and characteristics of these intrusions, and attempt to infer their effects on the heat, salt, and velocity structure of the lens. We also raise the question of whether they are driven by double diffusive transports or by momentum transports (the MacIntyre instability). It seems at this point that we can't answer that question for this experiment, and that it will be difficult to design an experiment to discriminate between the two mixing mechanisms.

POSSIBLE INSTRUMENTAL EFFECTS CONTAMINATING INTERDECADAL TRENDS IN SHIP-BASED SST OBSERVATIONS.

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There has been much recent interest in interdecadal variations of the marine climate. Unfortunately, historical SST data from ship reports are thought to contain systematic errors resulting from changes in instrumentation and observing techniques. In particular there is the change from the use of uninsulated buckets for water temperature sampling in the pre-WWII period to that of engine intake temperature after the war. We are attempting to assess the magnitude of this effect by comparing ship-based SST records with nearby coastal station time series which should be free of these systematic errors. The study makes use of the Comprehensive Ocean-Atmosphere Date Set (COADS) and a number of coastal stations on both sides of the North Atlantic with records starting early in the century.

T/S PROPERTIES OF THE ARCTIC OCEAN NEAR THE ALPHA RIDGE

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Data collected from sea ice landing sites in the vicinity of the CESAR ice camp and Yelverton Bay, Ellesmere Island shed new light on the oceanography of this sparsely studied area of the Arctic Ocean. Differences between the Canada Basin ,south of the Alpha Ridge, and the Makarov Basin, north of the Alpha Ridge are found well above the ridge depth indicating a dynamical separation between the waters over the two basins. Step features show marked dissimilarities and may be useful as tracers to the origins of the waters in the two basins. T/S correlations in the shelf and slope regions off Ellesmere Island show evidence of a much more

energetic shelf regime. Geostrophically derived currents indicate southwesterly flow at all depths, somewhat at odds with the normally accepted current patterns.

SESSION 6C BIOLOGICAL OCEANOGRAPHY II Thurs. 1050-1230

Chairperson J. Anderson, Northwest Atlantic Fisheries Centre

Room M2025

THE IMPORTANCE OF SPATIAL SCALE IN CHARACTERIZING BENTHIC COMMUNITY COMPOSITION AND ITS RELATION TO THE SUBSTRATUM.

Jean-Marc Gagnon, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9.

The epibenthic megafauna photographed along five transects in the Hibernia region of the Grand Banks was used to investigate the relations between species assemblages and environmental gradients over a wide range of spatial scale. Nonmetric ordinations were produced for several scale intervals along each transect. The statistical significance of the observed trends in the variance explained by the components (factors) was evaluated through randomization tests. The spatial scale at which observations are made is shown to have a significant effect on the quality of the observations and their interpretation. The first ordination component is interpreted as a substrate gradient. The variance accounted for by this component is low at local scale (single frames) but shows a significant increase with length scale. Interpretation of the megafaunal data at a local scale indicates that stochastic processes are dominant. At spatial scales greater than 100 metres however, species assemblages are closely associated with substrate variability. The appropriate choice of sampling scale is therefore, at least in part, determined by the group of species under investigation, and is defined by the degree of mobility of the individuals. It is also influenced by the degree of heterogeneity or patchiness of the habitat.

LOCATION, DEMOGRAPHY AND MICRODISTRIBUTION OF 'COLD SEEP' BENTHIC COMMUNITIES IN THE JAPAN TRENCH SYSTEM: BIOLOGICAL REFLECTION OF GEOLOGICAL PROCESSES

S. Kim Juniper* and Myriam Sibuet, Dept. of Biology, University of Victoria, Victoria, BC, V8W 2Y2

Submersible exploration of the subduction zones around Japan has revealed scattered "cold seep" benthic communities, dominated by the bivalve Calyptogena, down to depths near 6000 m. These apparently chemo-synthesis-based communities are localized at sites where methane-rich deep sediment pore-water vents through the seafloor as a result of the subduction process. Discovery of this type of biological community is very recent and their ecological functioning is virtually unknown. We have used photo and video imagery obtained by submersible

to study the influence of topography and substrate on the nature of the cold seep megafauna. As well, microcartographic reconstructions of three seep sites were used to study microdistribution of the megafauna. Analyses reveal that cold seeps, as revealed by faunal aggregations, are restricted to zones on major faulting, that sediment cover or manganese crusts can restrict seepage of pore-water from underlying rock, and that biological exploitation of cold seeps is influenced by erosion, sedimentation and the nature of the substrate. Microcartography indicates both direct utilization of venting pore-water by the Calyptogena-bacteria symbiosis and two forms of indirect exploitation of organic matter enrichment by omnivorous and detritivorous organisms which surround the calm colonies. Cold seeps appear to be ephemeral, and calm colony demography may reflect recent history of pore-water venting in areas of subduction zones, information of current interest in studies of earthquake forecasting. This paper emphasizes the value of visual imagery in the study of relationships between deep-sea benthic communities and their environment.

THE GEOGRAPHICAL DISTRIBUTION AND LIFE HISTORY OF *Boreomysis nobilis* G.O. SARS 1879 IN COASTAL NEWFOUNDLAND FJORDS

Munro, Kirsten and Jocelyn M. Richard. Department of Biology and Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X7

The hyperbenthic mysid, *Boreomysis nobilis* G.O. Sars 1879 is reported from 14 locations off southern and eastern Newfoundland for the first time. Previous studies report *B. nobilis* only from locations with water temperatures less than $0^{\circ}C$. In the present study *B. nobilis* was common in fjords containing cold Labrador Current Water and was absent in collections from the south coast of Newfoundland where the predomint water mass was relatively warm (4 - $6^{\circ}C$) Modified Slope Water. However, *B. nobilis* was collected from Belle Bay, located on the southern coast of Newfoundland, where bottom water temperatures may approach $2^{\circ}C$ during the winter months. This, combined with the greater abundance of *B. nobilis* from the headwater regions of fjords compared to more open waters, suggests that factors other than water temperature may influence local distribution patterns. An examination of the populations from Newfoundland fjords shows that *B. nobilis* has a prolonged breeding period extending from spring to late fall. This is in agreement with findings from previous studies in other areas.

STUDIES ON THE AUTECOLOGY OF *SAGITTA SINICA*, N. SP. (CHAETOGNATHA) AND OF ALLIED SPECIES FROM THE EAST CHINA SEA

Xiao Yichang, Institute of Oceanology, Academia Sinica, Tsingtao, People's Republic of China

Extensive plankton samples collected by the Institute of Oceanology, Academia Sinica, provide material for the study of Chinese chaetognaths. Three species are found in the East China Sea, one of which is new. The new species is confined to the western portions of the sea, and occurs much farther to the north than do the others. Ecological studies provide further support

for the separation of the species. The new species is characteristic of the warm-temperate coastal region, mainly in the mixing zone between nearshore and offshore waters in the coast of Jiangsu and Zhejiang Province. Analysis of size groups suggests that there are three breeding periods throughout the year. An allied species, Sagitta bedoti Beraneck occurs in greater abundance in the warmer coastal waters of the South China Sea. From summer into autumn, its distribution extends to the north and inshore and its abundance is greatly increased.

PREDICTABILITY OF COMMUNITY COMPOSITION IN DEEP-LIVING DEMERSAL FISHES
Richard L. Haedrich* and Nigel R. Merrett, *Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, St. John's, NF, A1C 5S7

Data from 9 major trawling surveys made around the North Atlantic Basin at slope, rise and abyssal depths provide directly comparable information on deep demersal fish distribution and faunal composition. 320 species in 57 families and 188 genera are recorded. Alepocephalidae, Gadidae, Macrouridae, Moridae and Ophidiidae comprise nearly 2/3 of all species taken. 282 species were taken at slope depths (200-2250 m), 93 at rise depths (2250-4250 m), and 29 at abyssal depths (>4250 m). Diversity and the rate of endemism were highest on the slope. The Norwegian, Caribbean and Mediterranean Basins appear to harbour impoverished versions of the adjacent Atlantic Basin fauna. Each species distribution appeared to be rather unique, and no repeatable patterns could be found.

SESSION 6D DISPERSAL OF TRACERS IN THE ATMOSPHERE AND OCEAN
Thurs. 1050-1235

Chairperson V. Koutitonsky, INRS Rimouski Room M2017

COMMENTS ON DIFFUSION IN THE LAGRANGIAN FRAMEWORK
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Three different "Lagrangian" coordinate systems are identified. True Lagrangian coordinates, TLC, are attached to a parcel of fluid that always consists of the same matter. In Lagrangian coordinates, LC, a fluid parcels surface is advected by the macroscopic velocity field. In LC molecular motion diffuses material through the surface of a fluid parcel. The fluid parcel therefore losses its particle identity and can only be defined in terms of the macroscopic velocity field. In averaged Lagrangian coordinates, ALC, a parcel of fluid is advected with the "large" scale advective field and "small" scale turbulence (and molecular motion) diffuse material through the parcels surface.

For an Eulerian observer both advection and diffusion are necessary for the occurrence of the shear effect, while for an averaged Lagrangian observer time-dependent dispersion coefficients describe the process. In ALC and LC

material diffuses relative to the coordinate system. In a TLC all motion must be regarded to be advective; even molecular motion.

We use the method of Taylor (1921) to study dispersion of a patch of material in TLC. In a TLC there is no such thing as shear-diffusion. However motion consisting of diffusion across a shear in the Eulerian frame is shown to have a diffusive component acting along the shear in the Lagrangian frame. Dispersion of material is calculated from the Eulerian velocity auto-correlation coefficient and linear velocity gradients.

The instantaneous rate of change of variance of a spreading patch of material is completely specified by the instantaneous divergence obtained over the area occupied by the patch. This is only true for instantaneous values of divergence, because Lagrangian and Eulerian coordinate systems can only be equivalent for an instant. In order to describe patch spreading from divergence measured over longer periods it is also necessary to consider diffusion.

RANDOM WALKS IN NONHOMOGENEOUS TURBULENCE

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There is growing interest in modelling dispersion in nonhomogeneous nonstationary turbulence, using random walk and random flight models. These have been described by nonlinear stochastic differential equations. It will be argued that only linear equations are appropriate. Boundary conditions for such equations will be discussed.

SIMULATED FLOAT STATISTICS OFF VANCOUVER ISLAND

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A dense current meter array was deployed for 100 days in 1985 off the west coast of Vancouver Island. Objective analysis was used to compute the velocity field in and around the array and thence to compute the trajectories of simulated floats released in the array. For one period of 2 weeks duration drogued surface drifters were deployed in the array and we were able to compare the trajectories of real drifters with simulated trajectories. The results are entirely satisfactory.

Given that realistic trajectories can be computed from Eulerian measurements we then proceeded to simulate trajectories over the whole 100 day period and examine the Lagrangian statistics. The Lagrangian mean velocity is significantly different from the Eulerian mean. This difference may result from the strong polarization of the eddy field defined by the large negative values of $\overline{u(t)v(t+\tau)}$ for positive values of τ. The time that a particle is trapped in the array is examined. Though this time varies enormously with launch time, the trapping time seems only vaguely related to the eddy activity in the array.

VELOCITIES RELATIVE TO THE CENTROID OF A CLUSTER OF DRIFTERS

Badal K. Pal and Brian G. Sanderson, Dept. of Physics, Memorial University of Newfoundland, St.John's, Newfoundland, Canada A1B 3X7.

Drifter observations of near-surface coastal currents are used to investigate the scale dependence of the rms relative velocity field (relative to the centroid of a cluster of drifters) and velocity gradients. The rms relative velocity field is found to be proportional to distance, L, from the centroid raised to the power of approximately 0.4 ± 0.05. Divergence, shear, vorticity and stretching deformation rate vary as scale to the power of -0.6 ± 0.1, -0.5 ± 0.1, -0.5 ± 0.1 and -0.7 ± 0.1 respectively. A correction to Okubo and Ebbesmeyer's (1976) method of calculating velocity gradients is proposed.

The behaviour of autocorrelation coefficients is investigated. An integral time scale of the order of 140 min for correlations of velocity components in alongshore and cross-shore directions is estimated from winter experiments. The integral time scale for summer experiments is approximately 10 min. The analysis leads to the conclusion that the dynamics in the coastal water are dominated by wave activities in the summer. Lagrangian diffusivities during winter and summer are calculated and presented.

INTERANNUAL VARIABILITY OF TRANSBOUNDARY SULFUR MASS FLUX

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A study was conducted by the Atmospheric Environment Service (Air Quality and Inter-Environmental Research Branch) to compute the transboundary sulphur flux between eastern Canada and the United States on a monthly and annual basis. The years 1980 to 1983 were used because archived meteorological data and emissions inventories were available.

The sulphur fluxes were calculated by the AES Lagrangian model which computed SO_2 and SO_4 concentrations at 16 line segment mid-points along the Canadian-U.S. border from western Ontario through Quebec to the Maritimes. The sulphur mass fluxes were computed at 6 hour intervals and summed over monthly and annual time periods and over all the segments to obtain the total transboundary sulphur mass flux. By using only the Canadian and only the U.S. emissions, the total sulphur mass flux contributions from each country could be determined.

Canadian and U.S. emissions declined from 1980 to 1982 by 20% and 11% respectively, then increased slightly in 1983. The total annual sulphur mass flux from the U.S. to Canada ranged from 1.86 MTonnes S (1980) to 1.61 MTonnes S (1983) and the flux from Canada to the U.S. ranged from 0.75 MTonnes S (1980) to 0.52 MTonnes S (1982). The total flux between both countries was highest in the winter because of the stronger winds and higher SO_2 concentrations. The fluxes were lowest in summer because of the lighter summer winds and lower SO_2 concentrations. However, the SO_4 mass flux peaked in the summer because of the higher chemical conversion rate.

The annual transboundary fluxes were observed to change by up to 20% in response to emissions changes and meteorological variability and these two influences should be considered together.

CROSS-FRONTAL FLUXES OF HEAT AND NITRATE ON GEORGES BANK

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The summertime fluxes of heat and nitrate across the tidal front on the northern side of Georges Bank are estimated from moored measurements of current and temperature, ambient measurements of temperature and nitrate which are used to construct a nitrate time series at the mooring site, and simple models for shear dispersion and the barotropic and baroclinic tides. Using "eddy" fluxes estimated from either co-spectral, covariance or harmonic analyses, it is found that both the eddy fluxes and the mean flow fluxes contribute significantly to the loss of heat from, and the supply of nitrate to, the Bank. The simple models are used to investigate the physical processes responsible for these Eulerian eddy fluxes, which occur primarily in the semidiurnal tidal band. It is found that a shear dispersion mechanism involving horizontal tidal advection in concert with vertical mixing can account for the sign of the eddy fluxes but the additional effect of vertical motion at the tidal frequency is required to account for their magnitude. However, it is also found that an Eulerian eddy scalar flux in the tidal band arises from tidal motion in the absence of mixing, provided that there are orthogonal components of tidal velocity in quadrature and a scalar gradient in one of these directions. This "skew" eddy flux is directed perpendicular to the scalar gradient and is, in part, the Eulerian signature of the scalar transport by the Stokes velocity associated with nonlinear tidal current interactions, and in part, nondivergent (thus not affecting the mean scalar concentration). It is pointed out that similar eddy fluxes, which have been recognized for some time to occur in the atmosphere, are associated with many other oceanic waves.

HORIZONTAL MIXING OF PLANKTON BY INTERNAL WAVES, SURFACE WAVES AND SMALLER SCALE TURBULENT MOTION

Brian G. Sanderson, Badal K. Pal and Allan Goulding, Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7

Second order solutions for surface and internal waves will mix a passive scalar in the horizontal plane. We have analyzed the interaction of such solutions with smaller scale turbulent motion by using a perturbation expansion of the Lagrangian diffusion equation. The diffusivity is treated as a small parameter. The way various combinations of first order, second order and turbulent motion redistribute patches of material has been studied graphically. The interactions of such solutions with self-limiting growth have also been analyzed.

SESSION 6E: POSTERS Thurs. 1050-1230

Room M1034

SATELLITE SCATTEROMETER APPLICATIONS FOR ARCTIC ICE/WATER BOUNDARY IDENTIFICATION

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A recently published report by NASA "Passive Microwave Remote Sensing for Sea Ice Research", December '84, shows variations in Antarctic sea ice extend over a ten year period. The sensors used for this were several generations of Passive Microwave Radiometers. Ten years of data (Jan. 1973 - January 1983) show a significant decrease in mean ice extent during mid-1970's and a rebounding of the ice cover in subsequent years.

The authors identify the need for additional data and studies for determining long-term trends and for understanding the causes of observed inter-annual variability. Passive Microwave Radiometers are able to detect the Antarctic ice water boundary.

The same measurements can be made with Radar Scatterometers with some advantages. Passive Microwave Radiometer observations are contaminated by nearby land and ice whereas Scatterometers do not have this deficiency. In addition, Passive Radiometers have been known to show ice where it is known to be non-existent, i.e., the west coast of Spain and France and the North Sea in summer.

Using marine analyst de-aliased satellite scatterometer data it is possible to identify Arctic ice/water boundary with sufficient accuracy to be useful for climate studies.

THE LIGHT ENVIRONMENT OF GREENHOUSE-GROWN CONIFER SEEDLINGS

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The increased availability of suitable instruments and appreciation of the role of quality of light in ecological processes has led to a proliferation of studies reporting the spectral composition of solar radiation above and below forest canopies. This paper extends this type of study from natural canopies to Douglas-fir seedling canopies in greenhouses.
Measurements were taken and integrated over specific segments of the 300 - 1100 nm wavelength interval; outside, and above and below the seedling canopy in two greenhouses: one of polyethylene, the other of fibreglass. Observations were taken near noon at approximately one month intervals from June 18 through September 24.
The polyethylene consistently transmitted more solar radiation than did the fibreglass (mean transmittance 13 percent greater). The difference was

greatest at the shorter wavelengths (ultraviolet and blue-violet) where both materials had their greatest depletion effect. The polyethylene also transmitted more photosynthetically active radiation (PAR).
Canopy transmittance was greatest in the near infrared and least in the red and blue-violet photosynthesis bands. Transmittance within the PAR interval reached a peak in the green. This pattern is similar to that reported for mature broadleaf and spruce canopies but not for pine canopies. Closely spaced seedling canopies are very dense and the transmittance of PAR was about 0.35 percent in September.
The differences in spectral composition below the polyethylene and fibreglass are sufficient to have an effect on the shape of the seedlings. The light intensity below the closed canopy is too low to affect the sporulation of Botrytis cinerea, a fungus that is a problem on container grown seedlings.

TEMPERATURE ANALYSES FROM NEAR REAL-TIME OCEANOGRAPHIC OBSERVATIONS

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With the availability of oceanographic surface and subsurface observations in near real-time from participants in the Integrated Global Ocean Station System (IGOSS), the Marine Environmental Data Services Branch (MEDS) can now generate horizontally or vertically contoured maps of these data. MEDS can also generate anomalies based on either historical digital monthly atlases as available from the National Oceanic and Atmospheric Administration (NOAA) or its own historical national archives of physical oceanographic data. This paper describes the data sources, analysis and display techniques, and some limitations when attempting to generate near real-time data products from these datasets.

REAL-TIME AND NEAR REAL-TIME DATA AND DATA PRODUCTS AVAILABLE FROM MEDS

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With the advent of improved communications systems and on-site processing hardware in recent years, the Marine Environmental Data Services Branch (MEDS) now makes available real-time and near real-time "in-situ" oceanographic, wave, and tides and water level data to its user community. Oceanographic data accessed from the Integrated Global Ocean Station System (IGOSS), for data collected within one month of observation, is quality controlled, archived and accessible to users on a weekly basis. Surface gravity wave spectra collected by MEDS are accessible on a daily basis through the same network. Tides and water level data are also accessible on a daily basis through the Tidal Acquisition and Telemetry System. This paper describes the data sources, communications and processing systems, quality control criteria, and some data products presently available of these data from MEDS.

ENVIRONMENT CANADA NATIONAL CLIMATE DATE ARCHIVE

Mike Webb, Canadian Climate Centre, 4905 Dufferin Street, Downsview, Ontario, M3H 5T4

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".

COLD OCEAN PRODUCTIVITY EXPERIMENT (COPE 86); PARTICLE FLUX, NUTRIENT, AND SESTON CHARACTERISTICS

R.J. THOMPSON, D. DEIBEL, L.R. POMEROY, D.J. DOUGLAS AND P.C. GRIFFITH (Memorial Univ. of Newfoundland, Marine Sciences Research Laboratory, St. John's, Newfoundland, Canada A1C 5S7)

In preliminary work Pomeroy and Deibel (1986) suggested that marine psychrophilic bacteria are inactive at temperatures below 4°C. However, most of the primary production on the Newfoundland continental shelf occurs at <2°C and supports a substantial groundfishery. This implies that much of the phytoplankton production may reach the benthos. During the spring and summer of 1986, we measured particle flux by placing sediment traps at 40, 80, 150, and 240m at a station (270m) in Conception Bay, Nfld. We determined temperature, nutrient concentrations, and seston characteristics including phytoplankton pigments, particulate organic carbon, particulate organic nitrogen, and floristic analysis.

In early April nutrients were reduced in the surface layer. Chlorophyll a levels were 4-8 µg/l, significantly greater than winter values (<0.3 µg/l). Temperatures were low (<-0.7°C) throughout the water column. By the end of April nutrient depletion was observed to a depth of 60m. Particle flux peaked at 1.3 g/m^2 per day at 240m in early June. During April and May, the material reaching the benthos was rich in chlorophyll a (ca. 70% of total pigments) and was composed largely of intact diatoms (Skeletonema costatum and Chaetoceros spp.). There were almost no fecal pellets, and the C/N ratio was 7-9. It appeared that most of the spring bloom reached the benthos at 270m in just a few weeks as a pulse of high-quality food which had not been utilized previously by grazers.

COPE-86: RESPONSE OF HETEROTROPHIC BACTERIA AT LOW TEMPERATURE TO VARIED SUBSTRATE CONCENTRATIONS

LAWRENCE R. POMEROY, DON DEIBEL, R.J. THOMPSON, DONALD J. DOUGLAS AND PETER GRIFFITH (Institute of Ecology, University of Georgia, Athens, Georgia 30602)

Previous study of the spring phytoplankton bloom in Conception Bay, Newfoundland, showed exceedingly low rates of growth and metabolism of heterotrophic bacteria. In 1986, we experimented with the effects of changes in temperature and substrate concentration on natural communities of heterotrophic bacteria. Glucose and peptone were added to aliquots of water collected at several depths to make concentrations of 5, 50 and 500 mg/l each. These were incubated at -1, +2, and +6°C (ambient temp. = -1 to +2°C) in the dark. Changes in numbers and biomass of bacteria and in dissolved oxygen were measured over 2-3 weeks. After an initial lag, populations

grew, and at elevated temperatures and/or substrates large rods, 1 x 3 μm in size dominated. Effects of temperature and substrate were interactive. Increased substrate led to higher rates of respiration and growth, even at -1°C, but rates were higher still when both temperature and substrates were increased. While bottle experiments do not duplicate nature, they offer clues to natural processes, in this case the limits on utilization of the spring bloom by bacteria. Our results suggest that ambient dissolved substrate concentration is not consistently high enough to overcome inhibitory effects of low temperature.

COPE-86: SHORT-TERM TEMPERATURE RESPONSE OF HETEROTROPHIC AND PHOTOSYNTHETIC COLD OCEAN MICROPLANKTON

DONALD J. DOUGLAS, DON DEIBEL, R.J. THOMPSON, P.C. GRIFFITH AND LAWRENCE R. POMEROY (Institute of Ecology, University of Georgia, Athens, Georgia 30602)

During the early part of the spring diatom bloom in Conception Bay, Newfoundland, there were marked increases in bacterial production in surface waters when temperatures were <-1°C. Several weeks later, as the bloom descended through the water column, bacterial activity at depth increased from the low levels observed during the early bloom while surface values decreased. Bacterial production accounted for only a small proportion of primary production during most of the bloom period (<5%).

Short-term (< 4 h) temperature response of microplankton samples was investigated using a temperature gradient incubator. The microplankton were collected at ambient temperatures of -1 to 5°C. Dark incorporation rates of thymidine and amino acids and light incorporation rates of $^{14}CO_3$ were approximately linear between -1.5 and 10°C. Thus, our data suggest that a critical balance between temperature and substrate availability regulates bacterial growth during the spring bloom in cold ocean waters.

OBSERVATIONS OF AND FORECASTS FOR ROAD, BRIDGE, AND RUNWAY SURFACES

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An estimate of three (3) BILLION dollars spent annually on ice and snow control in North America is probably conservative and does not include damage and corrosion by salt and chemicals to automobiles, roads, bridges, runways, and other surfaces. In order to reduce this cost, one must be informed of when to and when not to apply sand, salt or other chemicals, and when to schedule maintenance crews in order to lessen the overtime and premium-hour pay. Can this be done without sacrificing the safety standards already established? The answer is yes; it can and has been done.

Forecasts for the pavement of roadways and motorways have been provided for the past few years in England with documented cost saving results. Not until the winter of 1986-87 was this type of service available to the United States and Canada. Now, surface sensor systems that monitor and record the pavement temperature and the presence of water, frost, ice, and chemicals are installed and operational on over seventy airport runways and many highways, streets, and bridges in the United States, Canada, and Europe.

The sensors observe the pavement temperature, the chemical factor, whether the pavement is wet or dry and when there is ice, snow or frost present on

the pavement. Forecasters collect the pavement observations and produce a pavement forecast from a centralized forecast facility. The forecast includes when the precipitation will occur and what type of precipitation it will be, when the pavement will freeze and how long it will remain frozen, and when pavement temperatures will change and the degree of change. The forecast product is designed to make it easier for the decision maker to plan and prepare for a winter weather situation.

This paper describes the surface sensor system which provides realtime surface condition information to maintenance personnel and to operational meteorologists, the computer software that interfaces with the sensor systems, the personal computer graphic displays tailored for roadway and runway pavement interpretation and monitoring, the computer forecasting model that forecasts and projects pavement temperature and moisture, and the centralized and specialized forecasting center.

DEEPSEA WAVE HINDCASTS IN THE NORTH PACIFIC

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To obtain boundary conditions for a shallow water coastal wave model of the Queen Charlottes, we adapted the North Sea parametric hybrid model (NORSWAM) to the north Pacific (40-60N, 120 - 180W). Our experiences in doing so and selected results from three hindcasts are presented. Two hindcasts modelled the generation and propagation of swell, the third treated intense local generation. The NORSWAM model is a second generation wave model that parametrically represents windsea in terms of a JONSWAP spectrum; three free parameters were allowed: the peak frequency, the Phillips constant, and the peak enhancement factor. Swell is treated separately; after it is transferred from windsea it propagates as a series of wave packets along great circle paths. It continues to interact with the wind and may be reabsorbed into windsea if the wind stiffens.

The hindcasts were generally good, especially since the model was not calibrated for the North Pacific. The four major conclusions of this study are: (1) better swell propagation schemes must be devised for hybrid models if they are to be applied to very large regions in which the earth's curvature is significant; (2) the modelled area was not large enough to capture the initial stages of swell generating storms; (3) the model consistently under predicts the very low frequency part of the wave spectrum (periods exceeding 15 seconds) . In addition, two major flaws were found in the model formulation and should be corrected. An important term in the energy balance equation due to a turning wind was missed, and advection in the Phillips parameter balance equation is underestimated by about 40%.

A CASE STUDY OF SOME AGEOSTROPHIC WIND EFFECTS ASSOCIATED WITH A MODERATELY DEEPENING AND FAST MOVING LOW

K. H. Kirkwood, Newfoundland Weather Centre, P. O. Box 370, Gander, NF, A1V 1W7

This case study examines some ageostrophic wind effects associated with a deepening low pressure system that moved northwards across Western Newfoundland on January 24-25, 1987. In the wake of this system a brief period of storm-

force winds were experienced along the southwestern coastal areas of the Island of Newfoundland.

The storm-force winds can be viewed as a result of isallobaric and instability effects associated with the system and the airmass behind it. The results of these two ageostrophic effects contributed significant additions to the measured geostrophic flow so as to produce storm-force winds.

As the system approached Newfoundland little evidence of possible isallobaric components to the wind were present until shortly before the event occurred. The case illustrates the relatively short duration of isallobaric effects as well as the effects of instability. The study also demonstrates the utility of short-range forecast techniques in producing real values in an operational environment.

DOPPLER RADAR OBSERVATIONS OF A MESOSCALE CONVECTIVE COMPLEX IN SOUTHERN ONTARIO

P.I. Joe* and C.L. Crozier, *ARPP, Atmospheric Environment Service, 4905 Dufferin Street, Toronto, Ontario, M3H 5T4

On the 17 July 1986 a mesoscale convective complex (MCC) passed within the Doppler range of the King City Doppler (WKR) radar. The complex consisted of a large amorphous radar echo approximately 140 km x 240 km in size moving from the northwest at 24 m/s. Primary features were a leading narrow convective rain band, 20 km in width, with a trailing region of stratiform rain. The 20 dBZ echo contours of this band reached a height of 10 km and maximum reflectivities reached 40-50 dBZ. Vertical radar cross-sections of reflectivity perpendicular to the rain band show that there was a low reflectivity transition region 30 km in width immediately behind the convective band. A bright band at a height of 3 km and of reflectivity 40-50 dBZ existed in the stratiform precipitation region.

Distrometer data, collected at WKR which was at the northeast end of the convective rainband confirmed the radar measurements and showed peak rainfall rates of about 20 mm/hr in the rainband and about 10 mm/hr in the stratiform rain. The data clearly shows the break in the intensity of the rain at the ground in the transition zone.

The Doppler radar pattern shows the presence of a mesoscale rear inflow jet of about 24 m/s oriented perpendicular to the convective rainband. It appears that the jet narrows in depth and decreases in magnitude as it approaches from the rear of the MCC. Also, the jet may be elongated and tilted to the northeast with height or there may be two rear inflow jets. Further analysis of the Doppler data may provide additional insight.

SESSION 7A ATMOSPHERE/OCEAN COUPLING I Thurs. 1330-1510

Chairperson R. Greatbatch, Memorial University Room M1045

MODELLING THE RESPONSE OF THE OCEAN TO ATMOSPHERIC CARBON DIOXIDE INCREASE

Kirk Bryan, Geophysical Fluid Dynamics Laboratory/NOAA, Princeton, New Jersey 08542, U.S.A.

The ocean slows down climate change by its capacity to store or give up large amounts of heat. Some insight on this process can be gained from data on transient tracers, such as tritium and freon. Heat is different from a transient tracer, however, because it effects the buoyancy field of the ocean. Coupled models of the ocean and atmosphere provide a means to simulate the ocean's role in climate change due to a build-up of green house gases. A hierarchy of models with increasing detail in the geometry of ocean basins provides insight on the effect of land-sea distribution on the thermohaline circulation and its response to climate warming.

The simulated equilibrium thermohaline circulation in a high CO_2 climate has nearly the same intensity as that of the normal CO_2 climate. In the transient case, strong warming suppresses convection and weakens the thermohaline circulation. The result is an increase in thickness of the thermocline. The sequestering of heat in the ocean is enhanced by this process, compared to what would be predicted on the basis of the observed uptake of transient tracers. The result is a feedback which increases the thermal inertia of the ocean in response to CO_2-induced climate change.

AN EXTENDED FORECAST EXPERIMENT FOR JANUARY 1983

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Although predictability theory suggests the well known limit of about two weeks for deterministic forecast skill, these considerations are based on general features of the physical system. Enhanced predictability may perhaps be exhibited under some conditions such as the strong boundary forcing that occurs during an El Niño event.

The ENSO event of the northern winter of 1982/83 was one of the strongest El Niños on record. Several global objective analysis systems were operating during the period to supply data with which to initialize and to verify models. We use the Canadian Climate Centre general circulation model to perform an ensemble forecast experiment for January 1983.

THE EFFECT OF NORTH PACIFIC SEA SURFACE TEMPERATURE ANOMALIES ON THE JANUARY CLIMATE OF A GENERAL CIRCULATION MODEL

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Two perpetual January integrations of a general circulation model of the National Center for Atmospheric Research have been performed, each featuring a different sea surface temperature (SST) anomaly in the North Pacific. The observed SST anomaly for the 1976-77 winter was chosen as the basic anomaly, and 1200-day runs were carried out in which this anomaly was multiplied by +1 and +2. A third run was performed which combined the basic midlatitude SST anomaly from 1976-77 with a tropical Pacific SST anomaly representative of the mature phase of a warm El Niño/Southern Oscillation (ENSO) episode. An ensemble of eight, independent 90-day averaged realizations was extracted from each simulation. Maps of ensemble-mean differences from the model climatology are shown, together with estimates of the statistical significance of some of the features which appear on these maps.

The model response to the basic SST anomaly and to twice the basic SST anomaly is a midlatitude teleconnection pattern, the Pacific/North American (PNA) pattern, which has been found in previous experiments which used tropical Pacific SST anomalies. The amplitude of the model response increases at a slower than linear rate as the magnitude of the SST anomaly is increased.

The model response to the basic midlatitude SST anomaly is compared with the model response to tropical Pacific SST anomalies. When the basic midlatitude anomaly is combined with a tropical Pacific SST anomaly, such as commonly occurs during the mature phase of warm ENSO episodes, the model response to the combined SST anomalies is approximately equal to the sum of the model responses produced by the SST anomalies acting separately.

A SIMPLE MOIST MODEL RELEVANT TO THE ORIGIN OF INTRASEASONAL DISTURBANCES IN THE TROPICS

Toshio Yamagata (RIAM, Kyushu Univ., Kasuga 816, Japan)

A simple moist model useful to understand some basic properties relevant to the origin of the intraseasonal disturbances in the tropics is constructed by use of the linear shallow-water equations on a sphere. The dynamical equations are supplemented by the moisture equation as proposed by Gill(1982). The mutual interaction of equatorial dynamics and convective activity is demonstrated by releasing localized, initial anomalies for either temperature or velocity. In particular, it is found that there are two intrisic ways of large-scale moist adjustment processes in the tropics. Firstly, it is shown that the active heating region associated with the convergence of low-level winds propagates eastward spontaneously with expanding the zonal scale of the velocity field. The phase speed of this organized pattern is much smaller than that of the corresponding free Kelvin wave because the buoyancy effects are much reduced by the convergence-dependent heating. These results are consistent with the recent observational studies of the 30-50 day oscillation in the tropics. Secondly, the present model also demonstrates that the burst of westerly winds may excite a westward propagating cross-equatorial cyclone pair more easily than the burst of easterly winds. This vortex pair is mainly composed of the

gravest Rossby waves with moist processes and is quite similar to the long-lived cyclone pair often observed over the warm SST region in the western equatorial Pacific. It is suggested that the cyclone pair may evolve into the large-scale air-sea coupled mode now given the name ENSO.

THE ANOMALIES OF THE NORTH PACIFIC SEA SURFACE TEMPERATURE AND THEIR ROLE IN MID-LATITUDE AIR-SEA INTERACTION

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Sea surface temperature anomalies (SSTAs) have been studied by Namias and others to develop prediction systems for seasonal climate anomalies. In this study, we examine the variability of North Pacific SSTAs and their relationship with anomalies of total heat transfer from the ocean to the atmosphere. The relationship varies with season and location. The SSTAs have the least influence on the heat transfer in the western Pacific. Then the relationships between the SSTAs, the total heat transfer and the sea level pressure anomalies are studied. From these studies, the role of mid-latitude ocean-atmnosphere coupling can be better explained.

SESSION 7B OPERATIONAL METEOROLOGY Thurs. 1330-1515

Chairperson W. S. Appleby, AES Halifax Room M1032

AN OPERATIONAL CHECKLIST FOR FORECASTING EXPLOSIVE CYCLOGENESIS OVER THE EASTERN PACIFIC

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Rapidly deepening lows over the eastern Pacific Ocean present a considerable hazard to the marine community and a difficult forecast problem for the Marine Meteorologists. At the Pacific Weather Centre a detailed checklist has been developed which evaluates the factors which are significant for cyclogenesis and produces a score which can be related to the deepening rate.

The checklist begins by "typing" the situation according to patterns in the satellite imagery, and follows with 42 questions about those parameters which are related to development (or weakening). Among the predictors are trough-ridge amplitude, tilt of the trough line, upstream wind speeds, thickness change, diffluence aloft, low level stability, temperature advection, latent heat release and various satellite signatures. Parameters are both numerical and categorical, from operational computer models, satellite imagery and sounding data.

Subjectively determined values are assigned to each parameter, weighted according to the initial synoptic type and a final score is calculated from their sum. Initial results suggest some success in detecting those events which deepen most rapidly. The information collected will be used to refine the score assigned to each parameter, with the aim of improving the resolution of the technique in future years.

THE IMPORTANCE OF THE LOWER LEVEL WIND PROFILE IN TORNADO PREDICTION

David Patrick and A.J. Keck, Prairie Weather Centre, 9th Floor, 266 Graham Ave., Winnipeg, Manitoba, R3C 3V4

A Multiple Discriminant Analysis technique is used to select the most significant predictors to distinguish between tornadic thunderstorms and non-tornadic severe thunderstorms on the Canadian Prairies. The data sample chosen was from all severe weather from June through to mid-September of 1986 over Saskatchewan, Manitoba, and Northwestern Ontario. The severe weather was grouped into 20 tornado cases and 23 non-tornado cases. Some cases were filtered out of the dataset. The resulting dataset included 16 tornado cases and 22 non-tornado cases. Thirteen predictors were derived for each case by interpolating surface and upper air meteorological data to the severe weather location.

The most significant predictors were chosen by using a forward stepwise selection process and testing the significance of the predictors with a Mahalanobis D-square test. The first two predictors alone showed significant discrimination between tornado and non-tornado groups of well over 99.9%. Eighty-two percent of the cases were assigned to the correct group. If the first five predictors were used, 87% of the cases were correctly assigned.

The results show that the shape of the windshear profile in the lower four km, not the magnitude of the profile, is of major significance in the discrimination between tornado and non-tornado severe weather. A large angle between the surface wind direction and the wind direction at four km above ground is favourable for tornadoes. A large veering or backing in the windshear profile from the surface up to the cloud base, and beyond the cloud base up to four km above ground is favourable for tornadoes. The Lifted Index is of lesser importance, especially when veering or backing windshear tornadoes are considered together as one group.

FREEZING RAIN EVENT AT ST. JOHN'S, NEWFOUNDLAND ON MARCH 2ND, 1986

A.G. Earle and D.E. Steeves

On March 2nd, 1986 St. John's Airport received 16 hours of continuous freezing rain beginning mid-morning and lasting until midnight. Total amount was near 40 millimeters. The precipitation was associated with a moderately deepening low and associated frontal system which moved from south of Nova Scotia. The low center passed over St. John's shortly after midnight on the 2nd. This event occurred during an Intensive Observation Period (IOP) of the Canadian Atlantic Storm Project (CASP) field study and thus an increased data base was available.

An analysis and discussion of surface and upper air characteristics is presented, including reports from climatological stations, weather radar facsimile output, satellite imagery and rawinsonde reports from St. John's at 3 and 6 hour intervals. An empirical technique using thickness values for predicting precipitation type is evaluated utilizing in particular the extra rawinsonde reports.

DOPPLER RADAR DETECTION OF SEVERE WEATHER IN SOUTHERN ONTARIO

P.O. Joe* and C.L. Crozier, ARPP, Atmospheric Environment Service, 4905 Dufferin Street, Toronto, Ontario, M3H 5T4

Several severe weather events have passed within Doppler range of the King City radar (WKR). These include the tornadic events of 5 September 1985 near Lindsay, Ontario and 10 June 1986 near Minden, Ontario. The latter tornado was outside of Doppler range but other associated significant severe weather characteristics were observed on that day.

The detection of these events and others by Doppler radar will be examined. Detection techniques include velocity-azimuth displays (VAD), multi-moment displays, azimuthal shear track map and time evolution of azimuthal shear graphics. The recognition technique is based on the detection and identification of the mesocyclone since the tornado vortex is usually too small to be observed by Doppler radar.

Results show that the mesocyclone indeed can be detectable on Doppler radar well in advance (at least 20 minutes) of the time of the damage by the tornado. However, not all mesocyclones produce tornadoes (for example, the Oakville storm on the 7 July 1986). Azimuthal shear values often exceed 10 ms^{-1} km^{-1} without any confirming observation of tornadoes. Violent tornadoes have been found to occur with shear values greater than this value by the National Severe Storms Laboratory (NSSL). These results show that severe weather in southern Ontario is quite different from that found elsewhere say in the U.S. midwest severe storm area.

THE CO-EXISTENCE OF SPONGY AND GLAZE ICE ON HEAT CONDUCTING OBJECTS

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A one-dimensional model of the accretion and internal freezing of spongy ice in a conducting object has been developed. Non-stationary heat balance equations have been written for each of the three layers - the spongy layer, the glaze (completely frozen) layer, and the conducting substrate. By solving this set of differential equations numerically, the rate of advance of the growth front and of the freezing front can be determined. The influence of both the substrate material and the environmental conditions has been evaluated. The conditions under which spongy and glaze ice can co-exist have also been estimated.

A RATIONAL APPROACH TO EVAPORATION PAN OPERATION IN CANADA AND OTHER COLD CLIMATES

R.F. Hopkinson, Scientific Services Division, Atmospheric Environment Service, P.O. Box 4800, Regina, Saskatchewan S4P 3Y4

Evaporation pans are used throughout the world as the only practical direct measurement of evaporation from a water surface. The operation of evaporation pans in Canada is complicated by ice formation on the pan's water surface. Thus the Atmospheric Environment Service operates its evaporation pan network during the frost-free season, restricting the record to five or six months per year in most of southern Canada. Testing at the Regina airport over the past few seasons has demonstrated that the evaporation pan season can be extended by two months and hence more closely approximate the open water season of most shallow lakes or small reservoirs. The paper will describe how this was accomplished and how it could be applied nationally.

PREDICTION OF SURFACE WETNESS DURATION FROM OPERATIONAL METEOROLOGICAL DATA.

T.J. Gillespie, Agrometeorology, Univ. of Guelph, Ontario, Canada. N1G 2W1.

Surface wetness duration (SWD) is the length of time that moisture is retained on aerial plant surfaces. SWD is a controlling factor in the development of several plant diseases of economic importance. Prediction of SWD is therefore required in some schemes designed to schedule pesticide sprays. When spray timing is guided by weather data, good disease control can often be achieved with up to 50% reductions in chemical usage. Specialized instruments are available to measure SWD, but they are not generally used by growers.

Methods will be described which allow usefully accurate estimates or outlooks of SWD to be made from standard weather observations or aviation weather forecasts. The simplest methods, which involve only the dew point depression, are highly empirical and are specific to crop and location. More complex methods are more universally applicable, and utilize observations or forecasts of vapour pressure deficit, windspeed, and radiation (from sky cover data). Schemes will be described for estimating SWD caused by both dew and rain.

Such schemes could be readily implimented because they utilize observations or short-term forecast parameters that are currently available for other purposes. Past meteorological data could be more effectively used to understand and prevent the recurrence of historical plant disease outbreaks, and highly relevant guidance on SWD could be provided to operational crop protection programs through existing agricultural weather bulletins.

SESSION 7C BIOLOGICAL/PHYSICAL INTERACTIONS IN THE OCEAN
Thurs. 1330-1515

Chairperson G. Evans, Northwest Atlantic Fisheries Centre Rm M2025

TIME SCALES, SPACE SCALES AND FISH SCALES: VISCOUS VORTICES AND VOLUTED VIVARIA
Bowman, M. J., and R. K. Cowen, Marine Sciences Research Center, State University of New York

For certain species of fish and crustacea, coastal eddies which are relatively fixed in location and persistence can play a crucial role in the survival of pelagic eggs and/or larvae and the recruitment success to suitable habitats of a given year class. Specifically two situations are discussed. (i) Trapped eddies in island wakes. We examine how eddies may entrain and transport passive larvae near tropical islands and how these eddies may be crucial to the return of the larvae to those islands where no upstream source of larvae may exist. A number of dynamical scenarios of trapped and shedding wakes are investigated as to their possible roles in the transport of larval fish to coastal habitats. (ii) Non-linear residual eddies in wide coastal sea straits. We report on recent results into the dynamics of the "Rose Spit eddy" in eastern Dixon Entrance, B. C., and suggest that its properties and estimated rotation period (~100 days) are important to the recruitment success of Cancer magister (Dungeness crab) in the region.

ASSOCIATION OF PRIMARY PRODUCTION AND RECRUITMENT IN SUBARCTIC ECOSYSTEMS: THE APPRISE PROGRAM
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The goal of the APPRISE program is development of a predictive capability for larval recruitment which may be applicable to more extensive, less accessible fisheries areas. APPRISE is multidisciplinary, the better to achieve its objective of identifying relationships between environmental factors, primary and secondary production and the recruitment success of selected larval fish and shellfish. The research components of the participating institutions (Oceanic Institute, Hawaii; University of Alaska, Juneau; and University of Alaska, Fairbanks) stem from the hypothesis that interannual variability of recruitment potential of larval fish and shellfish is related to variability of primary production and subsequent secondary production during the spring bloom. The oceanographic component describes the sequence of planktonic variations which represent changing levels of food availability hypothesized by APPRISE to influence recruitment. Two consecutive years of fieldwork in Auke Bay, a semi-enclosed embayment in southeastern Alaska, have been analyzed. In both 1985 and 1986, the Auke Bay environment behaved as a light-limited system wherein the bloom was initiated in response to increased irradiance. Both years showed similar temporal patterns of chlorophyll biomass during the primary bloom. Photosynthetic-irradiance curves indicated the onset and duration of both primary and secondary blooms. Approximately 20% of organic material produced in the primary bloom sank out as intact cells, 6% during the secondary bloom. Both the 1985 and 1986 data show interannual variation in availability of the organic

material produced in the bloom. The interval between the biomass peak and its removal from the pelagic zone via sedimentation was 21 days in 1985 and 10 days in 1986. Higher production rates in 1985 together with similar relative sinking losses of intact cells imply that grazing by herbivores was greater in 1985. These interannual distinctions of planktonic fate reflect the ability to describe differences in food availability to higher trophic levels which may be related to interannual differences in larval recruitment potential.

VARIABILITY IN ICHTHYOPLANKTON ABUNDANCE SAMPLED DURING 24 H AND ERROR ESTIMATES ASSOCIATED WITH THEIR NON-CONSTANT DEPTH DISTRIBUTION

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As a measure of variability in fish larval abundance and mean length on the Flemish Cap bank, a single location was sampled every two hours over a 24-hour period. Larval redfish abundances ranged from 22.4 to 115.6 larvae m-2 (CV=4.7%). For replicate stations there were significant differences in larval abundance but not in mean length. A negative relationship between volume of water filtered and numbers of larvae m-2 indicated an error in estimates of standardized larval abundances. This error was attributed to a non-constant distribution of redfish larvae confined to surface waters and the presence of depth-dependent currents on Flemish Cap. Corrected estimates of larval redfish abundance (larvae m-2) were higher by a factor of 1.4 and densities (larvae m-3) by a factor of 7.2. The effect of measurement errors on abundance estimates in relation to fisheries recruitment studies will be addressed.

CAN INTERANNUAL VARIATION IN PLANKTON ABUNDANCE BE PREDICTED FROM OBSERVATIONS OF MIXED LAYER DEPTH?

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A model of the annual cycle of dissolved nutrients, two species of phytoplankton and herbivorous zooplankton was driven with a 27-year time series of observations of mixed layer depth for station 27 (near St. John's, Nfld.). Peak yearly herbivore and phytoplankton abundance showed no good correlation with any single environmental variable, although model performance is produced deterministically by the set of variables. This result casts doubt on one's ability to explain or predict variability in fishery recruitment from correlation analysis with environmental variables.

PREDICTING THE PRODUCTIVITY OF TIDALLY-DOMINATED ESTUARIES AND COASTAL WATERS

Graham R. Daborn*, David L. DeWolfe and Michael Brylinsky, *Acadia Centre for Estuarine Research, Acadia University, Wolfville, Nova Scotia, B0P 1X0

Shallow coastal waters and sites of extensive upwelling are commonly areas of high primary and secondary production because of the enhanced recirculation of essential nutrients that have descended below the euphotic zone. The energy causing vertical mixing may be periodic, as with tides and some longshore currents, or aperiodic, as in the case of wind or river outflow. Obviously,

more than one mechanism may be important at any given location. In tidally-dominated ecosystems, such as the Bay of Fundy-Gulf of Maine-Georges Bank (FMG) System, the strength of vertical mixing is proportional to the cube of current velocity which in turn increases with greater tidal range. Consequently, in the absence of contrary aperiodic influences, variations in the extent of vertical mixing should be predictable.

Tidal range in the FMG system varies by ±2.6% over the nodal cycle of 18.61 years. Significantly lower sea surface temperature in the Gulf of Maine and over Georges Bank is associated with the peak of the nodal cycle (i.e., years of maximum tidal range), indicating enhanced vertical mixing. Recently, we have examined long term fisheries statistics and found correlations between the stage of the nodal cycle and annual catches of cod, halibut, haddock and other species. Lag times in each case correspond to the time between hatching and recruitment to the fishery for each species. Cod catch data for the Grand Banks, where the tidal signal is very small, are unrelated to the nodal cycle. Although many other factors influence reported catches of fish, as much as 15-20% of the variations in fish catch can be explained by variations in tidal range over the nodal cycle for the periods of record (80+ years), leading to the conclusion that to some extent fish catches in this area are predictable. the relationship also permits prediction of the probable effects of tidal power development in the upper Bay of Fundy. The inexorable rise in sea level should also influence productivity of the FMG system because of its influence on the important water depth-current velocity (h/U) relationship.

THE EFFECTS OF ENTRAINMENT OF SHELF WATER BY WARM CORE RINGS ON NORTHWEST ATLANTIC FISH RECRUITMENT

Myers, Ransom, A., Fisheries Research Branch, Department of Fisheries and Oceans, St. John's, NF

We develop tests for the hypothesis that the entrainment of shelf water by warm core rings decreases recruitment of fish from the Northwest Atlantic from Mid-Atlantic Bight to the Grand Banks. The indices for the extent of entrainment are estimated weekly for the nine principal shelf banks in the Northwest Atlantic using satellite imagery. An entrainment index for each stock is constructed based on independent data for the distribution in space and time for the planktonic stages. Our analysis is exploratory; its purpose is to develop hypotheses that can be rigorously tested using the portion of the data we have not yet analyzed.

SESSION 7D SEA ICE AND ICEBERGS I Thurs. 1330-1510

Chairperson J. Lewis, Memorial University Room M2017

THE CALCULATION OF WATER CURRENTS APPLICABLE TO MODELS OF SEA-ICE DYNAMICS

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The water-to-ice stress is one of the important stresses in the momentum equation of sea-ice. It is usually parameterized by a quadratic law which involves the relative velocity between ice and water. Thus an accurate specification of water-stress in models of sea-ice dynamics requires a knowledge of water currents beneath the sea-ice cover.

The classical study of Reed and Campbell (RC, 1962) considered a balance of forces between the air stress, the water stress and the Coriolis force and obtained the ice-velocity solution invoking the well-known Ekman dynamics. In the present study, the classical RC solution was modified in the light of recent observational and theoretical studies on water currents. The modified RC solution was found to provide a closer agreement with water currents and ice-drift observations collected over the southeastern Beaufort Sea during the summer of 1976.

This modified solution was incorporated in the Regional Ice Model (RIM) developed in the Meteorological Services Research Branch of the Atmospheric Environment Service. The model was applied to selected case studies over the Beaufort Sea area as well as over the Gulf of St. Lawrence area. Some of the model results will be presented and discussed.

PREDICTION OF SHORT TERM-ICE EDGE DRIFT

Mona EL-Tahan*, Greg Warbanski, *Fenco Newfoundland Limited, 189 Water Street, P. O. Box 248, St. John's, Newfoundland, Canada, A1C 5J2

This paper presents a method to predict the drift of pack ice edge, based on a simple model to predict ice-floe drift. The model considers wind forces, wind generated currents, residual currents, Coriolis acceleration and sea-surface slope (pressure gradient). Model performance is evaluated in a strategic ice management context by comparision of real-time forecasts with the observed ice edges for the first time during the 1986 winter season. From most of the cases studied, the model proved to be a useful tool in forecasting pack ice edge drift in support of drilling operations on the Grand Banks. The accuracy of the forecast model is discussed and recommendations are made for future improvements to the model.

DYNAMIC MODELLING OF ICEBERG DRIFT USING CURRENT PROFILES

Stuart D. Smith and Norman R. Donaldson, Department of Fisheries and Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2

Dynamic models of iceberg drift tracks require as input the currents and winds which drive the iceberg motion, but in the past it has not been possible to obtain adequate data on currents. Three cruises of CSS Dawson have collected data for the testing and development of a dynamic iceberg drift model, with current profiles continuously monitored by a hull-mounted acoustic doppler current profiler, usually within 1 to 2 km range of an iceberg. Winds were measured by a propellor anemometer on a bow mast. The iceberg tracks were logged by radar ranges and bearings, while the ship was positioned by LORAN C. Sonar profiles and photographs were analyzed to estimate the mass and the cross-sectional areas in air and in water.

The 14 tracks of 9 icebergs reported have been compiled at 10 min intervals for periods of 12 hours to 3 days. A dynamic model with quadratic air and water drag, Coriolis, and pressure gradient forces reproduces the tracks of nearby icebergs (mean range 4 km) with an average rms position error of only 5% of the distance travelled. Errors are larger for more distant icebergs for which the measured currents are less representative.

SHORT TERM PREDICTABILITY OF ICEBERG PATHS

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The necessity for iceberg avoidance and control for drill ship operations in Eastern Canadian waters poses a unique requirement for real time oceanographic forecasting. Early attempts at short term iceberg trajectory forecasting were based on a deterministic consideration of iceberg motion. These have largely failed as operational tools because they basically neglect the stochastic nature of large scale oceanographic turbulence which largely drives iceberg drift. We have taken an approach recently proposed by several authors which combines deterministic and probabilistic approaches to the problem. An aid for operational decision making was developed for the Grand Banks using these techniques. This micro-computer based tool assesses the risk of impact of a rig by an iceberg as a function of time, and as such, provides a rational basis for decision making, as opposed to the usual prediction of a single trajectory which can represent only one of the paths the iceberg could follow.

The implementation of this technique required extensive analysis and interpretation of iceberg and oceanographic data in order to characterize the statistical properties of the flow field and iceberg drift. Iceberg data from the 1984 and 1985 seasons on the Grand Banks were analysed for correlation with wind and tides. With these components removed, the spatial distribution of mean drift and flow variance were evaluated, and compared well with estimates obtained from other sources (satellite drifters, currents meters, etc.). This analysis shows that a large portion of iceberg motion (over 50% of the

variance) is uncorrelated with winds or tides, and is best considered statistically. An autocorrelation analysis of residual iceberg drift reveals that the signal is correlated over a time scale of about 25 hours. .In an operational situation one can therefore take advantage of present observations of a drifting iceberg to infer its likely drift for a period of up to 25 hours. The application of these results is not limited to the consideration of iceberg drift, but could also be used for real time drift forecasting in oil spill management and search and rescue operations. From an oceanographic point of view our results can be used to assess large scale eddy diffusivities, the flow variance and the circulation pattern on the Grand Banks.

A PROBABILISTIC ICE CLIMATOLOGY FOR CANADIAN WATERWAYS

M. Perchanok*, C. Ferregut, C. Daley, R. Brown, *Arctec Canada Limited, 311 Legget Drive, Kanata, Ontario, K2K 1Z8

The occurrence and characteristics of sea ice and icebergs in the Canadian Arctic are by nature highly variable in time and space. Because of the variability and the incompleteness of observational data, climatological conditions are difficult to characterize in terms which are useful to ship designers and regulatory agencies. In other fields, environmental properties of significance to engineering design are stated in probabilistic terms, but this has been undertaken only as a site-specific basis in the case of floating ice.

A probabilistic climatology for marine environmental variables which affect shipping risk has been developed for the Canadian Arctic. In its present form, the climatology includes the thickness, coverage, and floe size of sea ice, the frequency and size of ice ridges, the frequency and size of the icebergs and the frequency of restricted visibility. It was developed in three stages. First, consistent historical data were compiled for each variable. Second, probability distributions were developed and mapped, and third, a geographical data base of distribution parameters was constructed.

The data base provides a unified climatology of marine environmental conditions for the Canadian Arctic, stated in terms which are useful for engineering design, for risk modelling and for other purposes.

PREDICTING SEVERE ICEBERG SEASONS ON THE GRAND BANKS OF NEWFOUNDLAND

L.W. Davidson, Seaconsult Limited, 301 Victoria Hall, 187 Gower Street, St. John's, Newfoundland, A1C 1R2

The annual number of icebergs reaching the Grand Banks of Newfoundland is highly variable (ranging from 0 to 1966 to 2204 in 1985) and is without well-defined periodicity. Past attempts to forecast this annual flux have been unsuccessful. A new statistical prediction method has shown considerable skill in forecasting iceberg season severity at least three months in advance of the season peak. This technique has been particularly successful in accurately predicting the occurrence of extreme years, having an annual flux in excess of 500 icebergs at 48^{o}N.

Presentation of the basic technique illustrates the means by which potentially useful predictors are isolated from historical atmospheric temperature, pressure, geopotential height and thickness fields, by testing the time-lag correlation of dominant Empirical Orthogonal Function (EOF) coefficients against an iceberg

severity index. Physical conditions favouring severe iceberg seasons are identified and explained in terms of these dominant EOF patterns. The results of extreme year hindcasts over the interval 1951-1980 are reviewed for various forecast lead times. It is demonstrated that forecasts issued as early as November show substantial skill in predicting severe iceberg conditions in the subsequent April to June.

SESSION 8A ATMOSPHERE/OCEAN COUPLING II Thurs. 1530-1710

Chairperson K. Bryan, Princeton University Room M1045

THE STEADY STATE RESPONSE OF THE ATMOSPHERE TO MIDLATITUDE HEATING WITH VARIOUS ZONAL STRUCTURES

Andrew J. Weaver, Lawrence A. Mysak and Andrew F. Bennett
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Vancouver, B.C., V6T 1Y4

The effect of the horizontal structure of midlatitude oceanic heating on the stationary atmospheric response is examined by means of a simple continuously stratified quasi-geostrophic model, linearized about a basic state with constant zonal flow U_0 on a beta plane. Solutions are obtained for three non-periodic zonal heating structures (line source, rectangular, and segmented cosine), and these are compared with the solution for the frequently used zonally periodic heating distribution. All four heating distributions assume an $e^{-\alpha z}$ vertical structure and a cos*ly* meridional structure.

The solutions for the rectangular and segmented cosine heating structures have a response in the neighbourhood of the forcing which increases in magnitude with decreasing horizontal heating extent. In the far field, the response in all three non-periodic models is constant. Decreasing the meridional wavenumber l has the effect of increasing the magnitude of the local response.

The land and sea thermal contrast between eastern Asia and the western Pacific is also modelled, in an attempt to explain the large correlations observed between winter Kuroshio oceanic heat flux anomalies, and the winter atmospheric surface pressure and 500 & 700 mb geopotential heights, both upstream and downstream of the heating region. It is found that the inclusion of Siberian cooling creates a large positive local response. If the heating over the Kuroshio region is considered alone, then the model response is consistent with the observed correlations. When western North Pacific heating and eastern North Pacific cooling are introduced into the model, a large low pressure response is observed over the central North Pacific. This feature is in excellent agreement with the observed correlations.

THE RELATIONSHIP BETWEEN SUB-SAHARAN RAINFALL AND GLOBAL SEA SURFACE TEMPERATURES

F.H.M. Semazzi*, V. Metha and Y.C. Sud, *Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

The relationship between monthly mean sea surface temperature and rainfall

anomalies over North Africa for the last fifteen year period (1970-84) has been examined. The SST data is from Reynolds and Gemmill (1984) objective analysis for global oceans between 40S and 60N. The rainfall data consists of annual mean rainfall indices for Sahel and Soudan belts over north Africa which are taken from Nicholson and Entekhabi (1985).

Empirical Orthogonal Function analysis of the SST data was carried out for Atlantic, Indian and all ocean regions. The results show that the El Nino related SST pattern is the most dominant eigenmode in all the analyses; it is characterised by warming over central Eastern Pacific, cooling over eastern mid-latitude Pacific and warming over the entire Atlantic and Indian ocean basins. The second (Atlantic EOF) or third (Global EOF) shows a dipole (North South see-saw) pattern. The third EOF of SST for the Atlantic which corresponds to the second EOF for the global analysis has the same sign over the entire Atlantic basin.

The correlation between sub Saharan monsoon rainfall which comes mainly in the season of July-August-September and SST was examined. EOF1 shows a consistently high correlation with rainfall. EOF2 (corresponding to the Atlantic) has a dipole pattern and shows highest negative correlation in October. Its growth during the monsoon period suggests that it may be a response rather than a cause of the interannual fluctuations in the monsoon rainfall.

PACIFIC OCEAN SST AND INDIAN MONSOON RAINFALL

B. Parthasarathy, Jon K. Eischeid and Henry R. Diaz*, *CIRES, University of Colorado, Boulder, CO 80309-449, USA

The prospect of using sea surface temperature variations over the Pacific Ocean to obtain seasonal predictions of Indian monsoon rainfall has been suggested by many scientists. A detailed statistical investigation of the relationship between Indian summer monsoon (June to September) rainfall and sea surface temperature (SST) over the Pacific Ocean has been made for the recent data period 1951-86. The area considered over the Pacific Ocean is contained within latitudes 20°N to 20°S and longitudes 120°E to 60°W; this region has been divided into 55 twelve degree-square areas. The monthly SST values for each grid have been grouped into the four standard seasons (DJF, MAM, JJA, SON) in order to examine the relationships with Indian monsoon rainfall.

The correlation coefficient (CC) between All-India (India taken as one unit) monsoon rainfall and Pacific SST of DJF season (two seasons prior to monsoon, lag-2) indicates that the association is positive for almost all grid points, six of which were found to be locally significant to at least 5% level. The CCs with MAM season SST (one season earlier to monsoon, lag-1) indicate that the association is principally negative with few significant values. The CCs with the JJA (same season of monsoon, lag 0) and SON (one season after monsoon, lag +1) seasons reveal a strong negative (significant to at least the 5% level) association over several contiguous regions.

The gridded correlation charts for the four different seasons indicate the existence of three different regions over the Pacific Ocean which demonstrate a systematic relationship (good signal) with Indian monsoon rainfall as seasons advance. These regions are (i) 14°-26°; 128°-140°E, (ii) 14°-2°N; 176°E-160°W and (iii) 10°S-14°N; 148°-100°W.

The above three regions have been studied in detail and results are reported

regarding plausible physical mechanisms for the statistical relationships as well as development of a regression equation to predict Indian monsoon rainfall.

SESSION 8B LABRADOR CURRENT OCEANOGRAPHY Thurs. 1530-1715

Chairperson S. Narayanan, Memorial University Room M1032

THE BAROCLINIC CIRCULATION IN HUDSON STRAIT

Paul LeBlond and Josef Cherniawsky. Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5.

The baroclinic circulation in the mouth of Hudson Strait is modeled using general results for semi-geotrophic flow along an indented coastline. A simple T-junction model is first discussed, followed by a somewhat more faithful idealization which includes the sharp northern tip of Labrador, the southwest tip of Baffin Island and part of Ungava Bay. The results show that the mouth of Hudson Strait does not present a significant obstacle to baroclinic flow in and out of it. We thus conclude that the observed recirculation must be due to other effects.

LOW-FREQUENCY CURRENT VARIABILITY ON THE LABRADOR SHELF

I. Webster, S. Narayanan and D. Holland, Department of Physics, Memorial University of Newfoundland, St. John's, NF, A1B 3X7

One might expect that a source of variability of the current on the Grand Banks of Newfoundland is due to shelf waves propagating onto the banks from the Labrador Shelf.
To study the shelf wave climate on the Labrador Shelf, we examine data from two current meter moorings which were in place during the 1980 OLABS experiment. These moorings were located within the northern third of the shelf. The current data are compared in the frequency domain to the results of a barotropic model of the wind-driven circulation for the region. To assess the qualitative effects of having a baroclinic jet at the shelf break (the Labrador Current), the shelf wave model of S. Narayanan is also applied. The results of the comparisons between the models' results and observations are used to address the question 'How much of the energy at the northern end of the shelf is due to local generation and how much is propagated onto the shelf through or across Hudson Strait?'.
The results of the shelf wave climate study (for the northern end of the shelf) and the study of shelf wave transmission characteristics together will enable us to assess the importance of events occurring beyond the northern end of the Labrador Shelf in determining the low-frequency circulations on both the Labrador Shelf and the Grand Banks.

THE INTERACTION OF TOPOGRAPHY WITH THE BAROTROPIC AND BAROCLINIC LABRADOR CURRENT

David Greenberg, Brian Petrie, Dan Wright
Department of Fisheries & Oceans, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2

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. Using historical observations, new estimates of the transport across different sections have been made. The model results compare very favourably with the observations.

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.

RENEWAL OF DEEP WATER OVER THE LABRADOR SHELF

John R.N. Lazier, Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada B2Y 4A2

Three years of continuous measurements at 200 m, and occasional CTD sections over the Labrador Shelf, show seasonal variations in temperature and salinity that are not solely the result of vertical mixing. Many of the deep isopycnals, nearly horizontal over the shelf, rise steeply in the strong shelf break front and in winter terminate in the surface layer. Air-sea exchanges, mainly cooling, create, on these surfaces, new water which subsequently slides down in the frontal zone and moves across the shelf. Stages in these processes are illustrated with data obtained in the vicinity of Hamilton Bank between 1978 and 1986.

CURRENT METER OBSERVATIONS FROM THE NORTHERN GRAND BANKS, 1986

B. de Young and C.L. Tang
Department of Fisheries and Oceans, Atlantic Oceanography Laboratory, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2

Results from six months of current meter data from three moorings on the northern Grand Banks will be discussed. The mean flow was observed to be weak and variable. Energy was concentrated in four bands: the semi-diurnal (M_2) and diurnal (K_1) tides, inertial motions and low frequency (2-5 day) motions. The different oceanic response to two intense storms will be

described. Wind forcing of the inertial oscillations will be modeled. The influence of the Labrador Current on the low frequency motions will be discussed.

OBSERVATIONS OF AN OCEAN FRONT SOUTH OF FLEMISH PASS

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During the period from 26 April to 17 May 1986, International Ice Patrol (IIP) conducted a coordinated aerial radar and surface hydrographic survey of an ocean front in the North Atlantic Ocean south of Flemish Pass. Aerial surveys of the region (44°N - 46°N, 45°W - 48°W), made once a week for four weeks using a U. S. Coast Guard HC-130 equipped with a side-looking airborne radar (SLAR), showed the evolution of a sharply-defined front associated with a warm-core eddy forming from the North Atlantic Current (NAC). A concurrent hydrographic survey, consisting of multiple CTD/XBT transects across the front, documented the water mass characteristics on both sides and provided surface-truth for the remotely-sensed data.

The front, which was oriented in the east-west direction at approximately 45°N, formed the boundary between warm and saline NAC water (>12°C and >35.5 ppt) to the south and cold and fresher water (<2°C and <34.3 ppt) of Labrador Current (LC) origin to the north. The motion of satellite-tracked bouys, drogued at 50m and deployed on both sides of the front, showed vigorous currents parallel to the front. In the case of the buoy deployed in the LC, average speeds of 60-70 cm/s were recorded.

ON THE EFFECTS OF FRICTIONAL TORQUE ON THE DOWNSTREAM EVOLUTION OF A WEAKLY NON-LINEAR LABRADOR CURRENT

Hay, A. E., Department of Physics, Memorial University of Newfoundland

The effects of torque due to bottom friction on the downstream evolution of a buoyancy-driven shelf break jet are examined. The jet Rossby number based on mean speed and jet halfwidth is taken to be small. As a result, cross-stream shear enters the problem through the vorticity balance, not the momentum balance, at zeroth order in the Rossby number. Bottom torque produces onshelf flow at the shelf break and, because the onshelf flow is nearly geostrophic, imposes a pressure gradient parallel to the shelf at the shelf break. It is found that the onshelf transport is significant, being easily comparable to wind-driven Ekman transports. Over the shelf, bottom torque is balanced by changing planetary vorticity. These results are applied to the offshore branch of the Labrador Current and compared to observed features of the Current and the mean circulation over the adjacent shelf.

SESSION 8C METEOROLOGICAL AND OCEANOGRAPHIC INFLUENCES ON SOCKEYE *TRACKS: MOIST* Thurs. 1530-1710

Chairperson R. Hooper, Memorial University M2025

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

Lawrence A. Mysak, Climate Research Group, Department of Meteorology, McGill University, 805 Sherbrooke St. W., Montreal, Quebec H3A 2K6.

An 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 McGill, UBC 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 summers 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 Nino-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 summers of 1985 and 1986 from the "inside passage" of British Columbia (the water between Vancouver Island and the mainland), (4) fish tank experiments on the response of sockeye to different water temperatures and salinities, (5) 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.

ON THE PHYSICAL OCEANOGRAPHY OF BRITISH COLUMBIA'S " INSIDE PASSAGE "

B.A. terHart and Thomson, K.A. Department of Oceanography, 6270 University Boulevard, Vancouver, B.C., Canada, V6T 1W5.

Data collected from six conductivety-temperature-depth surveys conducted during 1985 and 1986 in support of project MOIST- Meteorological and Oceanographic Influences on Sockeye Tracks- are used to describe the salient oceanographic features of the waters lying between Vancouver Island and the British Columbia mainland coast. Using these data, four oceanographic regimes are clearly defined on the basis of salinity struc-

ture. Temperature-salinity diagrams are used to discuss water types and mixing ratios in these regimes. Rigorous tidal mixing over constricted sills produces hybrid tidally mixed fronts throughout the "inside passage" which serve to separate the oceanographic regimes. The tidal evolution of the fronts located near Weynton Passage and Cape Mudge are described by means of twenty four stations and horizontal temperature/salinity mapping. Geostrophic surface velocities, determined by applying a very simple two-layer model to thirteen cross-channel sections, show a northwestward surface flow from the Strait of Georgia to Queen Charlotte Sound. A description is given of the annual and seasonal changes in the general hydrography.

OCEANOGRAPHIC INFLUENCES ON SOCKEYE SALMON MIGRATIONS: TELEMETRY RESULTS
Thomas Quinn and B. terHart. School of Fisheries, University of Washington, Seattle, WA 98195, U.S.A.

The factors guiding salmon from their oceanic feeding grounds to the rivers where they spawn are poorly understood. Oceanographic features, particularly temperature, have been correlated with the interannual variations in timing and route of migration for some populations. To better understand the biological basis of these correlations, we used ultrasonic telemetry to study the vertical and horizontal movements of sockeye salmon in relation to ambient oceanographic conditions. The sockeye salmon used in this study were migrating between the mainland of British Columbia and Vancouver Island and were destined for the Fraser River. Depth-sensing transmitters in the stomachs of the salmon revealed their horizontal and vertical movements, and CTD casts and drogues deployed along the tracks of the fish permitted us to characterize the environment through which they were migrating. The average depth of travel of sockeye salmon was closer to the surface in cool, salty, relatively well-mixed water than in regions with warmer, less salty surface water. However, average depth of travel also varied between years in a region where oceanographic conditions were similar between the years. The salmon swam about 2.5 km/h and generally swam in a southeasterly direction (i.e. towards the Fraser River) or in the opposite direction. Their movements suggested compass orientation and/or responses to tidal currents. In general, it appears that temperature and salinity influence the depth of travel but that horizontal movement is relatively independent of these variables when the salmon are actively migrating home.

TEMPERATURE AND SALINITY INFLUENCES ON SOCKEYE SALMON COASTAL MIGRATIONS (MOIST 85 AND 86)
Keith A. Thomson and B.A. Terhart. Dobrocky Seatech Ltd., P.O. Box 6500, Sidney, B.C., V8L 4M7

The influences of temperature and salinity on the coastal migrations of adult Oncorhynchus nerka are examined using the ultrasonic fish tracking and CTD data collected by MOIST in 1985 and 1986 in the inside passage of British Columbia. Time series of three "ambient oceanographic variables" (AOVs) - depth, temperature and salinity - are obtained for each of 29 fish from the temperature and salinity profiles and the fish depths. Time series statistics will be used to relate the vertical excursions of the individual sockeye to the vertical gradients, temperature and salinity of the water column. Composite AOV statistics will be used to investigate trends in the

behaviour of: fish in the different stratification regimes of Queen Charlotte Strait, Johnstone Strait, Discovery Passage, the Strait of Georgia and the Fraser River plume; fish exhibiting directed versus meandering horizontal movement; and fish in the Horsefly River run (1985) and the Adams River - Chilco River run (1986).

NUMERICALLY MODELLING THE INTERANNUAL VARIABILITY OF THE NORTHEAST PACIFIC OCEAN.

William W. Hsieh and Warren G. Lee, Dept. of Oceanography, Univ. of British Columbia, Vancouver, B.C.

A 3-dimensional, finite-difference, primitive equation model of the N. Pacific from 42°N-60°N has been used to study the separate roles of windstress and surface heatflux forcing of the seasonal cycle. Due to the unrealistic southern boundary used to isolate the subarctic gyre, work is underway to extend this model southward to include a coarsely resolved subtropic gyre. Prescription of air temperature is also favoured over the prescription of surface heatflux. Hindcasting the temperature and circulation over a few decades is planned with this model.

SESSION 8D SEA ICE AND ICEBERGS II Thurs. 1530-1710

Chairperson G. Warbanski, Husky Bow Valley Room M2017

SEA ICE DIVERGENCE AND BANDING IN THE MARGINAL ICE ZONE: NUMERICAL EXPERIMENTS

Michael Steele (Geophysical Fluid Dynamics Program, Princeton University, Princeton, NJ 08542)

A numerical model for the study of sea ice - ocean interaction has been developed. The model is time dependent, two-dimensional (x,z,t), and includes coupled interactions between sea ice and ocean dynamics and thermodynamics. A "free drift" balance is assumed for the ice, though several experiments have been run successfully which also include internal stress terms. The ocean model is essentially a 2D version of one originally developed by Blumberg and Mellor (JGR 88 4579-92, 1983), which includes a second order turbulence closure scheme for the modeling of mixed layer dynamics. Momentum coupling between ice and ocean is accomplished through ice-ocean stress terms, while the boundary fluxes due to melting and/or freezing come from simple enthalpy and salt balances at the interface.

An experiment has been performed which simulates sea ice edge divergence and banding in the Marginal Ice Zone (MIZ). Off-ice winds force the ice into (relatively) warm water, where vigorous melting at the edge leads to a drastic alteration of the surface boundary layer structure in the ocean. This then feeds back onto the ice motion, creating an ice velocity profile which is greatest at the edge, dropping off quickly with distance into the pack. The scale of the resultant ice edge bands depends on the scale for mixed layer formation. The width and spacing of the bands agrees well with observations.

INTERMITTENT MOMENTUM TRANSPORT IN THE VISCOUS SUBLAYER AND BUFFER LAYER UNDER SMOOTH SEA ICE- RESOLUTE, N.W.T.

T.M. Chriss and E.P.W. Horne, (Mailing address (Chriss): Dept. of Earth & Environmental Sciences, Wesleyan University, Middletown, CT 06457, U.S.A.)

In laboratory studies of smooth-walled turbulent boundary layers, large contributions to the time-averaged Reynolds stress are generated by intermittent ejections of low speed fluid from the region immediately adjacent to the boundary (the viscous sublayer and buffer layer). These ejections and the associated movement of high speed fluid toward the wall have been collectively referred to as the "bursting" phenomenon. In order to evaluate the extent to which similar processes occur in the viscous sublayer and buffer layer under smooth sea ice, we have used heated thermistor current sensors to obtain time series of velocity fluctuations within a few millimeters of the ice-water interface. Analysis of selected data using the VITA burst detection algorithm (Blackwelder and Haritonidis, 1983) suggests that the average time interval between bursts under sea ice is more than an order of magnitude greater than might be expected from laboratory scaling relationships. Probability density distributions of velocity fluctuations in the wall region and simultaneous measurements of the thickness of the viscous sublayer both appear consistent with the hypothesis of a reduced burst frequency. Additional analysis is underway to determine the extent to which these unexpected results are representative of turbulent boundary layer processes under smooth sea ice.

Blackwelder, R.F. and J.H. Haritonidis, 1983, Scaling of the bursting frequency in turbulent boundary layers, J. Fluid Mech., 32, 87-103.

INVESTIGATIONS INTO THE WAVE-INDUCED MOTION OF SMALL GLACIAL ICE MASSES

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Small glacial ice masses (bergy bits and growlers), pose a unique hazard to offshore structures: the possibility of a wave-driven impact. A program has been developed jointly through the Faculty of Engineering and the Centre

for Cold Ocean Resources Engineering (C-CORE) to investigate the scope of this hazard.

Wave tank studies have shown that bergs smaller than 1/10 of a wavelength move at fluid particle orbital velocities. A probabilistic theoretical model has been formulated to update iceberg drift velocity statistics to include a wave-induced velocity component derived from predicted berg response and sea state statistics. The underlying assumptions incorporated into this model have recently been investigated in the wave tank. The accuracy of motion prediction is found to depend strongly on iceberg shape, although spectral analysis techniques give good prediction of iceberg behaviour in irregular seas provided response in regular waves and wave energy spectral distribution are both know. Presently, tests investigating the behaviour of model bergs near a semi-submersible are being analysed to determine the deviation of impact velocity statistics from berg open water velocity statistics for the same sea conditons.

A field program to acquire full scale wave-induced iceberg velocities has been run in parallel with the aforementioned theoretical and experimental studies. Self-contained instrument packages were developed for direct deployment on bergy bits and growlers. These data will be used to assess how the velocity statistics of irregularly shaped ice masses in multi-directional irregular seas compare with those of regular ice shapes in unidirectional irregular seas.

At the end of this series of studies, guidelines will be formulated, based on risk analysis techniques, for the design of floating offshore structures resistant to wave-driven glacial ice impact.

METHODS FOR THE FRACTURING OF ICEBERGS

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The engineering feasibility of several potential methods for inducing the large scale fracture of icebergs has been investigated. These methods included conventional explosives and incendiaries, thermal fracture of ice, various sorts of directed beams (radiation, fluid or particles), injected pressurized fluid (both confined and unconfined) and cutting with an electrically heated wire. All methods required large quantities of materials and/or energy. Some methods, while technically and perhaps economically feasible, were unacceptable from an environmental viewpoint.

It has been determined that the cutting of an iceberg with an electrically heated small diameter tube stands out as the most practical approach to iceberg fracturing. The tube is heated with a DC current of several hundred amperes and simultaneously moderated with a flow of fluid to prevent burnout. The electric power requirements are manageable in the marine context (a few hundreds of kilowatts) and the equipment is fairly conventional; hence not overly difficult to obtain and configure.

A field program carried out within the context of the present study has demonstrated the functionality of the hot wire cutting method. Based on the results of this program, the design for a fully operational full scale version of an iceberg cutting system has been outlined. This hot wire fracturing method is judged appropriate for serious consideration in developing iceberg management strategies for Canada's East Coast oilfields.

THE DEGRADATION AND INFILLING OF ICEBERG SCOURS

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Icebergs pose one of the major environmental threats to the safety of hydrocarbon production facilities in many areas of the Canadian offshore. Icebergs can severely damage both surface structures through direct impact and bottom facilities such as pipelines through the effects of icebergs scouring the seafloor. Thus, the frequency of iceberg scouring is an important parameter in risk analysis and design of bottom structures.

Analysis of seabed morphology has the potential to provide a historical record of variations in the frequency of iceberg scouring events. Seismic records provide information on the spatial characteristics of iceberg scours but do not indicate the age of scours or the rate of scour occurrence. Calculation of the rate of degradation of scours may assist in assessing the time scales of scour formation and degradation.

This paper presents the results of a project with two goals: (1) to identify the major mechanisms leading to degradation and infilling of iceberg scours through review of existing data including seismic records and video records from submersible dives, and (2) to develop a methodology for numerically predicting the rates of degradation and infilling. Study results may also be applicable to man-made seabed depressions including pipeline trenches and dredged navigation channels.

SESSION 9A NUMERICAL WEATHER FORECASTING Fri. 0830-1030

Chairperson A. N. Staniforth, AES Dorval Room M1045

EXTENDED PREDICTABILITY DUE TO INTERNAL DYNAMICAL MECHANISMS

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The prediction of monthly or seasonal anomalies in mean fields such as temperature or 500mb height is a difficult and elusive goal. The variation in mean fields from year to year is termed "interannual variability" and may be thought of as being comprised of the effects of unpredictable "climatic noise" (short timescale phenomena) on the means together with the effects of long timescale "potentially predictable" signals, if they exist.

The so-called potentially predictable part of the interannual variability is usually ascribed to external forcing of the system and has been studied for the atmosphere. A similar study for the results of the Canadian Climate Centre general circulation model finds potential predictability to be present despite the absence in the simulation of external forcing. The potential predictability must be due to long timescale internal dynamical mechanisms.

Despite the use of the term "potential predictability" for the excess of interannual variability beyond that due to climatic noise, the potential predictability study gives no evidence of actual predictability. A particular extended anomaly contributes in a major way to the analyzed potential predictability in the model. The GCM is used in a "perfect model" study of the extended predictability of this anomaly.

POSITION AND DEPTH OF LOWS IN THE EASTERN PACIFIC:
A COMPARISON OF THREE NUMERICAL MODELS

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From March to December 1986, the position and depth of each low appearing on the Pacific Weather Centre's 0000 UTC analysis was compared to the forecast from three numerical models: the Canadian Spectral and Finite Element models and the U.S. Nested Grid model. For each low, the central pressure and the distance and direction of the model position from the subjectively analyzed center was determined. The aim was to discover characteristic errors in each model which could be incorporated into operational use.

Mean depth and position errors were calculated for 24, 36 and 48 hour model predictions, for a number of categories of lows. Though no single model proved to be dominant, several useful operational corrections were established.

APPLICATION OF THE SEMI-LAGRANGIAN METHOD TO A SPECTRAL MODEL OF THE SHALOW WATER EQUATIONS

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Previous tests with grid point numerical weather prediction models have shown that semi-Lagrangian schemes permit the use of large time steps (roughly three to six times those permitted by the Courant-Friedrichs-Lewy (CFL) stability 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.

The objective of this study is to see if similar results can be achieved in spectral models. Interpolating and non-interpolating versions of the semi-Lagrangian scheme are applied to a spectral model of the shallow water equations expressed in momentum form. For time steps that far exceed the CFL limit, the stability and accuracy of the semi-Lagrangian versions are examined by comparing their performance with that of a conventional Eulerian spectral treatment of the shallow water equations.

APPLICATION OF A TWO-TIME-LEVEL SEMI-LAGRANGIAN METHOD TO A SPECTRAL MODEL OF THE SHALLOW-WATER EQUATIONS

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The usual semi-implicit Eulerian integration scheme is limited in time step size by the CFL stability criterion which results in time truncation error much smaller than the spatial truncation error. The semi-implicit semi-Lagrangian integration method of Robert eliminates the CFL constraints due to advection and allows for time steps 5 to 6 times larger without loss of accuracy.

An additional factor of 2 has been obtained by Staniforth and Temperton, in the context of a finite-element barotropic shallow-water model, using a two-time-level scheme rather than the aforementionned three-time-level schemes. This work describes the application of this method in a spectral model.

SENSITIVITY EXPERIMENTS TO SOUTHERN HEMISPHERIC INITIAL DATA ON NORTHERN HEMISPHERIC MEDIUM RANGE FORECASTS.

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Using a spectral shallow water model, it is shown that the forecast difference in the Northern Hemisphere between a global model and a model using only large scales initial data in the Southern Hemisphere can be very well controlled and is much smaller than for an hemispheric model. This finding is consistent with the new approach adopted in the regional models that require only large scales be given at the boundaries.

COMPARISON OF MOS AND PERFECT PROG SYSTEMS IN PRODUCING NUMERICAL WEATHER ELEMENT FORECASTS

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In view of the numerous changes being made to the operational Finite Element Model and the uncertainty of the status of the High Resolution Spectral Model-V9, a set of perfect prog equations have been developed for over two hundred stations to back up the operational MOS system. This also presents an excellent opportunity to compare the MOS and Perfect Prog systems.

Forecasts are prepared for the probability of precipitation for 6 and 12 hour periods, the probability of precipitation amounts above certain threshold values for 12 hour periods, cloud amounts and spot temperature forecasts at three hour intervals.

The development and comparison as well as the weaknesses and strengths of each of the systems will be discussed with respect to each of the elements. Comparative verifications will be shown to indicate the relative merits of each system. These results will be used to decide which system will be used operationally.

COMPARISON OF AUTOMATED WEATHER ELEMENT FORECASTS WITH FORECASTS ISSUES BY THE WEATHER CENTRE AND WITH DIRECT MODEL OUTPUT

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An evaluation is made of the automated weather element forecasts produced at CMC by comparing them with direct model output and the subjective forecasts prepared at the weather centers.

The Techniques Development Section at the Canadian Meteorological Center has developed a MOS SPOT Temperature System which produces temperature forecasts at three hour intervals out to sixty hours. The MOS Spot temperature forecasts are compared to the direct model output of surface temperatures for the same locations. The mean absolute errors of the MOS forecasts are from one quarter to one degree lower and the skill scores (Brier skill score) are from 10 to 60 percent higher.

The lowest and highest temperature forecasts are extracted from the spot temperature forecasts for the local time windows that compare to the overnight minimum and daytime maximum periods and they are compared to forecasts issued by the weather offices. The mean absolute error of the MOS forecasts is about 0.2 deg. lower than the local forecasts for the minimum and maximum for day 2 for the summer months. For the winter period the mean absolute error of the local forecasts is about 0.2 deg. lower.

The 12 hour probability of precipitation forecasts based on the MOS system are also compared to the local forecasts for the today, tonight and tomorrow periods. The local forecasts improve upon the MOS forecasts for the today period. The skill scores for the tonight period are similar. However the MOS forecasts have Brier Skill scores that are about 5 percent higher for the tomorrow period.

SESSION 9B CANADIAN ATLANTIC STORMS PROGRAM (CASP) I: OCEAN Fri. 0830-1030

Chairperson P. C. Smith, Bedford Institute of Oceanography Room M1032

OCEANIC VARIABILITY DURING THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)

Carl Anderson and Peter C. Smith, Physical and Chemical Sciences Division, Science Branch, DFO, Bedford Institute of Oceanography, Dartmouth, N.S. B2Y 4A2

During the CASP oceanographic field program (winter 1985-86), oceanic variables (current, water properties, and sea level) were observed on the Scotian Shelf by a dense array of instruments. The data are described in terms of their estimated means and autospectra. Energy concentrations are found in the meteorological, diurnal, inertial, semi-diurnal, and supratidal frequency bands. Spatially - coherent motions are described in terms of coherence/gain/phase maps of the study area, and as empirical orthogonal functions.

Preliminary results of a search for coherent events on time scales (T = 0 2-10 hrs.) time scales corresponding to mesoscale features in the meteorological forcing, are also presented.

INERTIAL OSCILLATIONS NEAR THE COAST OF NOVA SCOTIA DURING CASP

Peter C. Smith, Physical and Chemical Sciences Division, Science Branch, DFO, Bedford Institute of Oceanography, Dartmouth, N.S. B2Y 4A2

Inertial oscillations observed over the inner half of the Scotian Shelf during CASP are found to be most energetic in deep water near the

surface. Bursts of internal wave energy are highly intermittent with peak amplitudes of order 0.2 ms^{-1}. In the deeper waters, the inertial oscillations are highly coherent ($\gamma^2 \geq 0.8$) both horizontally over the scale of the array (0 100 km), and vertically over the full depth (0 100-150 m). Horizontal wavelengths are of order 200 km with cross- isobath propagation while vertical wavelengths are comparable to the local depth. At the 150 m, upward phase propagation at rates of $2\text{-}3 \times 10^{-3}$ ms^{-1} is found throughout the water column, while the timing of inertial energy bursts at different depths is used to infer downward energy propagation at $0.5\text{-}1.0 \times 10$ ms^{-1}. Inshore from the 100 m isobath, inertial energy densities and coherences fall rapidly.

Simple models for the generation, propagation and decay of inertial waves will be explored in an effort to interpret these observations.

RESPONSE OF THE SCOTIAN SHELF TO LOCAL METEOROLOGICAL FORCING - PRELIMINARY OBSERVATIONS FROM CASP

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Carl Anderson, Bedford Institute of Oceanography, P.O. Box 1006 Dartmouth, Nova Scotia B2Y 4A2 Canada

Oceanic response of the Scotian Shelf to meteorological forcing occurs on synoptic and mesoscale spatial scales. However variability between and within storm systems results in an uncertain shelf response. Observations made during the Canadian Atlantic Storms Program (CASP) provide an opportunity to determine variations in this response.

Data obtained during the CASP measurement program (December 1985-March 1986) are applied to a frequency-dependent multiple regression model to estimate the transfer functions between atmospheric forcing and several oceanographic parameters at subtidal frequencies. The model uses the two components of Sable Island wind stress along with atmospheric pressure from three sites on the Nova Scotia mainland as independent variables. Oceanographic components modelled include coastal sea level, subsurface pressure, alongshore and cross-shore current, temperature, and salinity.

The transfer functions determined by the model are used to recreate oceanographic time series based on forcing contributed by representative winter cyclones observed during CASP. These series are compared to observations to determine which parameters of a moving system influence shelf variability. Results from these comparisons will also be used to verify conditions under which quasi-steady ($\omega/f \approx 0$) and frequency-dependent analytical models are appropriate for winter conditions on the Scotian Shelf.

LAGRANGIAN DRIFTER DEPLOYMENT DURING CASP

R. Ian Dempsey*, Dr. D. J. Lawrence, *Seismic Limited, 1378 Bedford Highway, Bedford, Nova Scotia, B4A 1E2

An innovative design concept was used in the construction of a number of Lagrangian Drifters deployed during the Canadian Atlantic Storm Project (CASP). This paper reviews some of the details concerning their deployment and performance during these experiments. Future analysis work will be covered, including comparison with CASP H. F. radar measurements of ocean surface currents.

Plots of position of the ten units deployed together during CASP are included. Designed to be 'expendable', some of the concepts employed to make them low cost, robust yet easy to deploy and retrieve are reviewed. Potential uses are explored; from tracking the movement of oil spills to enhancing their data-collecting capabilities and employing them as a more elaborate scientific instrument. Data is retrieved using the ARGOS satellite system.

MODELLING THE CANADIAN ATLANTIC STORMS PROGRAM WAVE DATASET

Will Perrie*, & Bechara Toulany, *Department of Fisheries and Oceans, Bedford Institute of Oceanography, P. O. Box 1006, Dartmouth, Nova Scotia, Canada, B2Y 4A2

During the Canadian Atlantic Storms Program (15 January - 15 March, 1986) a large set of wave height and directional spectra were collected from an array of 6 Datawell Waveriders and 3 Wavecs extending 40 km to the south south-east from Martinique Beach, Nova Scotia. The accumulated time series of wave conditions at the array was nearly (~80%) complete. A greatly enhanced meteorological observation network provided mesoscale-density analyses from numerical models of selected storms for the 16 intensive observation periods which occurred.

The explicit physics of wind generated waves was modelled in the third generation WAM (Hasselmann and Hasselmann 1985 Max Planck Inst. rep.) model will be validated on this dataset. The model integrates the conservation equation for 2-D ocean wave spectra $F(f, \theta, \phi, \lambda, t)$

$$\frac{dF}{dt} = S_{IN} + S_{NL} + S_{DS}$$

where source functions represent wind input, nonlinear wave-wave interactions and dissipation respectively. S_{IN} is taken from the Bight of Abaco experiment of Snyder, Dobson, Elliott and Long (1981, JFM) S_{NL} is the discrete interaction approximation using near-neighbor interacting quartets of Hasselmann and Hasselmann (1985, JPO). S_{DS} is the white capping, wave-breaking parameterization of Komen, Hasselmann and Hasselmann (1984,JPO).

In shallow water, shoaling is represented by using the general depth dependent dispersion relation so that group velocity and phase velocity depend on depth. A bottom dissipation term is included as an additional source term following the linearized friction inferred in JONSWAP. Wind input becomes depth dependent by using a depth dependent phase velocity in the functional form given by Snyder et al. Dissipation is represented in wavenumber space with the assumption that length scale, not time scale, determines breaking, and then made depth dependent via the shallow water dispersion relation, and similarly for the high frequency tail parameterization of the spectrum and the limitation on growth per time step to avoid instabilities because of imbalance between source terms. Nonlinear wave-wave interactions are made depth dependent by scaling of Herterich and Hasselmann (1980, JFM).

AN INTERCOMPARISON STUDY OF OCEAN WAVE MODELS DURING THE CANADIAN ATLANTIC STORMS PROGRAM (CASP)

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An intercomparison study of selected ocean wave models was made over the Canadian Atlantic during the CASP field project, January - March 1986. Among the models selected for the intercomparison study were the operational parametric wave model of the Atmospheric Environment Service and two spectral wave models which were tested in an operational mode during the CASP field project. Besides these three wave models, the wave products from the operational wave charts prepared by the METOC (Meteorology and Oceanograpy) centre in Halifax were also included in the intercomparison study. All the three models were driven by winds obtainable from the operational weather prediction model at the Canadian Meteorological Centre (CMC) in Montreal. In addition, one of the spectral wave models was also driven by winds from the LFM (Limited-area Fine Mesh) model of the National Meteorological Center in Washington, U.S.A.

The wind and wave products from the three wave models as well as from the METOC charts were evaluated against the wind and wave data collected during the CASP field project. The evaluation included analyzed as well as forecast products. Selected results of this evaluation will be presented and the predictability of sea-state at various locations in the Canadian east coast offshore will be discussed.

ANALYSIS METHODS FOR THE ESTIMATION OF OCEAN SURFACE PARAMETERS FROM GROUND WAVE RADAR DATA

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Ground wave radars are finding increasing use for the remote sensing of ocean surface parameters (e.g., significant waveheight and directional waveheight spectrum). Our main interest lies in developing analysis techniques to obtain such information from the signal return of ground wave radars. As a preliminary step to the development of such techniques, a study has been conducted of an existing parameter extraction model developed by Lipa and Barrick (B.J. Lipa and D.E. Barrick, "Analysis methods for narrow-beam high-frequency radar sea echo", NOAA Tech. Rep. ERL 420 - WPL 56, Boulder, U.S.A., 1982). This analysis model is based on Barrick's expression for the radar cross-section of the ocean surface. After implementation of the Lipa and Barrick model into computer software, the study was carried out by applying the model to radar data collected under the C.A.S.P. project off the coast of Nova Scotia and comparing results with buoy estimates provided by the Bedford Institute of Oceanography. In many of the cases which were considered, close agreement was found between the model's result and the buoy estimate. However, the model is restricted in being able to extract information for long ocean waves only. This restriction limits the application of this model, especially when a significant amount of energy resides in short wavelengths.

With the benefit of this study, alternative analytical techniques are being considered which, among other things, provide the ability to extract

information over a much wider range of ocean wavelengths. A major distinction from present methods will be the incorporation of a different expression for the radar cross-section of the ocean surface. This expression has been derived using a different scattering analysis and may provide a better estimate of the relevant radar return.

SESSION 9C REMOTE SENSING Fri. 0830-1030

Chairperson J. Walsh, Memorial University Room M2025

OCEAN ACOUSTIC TOMOGRAPHY - ITS ADVANTAGES, DISADVANTAGES, AND INTEGRATION WITH OTHER REMOTE SENSING SYSTEMS

Dr. J. Lynch, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

Ocean Acoustic Tomography (OAT) is now entering its second decade since its proposal by Munk and Wunsch in 1977. Several major experiments have demonstrated its efficiency in observing eddies, currents, and fronts, with the main emphasis so far being on the mesoscale. More recently, different scales of oceanographic observation have been pursued using tomography. Spiesberger et al. have been monitoring gyre scale transmissions in the Eastern Pacific Basin, and another gyre scale experiment is planned for the Greenland Sea in 1988. Toward smaller scales, Flatte' et al. (1986) have monitored internal wave properties with tomography, DeFerrari et al. (1986) have extended tomography to strongly boundary interacting continental shelf regions, and Lynch et al. (1987) have recently shown tomography capable of observing surface wave frequency-directional spectra.

An interesting and powerful new direction for OAT is its combination with other remote sensing systems, particularly satellites. This is a particularly effective combination, since satellite measurements can nicely describe surface features and barotropic behaviour, but fail to describe baroclinic behaviour at depth, whereas tomography has trouble near the ocean surface, but is best at depth. Chiu et al. (1987) have shown how well such a system can work using a Greenland Sea mesoscale eddy as an example, and these results will be presented as a demonstration of system integration. Future directions for this and the other aspects of tomography will be discussed.

MATCHED FIELD ESTIMATION OF ENVIRONMENTAL PARAMETERS

A. Tolstoy (Code 5120, Naval Research Laboratory, Wash. DC 20375 USA)

The ability to predict the acoustic field in an underwater environment is highly dependent upon the ability to accurately describe what may be the relevant environmental parameters, e.g., rms height of sea surface roughness. The exact dependence, i.e., sensitivity, of the field to any particular parameter is difficult to predict without analysis of model results to test a range of values for the parameter. Once such sensitivity results are understood it can be difficult to experimentally measure the desired parameter with sufficient

accuracy to meet the requirements indicated by the analysis. In this paper we propose that matched field analysis can be used to easily predict field sensitivity to a given parameter for a time-harmonic source at a specified frequency and in addition can be used to refine measured estimates of that parameter to the desired level of accuracy. To judge sensitivity a family of predictions is generated by means of an appropriate acoustic model (such as normal mode or FFP) corresponding to a range of values for the parameter of interest. Then, these component fields are cross-correlated to generate ambiguity surfaces which indicate source location. When the mismatch is sufficiently strong to incorrectly locate the source we conclude that the parameter must be measured more accurately than the range considered. If experimental data is available but the parameter is not known to the desired degree of accuracy, then the data can be cross-correlated with model predictions until the source has been correctly located and signal power is maximum for a particular value of the parameter. We conclude that matched field processing can be a valuable tool in "measuring" and/or refining those oceanographic parameters which impact on acoustic propagation.

EXPLICIT POINT-TO-POINT RAYPATHS FOR VELOCITY PROFILES WITH RAMP SEGMENTS AND GRADIENT REVERSALS

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A velocity profile in the ocean can usually be well approximated by one or two or a few non-discontinuous ramp velocity segments, these having often differently signed gradients. For each such ramp velocity segment the raypaths are circular arcs, individual rays being further qualified by ray parameter value or ray departure angle at the source. When a ray is to pass through some desired ray arrival point, such specification has not been expressible through an analytical expression for the ray parameter, but rather, it has been accommodated through interpolation between p-indexed rays, or through iterative correction of ray parameter in raytracing methods.

A novel parametrization of the ramp profile and rays for specified source and arrival points leads to explicit expressions for the ray parameter and for raytime of such 'arrival point targeted rays' as follows:

coordinates/velocities (x_1,z_1,v_1); (x_2,z_2,v_2);

$$v_2 = v_1 + g(z_2-z_1)$$

velocity contrast factor $q = (v_2 - v_1)/(v_2 + v_1)$;

ray parameter

$$p = \frac{\dfrac{2(x_2-x_1)}{(v_1+v_2)(z_2-z_1)}}{\sqrt{\left[1 + \left(\dfrac{x_2-x_1}{z_2-z_1}\right)^2\right]\left[1 + \left(q\,\dfrac{x_2-x_1}{z_2-z_1}\right)^2\right]}}$$

raytime $$t = \frac{1}{g} \ln \left\{ \frac{\sqrt{1 + \left(q \frac{x_2 - x_1}{z_2 - z_1}\right)^2} + q \sqrt{1 + \left(\frac{x_2 - x_1}{z_2 - z_1}\right)^2}}{\sqrt{1 + \left(q \frac{x_2 - x_1}{z_2 - z_1}\right)^2} - q \sqrt{1 + \left(\frac{x_2 - x_1}{z_2 - z_1}\right)^2}} \right\}$$

For media with two or three ramp segments and horizontal reflecting boundaries the above and ancillary expressions can be combined with the ray geometric constraints at segment junction 'interfaces' and at the reflecting boundaries to give low order polynominal equations for the x-coordinates of ray segment transitions. The root solutions of these allow then again construction of the 'arrival point targeted rays' and direct evaluations of raytime by segments, without the need for raytracing.

COMPARISONS OF NUMERICAL MODEL RESULTS AND ACOUSTIC BACKSCATTER OBSERVATIONS OF A SUBMARINE SPRING PLUME

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The results of our latest investigations of the submarine spring in Cambridge Fiord, Baffin Island, are presented. The buoyant plume of fresh water rising from the spring was mapped using a Ross Laboratories 192 kHz acoustic sounder and a microwave positioning system. CTD profiles and acoustic backscatter data were acquired at different spatial positions relative to the plume axis. In addition, visual observations together with CTD and current measurements were made at the vent location 47 m below the surface using the submersible, PISCES IV. The initial geometry and water properties of the flow at the vent together with the ambient stratification are used as inputs to a standard numerical buoyant plume model. The numerical results, which include maximum height of rise, plume widths as a function of height and vertical velocity profiles, are compared to the measured spatial characteristics and vertical velocities obtained in part from digitally enhanced acoustic images of the plume. The maximum height of rise calculated by the model is within the range determined from the acoustic images. The experimentally determined plume widths are within approximately 20 percent of those calculated numerically. Although the vertical velocities predicted by the model are of the same order as those inferred from the acoustic images, there are discrepancies between the predicted and observed variation of velocity with height.

CONTRIBUTION OF OFF-PATCH SCATTER IN RADAR RETURN FROM THE OCEAN SURFACE

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In recent years, there has been a great deal of interest in remote sensing of ocean surface parameters (e.g., significant waveheight and directional waveheight spectrum) using ground-wave Doppler radars. To extract these information from radar data, the model presently used for the second-order

cross-section (spectrum) for a patch of ocean surface is provided by Barrick (D.E. Barrick, "Remote sensing of sea state by radars", in Remote Sensing of the Troposphere, V.E. Derr, Ed., Washington, DC: GPO, ch. 12, 1972). This model characterizes the case where both first and second scatterings occur on the patch. In this paper a study has been carried out on the contribution of the additional second-order cross-section (spectrum) term derived elsewhere (J. Walsh, S.K. Srivastava and B.J. Dawe, "Analytic model development for the study of ground-wave radars as remote sensors in an ocean environment", Tech. Rep. prepared for the Dept. of National Defence, Govt. of Canada under a D.S.S. contract #25V84-00152, 184 pp., 1986). The additional term corresponds to the case where at least one scatter occurs off the patch. In an effort to examine the effect of off-patch scatter, a software model has been developed and theoretical cross-section or Doppler spectra are produced for different radar frequencies and sea states, assuming a narrow-beam receiving antenna. The model involves solving a non-linear equation under certain constraints and finally evaluating an integral to generate the spectrum. It is found that in general off-patch contribution is very significant compared to on-patch (Barrick's result) even in those Doppler frequency regions which are presently used in extracting the surface parameters. Thus it is important to include the off-patch term in the present scattering model so that an improved estimation of the relevant ocean surface parameters may be obtained.

THE KING CITY DOPPLER RADAR

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A new C band Doppler radar has been in operation in the Toronto region since 1985. The present radar operating program consists of a continuous volume scan of the atmosphere and 2 Doppler PPI (plane position indicator) scans on a ten minute cycle. The real-time conventional radar maps produced and distributed are: constant altitude plane position indicator (CAPPI), maximum reflectivity (MAX R), echo top, severe storm map. The latter map is a synthesis of lightning data from a co-located lightning direction finding system (LLP magnetic field type) and the radar data. Primary real-time Doppler maps are PPIs of reflectivity and radial velocity. Two radial velocity maps are generated from the 2 Doppler PPI scans at separate elevation angles. All of these map displays are transmitted to the Ontario Weather Centre. Other instrumentation at the radar site includes a (Joss) distrometer and an instrumented meteorological tower.

An overview of mainly the Doppler aspects of the radar is presented: the identification of synoptic and meso-circulations, convergence zones, low level jets; and comparisons of Doppler estimated wind profiles (assuming a uniform wind field model) with rawinsonde ascents, and of aircraft and radar measured turbulent wind fields. Results show that large scale wind flow patterns can be identified very well, whereas the finer scale features, such as mesocyclones require some extra image manipulation for positive identification. Favorable comparisons between the Doppler winds which are based on assumptions of a uniform wind field and rawins are achieved with widespread precipitation and with some convective situations.

SIMULTANEOUS PHYSICAL RETRIEVAL OF TEMPERATURE AND RELATIVE HUMIDITY FROM THE TIROS-N OPERATIONAL VERTICAL SOUNDER (TOVS)

J.D. Steenbergen, B.T. Greaves and T.C. Yip
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Downsview, Ontario M3H 5T4

Operational temperature and water vapour soundings which are available from TOVS use statistical algorithms based on regression between satellite measurements and collocated radiosondes. The effects of clouds and the effect of the changing angle at which the instrument looks through the atmosphere are also accounted for statistically. Physical retrieval methods based on radiative transfer models are believed to have the potential to extract more information from the raw sounding data.

Measurements in different sounding channels are strongly correlated, and each measurement depends in a complicated way on the temperature and moisture profiles, the viewing angle, the cloud height and amount, and the surface skin temperature. Recently new physical retrieval schemes have been proposed in which these interdependencies are explicitly taken into account to obtain simultaneous estimates of all the above quantities. However, if the statistical structure of the atmosphere is not considered the solution which best fits the measurements may be meteorologically unrealistic.

We are developing a simultaneous retrieval algorithm which includes statistical information through the use of empirical orthogonal functions of temperature and relative humidity as basis functions for the retrieval profiles. The empirical orthogonal functions are computed from a sample of radiosonde data which need not be collocated with satellite data. Results from the scheme in clear and cloudy conditions are presented.

SESSION 10A CLIMATOLOGY Fri. 1050-1230

Chairperson C. Banfield, Memorial University Room M1045

ALPINE CLIMATES AND SUMMER GROUND TEMPERATURES, GASPE,QUEBEC.

Thomas W. Schmidlin
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Ground and air temperatures were examined during mid-June 1986 in the alpine and subalpine zones of Mont Jacques-Cartier. This is the highest peak in southeastern Canada with an elevation of 1268 m. Treeline is at 1100 m. Mean annual air temperature at the summit is estimated to be -4.2°C and there is substantial permafrost. Questions remain concerning the climate of the summit, the extent of permafrost, and climatic controls on

permafrost in the region. Snowcover is an important factor in the distribution of permafrost since it insulates the ground from cold in winter and from warmth in summer.

This research was completed to determine shallow ground temperatures under various vegetation and slopes during the critical period of high sun and rapid warming in the alpine region. Ground temperature measurements were made using bimetallic thermometer probes and an electronic data-logger. Mean air temperature at 1200 m was 8.7°C during the study period.

Only small differences (<1°C) in ground temperature at 40 cm depth were found among various slope aspects. This is due to the cloudy climate and gentle slopes. Ground temperature at 40 cm depth on the level summit was 4°C. Large differences in temperature were found between tundra soils and soils under krummholz (stunted trees) below treeline. Tundra soils, which are swept bare of snow by winds and therefore warm quickly in spring, ranged from 6° to 13°C at 2 cm depth over a 3-day period. Ground temperature under krummholz near the treeline ranged from 1°C to 2°C and frozen ground was common within 10 cm of the surface.

Krummholz shades the surface, reduces wind movement, and accumulates deep snow during the winter and spring. These factors cause slower thaw and cooler summer ground temperatures compared to the higher tundra and may contribute to permafrost development below treeline.

AES EXPERIMENTAL MONTHLY AND SEASONAL FORECASTS

P. Scholefield, A. Shabbar and A. Caillet

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In March 1985, the Atmospheric Environment Service of Canada began issuing experimental monthly and seasonal forecasts. The forecasts are based mainly on regression statistics developed on nearly 40 years of 50 kPa geopotential height (gph) data, supplemented by analog techniques and numerical weather prediction guidance to day 10 from several national weather centres.

The basic forecast product is a subjective prognostic 50 kPa gph hemispheric anomaly field from which temperature and precipitation forecasts are derived for Canada. Regression specification equations are used to obtain the surface temperature patterns. The forecasts are expressed in map form in two classes, above and below normal for temperatures and above and below median for precipitation. The forecaster's confidence of the occurrence of these two classes is expressed in terms of probabilities.

Verification on nearly two years of data indicates some skill over persistence in the temperature forecasts but no skill in the precipitation forecasts.

A WINTER CYCLONE CLIMATOLOGY OF THE CCC GENERAL CIRCULATION MODEL

Steven J. Lambert
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M3H 5T4

The cyclone event climatology is presented for a five-year simulation by the Canadian Climate Centre General Circulation Model. Winter results are given for the extra-tropical regions of both the Northern and the Southern Hemispheres. The model results are compared to an event climatology based on five years of observed data.

THE STRUCTURE AND DISTRIBUTION OF PERSISTENT CIRCULATION ANOMALIES IN A GENERAL CIRCULATION MODEL

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McGill University
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H3A 2K6

The structure and distribution of persistent circulation anomalies is studied. The data set comes from a 20 year global simulation of the Canadian Climate Centre general circulation model at triangular 20 spectral resolution. Anomalies occur when the rotational stream function at 500 mb departs from an annual cycle value at a particular point by a specified amount for a long enough interval. The different seasonal and hemispheric distributions of anomaly are identified. The data set is then analyzed in terms of empirical orthogonal functions. The basic time and space structures of events are thus found in terms of hemisphere, position within the hemisphere and finally, in terms of the time of year.

VARIATION OF NORTHERN HEMISPHERE 50 KPA HEIGHT 1946-1985

John L. Knox *, Kaz Higuchi, Amir Shabbar, and Neil E. Sargent
* Present address: 285, Deloraine Ave., Toronto, Canada, M5M 2B2

There is accumulating evidence in the literature, that different short-period climate regimes (sub-climates) may have characterized the Northern Hemisphere during the past 40 years. We therefore investigate the 40-year record of 50 kPa height (1946-1985) and analyze the time series of zonal anomalies stratified by season and latitude. We find that there appear to be two contiguous regimes, with a rather abrupt transition during the early 1960's, which had significantly different means, trends and degrees of variability. The results are compared with those from recent investigations of Northern Hemisphere surface and/or tropospheric temperature variation. The possibility of a

"climatic jump" during the early 1960's is discussed in the context of the theory (Lorenz, 1976) that the Atmosphere-Ocean-Cryosphere system may be "almost-intransitive" for short time scales (the order of a decade). Our results raise the question of an appropriate period to use for determining "normal" attributes of standard level surfaces. We shall also discuss the significance of the latest trends (1980-1985).

THE COUPLED EFFECTS OF INCREASED TRACE GAS EMISSIONS AND VOLCANIC AEROSOLS ON ATMOSPHERIC CHEMICAL AND THERMAL STRUCTURE AND SURFACE CLIMATE

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M3H 5T4

A coupled one dimensional radiative-convective and photochemical diffusion model is used to assess the possible effects of past historical and projected future emissions of major anthropogenic trace gases and volcanic aerosols on atmospheric chemical and thermal structure and surface climate. Two types of experiments are carried out. The first involves the calculation of equilibrium response of the atmosphere to a step wise increase in the trace gas emissions with background aerosols. The second experiment which also considers the major volcanic events of the past, calculates the transient atmospheric response to a time varying trace gas concentrations. It is found that in both cases, the direct and indirect effects of non CO_2, major trace gases (N_2O, CH_4 and CFC's) and volcanic aerosols play a significant in determining the long term changes in atmospheric chemical and thermal structure and surface climate. The results in the first experiment indicate that the calculated surface warming of about 1.5 K due to CO_2 increase from 1850 to year 2050 is enhanced by more than 100% by the direct plus indirect heating contributions of non-CO_2 major trace gas emission increases during the same period. Based on the results in the second experiment it is shown that for the combined time varying trace gas increase scenario (including CO_2), that the surface temperature increases steadily from 1850 to a value of 3.25 K by the year 2050 except during the major volcanic episodes when the heating is replaced by a slight cooling temporarily. The changes in the ozone column which contribute indirectly to surface temperature changes suggests that one expects a small increase (up to 1.5%) until the year 2000 except under the conditions major volcanic events when the ozone increase is temporarily replaced by a decrease. After the year 2000 the total ozone column decreases rather rapidly to a value of 7.5% as we approach year 2050.

Also discussed are the calculated changes in the stratospheric temperature, ozone and other minor constituents and the effects of altering the heat capacity of the lower boundary on surface temperature changes.

ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE ON ENERGY, FORESTRY AND AGRICULTURE IN QUEBEC

Bhawan, Singh, Department of Geography, Universite de Montreal, Montreal, PQ.
Under Contract with Atmospheric Environment Service, Quebec Region.

The main purpose of this study is to evaluate the potential socio-economic impacts of climatic change as produced by increasing levels of atmospheric CO_2

on selected sectors of the economy of the province of Quebec. These sectors will include energy, forestry and agriculture.

In the energy sector, emphasis is on hydro-electric power generating potential of the James Bay Territory and secondly on interior space heating and cooling requirements for the southern part of the province.

In the forestry sector, particular attention is paid to the potential for the displacement of tree communities, to anticipated changes in tree growth rate and to the possible influence of climate change on forest fire frequency and on logging operations.

Finally, in the agriculture sector, the study focuses on the effects of increasing CO_2 levels on crop growth and productivity and on changes, cropping pratices and irrigation requirements.

SESSION 10B CANADIAN ATLANTIC STORMS PROGRAM (CASP) II: ATMOSPHERE — Fri. 1050-1230

Chairperson R. E. Stewart, AES Downsview — Room M1032

RAIN/SNOW BOUNDARIES AND FREEZING PRECIPITATION IN CANADIAN EAST COAST WINTER STORMS

Ronald E. Stewart, Cloud Physics Research Division, Atmospheric Environment Service, Downsview, Ontario, M3H 5T4

Utilization data obtained during the recent Canadian Atlantic Storms Program (CASP) field project, studies are underway to determine conceptual models of Canadian East Coast winter storms. In the presentation, rain/snow boundaries and freezing precipitation in these storms will be discussed.

Rain/snow boundaries and freezing precipitation regions occur in almost all storm sectors, but their characteristics are independent of sector. They also are normally coupled features in that freezing precipitation is a stage in the transition from snow to rain. The passage of the features over a site is associated with wind, temperature and pressure transitions. The heaviest snowfall rates in almost all of the storms have been found to occur in the snow region adjacent to these features. The occurrence of freezing rain alone is relatively rare. It usually occurs in association with other precipitation types. A number of the characteristics of the rain/snow boundaries and freezing precipitation regions are consequences of the melting of snow itself. Rain/snow boundaries and freezing precipitation also occur within rapidly deepening storms and play a significant role in the deepening process.

SYNOPTIC ANALYSIS OF CASP IOP 14

Michael Jean* and M.K. Yau, *Department of Meteorology, McGill University

The CASP experiment off the East Coast was a success because of the abundance of storms. One of the storms, IOP 14, deepened 24 mb in 24 hours between 0000Z March 7 and 0000Z March 8 when crossing the CASP network. Its deepening rate classified it as a "bomb".

A review of the synoptic situation leading to this moderate explosive event will be presented. A comparison is made with other explosive cyclones reported in the literature. We will focus on the similarities and differences of the various cases.

A diagnostic study using a version of the Sanders model (Monthly Weather Review, 1971) showed that the quasi-geostrophic forcing cannot explain the observed deepening. Other forcing mechanisms appear important and are being investigated.

We will also comment on the errors from the objective analysis (especially for the upper air fields) and the behaviour of the numerical weather prediction models.

UPDRAFTS WITHIN A CASP STORM

A. Frigon and I. Zawadzki
Dept. de Physique, Université du Québec à Montréal, H3C 3P8

Abstract

Time sequences of radar volume scans of a winter storm were analysed to obtain vertical motions within precipitation regions. In winter storms the horizontal gradients of radar reflectivity factor are one order of magnitude smaller than the vertical gradients, thus, the conservation equation for precipitation permits the estimation of vertical velocity if the rate of generation of precipitation is known. In this work, expressions for the generation term as well as the expression for transformation of reflectivity into precipitation mass content were obtained from numerical cloud modeling.

VERIFICATION OF SOME STATISTICAL WEATHER ELEMENT FORECASTS FROM THE CASP PERIOD

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As part of the Canadian Atlantic Storms Program (CASP), a special forecast desk was established. The Forecast Research Division of Meteorological Services Research Branch used the opportunity to field test some experimental statistical forecast products. Following the CASP operational phase, attention turned to the verification of the experimental products. The purpose of the verification is to determine the overall quality of the forecasts and to assess the errors in order to form a basis for future improvements in the products. A secondary purpose is to help determine the most relevant verification tools to use in future systems.

Accordingly, a verification system was developed and designed to facilitate summary verification of all the point-specific guidance products produced for the special forecast office. The system produces usual verification products such as mean absolute error, bias, percent correct, the heidke score, the rank probability score, contingency tables, time series, and other measures appro-

priate to individual elements. A significant feature of the system is the use of a mix of mainframe and microcomputers, giving relatively easy access to a variety of display methods for the verification output, while at the same time allowing processing of relatively large amounts of data.

Verification results for the operational MOS winds will be shown, along with results for several experimental products including MOS ceiling, visibility, precipitation type and cloud opacity. In addition, the presentation will include some skill score results not produced by the verification system. The system itself will also be briefly described.

PROCESSING AND QUALITY CONTROL OF THE CASP SOUNDING DATA

G. S. Strong, Atmospheric Sciences Department, Alberta Research Council, 4920 - 51 Street, Red Deer, Alberta, T4N 6K8

The atmospheric sounding program during CASP was an essential part of this mesoscale experiment. In order to achieve mesoscale temporal and spatial resolution for intense operating periods, two major operational commitments were necessary. These were to increase the number of soundings from the synoptic network sites over eastern Canada from two to as many as eight daily, and to operate several additional special sounding sites over a limited area. The latter resulted in six quite different sounding systems, with resulting differences in the way in which data were collected and processed. These differences and other logistics problems were the source of a number of major types of data error and uncertainty.

The final data set is of generally high quality, and is unique for mesoscale analysis of severe, maritime, winter weather systems, but some problems remain. These problems and the data quality control procedures used to remove errors or estimate missing values during the upper air data processing will be reviewed. Discussion will include a description of the data quality codes used for each raw data variable, and the file structures and formats used in the final versions of the processed data. The identification of data errors or estimates appearing in the final processed data is important to any scientific analysis based on these data.

SESSION 10C COASTAL AND SHELF OCEANOGRAPHY III: TIDES Fri. 1050-1230

Chairperson I. Webster, Memorial University Room M2025

REAL-TIME CURRENT AND TIDE MEASUREMENTS IN NUMERICAL MODELLING AND PREDICTION

John G. Hayes, National Oceanic and Atmospheric Administration

The development of real-time measurement systems and the need to couple these to modelling systems, has been a long time standing requirement in the process of ocean circulation prediction. A real-time data acquisition system, in its most basic form, consists merely of an instrument in the field, a telemetry

system to transmit the data, in a relatively short time after it is taken, and a system to receive the data at another location. A real-time model system is an enhancement of this that can be used to extend the value of the data in conjunction with hydrodynamic considerations, into a predictive model of operation. The National Oceanic and Atmospheric Administration, Office of Oceanography and Marine Assessment, has developed several real-time modelling systems in coastal and estuarine areas along the U.S. Coastline. Recent projects in the Delaware Bay and River and Charleston Harbor will be reviewed. The aspects of Remote Acoustic Doppler Sensing (RADS) and real-time tide gages will be explored as they relate to supplying the basic data for model generation as well as quality control and assurance. Examples of new data acquisition and display programs will illustrate the economics and efficiency of this system for use in areas of circulation prediction, oil and hazardous material clean up, maritime navigation, and environmental management.

3-D TIDAL MODELLING OF CUMBERLAND BASIN

Sylvain de Margerie and Dave DeWolfe
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The possibility of harnessing tidal energy in the Bay of Fundy for electric power production has long been considered. Recently, Cumberland Basin, at the head of the bay, has been identified as the most likely candidate for initial implementation of a large scale power production system. In preparation for environmental impact assessments, as well as for operational considerations, it is necessary to identify the details of the basin's hydrodynamic regime under natural conditions and as modified by the operation of a tidal barrage. For this purpose a hydrodynamic numerical model is used. In view of the important role of the vertical velocity structure in dispersion processes and sediment transport in Cumberland Basin, a three dimensional representation of the flow field is used. The model uses a fine grid (400m) for the horizontal space dimensions, with a continuous representation of the vertical using a superposition of Legendre polynomials. Simulations for natural conditions are undertaken for the M2 tidal constituent as well as over a fortnightly cycle. Computed bottom stress distributions for natural conditions are relatively uniform, indicating that the basin may have reached an equilibrium configuration with respect to the bottom materials available in the area. Simulations of a tidal barrage operation for the M2 tide show drastic modifications of the residual circulation patterns as well as the bottom stress distribution. Although this would tend to favour siltation of the upper reaches of Cumberland Basin, definite predictions on the impacts of tidal power exploitation cannot be based on a consideration of the hydrodynamic regime alone, and will require further studies for which the present results offer a strong basis.

INTERNAL TIDE GENERATION AT THE HEAD OF THE LAURENTIAN CHANNEL
Y. Gratton and F. Saucier, Département d'Océanographie, UQAR, Rimouski, QC, Canada, G5L 3A1

We discuss the interaction between the barotropic and first baroclinic waves of tidal frequencies over a rapidly shoaling region, when the topographic length scale is of the same order of magnitude as the internal Rossby deformation radius (~ 10 km). A simple linear, two-layer model is used to generate the internal tides observed in the St.Lawrence middle and lower estuary.

TIDAL STRESS ; A GENERATING MECHANISM FOR MESO-SCALE EDDIES IN DIXON ENTRANCE.

Visser, A.W. and Bowman, M.J., Marine Sciences Research Center, State University of New York at Stony Brook, Stony Brook NY 11794, USA, and **Crawford, W.R.**, Institute of Ocean Sciences, PO Box 6000, Sidney, B.C., V8L 4B2 Canada.

We investigate the tidal residual circulation generated by non-linear tidal interactions within wide coastal channels with large along-channel bathymetric variations. We utilise a parameterisation of the non-linear tidal interactions as *Tidal Stress*. This approach essentially decomposes the non-linear problem into two coupled linear problems so that the causal relationships governing the generation and dynamics of tidal residual currents may be more easily investigated. Non-linearities associated with advection of momentum (or vorticity) modulated by spatially varying friction are particularly important in regions of strong topography and lead to residual current - tidal current interactions. The method is extended to investigate the effects of stratification on surface intensification of the residual circulation.

Results indicate that such effects together with coastal boundary constraints may induce recirculations of the residual current of a scale much larger than the tidal excursion or the region of generation. These general results are compared with observations of a robust meso-scale eddy found in Dixon Entrance, British Columbia, and show that the observed eddy motion is consistent (in scale, location and sense of rotation) with tidal residual current generation over strong topograpy.

ON TOPOGRAPHIC RECTIFICATION OF TIDAL CURRENTS NEAR THE ENTRANCE OF THE ST. LAWRENCE ESTUARY

V.G. KOUTITONSKY and R.E. WILSON
INRS-Océanologie, 310 avenue des Ursulines, Rimouski, (Québec), G5L 3A1

Infrared satellite imagery and previous circulation studies in the lower St. Lawrence estuary have revealed an anticyclonic structure in the subtidal motion there, and flow separation from the north shore at the entrance. On the other hand, bottom topography in the region exhibits an isolated underwater mount offshore Manicouagan river mouth. A three-dimensional circulation model was developped for the region in order to study the role of

topographic rectification of tidal currents in controlling the anticyclonic structure and flow separation at the entrance. Preliminary model results are presented for homogeneous density, and on-going modelling efforts are discussed.

SESSION 10D WAVES Fri. 1050-1230

Chairperson P. H. LeBlond, University of British Columbia Rm M2017

NEW MEASUREMENTS OF WAVES AND SUB-BOTTOM POREWATER PRESSURES IN THE BEAUFORT SEA

Donald O. Hodgins, Ph.D.
Seaconsult Marine Research Ltd.
820 - 1200 West 73rd Avenue
Vancouver, B.C. V6P 6G5

During the 1986 open-water season a unique set of measurements was obtained at two shallow water sites off North Head, Richards Island in the Beaufort Sea. The objective was to measure coincident directional wave spectra, wave-induced currents, suspended sediment concentrations and transient porewater pressures during one to two storms, and to establish correlations between these parameters. The central issues behind this program concern wave-induced liquefaction of the sea bed, and the timing and mechanics of mass sediment movements in areas comprised mainly of silts in the surficial soil layers. Two sites, located in 5 m and 10 m of water adjacent to the 1984 AGC/GSC borehole line, were occupied. At the deeper site a Sea Data 635-12 current meter was used to measure directional wave spectra and wave-induced currents. At the shallower 5-m deep site, Sea Data 635-9 and 635-11 meters were used to measure directional wave spectra, wave induced currents and one-dimensional wave spectra. Suspended sediment concentrations 100 cm above the sea bed and porewater pressures at -80 cm and -180 cm were also measured at this location. Porewater pressures were monitored with a new piezometer probe designed for this study. Highlights of the field program and the instrumentation will be described in this paper. Burst-sampled data during two storms will be presented and variations in waves, currents, suspended sediments, and porewater pressures over the 38-day monitoring period will be discussed. The implications for liquefaction, sediment transport and soft-bottom wave attenuation will be presented.

WAVE GROWTH IN SCATTERED SEA-ICE

Diane Masson and Paul H. LeBlond. Department of Oceanography, University of British Columbia, Vancouver, B.C. V6T 1W5.

The Marginal Ice zone includes wide areas covered by dispersed ice floes in which wave conditions are significantly affected by the ice. When the wind

blows from the solid ice pack, towards the open sea, growing waves are scattered by the floes, their spectral characteristics being modified. The waves also push the ice into banded structures at right angles to the wind. To further understand this coupled wave-ice problem, we developed a model for the growth of wind waves in a sparse field of floating ice floes. Wave growth is obtained from a discrete spectral model using the computations of the exact non-linear transfer integral. Wave scattering by a single floe is represented in terms of far-field expressions of the diffracted and forced potentials. The combined effect of a homogeneous field of floes on the wave spectrum is obtained in terms of the Foldy-Twersky integral equations. The formulation of the model is explained and preliminary results presented.

WAVE-CURRENT INTERACTION IN THE QUEEN CHARLOTTES

J.A. Stronach and J.A. Helbig
Pacific Ocean Sciences Ltd., 301A-3700 Gilmore Way, Burnaby, BC V5G 4M1

The interaction of wind waves with currents in the Queen Charlottes was studied by coupling a wave model with a barotropic model of the tidal flow (which accounts for 70% or more of the surface current variance). For waves, we used a first generation model describing the balance of wave action along time-dependent rays determined jointly by bathymetry and currents. Wind forcing and simple dissipation were included but not wave-wave interaction. Results from real and simulated hindcasts are presented. Open boundary conditions for the tidal model were taken from the larger scale, coarser Flather model. For the real world hindcasts, the open boundary directional spectra were obtained from a parametric hybrid model of the North Pacific.

Two effects were considered: wave refraction by currents and wave-current interaction in which energy is exchanged with the mean flow. Order of magnitude estimates of current refraction are often based on the local ratio of current shear to the bathymetric change in phase speed. However, wave-current interaction is global, not local, and the net effect in the Charlottes can be significant when integrated along a ray. Moreover, since sheared currents are often tied to specific bathymetric features, current refraction often partially opposes topographic refraction.

Without taking into account enhanced dissipation, we found that wave energy could more than double in some areas on a spring tide. Even more dramatic results were found for the mean wave slope since wave-current interaction increases with frequency. In general, wavefields with dominant periods less than about ten seconds were significantly modified by currents. Fortunately, most of the wave-current interaction can be computed locally from wave action conservation by computing the change in local intrinsic frequency. The implications of this for wave modelling are discussed.

Finally, we found that the directional spread of the wavefield incident on the open boundary governed the importance of both current and bathymetric refraction. If the spread is large, refraction can be neglected in most areas.

KINEMATIC INTERPRETATION OF WAVE-CURRENT INTERACTION

J.A. Helbig
Pacific Ocean Sciences Ltd., 301A-3700 Gilmore Way, Burnaby, BC V5G 4M1

The interpretation of the interaction of slowly varying wavefields with sheared currents is aided by exploiting the tensorial properties of the radiation stress and the current shear tensors. Specifically, these tensors are decomposed into mutually orthogonal components of different weight: traceless symmetric, antisymmetric, and isotropic. Two cases are considered, the interaction of wind waves with horizontally sheared mean currents and the interaction of internal waves with three-dimensionally sheared flows. In both cases, the change in wave energy density as well as wave refraction are described.

For wind waves the rate of change of wave energy density depends jointly on the purely sheared part of the flow and the divergence. The latter effect is isotropic, but the former is highly directionally dependent and is maximal along the principal axes of the shear. Vorticity cannot directly alter wave energy, an expression of the irrotationality of surface gravity waves. Waves are refracted by the pure shear flow towards the minor principal axis and are turned at a constant rate by the vortical component of the shear. Flow divergence does not deflect waves.

Results for internal waves in a three dimensional shear flow are also presented. Unlike wind waves, the group velocity does not point in the direction of wave propagation, and this, coupled with the three dimensionality of the flow, leads to a more complex interpretation. For internal waves, the horizontal vorticity components contribute to energy exchange as does the pure shear, but neither the vertical vorticity nor divergence can alter wave energy. A simple example is given.

ON THE IMPACT OF OFFSHORE WAVE MONITORING BUOYS ON SEVERE SEA STATE FORECASTS IN B.C. COASTAL WATERS

Donald O. Hodgins, Ph.D.
Seaconsult Marine Research Ltd.
820 - 1200 West 73rd Avenue
Vancouver, B.C. V6P 6G5

The impact of offshore wave monitoring buoys on 6 to 12 hour severe sea state warnings in British Columbia coastal waters has been examined by detailed wind-wave hindcasting of eight important storms. Three hypotheses were tested: (1) that sea state warnings could be made using buoy measurements alone, allowing for propagation and wave growth due to the wind; (b) that sea state warnings could be made using buoy measurements in conjunction with conventional synoptic weather system analysis; and (c) that suitable warnings could be made using the buoy measurements in conjunction with a spectral wave prediction model. In each case the optimum number and position of buoys was considered. It was found that buoy data in themselves are too limited to give reliable wave predictions. Some improvement was made by considering the synoptic coupling between weather system fronts and sea state conditions; this resulted in better predictions of the time of maximum waves but gave only very approximate estimates of sea state severity. Optimum use of the buoy data was achieved when it was combined

with a wave prediction model forced by the storm wind fields. It was concluded that four buoys positioned about 400 km offshore, capable of measuring hourly directional wave spectra, would meet operational requirements. Wave hindcasting and forecasting procedures used in this study, the methods for testing each hypothesis, and the results are discussed in this paper.

RECENT DEVELOPMENTS IN WAVE DATA SYNTHESIS, ANALYSIS AND PREDICTION APPLIED TO THE CANADIAN OFFSHORE

J.D. McClintock, Seaconsult Limited, 301 Victoria Hall, 187 Gower Street, St. John's, Newfoundland, A1C 1R2

The synthesis of irregular sea states is of fundamental importance for marine hydrodynamics simulation and research. A software system (SEAWAV-P) has been developed by Seaconsult at the NRC Institute for Marine Dynamics (IMD) in St. John's for the synthesis, generation, and analysis of nondirectional waves in a laboratory wave tank. The key features include reproduction and control of prototype or theoretical energy spectra, time domain grouping characteristics, and the decomposition of measured spectra into incident and reflected spectra. Results of recent physical testing in the clearwater tank at IMD are presented. This illustrates the merits of the synthesis methods employed and typical modes of operation of SEAWAV-P.

A complimentary advanced wave data analysis software system (SEAWAV-A) has also been developed for fundamental time and frequency and frequency domain analysis of ocean waves, and for specific interests such as wave grouping and evolution of high sea state conditions. SEAWAV-A has successfully been applied in predicting extreme wave conditions and in wave climatology studies and is directly applicable to hydrocarbon exploration and production in Hibernia and the Scotian Shelf.

JOB ADVERTISEMENTS

ATMOSPHERIC SCIENCE

Dalhousie University

The Atmospheric Environment Service and Dalhousie University are submitting to the Natural Sciences and Engineering Research council a proposal for the establishment of a centre of excellence and graduate programs in atmospheric science. It is envisaged that there will be four tenure-track positions, one senior and one junior in each of the two general areas of climate research and marine meteorology.

Further information on the positions and on existing teaching and research programs at Dalhousie, Bedford Institute of Oceanography and AES, Bedford may be obtained from Dr. C. Garrett, Department of Oceanography, Dalhousie University, Halifax, NS, B3H 4J1, Canada, to whom applications for both senior and junior positions should be sent.

In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. With respect to the employment of women faculty, Dalhousie University is an affirmative action employer.

JOB ADVERTISEMENTS (Cont'd)

TWO PHYSICAL OCEANOGRAPHY POSITIONS

Memorial University of Newfoundland

Applications are invited for one new and one replacement tenure-track faculty position in Physical Oceanography. Appointments will be made to the Department of Physics, Memorial University of Newfoundland, subject to final budgetary approval. Rank and salary are negotiable and commensurate with the qualifications of the appointee. Experience beyond a Ph.D. degree is preferred. The position offers a challenging academic career with stimulating research opportunities focussing on the Northwest Atlantic and the Labrador Current. The Department's Physical Oceanography Group is engaged in theoretical and experimental studies of coastal and continental shelf oceanography, deep ocean circulation, Lagrangian formulations of dynamical and dispersion problems, numerical modelling and acoustic remote sensing.

Interested candidates should send their applications, including curriculum vitae and the names of three referees, or requests for information addressed to: either Dr. Alex Hay or Dr. D. H. Rendell (Head), Department of Physics, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7.

In accordance with Canadian Immigration policy, this advertisement is directed, in the first instance, to Canadian citizens and permanent residents of Canada.

APPLICANTS INVITED

POSITION: Director of Publications
Canadian Meteorological and Oceanographic Society (CMOS)

DUTIES: CMOS has four high-quality publications: two scientific journals (Atmosphere-Ocean and the Climatological Bulletin), a popular magazine (Chinook) and a Newsletter.

The Director of Publications provides a crucial linkage between the editors and the printers of the CMOS publications inlcuding setting production scheduling and costs, quantities to be printed, and mailing.

The Director also manages the advertising carried in two of the publications, assists in the promotion of journals, and provides financial information for budgeting and grant applications.

Present experience is that the workload amounts to 1-2 days per week.

COMPENSATION: This position is primarily a volunteer one but an honorarium of up to $2000 will be considered, plus reimbursement for reasonable expenses. The primary reward will be satisfaction in carrying out an important function for CMOS and in gaining business experience.

LOCATION: Since the printing is mainly carried out in Toronto, applicants from southern Ontario would be preferred. However, applications from other areas are welcome.

FOR FURTHER DETAILS, PLEASE CONTACT:

Mr. Bill Appleby
Atmospheric Environment Service
Department of Environment
1496 Bedford Highway
Bedford, Nova Scotia
B4A 1E5
Bus.: 902/426-9133
Res.: 902/864-4688

or

Mr. Uri Schwarz
Suite 903, 151 Slater Street
Ottawa, Ontario
K1P 5H3
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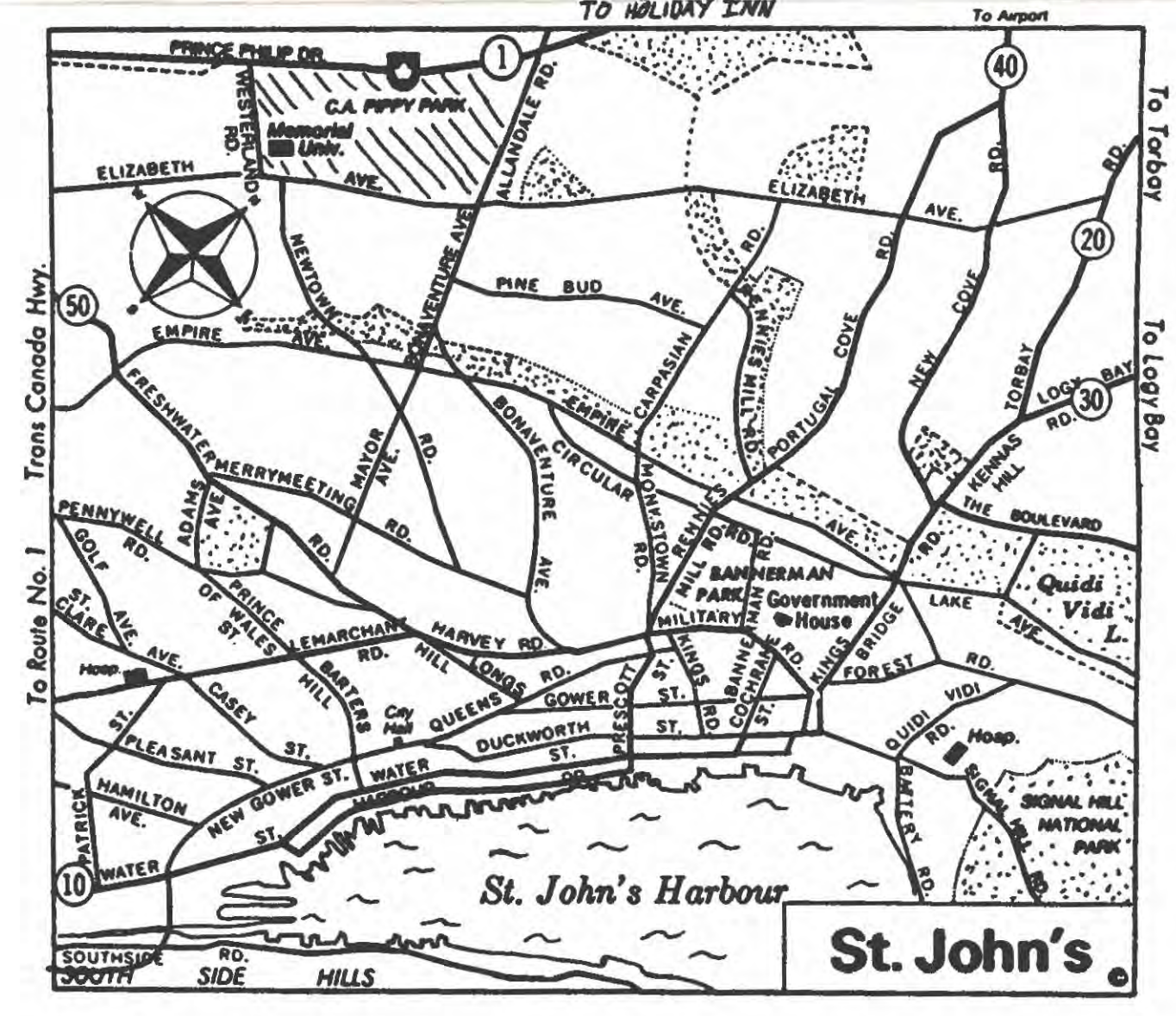
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