Proceedings of the 1982 Grand Banks Current Workshop

J.R. Benoit and J.C.H. Mungall

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Regional and headquarters establishments of Ocean Science and Surveys ceased publication of their various report series as of December 1981. A complete listing of these publications and the last number issued under each title are published in the *Canadian Journal of Fisheries and Aquatic Sciences*, Volume 38: Index to Publications 1981. The current series began with Report Number 1 in January 1982.

Rapport technique canadien sur l'hydrographie et les sciences océaniques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles mais que l'on ne trouve pas normalement dans les revues scientifiques. Le sujet est généralement rattaché aux programmes et intérêts du service des Sciences et Levés océaniques (SLO) du ministère des Pêches et des Océans.

Les rapports techniques peuvent être considérés comme des publications à part entière. Le titre exact figure au-dessus du résumé du chaque rapport. Les résumés des rapports seront publiés dans la revue Résumés des sciences aquatiques et halieutiques et les titres figureront dans l'index annuel des publications scientifiques et techniques du Ministère.

Les rapports techniques sont produits à l'échelon régional mais sont numérotés et placés dans l'index à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page de titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n^{o} 1 en janvier 1982.

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PROCEEDINGS OF THE 1982 GRAND BANKS CURRENT WORKSHOP

by

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ABSTRACT

Benoit, J.R. and Mungall, J.C.H. 1983. Proceedings of the 1982 Grand Banks current workshop. Can. Tech. Rep. Hydrogr. Ocean Sci. 28: iv + 43p.

On September 29 and 30, 1983, a Grand Banks ocean current modelling workshop was held at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. The objective of the workshop was to bring together scientific and industry personnel interested in the Grand Banks to formulate recommendations for future work aimed at developing a better understanding of the currents on the Grand Banks. Invited presentations are summarized and recommendations from working groups held during the workshop are presented.

RESUME

Benoit, J.R. and Mungall, J.C.H. 1983. Proceedings of the 1982 Grand Banks current workshop. Can. Tech. Rep. Hydrogr. Ocean Sci. 28 : iv + 43p.

Le 29 et 30 septembre 1982, un colloque au sujet des courants au-dessus des Grand bancs de Terre-Neuve eut lieu à l;Institut océanographique de Bedford à Dartmouth, Nouvelle-Ecosse. L'objectif du colloque était de réunir des représentants des domaines scientifique et industriel afin d'établir des recommendations pour des études futures sur les courants au-dessus des bancs. Un sommaire des présentations et recommendations est inclus dans le rapport.

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EXECUTIVE SUMMARY

ORGANIZATION

The Ocean Current Modelling Workshop was held at the Bedford Institute of Oceanography (BIO), Dartmouth, Nova Scotia, on September 29 and 30, 1982. The objective of the workshop was to bring together scientific and industry personnel interested in the Grand Banks to formulate recommendations so that studies of ocean currents would be undertaken in a timely, cost-effective, and technically sound manner. The workshop was organized by J. Benoit (Mobil) and C. Mason (BIO). C. Mungall (Mobil) acted as secretary.

INVITED PRESENTATIONS

The workshop commenced with an opening address by D. MacClelland (Mobil) and C. Mason that set the framework for the workshop by providing, respectively, the viewpoints of Industry and Government/BIO. D. MacClelland's presentation provided an overview of the Hibernia development scenario, describing semi-submersible and gravity-base production possibilities. Representative 1982 environmental design criteria parameters were given: a 115 foot wave, maximum height, a current profile varying from a conservative 3 knots at the surface to 1 knot at the bottom, and a 12 million ton iceberg (having a return period much in excess of 100 years) with a speed of 0.5 knots.

C. Mason provided information on the role of various government agencies in offshore affairs - COGLA; Dept. of Environment; Deptpartment of Energy, Mines and Resources; Ministry of Transport and Dept.of Fisheries and Oceans. Some of the ongoing research at the Bedford Institute of Oceanography was described: iceberg current profiling and shape determination; current meter deployment off Cape Sable, Grand Banks' circulation, internal wave solitons; modelling.

Consideration was given to the use of environmental data for operations by J. Benoit. Iceberg occurrence data were presented, and the topic of iceberg management was covered. Of particular relevance were iceberg size limits, iceberg crossing per degree squares. The status of the current measuring program was addressed - some 9 current meter years of data, described in 17 reports, having been collected and submitted to MEDS.

D. North's talk concentrated on structural design aspects, and the relative lack of sensitivity of the structures to direct current-induced loads (example waves, currents and waves).

Of importance, however, were the action of currents on slender members, vortex shedding, scour, oil spill trajectories, operations, and of course ice drift and impact.

The last presentation of the morning was by B. Petrie on the physical oceanography of the Grand Banks. A variety of important topics were covered, chief among which were: the relative insignificance of the mean current, a fairly small tidal component (of the order of 20 cm/sec.) and the importance of wave/wind - driven currents. A comment was made that summer stratification could result in more extreme wind driven surface currents than those produced by the highest wind speeds - which tend to occur in winter. The Labrador current and its meanders were described, as were solitons; although Hibernia may be outside their region of occurrence, there may be side effects. The effects would become of increasing importance as operations approach the shelf break.

The afternoon of the first day consisted of invited presentations by oceanographers whose experience in other regions would be of benefit to planning.

B. Beardsley described the five-year Georges Bank study with a view to providing insight for the planning of Hibernia studies. Many of the Georges Bank studies were aimed at providing seasonal mean currents - for which a prime requirement is a well-selected long duration data base. Noteworthy comments included: the need for analytical, then numerical, models to provide insight into processes; the use of remote sensing to locate rings; the use of satellite tracked drifters in quantities sufficient for the drafting of a current map, and the identification of water sources through isotope ratio tracers.

G. Csanady's talk centered on the use of analytical solutions to provide insight into current patterns over continental shelves and slopes. Such solutions, when applied to the Grand Banks, can be expected to aid in understanding basic currents and their driving forces, in planning measurement programs, and in evaluating numerical models.

Allyn Clarke described the Labrador current, concentrating on the Labrador, Grand Banks, and Flemish Cap regions, with particular emphasis on the region to the southeast of the Grand Banks. Noteworthy was the bifurcation of the current around the Flemish Cap, with its implications for iceberg distribution, and the complex Gulf Stream - associated northwards flow of the Labrador Current after its southwards passage along the Grand Banks.

D. Mountain described the approach used by the U.S. Coast Guard Oceanographic Unit to model the passage of icebergs down the Labrador coast and past the Grand Bank. The model, used in daily operations to estimate iceberg drift in the absence of air reconnaissance, includes Coriolis, sea slope, wind drag and water drag forces - the latter distributed over a maximum of four levels. Satellite measurements of sea slope were mentioned as being desirable in order to extend the existing geostrophic current data base.

S. Smith described Bedford Institute of Oceanography progress in iceberg drift modelling. Besides drift prediction, mention was made of the need for towing force and direction estimation. Comparisons between measured and predicted tracks were shown. The scatter in drag coefficients, as obtained through the fitting of measured to modelled tracks, was worrisome, and indicates the need for precision iceberg track measurement together with concurrent environmental measurements if substantial progress is to be made.

The focus of N. Heaps' presentation was his experiences with the United Kingdom storm surge level prediction model. The model, using wind stress input derived from the Met. Office 10 - level model, computes combined tide and surge -- the tide then being subtracted to provide storm surge level predictions. The experience gained in setting up and running this model on a frequent basis will be most helpful should currents have to be predicted in the Grand Banks region for iceberg, ship or oilspill drift predictions.

WORKING GROUPS

The second day of the workshop was spent producing recommendations for unified studies aimed at solving any outstanding design or operational problems. Three working groups were constituted: Processes (led by J. Elliott of BIO), Modelling (led by D. Wright of BIO), and Measurements (led by M. Sheppard of Mobil). Discussions, with occasional breaks for information exchange, occurred throughout the morning. Individual group reports were presented in the early afternoon.

1. Processes Group Presentation

Five topics were discussed by the process group: the Labrador Current, Grand Banks circulation, surface currents, iceberg dynamics, and sediment transport. The northern limit of the Labrador Current, for iceberg tracking purposes, was considered to be 52°N. It was recommended that efforts be made to understand the mechanism by which icebergs move away from the various branches and on to the shelf. Consideration of the Grand Banks as a whole was advised. Numerical, analytical and observational studies should be aimed at studying, amongst other items, the mean and wind-driven circulation on the Grand Banks. Iceberg dynamics appeared to be an area of weakness. Lastly, sediment transport was briefly addressed, and the importance of including surface wave effects on bottom stress was mentioned.

In particular, the group was dubious about achieving the accuracy required by Operations in the face of great uncertainty of values for iceberg lift, drag, and shape factors. In addition, mention was made concerning unknown, but perhaps contributing, factors such as the creation of eddies and fresh water pools in the proximity of the iceberg. The last topic, Sediment Transport, was considered primarily to be one of Modelling -- the responsibility of another group, and one in which driving forces - currents - would be covered in the previously-mentioned topics. An exception was the phenomena of the need for bottom stress information, which has been shown to be quite dependent on waves.

2. Modelling Group Presentation

The modelling group covered three topics: two dimensional models, localized current prediction models, and iceberg drift modelling. First, it was stressed that models evolve, both with technology and with regional knowledge. One should not, therefore, be surprised if, during the study, models become superseded. It was hoped that it would prove feasible to run a two dimensional model of the Grand Bank that would have the 400 m isobath as a boundary. The appropriateness of this might have to be justified initially through the use of a model extending to abyssal depths. Analytical models may prove useful in the investigation of the nearby Labrador Current. Simple, single point models should be investigated. Such models, capable of being implemented on rig-located computers, could perhaps be used operationally to provide iceberg drift or towing information. Lastly, iceberg drift models were addressed. It was mentioned that the use of deterministic models should not be ignored even though it is recognized to be of great difficulty to compute hydrodynamic forces on an object whose shape would be largely a matter of conjecture. A coordinated iceberg shape/movement/environmental measurement project was advised.

The third topic, Iceberg Drift Modelling, addressed both design and operational considerations, and the need to perform additional mathematical investigations aimed at improving drift forecasts. Design and operational considerations mentioned included maximum iceberg velocity calculations for design purposes, the concept of reverse modelling -- a means by which hazard zones could be predicted, and the use of models to provide iceberg towing feasibility estimates. The need to perform additional mathematical investigations centered on the perceived difficulty of forecasting the drift of an iceberg when little is known of its underwater shape, or of its orientation (and hence drag) as a function of time. In particular, it is felt that more attention should be paid to non-deterministic models (based on statistical relationships between prior met/ocean conditions and iceberg movement history). Such an investigation would include determination of the nature of the driving forces through analysis of meteorological and oceanographic records, and of iceberg accelerations.

3. Measurements Group Presentation

The measurements group focussed on the topics of modelling input requirements, spatial scales of variability, and field programs. The first two topics are linked, in that modelling strategy depends on spatial scales, and measurements - if aimed at providing input to models - should be made with these scales in mind. The need for assessing available current and wind data was stressed as a precursor to costly measurements. It was recommended that a tide monitoring program be initiated as soon as possible on the Grand Banks. A pilot study was also suggested that would have as its goal the determination of scales of motion within an area some tens of kilometers in extent using repeat eddy tracked drifters travelling through an array of five current meter strings.

MOBIL - BIO
CURRENT WORKSHOP SCHEDULE
DARTMOUTH, N.S.
SEPTEMBER 29-30, 1982

0900 - 1230

0900-0940	Requirements of the Offshore Developments	Senior Mobil Representative - MacClelland
0940-1020	Government/BIO Perspective	Mason - BIO
1020-1030	- BREAK -	
1030-1110	Concerns to be faced	Benoit - Mobil
1110-1150	Offshore Design Considerations	North - Mobil
1150-1230	Oceanography of the Region	Petrie - BIO
	- BREAK -	

1330 - 1700

1330-1410	i) Georges Bank Study ii) Shelf Modelling (Numerical) iii) Experimental Approaches to Continental Shelf Dynamics	Beardsley - WHOI
1410-1440	Dynamics of Continental Shelves	Csanady - WHOI
1440-1510	Tail of Grand Banks and Newfoundland Basin	Clarke - WHOI
1510-1550	North Sea Modelling (Real Time, Predictive Models)	Heaps - IOS
	- BREAK -	
1600-1630	International Ice Patrol Studies	Mountain
1630-1700	Iceberg Dynamic Studies	S. Smith - BIO

- EVENING -

2030-0100 Informal discussion meeting. Open bar until 2300 at the Kesagose Room, Chateau Halifax.

On the second day, three working groups will discuss specific problems. These will be:

a) Processes Group - Leader: Elliott - BIO
Secretary: Petrie - BIO

Wind/waves/currents; time and distance scales; buoyancy fluxes; boundary effects and upwelling; variability and instability in the Labrador current; propagation of deep ocean energy onto the shelf; inertial period motions; non linear interactions between waves/currents; bottom drag coefficient changes in presence of large waves/currents.

b) Modelling Group - Leader: Wright - BIO
Secretary: Mungall - Mobil

Appropriate uses of diagnostic and predictive models; measurement strategies; usefulness in providing relationships between quantities; extent of the models and open boundary problems; evaluation of numerical models vs simpler models; role of statistical models; model analyses; future applications either on site at the production site or at a land based laboratory.

c) Measurements Group - Leader: Sheppard - Mobil
Secretary: Coolen - Mobil

Evaluation of existing data bases; evaluation of technology - drifters/CODAR/HF Radar/current meters; identification of data gaps; suggestions for measurements that are both feasible and useful; analytical techniques and reprocessing of existing data; costs of data acquisition.

Time Schedule for Discussion Groups

0830-1030	Group Meetings
1030-1100	Break, plenary exchange of information Group meeting to prepare recommendations for needed programs
1330-1500	Group reports and discussion

- BREAK -

1530	Closing summation: Garrett - Dalhousie

Chris Mungall will act as secretary for the plenary sessions.

HIBERNIA OCEAN CURRENT MODELLING WORKSHOP

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REQUIREMENTS FOR OFFSHORE DEVELOPERS

D.J.A. MACCLELLAND, MOBIL OIL CANADA

INTRODUCTION:

A brief overview of Hibernia development plans was presented. For the past 3 years, Mobil Oil Canada has been gathering current data at specific locations on the Grand Banks. These data, although useful for the design of offshore structures, have provided limited information on the current circulation on and around the Grand Banks. Furthermore, some modelling efforts have been initiated by Mobil to investigate maximum design currents for the Hibernia. These models have been critizied and their application to the Grand Banks should be properly evaluated.

Mobil has drilled over a dozen wells since 1979 and ocean currents have been gathered at most of these wells. Presently, at each rig, there are various current measurements that are being made:

1) Surface Currents:

Each rig is equiped with Orion buoys and receivers. These buoys are primarily used in the event of an oil spill and therefore are not deployed on a regular basis.

2) Currents Measured from the Drilling Unit:

A current meter is suspended from one rig 20 meters below the surface. The information received from this current meter is primarily used in support of diving operations and is of limited use in studying currents due to the contamination caused by the legs of the drilling rig.

3) Moored Current Meters:

Two moorings are required at each rig. One is to contain only a near surface current meter at a depth of 20 meters and a sub-surface buoy at a depth of 15 meters. The meter on this mooring needs to have a capability for operations in the wave zone, i.e. vector averaging current meter. Another mooring is for measurements at or near mid-water depth and approximately 20 meters from the bottom. The main mooring support buoy should be located 5 to 10 meters above with a recording interval of every 10 minutes. Moorings are to be left in place for as long as possible and need not be moved with every relocation of the drilling unit in a particular area.

As a result of these investigations, it has been made clear that additional work was required to better understand the circulation patterns on the Grand Banks. Increased knowledge in this area will be useful for iceberg drift prediction, ice mass velocity studies, iceberg scour estimates, subsea excavation infilling and oil spill contingency planning.

Therefore, this workshop should address some specific questions relative to current modelling and its use on the Grand Banks:

- What accuracy in a current model is required for the design of an offshore production system on the Grand Banks?

- Can a model be developed which will satisfy all requirements?

- Can a real time model be developed for iceberg drift? What are the restrictions?

- What in-situ measurements need to be made?

- How different is the Grand Banks area from other continental shelf areas?

- Can surface currents be measured accurately?

INTRODUCTION TO THE BEDFORD INSTITUTE OF OCEANOGRAPHY AND SOME OF THE BIO STUDIES RELATED TO OFFSHORE OIL AND GAS DEVELOPMENT, CLIVE MASON, B.I.O.

The Bedford Institute of Oceanography is the principal oceanographic institute in Canada; it is an assemblage of people and facilities and operates within the framework of several different government departments; the staff are federal public servants. The facilities and research programs are well summarized in the BIO Review reports, published annually and available from the Industrial Liaison Office (BIOMAIL), Bedford Institute of Oceanography, P. O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2.

Many different federal agencies are involved in almost all aspects of offshore development from Revenue Canada customs agents to government research scientists; each has a relatively well defined responsiblility and it is important to clearly perceive what the job of each of us actually is and not to let responsibilities become too "fuzzy" at the fringes.

Federal agencies most involved with the physical environment at offshore development sites include:

- Energy, Mines and Resources (EMR)
- Dept. of Indian and Northern Affairs (DINA)
- Dept. of Environment (DOE)
- Dept. of Fisheries and Oceans (DFO)

EMR and DINA are jointly involved in the Canada Oil and Gas Lands Administration (COGLA) which is responsible for procedures and regulations for offshore development. DOE is responsible for the Federal Environment Assessment Review Office (FEARO) which manages the review of the potential environment impact of a development. DFO manages the Canada Fisheries Act. These agencies also operate research facilities - at BIO the geology and geophysics studies fall into the Atlantic Geoscience Centre (AGC), while DFO operates the Atlantic Oceanographic Laboratory (AOL), the Marine Ecology Labratory (MEL) and the Marine Fish Division. AOL conducts programs in physical and chemical oceanography and the BIO scientists participating in the Current Modelling workshop are members of AOL.

There is a complex interaction of many different government departments, authorized by the Parliament of Canada wth diverse responsibilities for offshore resource management. There will be differences and conflicts between these agencies - which may ultimately need resolution by the federal cabinet forming the government of the day. In AOL we are resopnsible for providing information and knowledge about th physical and chemical environment offshore.

Our advice is sought by a wide variety of government and non-government agencies including both FEARO and COGLA. Official advice and matters of policy are communicated through the office of our Regional Director, and are coordinated within BIO by the Ocean Information Division. AOL welcomes the opportunity to particitpate in joint scientific and technical studies, with the objective of being better informed and doing peer review scientific studies. In our discussions of current modelling we hope to identify problems which can be solved, to establish joint study programs and to proceed in a spirit of cooperation to tackle problems of mutual interest to ourselves in AOL and the offshore operators.

CONCERNS TO BE FACED AT HIBERNIA

JACQUES BENOIT, MOBIL OIL CANADA

REVIEW OF HISTORICAL DATA

The physical oceanography of the Newfoundland Grand Banks has been of interest to scientists for many years. Bjerkan (1919) was one of the first to investigate the area.

Interest in the waters of the Newfoundland coast increased substantially after the sinking of the Titanic (1912) which resulted in the formation of the International Ice Patrol (IIP). Few temperature or salinity data are available for years before 1933; however, that year the U.S. Coast Guard began collecting a large amount of temperature and salinity data between April and July around the edge of the Grand Banks in an attempt to map the dynamic topography of the area.

Shortly after the Second World War, the USSR began investigating the Grand Banks with reference to commercial fishing. They determined that the Labrador Current, on approaching the northern slopes of the Grand Banks, divides into two separate streams, a minor coastal branch and an offshore branch.

The Soviet workers found that the bank waters and slope waters are of great importance in the general circulation of the Newfoundland Grand Banks. These waters are exposed to the influence of meteorologial conditions, and their characteristics fluctuate seasonally. In the northern part of the area, the bank waters interact with the polar waters of the Labrador Current. Waters of tropical origin penetrate the southern and southwestern parts of the Grand Bank and partially on to Green and Saint-Pierre Banks.

The lowest salinity in winter was found at the surface over the Saint Pierre and Green Banks. In the central region of the Grand Banks, salinity was between 32.6 - 32.9 0/00 from the surface to the bottom. Seasonal changes in salinity on the Newfoundland banks are also considerable. In the summer, the surface waters are diluted while the mean bottom layers become more saline.

Robe (1975), in an effort to verify the validity of the dynamic topography charts produced since 1933 by the U.S. Coast Guard and other agencies, moored two current meters 40m from the bottom on the southeast slope of the Grand Banks. The purpose was to verify the assumption that there was no motion at 1,000 dbars which was the reference level used for the construction of most of these charts. Robe of the U.S.C.G. found that even after having filtered his data to remove the tidal frequencies, there remained a high degree of variability in the current. He concluded that geostrophic current calculations should be considered as minimum estimates with the actual current speed being 10-30% higher.

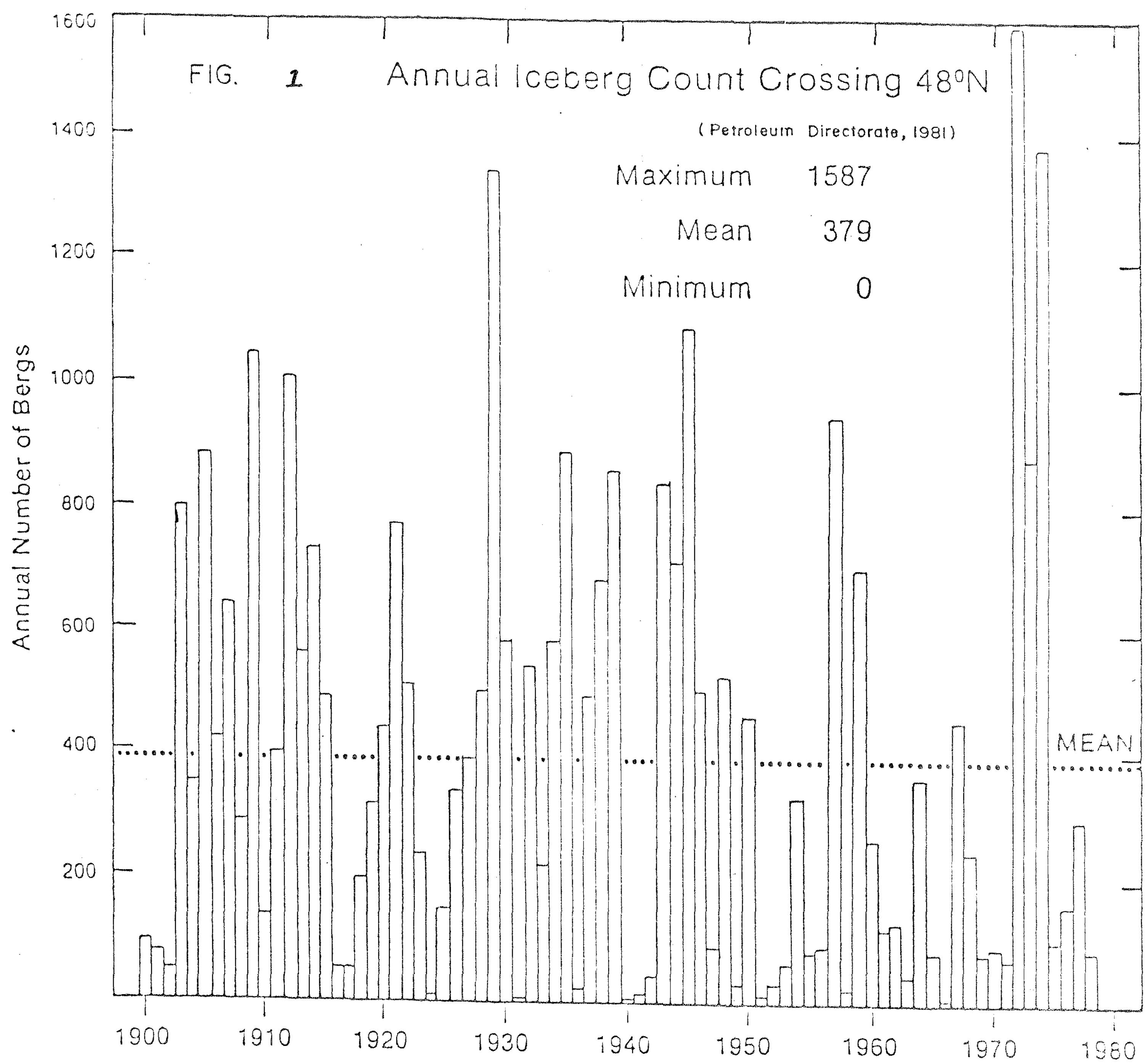
FIG. 1
Annual Iceberg Count Crossing 48°N
(Petroleum Directorate, 1981)
Maximum 1587
Mean 379
Minimum 0
MEAN
Annual Number of Bergs
1600
1400
1200
1000
800
600
400
200
1900
1910
1920
1930
1940
1950
1960
1970
1980

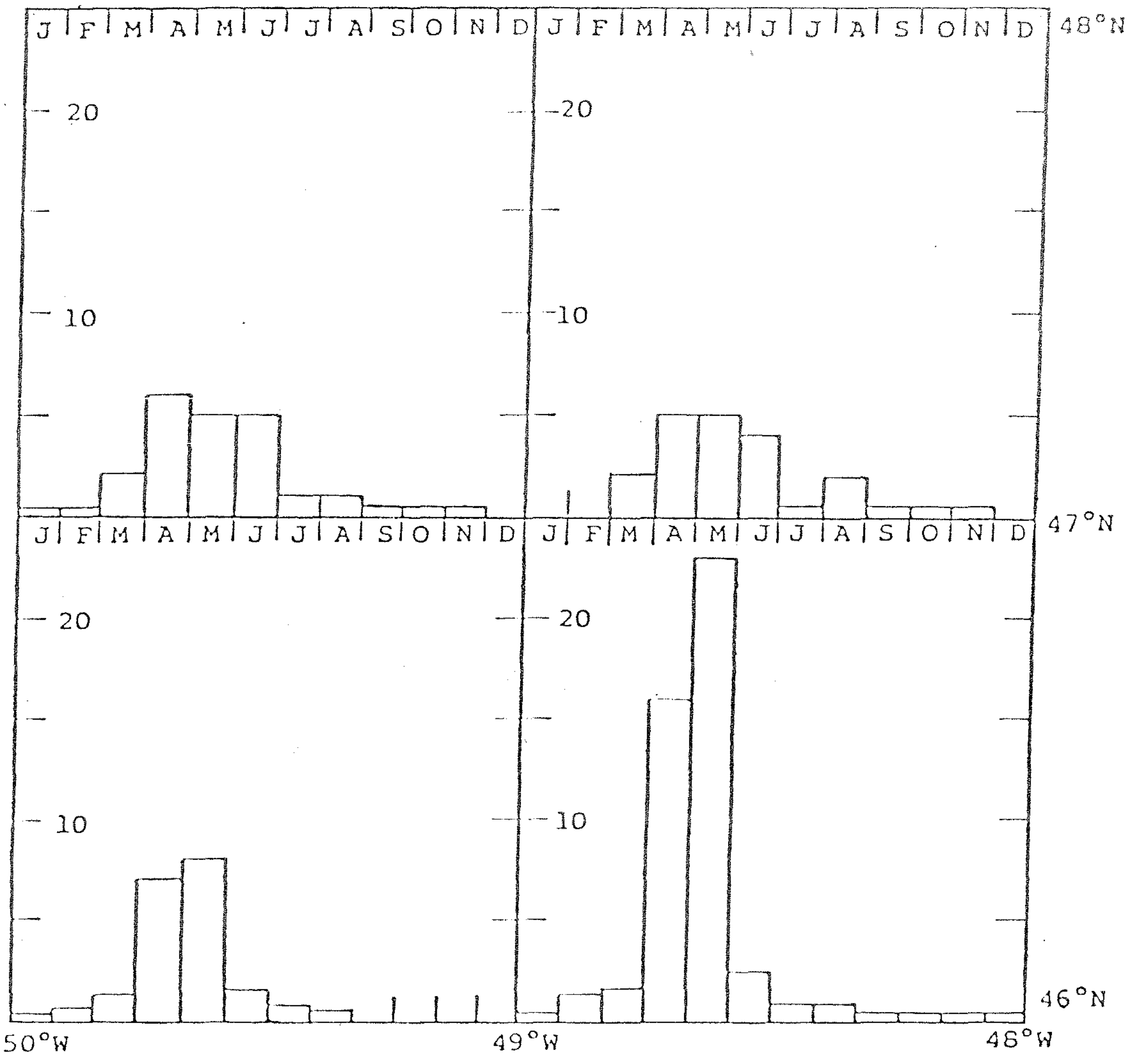

Figure 2 Mean monthly iceberg sightings per degree square for the Grand Banks. Hibernia, with approximate co-odrinates of 46° 47' N and 48° 45' W, is represented by the lower right distribution.

(Ice Engineering Ltd., 1980)

Mountain (1980) moored two current meters at approximately the same location as Robe (1975). His data shows that the mean current speed at 110m was 35% higher than the average geostrophic velocities at that depth; at 380 m, the mean current speed was 65% higher than the average geostrophic velocities at that depth referenced to 1,000 dbars. It has been suggested (Akenhead et al. 1979) that currents along the Newfoundland coast could be estimated using coastal sea level stations. The Department of Fisheries and Oceans, Coastal Oceanogrphy Section at the Bedford Institute of Oceangraphy, undertook a pilot program in the Avalon channel in the summer of 1980 in an attempt to resolve this question.

MacLaren Plansearch, under contract for Mobil Oil Canada Ltd., moored two current meter strings and a number of bottom current meters in the vicinity of the Hibernia well site in January, 1980. This program is ongoing, with data collection continuing in 1981. It is not expected, however, that these data will resolve the problem of circulation patterns over the Grand Banks as the spatial distribution of the moorings is too restricted.

ICEBERG FLUX

The yearly iceberg flux across 48 degrees north is shown in Figure 1. There is a significant variation in the number of icebergs crossing 48 degrees north in 1972 (the record year 1587) and none in 1966.

Figure 2 (Ice Engineering Ltd. Report, 1980) gives mean monthly iceberg sightings per 1 degree rectangle in the Northeast Grand Banks area. These were derived from IIP sightings made since 1946. Most of the bergs reach the Grand Banks in April, May and June with September to January being the period when the least number of bergs are reported. The reason for the greatly differing distribution shapes (particularly noticeable in the two distributions between 48 degrees and 49 degrees west) derives from variance between the actual occurrence of icebergs and sighted reports. Within any given area, it is possible that an iceberg may occur without being observed, or, a berg may be observed a number of times.

ICEBERG SCOURING

The type of ice cover on the Canadian Eastern Seaboard is different from the Artic ice pack. Recent field observations have shown that the drift of some icebergs is independent of the movement of ice floes. A major factor which influences the movement of icebergs is their drift and the consequent predominant role of the ocean currents on the submerged portion of the berg. Publications on iceberg drift studies based on field observations (Smith 1931, Murray 1969, NORDCO 1980), confirm that the hydrodynamic drag of the ocean currents is a major factor in the propulsion of large icebergs. Chari et al (1980) suggested that out of the four scouring modes the horizonal ploughing represents the most severe condition in terms of producing the deepest scours. In the mathematical model developed by Chari (1979), an idealized rectangular prismatic iceberg was considered to gouge the sea floor in the above mode. However, for locations where the seabed sediments are dense, this assumption is not realistic.

ICEBERG MANAGEMENT

ALERT ZONE DEFINITION

For contingency planning purposes, four alert zones have been established around each rig. These zones are concentric circles, and defined by time intervals - time for bergs to travel to rig - instead of distance intervals - distance of berg from rig. Time intervals are used since certain rig operations require a specified period of time for completion before they can be properly secured should a berg approach.

The alert zones are defined as follows:

GREEN ALERT ZONE:	Time interval extending from the time the berg is first sighted until it is within 36 hours travel from the rig.
YELLOW ALERT ZONE:	Time interval extending from the time the berg is closer than 36 hours travel from the rig but more than 24 hours travel from the rig.
RED ALERT ZONE:	Time interval extending from the time the berg is closer than 24 hours from the rig but more than 12 hours travel from the rig.
DISCONNECT ALERT ZONE:	Time interval extending from the time the berg is closer than 12 hours travel from the rig.

The radii of the alert zones are a function of the berg drift rate. Generally, drift rates are different for each berg. Also, the drift rate of an individual berg can vary with time.

Therefore, the zone radii in nautical miles varies for each berg, and for an individual berg, this radii may have to be decreased or increased if the drift rate of the berg decreases or increases.

OIL SPILL CONTINGENCY

A considerable amount of work has been done recently to get a better understanding of how an oil spill at Hibernia would disperse. Presently, the oil spill models being used on the Grand Banks use the International Ice Patrol surface current grid as input. This current grid, although useful to obtain a general understanding of the circulation on the Grand Banks, it fails to reflect the temporal and spatial variability. There is no doubt that a better understanding of the surface currents and the mechanics that affect them would be an asset to any oil spill contingency planning.

OFFSHORE DESIGN PROBLEMS

D. L. NORTH, MOBIL OIL CANADA LTD

The offshore structural design process includes a determination of the loads: environmental, accidental, live and dead acting on the structure and the geotechnical considerations governing the foundation. Based on these forces and considerations, a preliminary design is determined. This is followed by a detailed structural design and analysis to insure that the structural design conforms with a relevant design code such as the American Petroleum Institute, "Recommended Practice for Planning, Designing and Constructing Fixed Platforms, RP2A". If the structure complies with these codes, then the structural design is completed. If the design does not comply with the code, iteration of the design occurs until compliance is achieved. The determination of the environmental loads acting on an offshore structure is the subject of this workshop and particularly the relative importance of current to these loads.

The importance of current to the structural design is dependant on the type of structure and its location. A jacket type structure, for example, can have the current force between twenty and forty percent of the maximum wave force. In contrast, a Gravity Base Structure (GBS), where inertia forces are predominant has a current force of less than 2% of the maximum wave force. Thus at Hibernia, if a GBS were used, current would be a relatively small percentage of the load the structure must bear. It is Mobil's judgement that for the purposes of global structural design at Hibernia the maximum current velocities for the design recurrence interval (100 years) are of sufficient accuracy.

The effect of current on structural design as discussed above is a primary one. The secondary effects are, however, of importance in structural design. Icebergs, bergy bits and growlers may attain high velocities under the influence of waves, currents, and winds.

The biggest factor determining the velocity and hence the kinetic energy of large icebergs is the current acting on the berg.

To know the current velocity as accurately as possible is thus an important aspect of the design problem. To complete the design analysis estimates of extreme occurences are necessary. In addition, estimates of the uncertianty of measurement are necessary to enable the designer to determine a "safety factor" which will allow for this uncertianty.

In order to determine the design level kinetic energy of an iceberg colliding with a Gravity Base Structure, it is therefore important to know the depth averaged ocean currents as accurately as possible. This is particularly so because the bergs kinetic energy is proportional to the square of its velocity.

A mathematical model developed by Mobil indicates that large icebergs approach the steady state depth averaged current velocity within 5 to 50 berg lengths. Furthermore Mobil is conducting a series of physical model tests with the objective of establishing iceberg instantaneous velocity when acted upon by currents, waves and wind separately and in combination in order to validate this model.

The smaller the uncertianty, the smaller the "safety factor" which will be needed. A smaller "safety factor" normally results in a lighter and cheaper structure to resist the given environmental loading. There is a "trade off" therefore between measurement accuracy and structure cost. However just where this trade off occures is very difficult to define. The GBS design which now exists is capable of surviving collisions with the des.

The structure will not experience any local failure (i.e. punching shear) or significant global reation (tilt and laterial displacement) during collisions with an iceberg which has many times the design level energy (a 10 million tonne berg travelling at 0.5 knots). The major mechanism by which the iceberg energy is absorbed is by crushing failure of the ice. Moreover, recent model testing work by Mobil indicates that a central hit with a normal velocity by an iceberg on a GBS is an unlikely event. Bergs appear to be cushioned by the water before they strike the structure and are influenced by the flow around the structure which prevents them from striking the GBS "head on".

Another important secondary effect is the scour of foundations caused by sediment transport due to bottom currents. Understanding the bottom current regime, its velocity history and direction is important in assessing the adequacy of structural foundations. One other area where improved understanding of the current regimes is helpful is the prediction of iceberg drift.

It is concluded that for primary structural design, the currents are adequately known. However, in order to fully understand and assess the secondary effects, additional work is warranted to better determine near surface, bottom and depth variations of currents in both time and space.

PHYSICAL OCEANOGRAPHY OF NEWFOUNDLAND SHELF

BRIAN PETRIE, COASTAL OCEANOGRAPHY, B.I.O.

The purpose of this talk is to present the workshop participants with an overview of the physical oceanography of the Newfoundland shelf with particular reference to the Hibernia region. Topics to be covered include the mean circulation, the variability as a function of season, depth and frequency, the Labrador current, the temporal and spatial variations of stratification, tides, wind-forced motions and extreme currents.

a) Mean Circulation:

The average of one year of current meter data from the Hibernia site is 0.02 m/s, south at all depths. Just offshore is the Labrador Current with 0.30 m/s being a representative speed towards the south. The inshore (Avalon Channel) branch of the Labrador Current has a flow of about 0.10 m/s south as well.

b) Variability:

The Hibernia current data were divided into 4 bands: tidal, inertial, 2-10d (primarily wind driven), and - 10d. During fall-winter, the tidal and 2-10d energy dominated while during the summer the tidal and inertial bands were most energetic. On a seasonal basis, the ratio of root mean square amplitude of the subtidal variability to the mean current for the slope (Labrador Current) area was 0.2, for Hibernia 12, and for Avalon Channel 1.0. Thus, at Hibernia, the subtidal variance dominates the mean flow.

c) Labrador Current:

The Labrador Current lies about 90 km east of the Hibernia Site between the 200 - 300 m isobath and has a transport of $4\text{-}5 \times 10^6 m^3/s$. It does move up and down the slope and, based on the 0.1 m/s isotach and 8 irregularly (in time) spaced transects in 1968, moved to within 50 km of the Hibernia Site. The maximum horizontal displacement of the Current was 60 km in 10d. This is somewhat less (by a factor of 2) than the displacements associated with meanders and eddies of the Gulf Stream, south of Nova Scotia. Low frequency r.m.s. currents at Hibernia were half of those measured at the shelf break off Nova Scotia.

d) Stratification:

Vertical stratification is weak ($\Delta\sigma_t$ (0-75m) $\leq$ 0.4) for the months of December - May with maximum stratification in September (2.6).

e) Tides:

The major constituent is M_2 with an amplitude at Hibernia of about 0.11 m/s (2x the next largest). The tidal currents are predictable from a simple model using only coastal sea level amplitudes and phases. On average, the baroclinic tides appear to be small (maximum, 1 yr. data, 0.05 m/s). Solitons are possible when stratified conditions are present but less likely than for the Scotian Shelf since Hibernia is far from the shelf break (90 km) and tidal energy is less.

f) Modelling wind-forced motions:

A simple (acceleration + Coriolis force + forcing = 0) model was tried for 6 storm events, 3 during stratified conditions and 3 during unstratified conditions. Given the model simplicity and data quality, the results were promising. For unstratified conditions, the model tended to underestimate the currents, the opposite was true for the stratified cases. Statistical modelling proved less satisfactory.

g) Extreme Currents:

Based on 1 year of data, the extreme currents were 1.3 m/s, 0.95 m/s, 0.90 m/s and 0.45 m/s for the near surface, mid-depth, near bottom and bottom (1m off bottom) levels respectively. Using the 100 year storm projected from a 33 year A.E.S. geostrophic wind climatology and wind forced models with a range of bottom drag coefficients, the peak near surface current would vary from 1.65 m/s (for $C_D=1.6 \times 10^{-3}$) to 2.4 m/s (for $C_D=0.63 \times 10^{-3}$, the smallest value I found in the literature for shelf situations).

EXPERIMENTAL APPROACH TO
CONTINENTAL SHELF DYNAMICS
BOB BEARDSLEY, WHOI

1. Marine Boundary Layer

   New meteorological sensors allow good measurements of wind speed and direction and other variables to be made from small as well as large buoys. Satellite telemetry is also possible. Instrumented aircraft (like the NCAR research planes) are excellent tools to study the spatial structure of wind field, marine boundary layer, and surface temperature pattern.

2. Accurate in-situ current measurements can now be made with both mechanical (VACM, VMCM) and acoustic techniques throughout the entire water column. We have just conducted an intercomparison between VMCMs, VACM, and an upward looking acoustic unit and find exceptional agreement. A new profiler is under development at WHOI capable of measuring the 3-dimensional velocity vector (x,y,and z components). This will help greatly in mixed layer studies.

3. Recent advances in acoustic instrumention has allowed direct measurement of bottom turbulence and shear stress. These advances have led in turn to better understanding of bottom processes (including Sediment transport) and verification of theories on the importance of wave-current interaction in bottom stress.

4. A number of new Lagrangian drifters are under development which promise to be very useful for coastal studies.

A Coastal Ocean Dynamics Experiment (CODE) has been undertaken to identify and study the important dynamical processes which govern the wind-driven motion of coastal water over the continental shelf. The initial effort in this four-year research program is to obtain high-quality data sets of all the relevant physical variables needed to construct accurate kinematic and dynamic descriptions of the response of shelf water to strong wind forcing in the 2 to 10-day band. A series of two small scale, densely-instrumented field experiments of four-month duration (CODE-1 and CODE-2) is designed to explore and to determine the kinematics and momentum and heat balances of the local wind-driven flow over a region of the northern California shelf which is characterized by both relatively simple bottom topography and large wind stress events in both winter and summer. A more lightly-instrumented, long-term, large-scale component has been designed to help separate the local wind-driven response in the region of the small-scale experiments from motions generated either offshore by the California Current system or in some distant region along the coast, and also to help determine the seasonal cycles of the atmospheric forcing, water structure, and coastal currents over the northern California shelf.

The fundamental importance of wind-driven coastal currents in the entire ecology of the shelf and the conceptual simplicity of a primary energy source in the wind stress and energy sinks in friction and radiation provide a strong motivation for establishing reliable models for these motions. The theoretical problem is complicated, however, by the interaction of the effects of the Earth's rotation, density stratification, variable bottom topography, the possible importance of non-linearities in the governing equations, and poorly understood turbulent mixing and frictional processes. Several models have been developed by Allen and Kundu (1978), Csanady (1978), Hsueh and Peng (1978), and Clarke (1977) using different assumptions about the principal dynamical balances. In most of these cases, however, it is difficult to critically assess the applicabilty of the different models on the basis of existing data sets. For example, the extent to which the alongshore pressure gradient and bottom stress components enter the alongshore momentum balance is still largely unknown. The vertical structure of horizontal currents, the nature of the surface and bottom boundary layers, and the mechanism(s) of stress transfer through the water column are also unclear, primarily because many coastal moored array experiments have been conducted with relatively sparse vertical sampling, especially in the surface and bottom boundary layers. (CODE, WHO I-82-51, Technical Report)

DYNAMICS OF THE CONTINENTAL SHELVES

G. T. CSANADY, WHOI

Wind-driven currents over broad and flat continental shelves have often been calculated from the "Bretschneider formula" which assumes that wind stress equals local bottom stress. Although the order of magnitude of storm or hurricance-driven currents is correctly predicted by this approach, its results are inaccurate for the reason that alongshore pressure gradients of significant magnitude are set up by a wind-stress field, which oppose the wind in some places, support it in others. Early investigations of storm surges by Redfield and Miller (1957) have clearly shown the presence of alongshore gradients large enough to balance or double the wind stress.

Simple theoretical models of the response of a shelf sea with a sloping bottom to nonuniform wind have illustrated in detail the type of pressure fields to be expected. From such calculations one can readily show that maximum storm currents exceed the Bretschneider formula result by typically 50%. So far the theoretical models apply primarily under well-mixed (winter) conditions. When shelf waters are strongly stratified, their response becomes yet more complicated and could involve even stronger surface layer currents, because the force of the wind is distributed over the surface mixed layer instead of the whole water column. Further work on storm currents over a stratified shelf is urgently needed.

THE PHYSICAL OCEANOGRAPHIC REGIME OFFSHORE OF THE NEWFOUNDLAND GRAND BANKS

R.A. CLARKE BIO

The talk attempted to show the time/space scales of the oceanic variability known to exist on the shelf/oceanic boundary and offshore near the Newfoundland Grand Banks as well as the Labrador shelves.

The talk first dealt with the Labrador Shelf. LeBlond (1982) showed that there existed undulations of the offshore edge of the Labrador Current off Hamilton Bank. These undulations move the ice boundary on-offshore over distances greater than 50 km over periods of a few days. Other evidence suggests that the core of the Labrador Current undergoes similar oscillations and consequently the current at a site near the edge of the shelf can change rapidly with time. These undulations are generated through baroclinic or barotropic instability and may propagate as topographic Rossby waves.

Offshore of the shelf and upper slope, deep convection takes place in the Labrador Sea during some winters. As a final stage of this deep convective process, anti-cyclonic eddies, some 15-20 km in diameter, 2 km in depth, are formed in the western Labrador Sea. These eddies have a rotational speed of the order of 0.25 ms $^{-1}$ and exhibit a sharp frontal region along their boundaries. It is possible, therefore, that there is considerable horizontal shear associated with these eddies at their boundaries. It is not known what the lifetime of such eddies is nor how they might move through the ocean; however, similar features seen in the deep North Atlantic have been seen some 3000 km away from their possible source regions. The Labrador Sea eddies could therefore drift into the slope regions of the Labrador Sea and onto the slope off the Grand Banks.

The Labrador Current flowes southward through Flemish Pass and along the shelf break and then turns east and then north near 42 - 43^{o}N. As it flows back to the north, it flows alongside the warmer saltier North Atlantic Current. Other evidence has shown that there are a number of closed or distorted contours suggesting a more complex flow pattern at time amd space scales less than those resolvable by the data set. If we look at the water characteristics. We see that these complexities cause parcels of the warm salty offshore water to be found well up on the slope and the nearshore water to be found offshore.

During the same experiment, one of these patches of cold low salinity water was investigated in greater detail. Evidence has shown features, some 100 km in diameter in which the 10^{o}C isotherm had risen to a depth of less than 100 metres. The sharpness of the boundary is particularly noteworthy. A similar feature in the same area was studies by the U.S. Navy Oceanographic Group a few years later. The relative shear across the boundary is 0.4 ms^{-1} over 1370 m or $3.10^{-4}s^{-1}$.

These features are well documented as occurring in the offshore regime. Can similar warm core features appear inshore? Perhaps! Drifters drogued at 10 meters were released in the warm salty offshore water. One drifter as it passed Flemish Cap, it is caught in an anti-cyclonic circulation first over the lower slope and then around Flemish Cap itself before it moves back offshore again. Such evidence, plus some hydrographic data, indicates that lenses of offshore water can be moved onto the shelves and banks in this region.

Finally, we can look at Flemish Cap for evidence of low frequency variablity. As an attempt to measure this pattern directly, a current meter array was set. Many of these moorings were lost; however, those that were recovered show an energy peak in the 3-6 day frequency. This is the same frequency band in which energy is observed on the Labrador Slope and consequently the same processes may be occurring on Flemish Cap and even further south.

The observational evidence points to the slope regions off Labrador and Newfoundland being regions in which there is a great deal of energy at periods of 3-10 days and horizontal scales of 20-100 km. These processess involve considerable horizontal velocity shear and result in exchange of offshore and inshore water masses. Any monitoring program in this region must take account of these frequency and wave number ranges for this region if the results are to be used for any sort of short to medium time and space scale predictions (a few days, about hundred kilometers) for ice or oil spill trajectories.

NORTH SEA MODELLING
REAL TIME, PREDICTIVE MODELS
N.S. HEAPS, IOS

The development of numerical models for North Sea tides and storm surges is described. The work cited has been done at IOS Bidston during the last fifteen years.

The operation of a two-dimensional vertically-integrated numerical model for the prediction of surge levels and currents over the entire North-West European Continental Shelf is outlined. The model has been linked (for meteorological input) to a 10-layer model of the atmosphere and has been run twice-daily at the British Meteorological Office during the last four winter seasons. Each surge prediction extends forward through 36 hours and corresponds to a forecast of the atmospheric model starting at either midnight or noon of each successive day. Tides are generated in the model as a response to measured Atlantic tides along the shelf edge. The estimation of wind stress is discussed and examples are given of actual surge predictions.

The same model has been used to determine distributions of maximum tide and surge current; evaluation of the extreme surge currents was based on results obtained from running the model for sixteen major storm situations. Also, the model has been extended across the shelf edge (with the same spatial grid resolution: $1/3^{o}$ longitude x $1/2^{o}$ latitude) to cover a larger area of the North-East Atlantic Ocean. Tides have been generated in the extended model, particularly M_2 and K_1, accounting for the tide-generating forces and earth-tide effects. All this has been mainly the work of Dr. R.A. Flather of IOS Bidston.

Three-dimensional models of the North Sea, and the Irish Sea, have been employed to estimate the structure of tide and surge currents. These models, described in outline, use finite-differences in the horizontal and a functional representation through the vertical. The present stage is still one of development, research experimentation and testing against observations. With uncertainty about eddy viscosity coefficients, this phase of the work is likely to continue for some time - before such models are sufficiently reliable to be used in real-time prediction. Dr. A.M. Davies and myself are involved at Bidston.

ICEBERG DRIFT PREDICTION BY THE INTERNATIONAL ICE PATROL
BY DAVID O. MOUNTAIN, WHOI

The model used by the International Ice Patrol to predict the drift of icebergs was described. The model operates by solving differential equations which balance the iceberg acceleration with the water drag, the Coriolis acceleration, and a sea surface slope term. A fourth order Runge-Kitta technique is used. The water drag is summed over up to four layers of the iceberg by using a constant geostrophic current plus a time dependent Ekman current which is averaged over each layer. Inputs to the model are:

1. A mean geostrophic current field from historical data

2. Mean mass and size characteristics for various classes of icebergs.

3. Wind data from the U.S. Navy FNOC,

4. Initial iceberg positions from aircraft overflights.

Testing of the model has been limited by the relatively few observed tracks of icebergs. Errors were about 80 km over 20 days and 500 km of drift in one case. The errors are believed more related to errors in the inputs to the model than to the physics of the model itself. The primary sources of error are believed to be the wind and currents provided. Current measurements in the Labrador Current indicate considerable variation that cannot be attributed to an Ekman response to local wind forcing. Better understanding and prediction of local current variability will be required for more accurate iceberg drift predictions.

HINDCASTING OF ICEBERG DRIFT FROM OPERATIONAL DATA

STUART D. SMITH
OCEAN CIRCULATION DIVISION
ATLANTIC OCEANOGRAPHIC LABORATORY

Programs for monitoring and forecasting currents off Newfoundland and Labrador are motivated in large part by the need to forecast the drift of ice and icebergs. A hindcasting study has been carried out to determine how well the drift of icebergs can be modelled if winds and currents are available.

The tracks of a large number of icebergs off the coast of Labrador have been made available through COGLA, together with winds and currents measured at drillships, usually at hourly intervals, and estimates of iceberg size and shape. The current data containing many gaps, were logged by hand as spot readings rather than hourly averages and were available only at a depth of 50 meters. (Currents measured at 15 meters below the surface were not used since it was felt that they would be influenced by the hull of the ship; the 15 meter currents were also qualitatively seen to be less well related to observed iceberg drift).

A numerical model was constructed to apply quadratic wind and current drag forces to an iceberg and, given its estimated mass and cross-sectional area in air and in water, to compute its drift track. Coriolis force and sea surface tilt (assuming geostrophic currents) are taken into account. Lacking any measurement of air and water drag coefficients, which are expected to vary with iceberg shope, an iterative procedure is used to adjust the two coefficients to give a least-square fit of the modelled track to the observed track.

Results of modelling twelve iceberg tracks selected from the available data showed only about 1 km rms error over a drift track of 8 to 30 km in the majority of cases although in a minority of cases the reported winds and currents did not permit a reasonable representation of the observed drift. In certain other cases, the procedure has given a reasonable representation of the drift track by selecting very high or very low drag coefficients which did not appear physically reasonable. Towing forces can be inserted in the model and have been used both to estimate the potential effect of towing on a drift track and to estimate in hindsight the effect which actual towing has had on the paths of several bergs.

In cases where the fitting procedure produced reasonable results we are able to draw several conclusions: (1) The wind drift accounts for nearly as much of the hourly drift as the currents. (2) Towing forces can deflect but cannot fully control the drift of the larger icebergs. (3) Even the largest icebergs respond to changes in currents and winds within an hour, and will drift in a clockwise spiral typically of 2 km diameter or less if winds and currents cease. (4) A grounding event of a large iceberg has been identified and M. Lewis of AGC has identified the scour track on a sidescan sonar survey. We are using the model to estimate the bottom forces during the scouring event.

WORKING GROUP PRESENTATIONS

1. PROCESSES GROUP PRESENTATION

Initially, J. Elliott noted that there appeared to be three major concerns expressed by Mobil, namely, iceberg drift, Subsea Excavation filling and oil spill contingencies. Dealing with any of these requires a knowledge of currents.

Five topics were discussed: the Labrador Current, Grand Bank circulation, surface currents, iceberg dynamics and sediment transport.

Labrador Current

The Labrador Current carries icebergs to the Grand Banks. It was thought that, to produce current information for tracking icebergs, the latitude (52°N) of Belle Isle could serve as the northern (input) boundary for observational or modelling efforts. Attention should be paid to the strength and variability of upstream currents (north of Grand Bank), the spatial distribution of icebergs relative to the flow, and the possibility that the Grand Bank could be seeded with bergs by the inshore (Avalon Channel) branch of the current with subsequent eastward movement. Effort should be directed to understand mechanisms by which bergs move out of the offshore branch onto the shelf. Wind forcing and current instabilities were offered as possible candidates. Finally, attention should be given to understanding the driving forces of the Labrador Current and if these be of basin scale then consideration should focus on local mechanisms (thermohaline, for example) which could modify the flow.

Grand Bank Circulation

The group noted that the circulation on the Grand Bank must be considered as a whole and not be confined to one specific location. Processes which need study include the following:

o *Wind-driven circulation on the Grand Bank with attention paid to inertial oscillations, surface wave-current interactions and, for modelling, the open boundary conditions.

- *Mean circulation and dispersion.
- *Tidal circulation (as a generating mechanism for energetic, non-linear waves, as well).
- *The effects the Labrador Current and meanders of it on shelf circulation.
  - *Thermohaline circulation.
  - *Topographic effects (canyons, e.g.)

Tools for addressing these problems should consist of numerical, analytical and observational studies. Use should be made of available data which, besides conventional types, should include ice movements, distribution of biological variables, sea surface temperature maps, satellite photos, satellite tracked drifters and SAR data. Bottom pressure sensors could prove useful, especially, during periods of weak or no stratification.

Surface Currents

Surface currents were discussed primarily in the context of oil spills. The weak mean circulation on the Grand Bank leads to the dominance of wind induced flow. Residence times and the rate of dispersion on the banks need to be addressed. Thus, it was thought that Lagrangian drifters would be the most useful tool in studying these problems. These could include satellite tracked drifters or natural drifters (e.g. icebergs).

Iceberg Dynamics

Modelling the drift of icebergs is a problem confounded by difficulties in specifying inputs. The scatter of drag coefficients on bergs of models presently in use is worrisome. The 1983 field program outlined in the opening session was thought to be a good step forward. Other suggestions offered were wind tunnel modelling of forces on bergs and the study of the effects the microenvironment produced by melting around the berg would have on its movement.

Sediment Transport

The group thought that it was really not well-versed enough in this topic to offer definite suggestions. It was noted that other programs previously discussed would be only marginally relevent as they did not resolve/address the bottom boundary layer and that surface wave - current interaction would be an important consideration.

2. MODELLING GROUP PRESENTATION

At the outset, the point was made by N. Heaps that models of ocean circulation are in a rapidly evolving state. Any recommendations of the group are thus preliminary and subject to change as our knowledge of the region, and the development and understanding of particular models advances.

Three topics were discussed: Two Dimensional Current Prediction models, Localized Current Prediction models and Iceberg Drift models.

Two Dimensional Models

To determine the large scale (20km) features of the depth-integrated flow it was suggested that a two-dimensional model of the area be developed. This would be used to model the tides as well as the residual flow driven by tidal stresses, wind stress and atmospheric pressure. Such a model would initially be restricted to the Grand Banks region, excluding Flemish Cap, and would be bounded to the north by the Straits of Belle Isle, to the south by Cabot Strait and elsewhere by the 400m isobath. A grid spacing of order 10-15 km would be used. The need to understand the influence of motions occurring at greater depths was also recognized. Since the Labrador Current, the dominant source of deep water forcing, would not be reproduced by such 2-D models, it was thus suggested that the examination of this question might be better approached through the use of idealized theoretical models (this is currently an area of active research).

The successful development and implementation of models of this nature required the following data: (1) Open boundary tidal data with observations over a sufficient duration to evaluate meteorological influences on elevations at the boundaries; (2) Calibration and verification data (currents, elevations) both offshore and along the coast (particularly near areas of important application); (3) Collection of meteorological data and evaluation of its usefulness. A procedure for rapidly obtaining the necessary data in a readily useable format must also be developed.

At present, it is recommended that efforts be directed toward models capable of providing current profiles; large scale 2-D models augmented by local 1-D vertical models, large scale 2-D models extended to include depth varying currents.

Localized Current Prediction Models

The discussion concentrated on the possibility of using relatively small and uncomplicated models, which could be implemented on micro or minicomputers (or on a pocket calculator), to give estimates of the local current profile as a function of time. Such models include back-of-the envelope calculations (3% of the wind speed style); 1-D, time-dependent Ekman layer models including the influence of stratification in which the eddy viscosity is parameterized as a function of the local Richardson number. Such models could be used to estimate the local vertical structure and hence supplement large scale 2-D modelling efforts.

An additional possibility is the use of "statistical" models in which the local currents are related statistically to more easily determined quantities which are expected on dynamical grounds to be correlated with the local currents.

The point was made that models of the above type may be no less accurate than more complicated models and would probably be required for backup purposes regardless of other larger numerical models run at some distant operations centre.

Iceberg Drift Modelling

Discussions addressed design and operational considerations, as well as the need to perform additional mathematical investigations aimed at improving drift forecasts. Design and operational calculations mentioned included maximum iceberg velocity calculations for design purposes, the concept of reverse modelling -- a means by which hazard zones could be predicted, and the use of models to provide iceberg towing feasibility estimates. The need to perform additional mathematical investigations centered on the perceived difficulty of forecasting the drift of an iceberg when little is known of its underwater shape, or of its orientation (and hence drag) as a function of time. In particular, it is felt that more attention should be paid to non-deterministic models (based on statistical relationships between prior met/ocean conditions and iceberg movement history). Such an investigation would include determination of the nature of the driving forces through analysis of meteorological and oceanographic records, and of iceberg accelerations.

Long term iceberg drift models were also discussed. Models such as that developed by Dave Mountain for the International Ice Patrol warrant further investigation. In connection with the long term drift problem, examination of the spatial and temporal variability of the Labrador Current should also be undertaken. Studies should include the influences of local wind stress, large scale wind stress curl and thermohaline forcing.

Dynamical models should also be used to investigate the cross-isobath excursion of the Labrador Current onto the shelf as well as indirect influences which meanders of the Current may have on currents on the shelf.

3. Measurements Group Presentation

The Measurements summary covered three topics -- Models and Their Input Requirements, Spatial Scales of Variability, and Conclusions. The first topic mentioned three model types, iceberg trajectory, surface circulation, and sediment transport. The three model types have similar needs: wind and atmospheric pressure field, salinity and temperature (primarily needed for stratification determination) and wave field (as needed for surface effect and bottom stress calculations). The second topic briefly covered horizontal and vertical scale questions. Modelling of large scale processes requires information some 200 nm upstream, while small scale processes modelling requires information over some 10-50 nm. A determination of modelling strategy requires preliminary information on the spatial scales of currents, wind, and perhaps bottom pressure if estimates are to be made of the number of data gathering points. Although initial estimates might be obtained from the analysis of existing data, it is likely that field experiments will have to be performed. The third topic -- a statement of the group's conclusions -- covered six areas:

a) The need for the analysis of existing current data:

- o Quality assessment.
- o Spatial coherence computations.
- o Assessment of vertical profiles.
- o Assessment of seasonal variability.

b) The need for the analysis of existing wind data:

- o Spatial coherence computations.
- o Assessment of predictive schemes depending on land-based measurements.
- o Determination of improvement that could result given additional sea-based input.

c) Remote sensing investigation:

- o Historical IR data recorded by Shoe Cove (to be closed January 1983).
- o Environmental Data and Information Service (EDIS) NIMBUS-7, Coastal Zone Color Scanner (CZCS) Data (many tapes, few images yet processed).

Both for location of offshore currents and fronts.

d) Measurement program suggestions:

- o Solitons, using echo sounder, XBT's, and thermistor chains.
- o Improvements in wind measurements - location on rig, use of several sensors per rig.
- o Pilot study, combining current meter arrays with drifters (see below).

e) Technology consideration to be given to:

- o CODAR
- o Doppler current profilers.
- o Iceberg detection and tracking.
- o Mooring technology assessment before pilot study.
- o Data transmission.

f) Pilot study - to address any remaining unanswered questions after completion of a) and b) above. A typical study would comprise:

- o Some 8 drifters to be repeatedly tracked as they pass through an instrument array.
- o Instrument array to consist of 5 current meter strings spaced at center and ends of perpendicular cross with arms of unequal lengths.
- o Spatial coverage of experiment: some 30x30 km.
- o Duration of experiment: approximately 100 days.

After the workshop, comments by Bob Beardsley were received by the secretary. These have been added to the measurements group products. The comments are based on his Georges Bank experience.

STEERING COMMITTEE MEETING 9:00 AM, 1 October 1982

A meeting was held at the Bedford Institute of Oceanography on the morning after the workshop. Attending were:

J. Benoit	Mobil
J. Elliott	BIO
C. Garrett	Dalhousie
C. Mason	BIO
C. Mungall	Mobil
B. Petrie	BIO
M. Sheppard	Mobil

The purpose of the meeting was to summarize the workshop and to suggest means by which the workshop recommendations could best be implemented.

1. The workshop report format was discussed. It was concluded that a preliminary draft report should be produced with contents A through E as follows:

   A. Executive Summary

   B. Agenda

   C. List of Participants

   D. Summary*

   E. (Appendix): Abstracts

   A fuller description of the workshop should also be made available as a limited edition. The contents would consist of:

   A. Individual presentations:

      Abstract
      Copies of visual aids
      Text of presentation (when available)
      Suggested bibliography
      Pertinent reprints

   B. Working group results:

      Processes*
      Modelling*
      Measurements*

* Item could be transcribed from cassette

C. Steering committee recommendations.

D. Appendix: summary of audio recordings of presentations available on cassettes.

2. The composition and preliminary mandate of a possible steering committee was discussed. It was felt that the following should be represented on such a committee:

Universities:	
Newfoundland (Memorial)	- Alex Hay
Nova Scotia (Dalhousie)	- Chris Garrett
Government Scientific Institutions:	- Clive Mason
Bedford Institute of Oceanography	- Brian Petrie
Oil Industry	
Petro Canada	- Joe Buckley
Hibernia Operator (Mobil)	- David MacClelland
	- Jacques Benoit (represented as required by Chris Mungall)

The following items were identified as being likely candidates for inclusion in a mandate:

A. Discuss study objectives and time frames.

B. Ensurance of adequate timing and quality.

C. Coordination and avoidance of duplication.

D. Overview of other related work.

E. Pooling of data and summary of same and information exchange.

F. Identification of scientists who would provide advice or work on specialized topics.

3. A discussion was made of the first activities to be undertaken:

A. Determination of committee members and mandate.

B. Initiation of paper studies (yet to be identified).

C. Merging of BIO and industry 1982/83 winter field measurements.

D. Recommendations for data gathering - e.g., location, time intervals, depths, etc.

E. Recommendations for standard analysis procedures and data presentation formats.

It was hoped that a meeting could be set up at the earliest possible time to discuss the above and other items.

4. During and subsequent to the steering committee meeting, several types of studies using existing data were mentioned as being appropriate for early initiation. A partial list of such topics, mentioned variously by the committee or by Mobil, follows:

   A. Iceberg trajectory analysis - rotary spectra to determine the likely divisions of driving force on the basis of frequency.

   B. Horizontal rotary coherence: current-current, wind-wind, etc.

   C. Synthesis of Labrador Current knowledge - i.e., compilation of summaries by people such as John Lazier (BIO), J. B. Matthews (University of Alaska), and of references to the Labrador Current in recent oceanic-scale modelling papers or reports.

   D. Recommendation for preliminary analytical-type model of the Labrador Current (Csanady) for use in providing insight into the current.

   E. Preparation of annual summary reports on Mobil's current data, with supplementary information, statistics, as deemed appropriate.

   F. Using recently obtained paired Aanderaa and Marsh-McBirney current meter data, produce a technique for assessing the likely amounts of wave contamination present in near-surface data taken by BIO, Mobil or others using Aanderaa and similar older current meter types.

   G. As funds permit, apply the results of F) above to data sets of interest.

   H. Investigation of Mellor single point, stratified wind-driven current model operational characteristics. In particular, look into spin-up and spin-down behavior, estimate period that can be modelled before assumption of horizontal homogeneity contaminates model, etc.

5. The need for a joint measurement program addressing horizontal coherence scales should be discussed as soon as possible.

6. Other items requiring attention include:

   A. 2-D tidal models - to some 400m and/or to abyssal depths.

   B. Consideration of normal mode 3-D models to be used instead of above when inertial currents are deemed of interest.

   C. Acquisition of digitized bathymetry data base for use by modellers.

D. Acquisition, if possible, of U.S. Navy tidal <u>currents</u>, probably produced along with E. Schwiderski's Global Ocean Tide Data (11 sets of harmonic tide height constants for the world ocean) for use in estimating N.W. Atlantic tidal currents.

E. Consideration of satellite imagery for determination of Labrador Current variability.

7. The meeting ended at 10:00 AM.

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SUMMARY

Chris Garrett of Dalhousie University provided the closing summation. He first expressed pleasure at the presence of personnel from industry, government and university, pointing out the benefits that each sector can obtain from cooperation with the others. He then discussed the following key problems or ideas that had emerged from the workshop:

1) Given Mobil's serious consideration of a fixed production platform, it seems that the central problem we are concerned with is that of extreme currents for estimation of the potential effect of iceberg impact. (Although the design problems with respect to ice are hard to grasp and rather mind-boggling). There seems to be some confusion about the maximum currents that could be reached, the design currents are 1.5 ms^{-1} at the surface and 0.5 ms^{-1} near the bottom (but less for iceberg impact). Brian Petrie found values close to this by adding the maximum r.m.s. values in different frequency bands, but estimated 2 ms^{-1} as a possibility. Unless we are told by the design engineer that, say, 2.5 ms^{-1} presents no problem, a refinement of the estimates may be a top priority.

2) The talks by Petrie and Heaps showed how extreme oceanographic conditions can be estimated not only from an adequate oceanographic data base (seldom available) but also by matching a short oceanographic time series, via a regressive or dynamical model, to imputs such as tides and meteorological forcing for which longer time series are available. This is an important technique.

3) The workshop drew attention to the need for a hierarchy of models, including:

   (i) back-of-the envelope estimates (e.g. current = 3% of wind)
   (ii) 1-D models, analytical and numerical
   (iii) regression models
   (iv) semi-analytical models (e.g. Csanady's)
   (v) 2-D numerical models
   (vi) 3-D numerical models, homogeneous and stratified conditions

   It is interesting that no one at the workshop tried hard to sell elaborate 3-D models; we all appreciated that in their present state they probably would not tell us, reliably, anything that we cannot learn from simpler models. Also, it is important to realise the need to inter-relate models, i.e. to interpret the output from complicated models in terms of expectations from simple calculations.

4) Measurements are needed to back up model predictions. There appears to be considerable doubt about the quality of existing current data from the Hibernia area, due to problems of mooring motion and analysis. It is essential that the data be looked at very carefully, and that the dubious data be discarded before they mislead us. Better data on surface currents may require some rather new technology (VMCM's, range-gated Doppler sonar, etc. as discussed by the measurements working group).

5) We should also make full use of Lagrangian measurement techniques (drifters of various sorts), see if the weekly sea surface temperature maps tell us anything, and collect any available satellite IR data. These approaches are particularly relevant to the oil spill trajectory problem, but satellite imagery in the visible band may also provide useful information on internal solitons.

6) Any proposed observational scheme has to be assessed carefully for the contribution it will make to practical goals. For example, we can probably justify a program of bottom pressure measurements as an input to a tidal model and a check on a 2-D wind-driven model, but the need for fine-scale wind measurements or an elaborate current meter array is less clear. Further thought is required, using results from elsewhere in the world (e.g. on current coherence scales) and simulation studies.

7) The prediction of iceberg trajectories is a fascinating one, but there is considerable doubt about the value of the models that seem to be in use at the moment. For one thing, a model that hindcasts well is of limited value if the inputs to it are difficult to forecast. We need more simple estimates to help build our intuition, as well as, perhaps, different types of forecasting model. Basically, the iceberg moves with the water. If the sea surface slope term is left out for geostrophic currents, or put in for inertial currents, this cannot happen in the model. The error can be estimated as a spurious drift, at right angles to the flow, of order (HfV/C_D), where H is the berg depth, V the water speed and C_D a drag coefficient. If H=50 m, $f=10^{-4}$ s $^{-1}$, v=0.5 ms^{-1} and $C_D=1$, we have a drift of 0.05 ms $^{-1}$, which could matter. On the other hand, the drift off the mean current due to wind is 1 or 2% of the wind speed. The current speed is the key factor in iceberg drift, and it may turn out that the best prediction scheme will involve fitting an observed bit of track to predicted tidal currents plus arbitrary mean and inertial currents, plus an allowance for wind, then extrapolating the result.

   To back up this kind of approach, it would clearly be useful to analyse existing iceberg trajectory data, even if there are inadequate oceanographic and meteorological data to go with them.

8) There are reasons to doubt the value of the oil spill trajectory models that have been used. Their neglect of the substantial low frequency variability in shelf currents seems dangerous.

9) The establishment of an industry/government/university steering group, to coordinate further work and provide a forum for the exchange of information, is important. However, everyone agreed that continued goodwill and cooperation from individuals in government and universities will depend on a readiness on the part of industry to release information, on relevant studies, at an earlier stage than usual.

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