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THE CONTINENTAL SHELF PHYSICAL OCEANOGRAPHIC MODEL EVALUATION WORKSHOP

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JAYCOR

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FOREWORD

Some nine months ago JAYCOR — together with its team of distinguished consultants in oceanography from various universities — was awarded a contract by the U. S. Department of the Interior, Bureau of Land Management, to perform an assessment of the state-of-the-art of physical oceanography models and their utility for application to the South Atlantic

As the work on the project progressed it became clear to us that peer review by a cross section of the community would serve a number of purposes for the BLM, to include:

- Introduction of the latest work for consideration, including ongoing work not yet published
- Acquisition of a more complete spectrum of expert opinion on the various topics
- Assurance of objectivity in the conclusions of the model assessments.

An effective review of the assessment results would thus assure both the BLM and JAYCOR of a useful product.

With this in mind, the BLM asked JAYCOR to convene a small group of three or four experts to review each of the four topical areas assessed, i.e., surface, water column, sediment transport, and ocean-structure interaction models.

These proceedings are intended to reflect the full range of viewpoints expressed by both the working groups as a whole and by individual participants. The need to publish these proceedings in time for their use in the formulation of the next phase of the BLM South Atlantic OCS research has precluded either their broader review by the community or even by the participants themselves. Nevertheless, we at JAYCOR do not apologize for them; rather, we feel privileged to have been able to host this outstanding group and proud to reflect their opinions in these proceedings.

I, for one, feel the workshop was a complete success — a view I know, from discussions, that I share with both BLM representatives and the distinguished participants. Certainly the workshop served to focus on realistic solutions to very real problems being faced by BLM in its continuing program of OCS oil and gas development. Although highly sophisticated, state-of-the-art models of all kinds were discussed, the emphasis during group discussions was on those models which were most likely to produce meaningful results for BLM in the context of their management decisionmaking framework. This was perhaps the most unique feature of this workshop.

Needless to say, there are numerous problems to be solved if we are to improve our capability to utilize state-of-the-art models in management decisionmaking; but, as was clearly emphasized during the two-day meeting, a great deal can also be done with existing tools.

We are grateful to both the BLM and the participants for making the workshop possible. On the basis of the results, it is my hope that the ocean modeling community will conduct such activities on something like an annual basis.

R. Michael Dowe, Jr.
JAYCOR, Vice President for
Environment and Advanced Technology

ENVIRONMENTAL STUDIES PROGRAM OBJECTIVES AND THEIR RELATIONSHIP TO THE JAYCOR MODEL EVALUATION STUDY

DR. E. D. WOOD - COAR
New Orleans OCS Office - BLM

and

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The Department of Interior through the Bureau of Land Management (BLM) has the responsibility for the leasing of Federal lands on the Outer Continental Shelf (OCS). The protection of the marine environment and the assessment of impacts as a result of oil and gas (O&G) exploration and development activities are also part of the BLM mission as required by the OCS Lands Act of 1953, the National Environmental Policy Act (NEPA) of 1969, and the OCS Lands Act Amendments of 1978. BLM has been authorized to enter into a studies program to gather information needed to carry out this mission. The studies program for the South Atlantic OCS is coordinated through the New Orleans OCS Office which has the responsibility for leasing and studies on the OCS from the Texas-Mexico border to the North Carolina-Virginia border. The South Atlantic OCS Region, shown in Figure 1, extends from Cape Hatteras to Cape Canaveral and can be considered as two areas: the Georgia Embayment - Carolina Capes and the Blake Plateau.

The OCS studies program objectives are:

1. To provide information about the environment that will enable the Department of the Interior and the Bureau of Land Management to make sound management decisions regarding the development of mineral resources on the Federal OCS.

2. To acquire information which will enable BLM to assess the impact of O&G exploration and development on the marine environment.

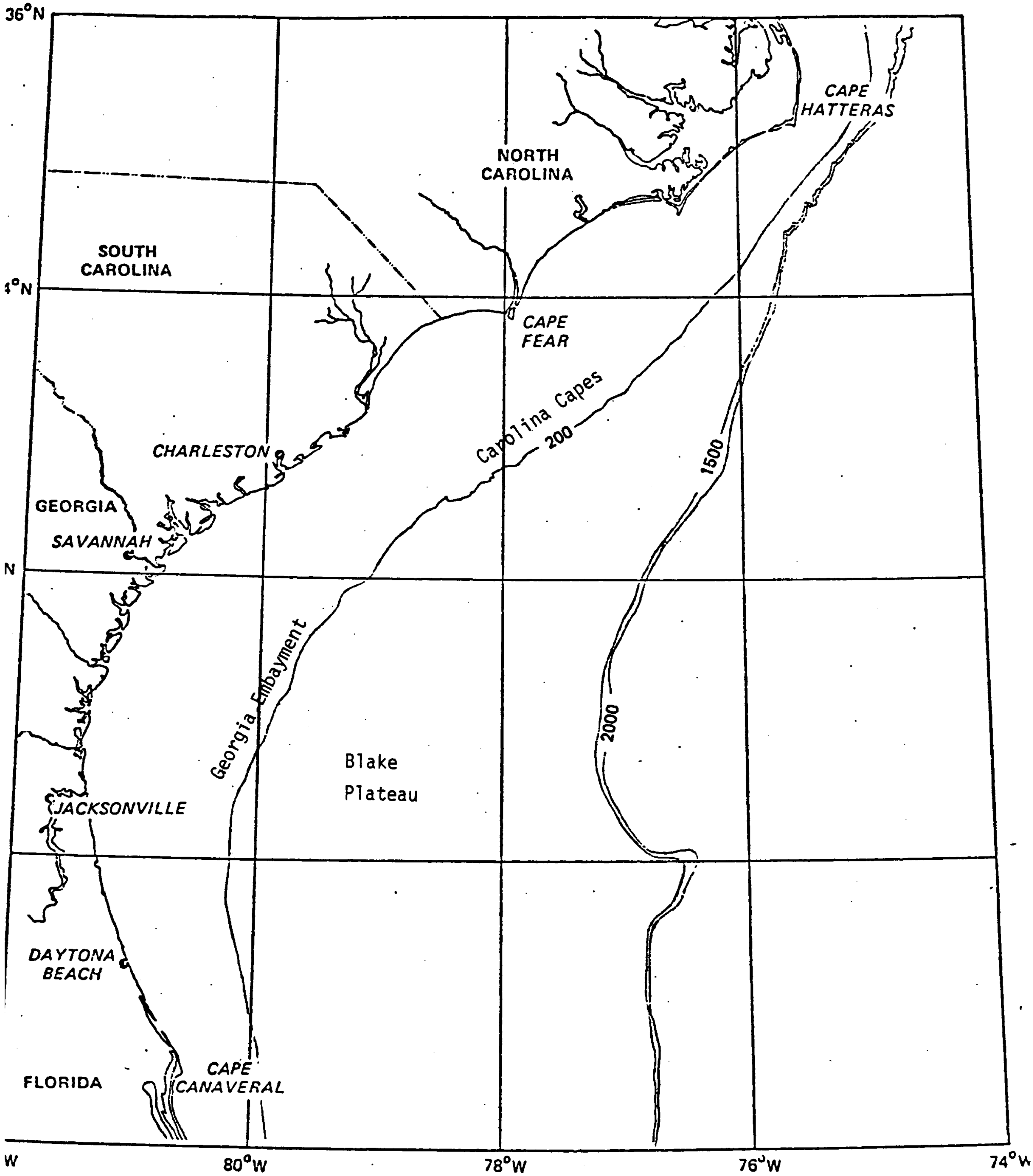


Fig. 1 South Atlantic Outer Continental Shelf Oil and Gas Lease Area.

3. To establish a basis for prediction of impact of OCS O&G activities in frontier areas.

4. To acquire impact data that may result in modification of leasing stipulations and OCS orders, notices, and guidelines which provide for efficient resource recovery in conjunction with environmental protection.

The program consists primarily of biological, chemical, physical and geological oceanographic investigations. The investigations include specific studies of effects of oil on marine organisms, fates of petroleum hydrocarbons in the marine environment, characterization and delineation of ecologically, commercially or recreationally important biological assemblages, distribution of marine mammals, seabirds and turtles; conflicts of petroleum development activities with other resources and space uses; determination of environment hazards (geologic, meteorologic and oceanographic) to OCS related structures and facilities; and coastal circulation patterns. Investigations of archaelogical resources, air quality, and socioeconomic impacts of petroleum development activities are also conducted.

Study activities in the South Atlantic OCS region began with a literature review by the Virginia Institute of Marine Sciences (VIMS) funded through the Council on Environmental Quality. This study covered literature through 1973.

In 1975, BLM held a conference/workshop in Atlanta, Georgia, to solicit recommendations from scientists, industry and the private sector. BLM subsequently funded studies which addressed about two-thirds of the nearly one hundred recommendations. Table 1 contains a list of studies active in the South Atlantic OCS including two that will be funded later this summer.

TABLE 1. SOUTH ATLANTIC OCS STUDIES
STATUS AND PLANNING

BENCHMARK PROGRAM	CT7-2	TI
GEOLOGICAL OCEANOGRAPHY	MU6-56	USGS
GEOLOGICAL OCEANOGRAPHY	MU8-13	USGS
GEOLOGICAL OCEANOGRAPHY	MU9-8	USGS
VIMS REPORT UPDATE	CT7-39	CNA
MARINE BIRD STUDY	MU8-12	USFWS
HARD BOTTOMS STUDY	CT8-25	CSA
LIVING MARINE RESOURCES	FY'79	
CULTURAL RESOURCES SURVEY	CT8-40	SAI
MARINE MAMMALS, TURTLES, BIRDS AND ENDANGERED SPECIES	FY'79	USFWS
PHYSICAL OCEANOGRAPHY LIT	CT7-16	ERT
PHYSICAL OCEANOGRAPHY FIELD - 1	CT7-29	SAI
PHYSICAL OCEANOGRAPHY FIELD -2	CT8-52	SAI
DATA BUOY	IA6-3	NDBO
DATA BUOY	IT8-37	NDBO
SATELLITE OCEANOGRAPHY	IA8-39	NASA
CIRCULATION MODEL EVALUATION	CT8-34	JAYCOR
CIRCULATION MODEL APPLICATION	FY'79	

Table 1.

Of the physical oceanographic studies, the literature survey and data analysis of the physical oceanography and meteorology information is nearly complete. The physical oceanography field study is in the second year of a planned three-year program. The draft progress report for the first year's study has been received for review.

A data buoy monitoring meteorological and sea state conditions was deployed off Charleston, South Carolina, in June of 1978. A second buoy was deployed in March, 1979 off Savannah, Georgia, and a third is due for deployment in June, 1979 off Jacksonville, Florida. All buoys are near the shelf edge on the 45 m isobath.

Sea surface information has been obtained through the analysis of GEOS-3 radar altimetry data by the Wallops Flight Center/NASA. The Circulation Evaluation Study is the one this workshop is to critique. The second phase of the modeling effort, Circulation Model Application, will be funded this summer.

BLM is now in the process of formalizing the study plans for Fiscal Years '80 and '81.

The tracts offered in lease Sale 43 in March, 1978, are shown in Figure 2. Also shown are the transects sampled by the benchmark study. Hydrographic stations were occupied on these and similar transects. Current meter data has been collected from the northern lease tract area by BLM and to a limited extent off Brunswick, Georgia. The Department of Energy (DOE) supported work has covered the area off Savannah, Georgia, and in Onslow Bay, North Carolina. The BLM and DOE programs have been well coordinated sharing ships, equipment and personnel.

The studies program in general and this modeling effort in particular are important to BLM in making decisions affecting O&G activities resulting from Sale 43, the next sale on the shelf, Sale 56, and a sale on the

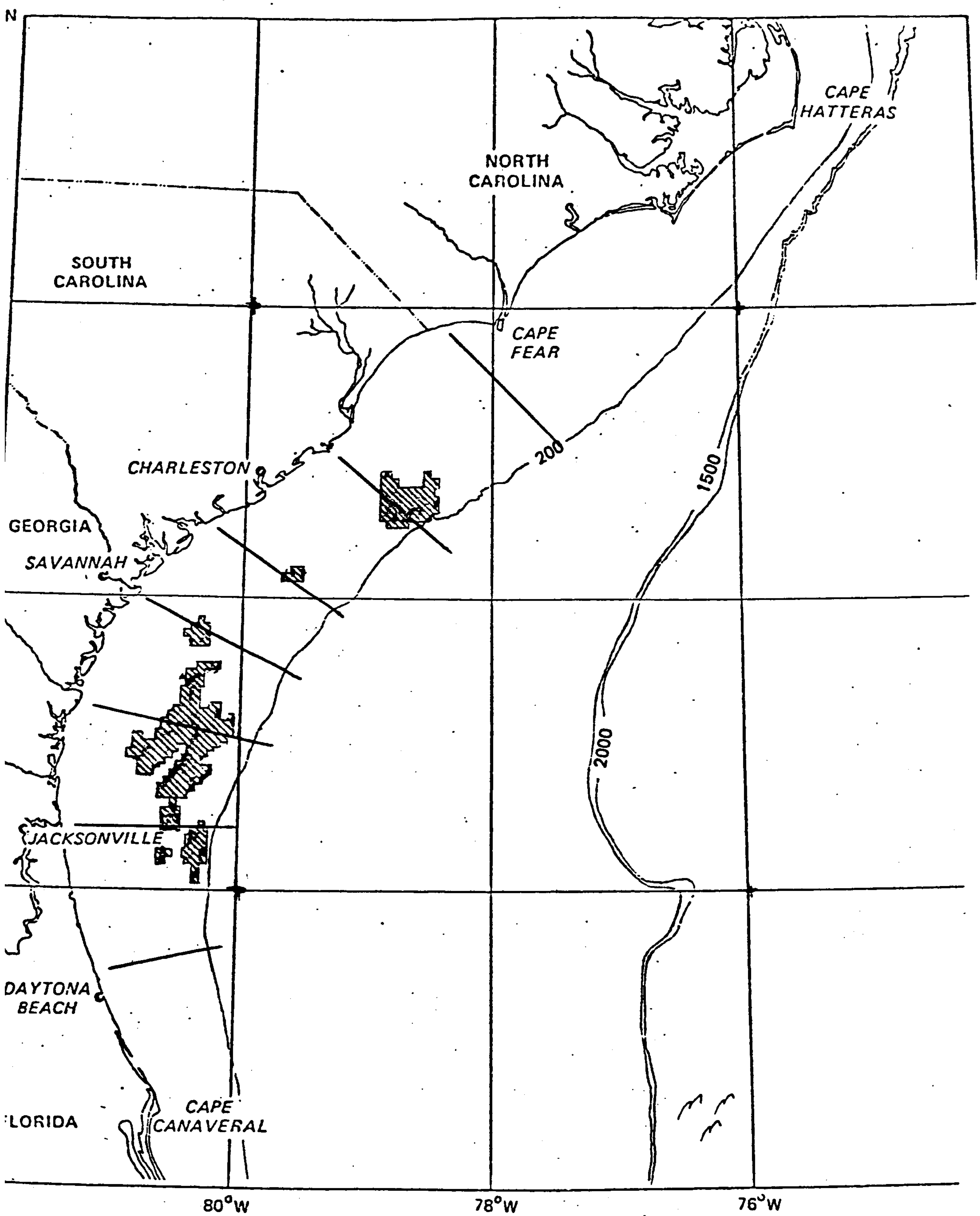


FIG 2. Tracts Offered for Lease in Sale 43 and Transect Lines Sampled by Several BLM Studies.

Blake Plateau. Nominations for Sale 56 are due in May, 1979, with the sale scheduled for April, 1981. The Blake Plateau Sale is tentatively slated for January, 1984.

Figure 3 shows nominations for a Blake Plateau Sale (54) that was cancelled. It is interesting to note that the meandering Gulf Stream covers most of the tracts nominated. This fact plus the water depths (200 to 1,000 m) will create problems for O&G exploration and development on the Blake Plateau.

Exploratory drilling will take place in the near future on tracts sold in lease Sale 43. A drill rig is presently in transit from the North Sea to begin drilling off Brunswick, Georgia, toward the end of May. Figure 4 shows the sites planned for drilling (note the difference in map scale from Figures 1, 2 and 3).

Circulation modeling is important in this area not only for the prediction of oil spill trajectories, but to determine the transport of drill needs and cuttings, petroleum hydrocarbons, and trace metals in the water column or along the bottom, especially in the proximity of sensitive biological habitats.

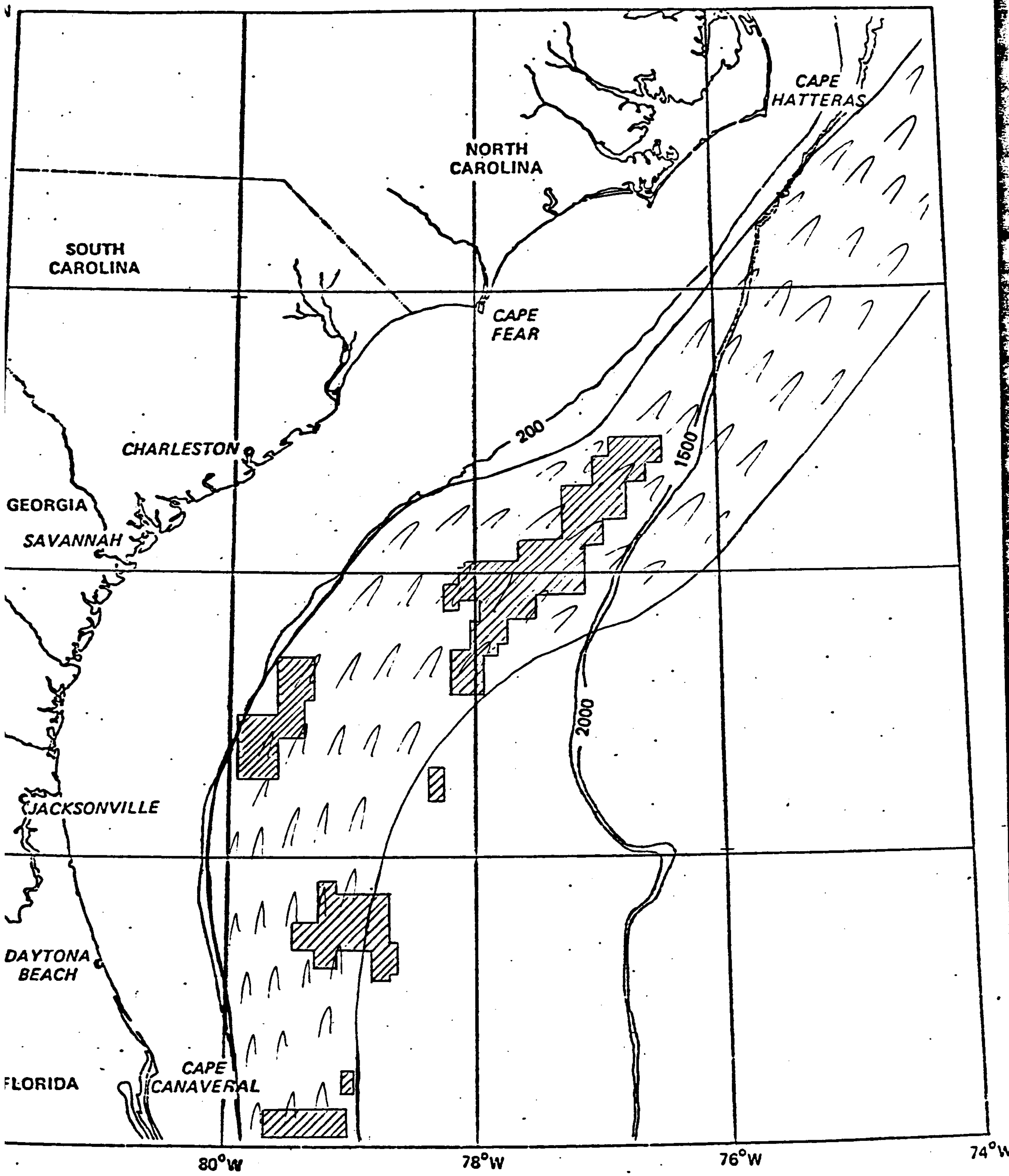
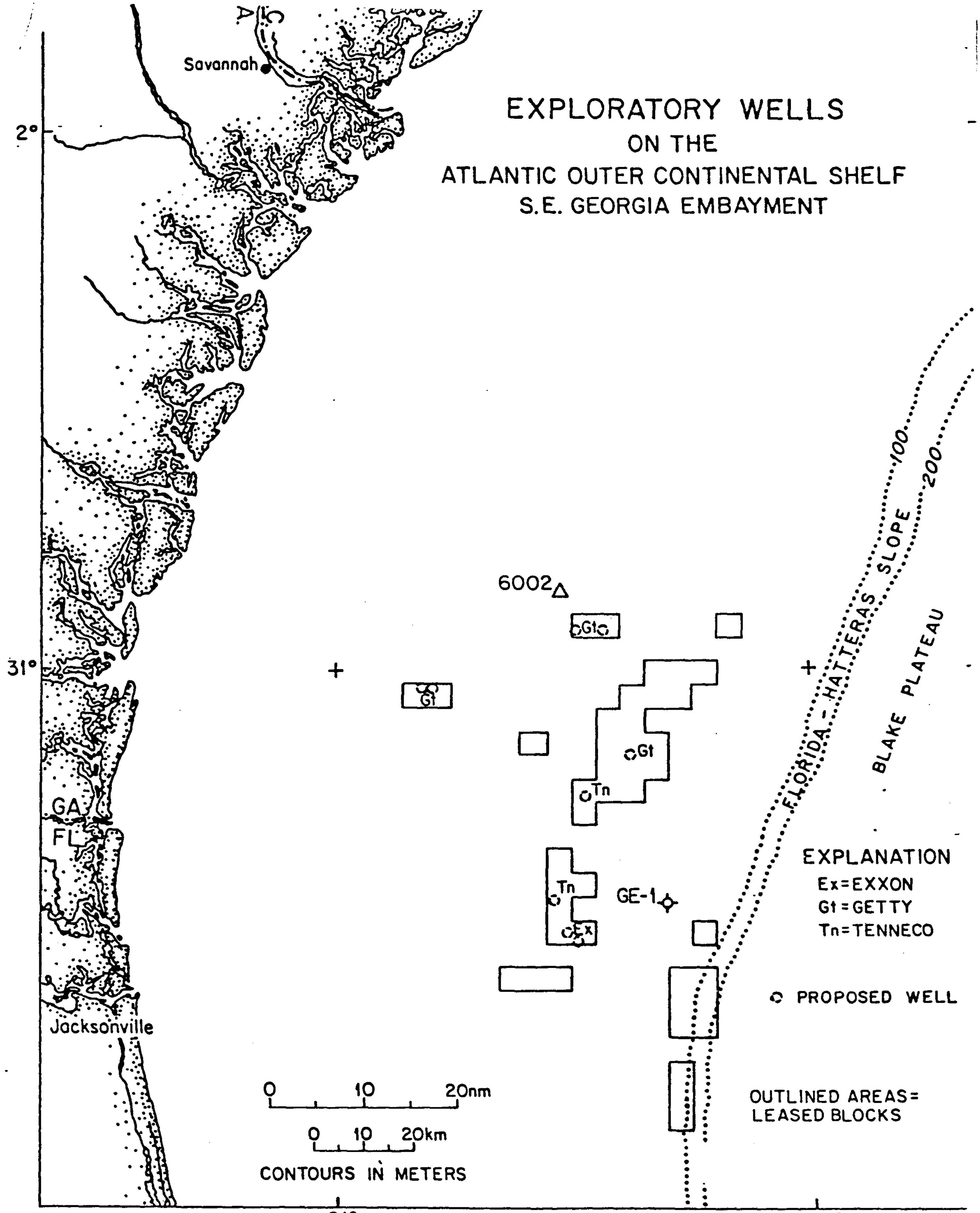


Fig. 3. The Gulf Stream covers most of the Sale #54 nominations.



AS OF 19 MARCH 1979

FIG. 4

The usefulness of modeling studies is demonstrated through increasing our understanding of processes, providing quantitative guidance for measurement programs and through provision of inputs to predictive studies. The modeling work under discussion will serve each of these purposes.

For tasks dealing with the surface and water column, our most pressing needs are for superior risk assessment of oil trajectories. There are similar needs for describing the transport of drilling fluids. Lastly, though by no means least important, we need to evolve a better understanding of the behavior of oil when released to the marine environment through pipeline spills. Some of the initial work addressing this topic may evolve in the discussions of bottom flow.

To the extent that our work here deals with prediction, we are concerned with events which may occur over the next 20 to 30 years. For example, consider the transport, or advection, of oil spills. Our assessment work deals with possible oil spills -- this is a probabilistic problem -- the treatment of events which may or may not occur. Using the example of oil spills, our concerns are with the probability of various trajectories. We are not addressing the forecast displacement of real time spills. Clearly there will be couplings between these purposes which stem from this work and will be of value to those engaged in forecasting the trajectories of real time spills; e.g., USCG and NOAA.

A word is in order of our efforts elsewhere. We are pleased to observe so many of you here who are performing similar research in other regions of America's OCS. Again using surface oil spill trajectories as an example -- for recent oil spill risk analysis performed by BLM and USGS in the Southern California area -- we utilized average monthly dynamic topography from the CalCOFI cruises of the past two to three decades to represent the surface flow. To these vectors were added a local wind drift vector using a 3.5%, + 20^{o} wind drift factor. The winds were derived from time series observations which were treated in a first order Markov fashion. For the Gulf of Alaska (that area surrounding Kodiak Island), we were fortunate to have available the output of Dr. Galt's diagnostic model as a source of surface currents. In the Bering Sea, we have a hydrodynamic model under development by Drs. Lenderstee and Liu. They are treating a largely tidal and wind driven system which is further characterized by its shallowness and seasonal ice canopy. As you know, the first and last trajectory risk analysis for the South Atlantic utilized Bumpus drift bottle data. This highlights, we trust, the need for the work we are pursuing here.

There is a general absence of physical oceanographic measurements on America's OCS. Perhaps this is a consequence of the fact that most, if not all, of our major oceanograhpic institutions have pursued research on the high seas and along foreign shelves -- not always by the choosing of the institutions -- often as a result of the concerns of the various research funding agencies. In any event, we in BLM seek the return of our oceanographic investigators to the home waters.

Let us remember the utility of ocean models for providing guidance to measurement design. Here in the South Atlantic a massive measurement program is under design -- it is entitled GABEX and is under sponsorship by the DOE. DOE and BLM have coordinated studies in the South Atlantic. We intend to continue this cooperative effort and are confident that our modeling efforts will serve the GABEX effort, to the betterment of our understanding of physical oceanography in the South Atlantic.

Again, let us express our pleasure with your attendance and participation. This gathering is significant in our view not only for the expressed purposes of the meeting but also for the fact that the meeting brings together investigators who are involved in other areas of America's OCS. This is indeed fortunate for our studies program.

Knowing most of you personally, we are confident that the meetings will be most productive. We anticipate and encourage frank discussions.

QUESTIONS AND COMMENTS ON PRESENTATION
BY PLENARY SESSION PARTICIPANTS

Plenary Morning Beginning Session

Dr. E. D. Wood

Question: Is BLM interested in aspects other than oil spill?

Answer: Yes, three aspects: Oil spills are one class; drilling spoils and other pollutants from resource exploration and development are also of concern on the OCS.

Question: What is the status of the BLM South Atlantic OCS physical oceanography Program?

Answer: It is winding up its second year of a planned three-year program.

Question: Are any further leases planned for the SAOS?

Answer: Yes, despite the disappointment with the earlier unsuccessful area (pointed out on map), plans are being made now for another go in the more hopeful area here (pointed out on map a general region at Blake Plateau now being considered).

QUESTIONS AND COMMENTS ON PRESENTATION BY PLENARY SESSION PARTICIPANTS

Dr. David Amstutz

Question: Are there programs to assess the adequacy of models by taking advantage of "oil spills of opportunity"?

Answer: Yes, we have teams set up to do this.

Question: Have they found first-order results to be valid at all?

Answer: Yes, for example, consider the Argo Merchant. Here, without near real-time winds, the results were poor but weren't bad later when the right winds were used. My positive response is, therefore, made looking at our long-term objectives in terms of prediction and risk analysis rather than present capability.

Comment 1: The Argo Merchant example proves that deterministic modeling requires the wind field with some skill for which the state-of-the-art is at most 72 hours today and no more than a week in the foreseeable future. Realistically, with reasonable probability, a couple of days is good now and could be available on a timely basis if set up right.

Comment 2: Hindcasting yields better results, of course; say about 5 percent variance over three days by prediction would be the best achievable.

Comment 3: Accuracy will depend for long-term prediction on adequacy of data base to feed autocorrelation.

JAYCOR CONTRACT OVERVIEW, WORKSHOP OBJECTIVES, AND WORKSHOP FORMAT

Dr. R. Michael Dowe, Jr.

Contract Overview

For the past nine months, JAYCOR personnel have been under contract to the Bureau of Land Management (BLM) to conduct an evaluation of physical oceanographic models that could have applicability to the South Atlantic Outer Continental Shelf (SAOS) area. The objectives of this evaluation were to determine:

- Which models, if any, were best suited to the BLM program needs in assessing the distribution of pollutants resulting from offshore activities and in assessing the probability of occurrence of circumstances hazardous to offshore structures;
- Which models best fit the physics of the SAOS region;
- The sensitivity of various models to data input; and
- The quantity and quality of existing input data to drive the models.

More than eleven hundred models have been reviewed qualitatively; a listing of these models was mailed to each participant in advance of the workshop (see Appendix C). This listing indicates that models were either "usable" or "unusable." What this means is that, for the qualitative model evaluation phase, these models were examined to determine whether or not the mathematical expressions that were used were based on sound physical assumptions and were complete, whether or not the models themselves were appropriate for the SAOS region, i.e., do the physics in the model match the physical processes in the SAOS, and whether or not the models had application to the BLM requirements for environmental assessment.

Those models which were labeled "unusable" were done so on the basis of their non-utility for this study; that does not mean that they are unusable for every OCS area. It should be further emphasized that many of the models examined were precursors of later, more sophisticated models and, although they were labeled "unusable," are, in fact, the building blocks for state-of-the-art models. It was also useful to look at the evolution of certain types of models, which is why the initial phase took us back to 1905. Not all of these models were examined in excruciating detail since it is fairly easy to separate rigorous from non-rigorous ones. However, all of the models listed were obtained and read. Those models labeled "usable" were subjected to further more intensive evaluation.

The tasks designed to achieve the project objectives are shown in Figure 1, and the schedule for completion of those tasks is shown in Figure 2. One of the remaining pieces for the SAOS Environmental Studies Program was the means for interfacing the large amount of physical oceanographic data being collected with the geological oceanographic data in the predictive environmental assessments to be conducted by the Department of the Interior. In this regard, the products of this evaluation were designed to be:

- A summary of the models reviewed, including the physics which they are capable of reproducing; approximations parameterization, and boundary conditions involved; and, most importantly, their relative expected accuracies when applied to the SAOS region. This summary was developed for general and interior circulations, surface trajectory, bottom sediment/boundary layer transport models, and ocean structure interaction models.

- Recommendations for the directions in which future model development should proceed in order to meet the BLM OCS program objectives.

- A time series analysis comparison of land-based and offshore meteorological data with the intent of producing a transfer function for onshore to offshore winds, thereby greatly increasing the available data base for use in surface pollutant trajectory calculations.

TASK 1. Review past and present attempts at modeling the general circulation, interior transport, surface layer transport and trajectories, and bottom boundary layer and sediment transport in the SAOS region.

TASK 2. Review other coastal models potentially applicable to the SAOS region.

TASK 3. Qualitatively assess the models under 1 and 2 with respect to the physics of the SAOS region.

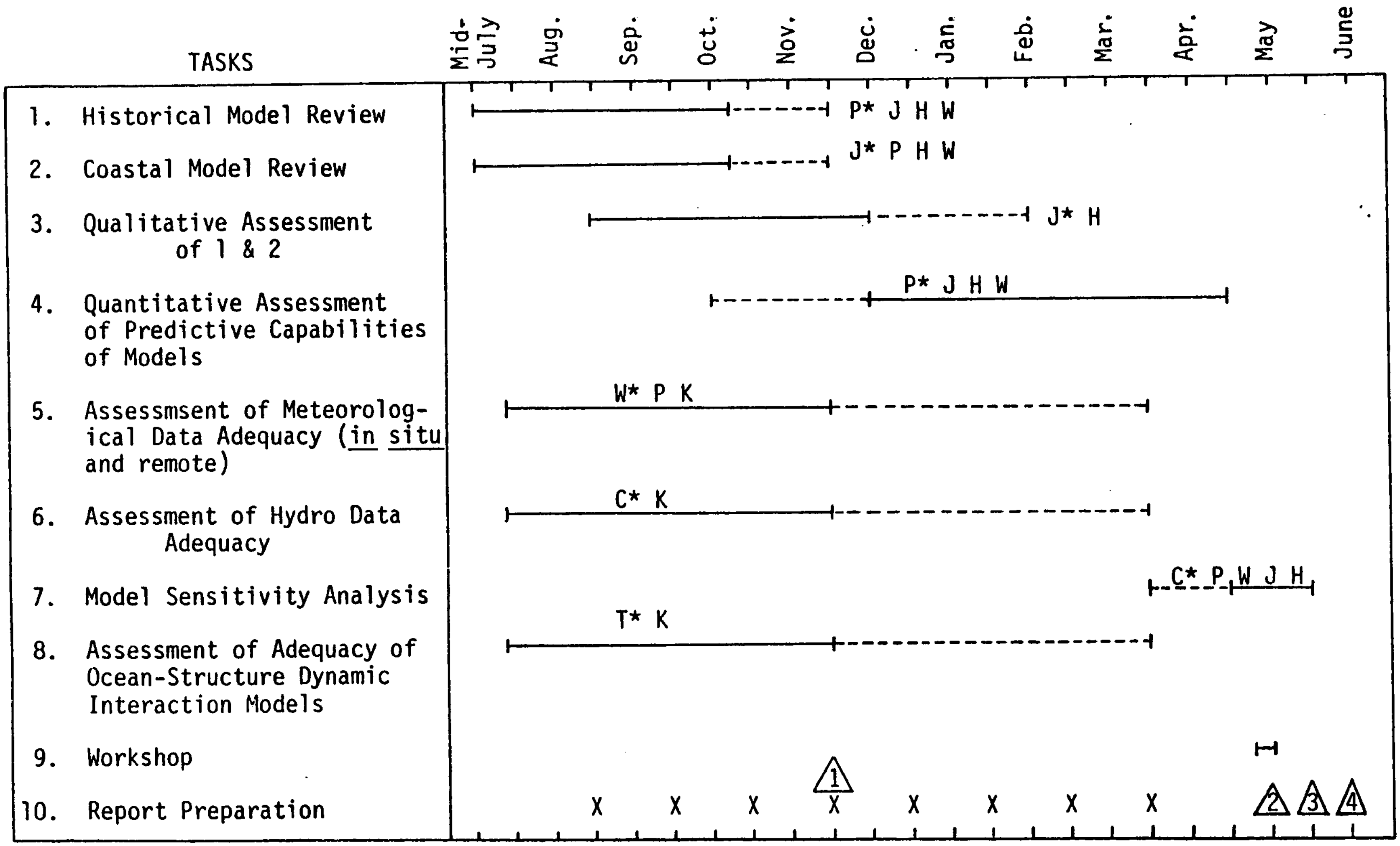
TASK 4. Quantitatively assess the predictive capabilities of these models based upon available results and data.

TASK 5. Assess the available coastal and at-sea meteorological and sea-state data sources (both from in situ and remote sensors) for support of predictive modeling in order to establish limitations of predictive models, based upon these existing data sources, and to recommend additional data sources required for support of predictive modeling.

TASK 6. Assess the adequacy of existing hydrographic data to meet predictive modeling goals.

TASK 7. Assess the adequacy of models addressing the potential for damage or rupture of structures and pipelines on the continental margin under varying atmospheric, ocean wave, and current conditions.

Figure 1. Physical Oceanographic Model Evaluation Tasks



LEGEND:

P - L. Pietrafesa
C - T. Curtin
H - P. Hsueh
J - G. Janowitz
K - J. Klinck
T - C. Tung
W - R. Weisberg

1 Mid-Term Program Review
2 Submission of Draft Final Report
3 Receive Review Comments from BLM
4 Submission of Final Report
X Monthly Status Report
* Lead Responsibility
—— Primary Activity
--- Secondary Activity

Figure 2. Task Schedule and Personnel Assignments

- Recommendations for additional meteorological, sea state, and hydrographic data monitoring in support of predictive modeling

- Recommendations for the formatting of data products for use in modeling.

- Assessment of remote imagery for modeling applicability.

Workshop Objectives

The purpose of this workshop is to involve leading modelers, outside the contract effort, in the review process in order to ensure inclusion of the latest possible model information, and to provide a means for testing the consistency of thinking of active modelers within and outside of JAYCOR. Many of the workshop participants are the same scientists whose models were most critically evaluated. Input from them on improvements in the models will ensure BLM of the most up-to-date evaluation possible.

It is also an objective of the workshop to obtain the views of the participants on a broad range of issues related to hierarchical arrangement of models. The possibility and probability of interfacing surface trajectory models with water column models with bottom and sediment transport models have been widely discussed. The four-part framework established for this model evaluation workshop provides fertile ground for more definitive deliberations on this topic.

Finally, it is important to address the problem of data requirements for driving the various types of models. There has been an extensive effort on the part of JAYCOR to evaluate the spatial and temporal coverage of various types of input data, its reliability, accuracy, availability, and utility. Obtaining outside views on these points in the context of BLM requirements is an essential adjunct to a discussion of models.

The desired output from the individual working groups, and ultimately from all of the participants, should include:

- Discussion of omission of significant models or new models
- Statements of differences with JAYCOR evaluation
- Suggestions for further analyses/evaluations
- Discussion of data coverage, adequacy, and collection requirements
- Discussion of model sensitivity and boundary conditions
- Suggestions for establishment of model hierarchies to meet BLM needs.

Workshop Format and Schedule

The format for this workshop is one that has been tried, tested, and proven to be effective in meeting the stated objectives in a short period of time. The workshop agenda (see Appendix A) reflects a three-part schedule: background and summary presentations, small-group deliberations, and plenary discussions. The individual working groups have been kept deliberately small to encourage greater input from all participants, and the sessions have been sequenced to culminate in the open discussion of individual group deliberations on the final afternoon.

It is our pleasure to have so many distinguished scientists take time to participate in this workshop. We feel that this level of involvement is an indication of the willingness of the physical oceanographic community to lend its assistance to BLM in this difficult job. The success of this workshop will be a function of the degree to which free and open exchange of ideas and opinions is achieved; this will be encouraged in every possible way and facilitated through the availability of whatever working materials are needed.

QUESTIONS AND COMMENTS ON PRESENTATION
BY PLENARY SESSION PARTICIPANTS

Dr. R. Michael Dowe

Question: Why was the South Atlantic chosen for the first modeling study of this type?

Answer: The concept for it was proposed by the JAYCOR staff and its university consultants who happened to already have a unique degree of familiarity with the circulation of the South Atlantic and of the relevant field data base. Since this was also an area of intense interest and physical oceanographic research activity by BLM, they elected to sponsor us as a supporting component of the overall effort.

Question: Didn't you forget something?

Answer: Oh, yes, I forgot at the start of the meeting that I was supposed to introduce our sponsor, Dr. Ed Wood. Sorry about that, Ed!

GEOSPECIFIC ASPECTS OF THE SOUTH ATLANTIC WITH SUMMARY COMMENTS ON THE BOTTOM AND SEDIMENT TRANSPORT MODELING

Dr. Leonard Pietrafesa

Geospecific Aspects of the South Atlantic

An overview discussion of the marine atmospheric climatology, coastal sea level, Gulf Stream frontal dynamics, hydrography and physical oceanography of the continental margin in the South Atlantic Bight was presented. The spatial and temporal scales of meteorological forcing, Gulf Stream phenomenological impositions on the dynamics of the outer continental shelf and marine hydrodynamic response were delineated both from observational and theoretical points of view.

The South Atlantic Bight is the continental margin along the southeast coast of the United States. On the landward side, a marshy, estuarine-dominated, low-lying coastal zone characterizes the southern part of the Bight, and a coastal plain characterizes the north. On the seaward side, the Gulf Stream, an oceanic western boundary current known as the Florida Current south of Cape Hatteras, flows northward.

Most past physical oceanographic studies in this area have been devoted to investigating the Gulf Stream, but the circulation on the shelf break and on the shelf proper have occasionally been considered by interpreting results of these studies. On the other hand, recent studies sponsored by the Department of Energy, BLM, and NOAA-Sea Grant have focused more specifically on the shelf circulation and have turned toward developing an understanding of the role of atmospheric forcing and the dynamic influence of the Gulf Stream in the interpretation of various features of the shelf circulation. Despite the absence of concerted studies on the interaction between shelf and Gulf Stream circulation, many useful inferences have been derived for the purposes of this presentation.

The collective experience obtained from direct and indirect observations on the South Atlantic Bight has revealed a number of important generalizations about both the driving forces responsible for inducing, maintaining or damping shelf circulation and the response of the shelf to these forces. These observations have been made in many specific locations, but are only recently leading to a general, coherent understanding of the physical processes that occur in the Bight, given the enormous variation in topographic configurations, atmospheric forcing, coastal boundary layer effects, offshore influences and tidal effects along, and across continental margins from local regime to regime.

Water motions in the South Atlantic Bight are caused by numerous physical processes. Synoptic- and seasonal-scale motions occur in response to direct forcing by the weather, principally wind and atmospheric pressure on synoptic scales, and variations in thermohaline inputs (heat and salt) on seasonal scales. Synoptic variability occurs predominantly over two to ten days, the scales of the cyclonic and anticyclonic perturbations of the wind field. Other low-frequency fluctuations occur in response to external forcing from the deep ocean, for example, eddies and Gulf Stream intrusions. Because of its sloping bottom, the continental shelf region can support free modes of oscillation generally spanning time scales similar to the atmospheric forcing. The free modes are commonly referred to as quasi-geostrophic, topographic Rossby, or continental shelf waves.

It was shown that: mechanisms for internal waves exist; that the semi-diurnal tide is a deterministic process, a bottom frictionally modified Poincare wave; the direct influence of atmospheric forcing is evident in currents and hydrography; the influence of topography ranges from regional to local scales in both the alongshore and cross-shelf directions; the Gulf Stream Front undergoes a lateral meandering process which evidentially appears to propagate downstream, but which locally controls the dynamics of the outer continental shelf; the Gulf Stream is deflected offshore by a topographic rise sitting on the continental slope due east of Savannah and directly offshore of Charleston (see Figure 1). The Gulf Stream occasionally sheds eddy-filaments which advect onto the shelf and are 10 to 15 km wide, 50 to 200 km long, and extend throughout the entire shelf water column; eddy events were characterized by hydrographic and current meter observations and in satellite VHRR imagery (see Figure 2). Various upwelling and downwelling mechanisms were discussed for both the shelf break and shelf proper.

Hydrographic and current meter mooring grids usable for diagnostic modeling efforts were delineated by site-specific and regional location (Figure 3) and availability of meteorological data from coastal and at-sea stations and coastal sea-level locations were presented. Finally, the "end of the Bight" and offshore" boundary conditions were discussed in terms of direct observational evidence and theoretical insights.

Circulation patterns based on the Bumpus drifter data are no longer valid. The availability of long-term, spatially extensive moored current meter data collected contemporaneously with hydrographic grid data provides some of the necessary tools for guiding the development of diagnostic and prognostic water column models. While the data are not as extensive as unlimited resources might have provided, the data were collected with the eventuality in mind of providing direction for input into and ultimate verification of diagnostic and prognostic models over the varying temporal and spatial scales deemed most important.

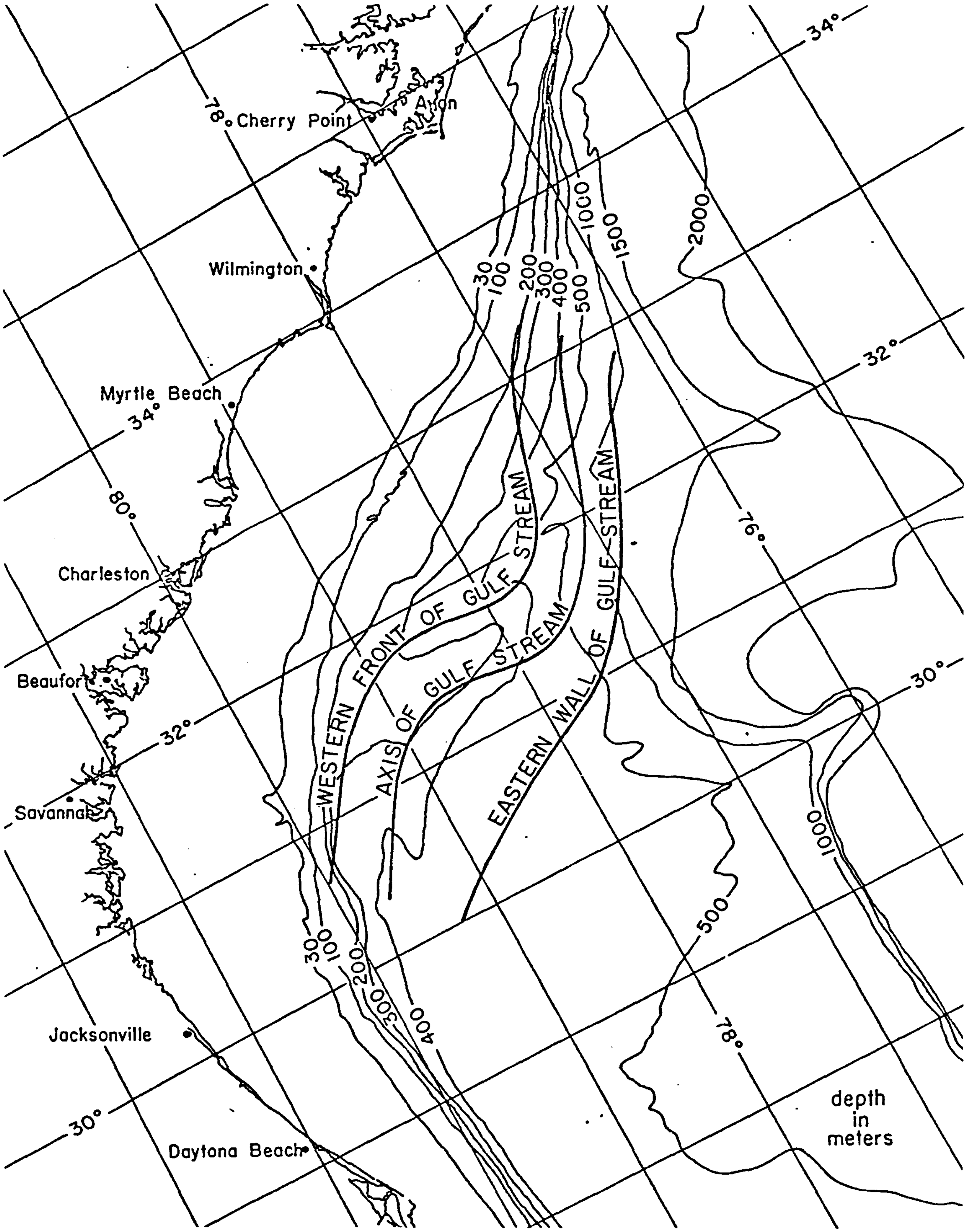


FIGURE 1. Mean Annual Position of the Gulf Stream in the area of the Charleston Rise.

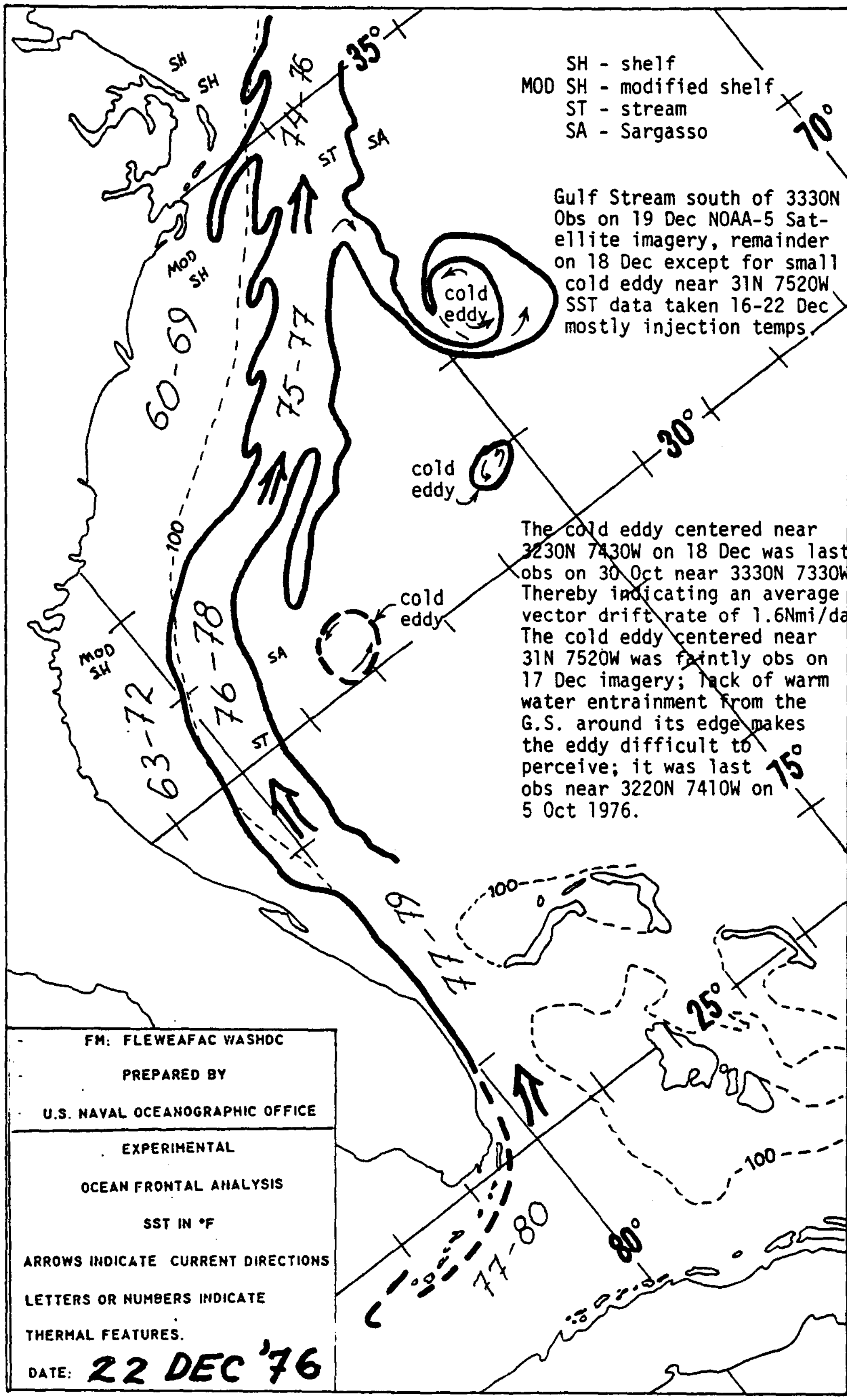


FIGURE 2. Map of the Gulf Stream showing eddys and filaments. Drawn primarily from VHRR and SST data.

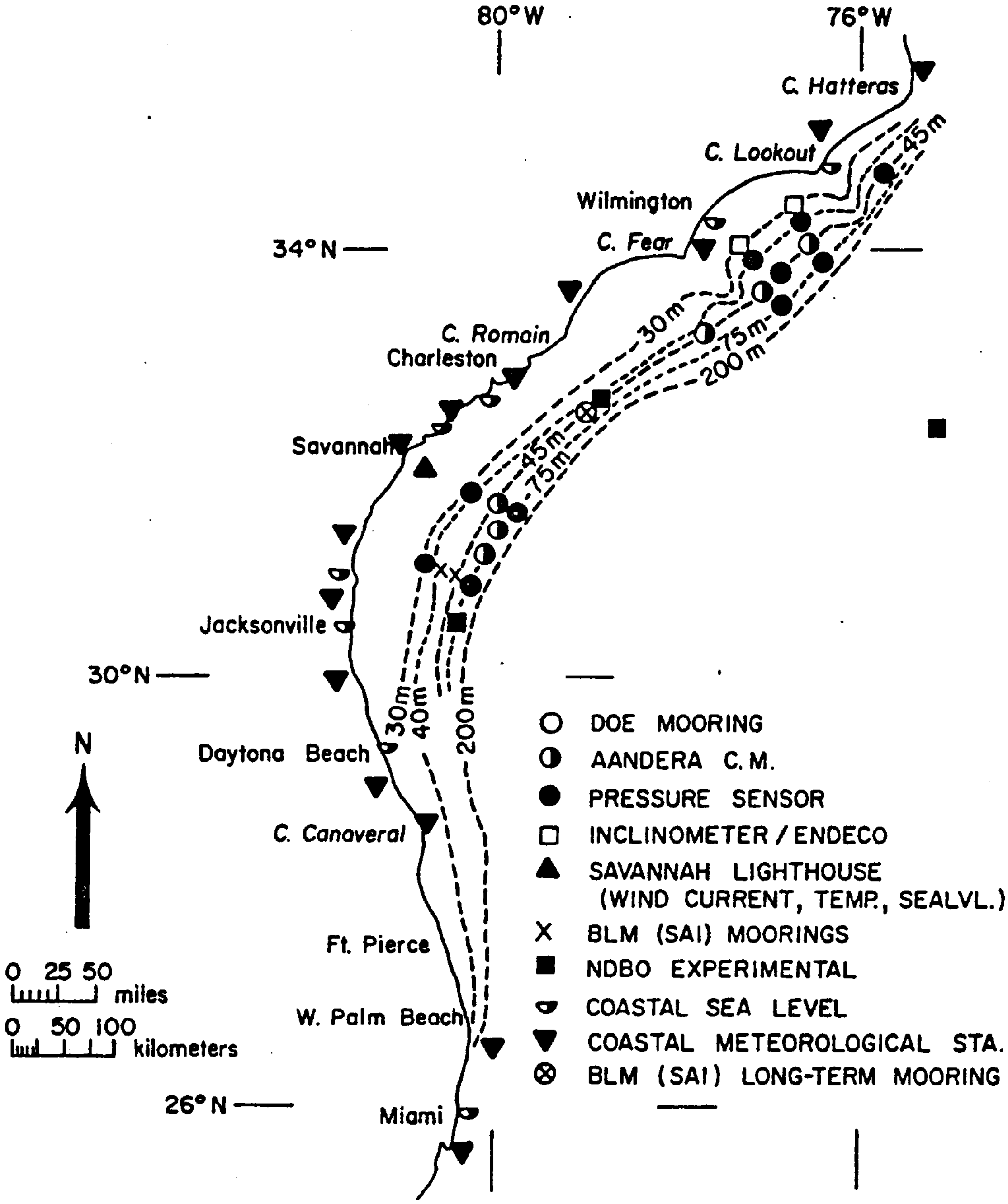


Figure 3 - Location of Moorings for Various Oceanographic measurements in the SAOS Region.

Summary Comments on Bottom and Sediment Transport Modelling

Up until a few years ago, most sediment transport models were either empirical in nature with little hydrodynamics in them or they were purely theoretical with little input from field data. Few, if any, of the theoretical models had ever been field tested, and when new observations were made that were contrary to the empirical models, the models were , of course, "fine-tuned." There were many theoretical treatments of sediment transport in fluid flow (see, for instance, Kuenen and Middleton), and laboratory flume studies (by Hand, Middleton, Kuenen and many others) which were designed to study bedform changes, initiation of grain movement, modes of sediment transport, and small-scale fluid dynamic-sediment interactions. In addition, there had been a significant amount of work done on the theoretical, experimental, and practical aspects of sediment transport in the surf zone and shallow nearshore areas with particular emphasis on beach protection (e.g. work by Inman, Bagnold, and Longuet-Higgins). Recent models such as those by Grant and Madsen, Madsen and Grant, Smith and McLean, Weatherly, and Taylor and Dyer have placed more emphasis on the application of hydrodynamics theory to sediment transport with subsequent field verification. In effect, they are treating shelf sediment transport in a more basic physical sense. The problem lies in the field verification of critical turns in the models such as total shear stress and skin friction. Given that the values for these terms were reliable, in a real world sense, the predicitions would be exact.

Recently there have been two significant, concerted efforts at solving some of the engineering and experimental problems related to field verification of some of these more physically sound sediment transport models. The first of these is called SANDS* and is under the direction of the National Science Foundation. It will concentrate on the problems related to shelf sediment dynamics and will be fully underway toward the

*Shelf and Nearshore Sediment Dynamics

end of 1979. The second of these, HEBBLE** is sponsored by NASA and will concentrate on the study of the benthic boundary layer primarily in the deep ocean. It covers all aspects of the problem of sediment entrainment, transport, and deposition and attempts to deal with theory, engineering, and experimental problems. Although the program is not yet fully-funded, it is likely it will be. Even it it were not, however, the preliminary planning and workshop sessions have addressed many of the key questions in a logical and thorough manner, and could serve as a comprehensive framework for future sediment transport mechanism studies in the deep oceam.

The question of availability of data in the SAOS region that could provide input to a sediment transport model is one that is fairly easily addressed. For several years now the BLM has been funding the U.S. Geological Survey (Woods Hole, MA) to gather information on the transport of sediments, including current meter data, suspended sediment data, sediment parameter data, and some related wave data. In addition, there were rather extensive studies done on the entire U.S. Atlantic Continental Shelf which were reported in Professional Series 529 that provide some of the same basic kinds of data. Wind data (and other simultaneous meteorologic data is being collected from three meteorological monitoring buoys located in the SAOS area. These data coupled with wave current meter and hydrographic data being collected through funding from BLM, NASA, DOE, NOAA, and the Corps of Engineers comprise one of the more extensive data bases for a continental shelf area. There are some significant shortcomings in the data base primarily in the fact that many of the separate measurement efforts lack a common basis for intercomparison of results. The absence of simultaneous measurements of high and low frequency components is also a drawback in solving the sediment transport mechanisms in the SAOS region.

** High Energy Benthic Boundary Layer Experiment

The state-of-the-art in bottom sediment transport modeling is such that a reasonable idea of the patterns or trends could be discerned using existing data augmented with some simultaneous near bottom wave-current measurements. Greater specificity and sophistication of prediction techniques must await future field verification of some critical terms in existing models.

QUESTIONS AND COMMENTS ON PRESENTATION
BY PLENARY SESSION PARTICIPANTS

Dr. Leonard Pietrafesa

Question: Are the spinoffs from the Gulf Stream occasional anomalies or do they occur at rather regular intervals?

Answer: They occur on the order of a couple of times a month and, because of the extent of their effects, they have to be thought of as more significant than occasional anomalies.

Question: How large are they?

Answer: They are of the order of ten to fifty kilometers wide and forty to a couple of hundred kilometers long.

Question: Are we going to have any more consistent long-term offshore meteorological data?

Answer: Three NOAA/NDBO data buoys will be operated in the South Atlantic OCS (Dr. Pietrafesa pointed out the locations on the map) courtesy of BLM funding.

Comment: Isn't it a coincidence that all the remote sensor data shown is for the period between September 1 and March 15 each year; it looks like the cloud fields make this kind of data impractical for most of the year.

Question: Do we really have a handle on the cloud field statistics?

Answer: Yes, the Air Force has it as a function of spectral band; Dr. John Gerring, of the AF Geophysical Laboratory, Hanscomb AFB, Bedford, Massachusetts, is one person who could provide it.

SUMMARY OF WATER COLUMN MODEL EVALUATION

Dr. Gerald S. Janowitz

Before going into a discussion of some of the circulation models that have been considered in our evaluation, I want to make a few preliminary comments. As oceanographers, fluid mechanicians, or applied mathematicians, we are interested in gaining an understanding of the dynamics and physical processes that are at work in the ocean. Analytical and numerical models are tools in helping us gain an insight into these processes. Some of the questions we ask as scientists relate to the factors influencing the formation of eddies, waves, and filaments; creation of the main current systems and density fields; and the roles of eddies and waves in the overall dynamics of the oceans. We are usually not concerned with merely knowing the velocity at a particular point in space and time. The "best" model from our viewpoint as scientists is that which gives the most insight for the least cost. Analytical models are particularly valuable in this regard. On the other hand, BLM does need to know what the velocity at a point in space is on the day an oil spill occurs there. The model, or algorithm, used to answer this question is not necessarily the best scientific model, as previously defined.

Since we are brought together by BLM to provide recommendations on how they can best meet their mandate, I will view the models from a BLM perspective. Criticisms of the various classes of model will be from the perspective of utility with respect to BLM objectives as well as from a scientific point of view. The models I will discuss all have scientific merit, with some defects in each formulation; they are not, however, all equally useful to BLM. This is not surprising, since most of these models were formulated to address specific scientific questions rather than to address management objectives.

Another constraint which will limit our discussion somewhat is as follows. As Dr. Pietrafesa has pointed out, the South Atlantic Bight is strongly stratified over nearly its entire area in the summer, and in the region of Gulf Stream influence is stratified throughout the year. Therefore, I will only discuss models which incorporate baroclinic effects. We have reviewed barotropic models, but I will not discuss those here.

The models I am going to discuss can be divided into three general categories: 1) Prognostic level models with a fixed grid in the horizontal and vertical, 2) prognostic layer models with a fixed horizontal grid and layers the thicknesses of which are dependent variables; and 3) diagnostic models where the density field is specified. I will discuss the physics rather than the numerics of these models, and will start with the prognostic level models. These are the most complete in terms of scientific approach, the most expensive to run, and require the most storage from a computational point of view.

If the turbulent mixing coefficients were known functions of the mean quantities, and if the boundary and initial conditions were correctly specified, the results of these models would be exact. Unfortunately, these conditions are not satisfied. The models differ in the treatment of turbulence and boundary conditions.

The first two models, shown in Figure 1, specify the density at the surface which does satisfy the real physical condition. Semtner and Mintz specify a heat transfer law, and the rest specify the heat flux. For short time periods (i.e., two weeks), specifying $\theta_z = 0$ (Madala and Piacsek, 1977) from some reasonable initial state would be appropriate. The other models specify θ_z. Most of the models set $\theta_z = 0$ at the bottom. When topography is present, then we should take $\underset{\sim}{n} \cdot (K_V \Theta_z \underset{\sim}{k} + K_H \Theta_x \underset{\sim}{i} + K_H \Theta_j \underset{\sim}{j}) = 0$. Otherwise, the system will lose heat from the bottom. The first three models use constant eddy coefficients. Semtner and Mintz (1977) use a constant vertical coefficient by a biharmonic horizontal damping, which is ad hoc, but damps numerical noise

Figure 1

PROGNOSTIC LAYER MODELS

Cox (1070) 1a, 2a, 3a

Holland (1973) 1a, 2a, 3a

Marchuk, Sarkisian, Kochergin (1973) 1a, b, 2a, 3a

Semtner, Mintz (1977) 1c, 2a, 3c

Madala & Piacsek (1977) 1b, 2b, 3c

Bennett (1977) 1b, 2a, 3c

Blumberg, Mellor (1978) 1b, 2b, 3d

1a: Θ specified
b: Θ_z specified
c: Θ_z-Θ specified

2a: rigid lid
b: free surface

3a: K's constant
b: Laplacian or Biharmonic horizontal mixing, K_z constant
c: Munk-Anderson formulae
d: Closure scheme for K_z, A_z.

while allowing eddies to form. The fifth and sixth models listed use the Munk-Anderson formula. The last model, by Blumberg and Mellor, uses a unique closure scheme which requires the calculation of turbulent intensities and a mixing scale which are fed into formulae for the eddy coefficients. Given the present state of other problems, for example initial and boundary conditions, it is not clear whether this scientific advance will really improve the accuracy of predictions, especially as horizontal mixing is usually treated in a fairly simple way. Madala and Piacsek use the free surface boundary condition and obtain an implicit formulation for the free surface which allows a large time step. Blumberg and Mellor also use a free surface condition, but with a small time step (30 seconds) to account for the surface gravity mode. These models all must start with some initial state, the choice of which will be important for the first few days of calculation; errors are inherent in the predictions in this initial time period. Boundary conditions on the open fluid boundary pose even more severe problems.

The second class of models is the prognostic level models (Figure 2). These are typically two-layered models and are relatively inexpensive to operate compared to the level models. The most easily observed oceanographic feature is usually the depth of the thermocline, and these models will provide information about the motion of the thermocline as well as predicting mean velocity fields. The fluid is divided into layers of different densities. The density in each layer is fixed. The equations of motion are vertically integrated and the dependent variables are the mean velocities in each layer and the layer thickness as functions of the horizontal coordinates and time. The problems associated with the vertical eddy viscosity are replaced with those associated with internal drag coefficient about which we know little. There are two problems associated with the internal drag formulations. First, the vertical diffusion of momentum is based on the differences in mean velocities across the interface. If the upper layer is more than a few Ekman thicknesses, the mean velocity may not coincide in

Figure 2

PROGNOSTIC LAYER MODELS

O'Brien and Hurlburt (1972) 1a, 2a

Simons (1974) 1b, 2b

Peffley or O'Brien (1976) 1a, 2a

Hurlbert, Thompson (1976) 1a, 2a

Hurlbert, Kindle & O'Brien (1976) 1a, 2a

1a: 2 Layer Model
b: 4 Layer Model

2a: Surface & Internal Wave Treated Implicitly
b: Surface Mode Treated Implicitly

direction with the actual velocity just above the interface, and it is the actual velocity which is responsible for the drag rather than the mean motion. This is a problem in common with vertically integrated, homogeneous models. Internal friction is not important for short time scales or small length scales. From a vorticity equation in the upper layer we can define time (T_i) and length (L_i) scales for internal viscous forces as :

$$T_i \simeq \frac{H_{upper}}{c_i\ \bar{q}} \qquad \text{and } L_i = \frac{H_{upper}}{c_i}$$

where c_i is the internal drag coefficient and $\bar{q}$ is some mean velocity defined in the model. For time periods which are small compared to T_i, the value of c_i will not be important. For time periods large compared to T_i, if predicted length scales are much less than L_i, then the value of c_i is unimportant. If, however, the length scales are of the order or L_i then the choice of c_i is crucial. There are also problems associated with initial and boundary conditions.

The last class of models are the diagnostic models (see Figure 3). The preceeding models are capable of providing insight into some of the physical processes which occur in the ocean; the diagnostic models are capable of explaining very little of the physics. The density field, derived from observations, is used as fixed input and, for the linear models, an elliptic equation governing the stream-function, surface and bottom pressure, can be obtained and solved via a relaxation technique. The model of Holland and Hirschman includes non-linear and horizontal frictional terms. With $\underset{\sim}{v} = o$ and ρ fixed, an integration to a steady state is achieved. The diagnostic calculation neglects past history and transients in the system. It explains none of the physical processes that occur and is a consistency type of calculation. However, given the baroclinic and nonlinear processes which occur in the South Atlantic Bight, and the associated difficulty in specifying correct boundaries, the diagnostic models may be the most appropriate type for BLM to adopt.

FIGURE 3

DIAGNOSTIC MODELS

HOLLAND AND HIRSHMAN (1972) 1A, 2A

GALT (1974) 1B, 2B

HSUEH AND PENG (1978) 1B, 2B

1A: NONLINEAR, HORIZONTAL MIXING
B: LINEAR, NO HORIZONTAL MIXING

2A: TIME DEPENDENT, ρ FIXED
B: STEADY, ρ FIXED

QUESTIONS AND COMMENTS ON PRESENTATION BY PLENARY SESSION PARTICIPANTS

Dr. Gerald Janowitz

Comment 1: Mellor's formulation with a horizontal mixing coefficient on the order of 10^4 cm^2/sec is of the proper scale for BLM purposes, but the accuracy of that number in terms of the real world is not very certain; this model also needs a large computer capacity. With regard to the upper boundary condition the Semtner and Mintz model includes Θ_z dependence on Θ which has some advantages except that it transfers the temperature flux problem to the atmosphere; thorough treatment of this problem would require a coupled oceanographic - atmospheric model which is far beyond the means of BLM.

Comment 2: A cold front in autumn may pose a real problem.

Comment 3: Norden Huang has a new vertical mixing formulation that is relevant to this case that he would like to introduce in the workshop session.

Comment 4: From a BLM point of view one must keep in mind that if a spill occurs there are two concerns: How far back do we need to go in integrations of the data and how well do we know, or need to know, the wind condition.

Comment 5: Another important aspect is resolution scale. Some models resolve radius of deformation baroclinically which is very important.

Comment 6: An important point is that today meteorologists are taking a hard look at model verification and then going back to identify where and why they missed in their predictions; oceanography is still a long way from that stage.

Comment 7: We don't know how sensitive the details of the circulation are to atmospheric forcing which would affect model choice.

Prognostic Layer Models

Comment 1: The Prognostic Layer Models pose different questions; here extensive sensitivity analyses are independent of the drag exchange for momentum; thus they allow turbulence independence.

Comment 2: Dana Thompson's mixing formulation should be included. Vertical mixing of mass and temperature near the coast is extremely important on a scale of a few days. Vertical mixing of momentum, on the other hand. is not important.

Comment 3: An important missing element in the approach taken here is the ability to get time steps to seconds for the interface slope where horizontal and vertical scales are different and require fine resolution; one can't have a front in level model economically. A small change vertically may coincide with a large change horizontally.

Diagnostic Models

Comment 1: With regard to diagnostic models, Orlansky has had the idea of having a model predict its own radiation conditions; non-linear conditions will seriously degrade model utility. Unlike the previous two changes of models here we are closer to engineering solutions suitable to BLM approval.

Comment 2: I agree with your preciminary conclusion that with the uncertainties of the boundary conditions, an improved diagnostic model with open boundary conditions resolved (as for example the Holland-Hirschman Formulation) may be the best thing for BLM. How can you treat such local problems as water spun off by the Gulf Stream?

Comment 3: No shelf model dominated by a strong western boundary current good or bad exists.

Comment 4: Takiuchi has a relevant treatment for the Sea of Japan (Japan Ocean. Journal).

Comment 5: Two requirements emerge: determine relevant scales and a level model, barolcinic, not wind driven

Comment 6: Chesapeake Bay Institute has ongoing work predicting shear mean veering; Shurhimoto is actually predicting shear motion in Japan - something not being done in the U. S.

Comment 7: Attention also needs to be paid to buoyant plume models

Comment 8: Going back a ways, there are really two different boundary condition problems: First, boundary conditions for something inside that moves outside (a major problem); Second, resolution of something coming into a region (a data problem). For example, they both bear on treatment of the "Filaments" Pietrafesa discussed earlier since the model must have resolution scales on the order of the features commonly occurring in the SAOS area.

SURFACE TRAJECTORY MODELLING ASSESSMENT

Dr. Robert H. Weisberg

A. INTRODUCTION

Several recent review articles on oil spill trajectory modelling and the behavior of oil on the sea surface are available as shown below.

OIL SPILL REVIEW ARTICLES

- Fallah M. H. & R. M. Stark (1976) Literature Review: Movement of spilled oil at sea. MTS Journal, 10, 1, 3-18
- Stolzenbach K. D., O.S. Madsen, E.E. Adams, A. M. Pollack, C. K. Cooper (1977). A review and evaluation of basic techniques for predicting the behavior of surface oil slicks. Ralph M. Parsons lab. For Water Resources & Hydrodynamics, Re #222
- Rath R. J. and B. H. Francis (1977). Modelling methods for predicting oil spill movement. A report to the Oceanographic Commission of Washington by the Oceanographic Institute of Washington, Seattle Washington 99 pp.
- Wheeler R. B. (1978). The fate of petroleum in the marine environment. Exxon Production Research Co. special request 32 pp.

These are inclusive and representative of the state of the art of oil trajectory modelling. Additional review articles are not needed at the present time. Rather, a critical assessment of the state of modelling and suggestions for improvements are required.

B. FACTORS AFFECTING OIL SLICKS

Several factors affecting oil movement and persistence on the sea surface are listed below.

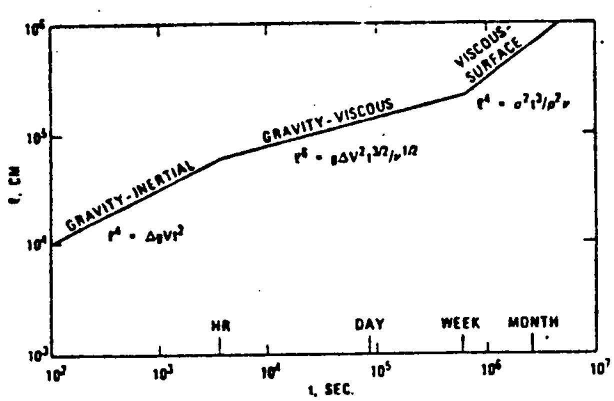
FACTORS AFFECTING OIL MOVEMENT & PERSISTENCE

- Spreading
  -via: pressure gradient, inertia, surface tension, turbulent diffusion
  -Primarily important during the first day of the spill
- Drift of advection
  -via: mean, tidal, and wind induced currents
  -important over the life of the spill
- Evaporation
  -depends upon wind, temperature, sea state, and oil composition.
  -50% of the oil volume may evaporate during the first day.
- Dissolution
  -solution into the water column depends on oil composition, turbulent mixing, & temperature.
  -may be very important for subsurface spills
- Emulsification (chocolate mousse)
  -depends upon oil composition & sea state
  -impedes further weathering, ignition, or skimming
- Sedimentation
  -Adhesion to detritus & increased density due to evaporation
- Biodegradation & Autooxidation
  -deterioration by organisms (bacteria, yeast) and by oxidation
  -important after about 4 days

Treatment of these factors are available to varying degrees in the review article. Problems requiring additional research and understanding exist in all of these areas.

Several of the oil spill trajectory models; for example, The USGS model used for risk analysis related to the Department of the Interior offshore lease sales., neglect all but the second item listed above. The last five items are distinct in that being non-conservative effects they tend to dissipate the oil, whereas the first two change the configuration and position of the oil. From an engineering point of view, therefore, neglect of the last five results in a trajectory impact model with a built in safety factor of perhaps 2 or more depending upon the time to landfall. This is a reasonable approach.

The initial spreading of oil on the sea surface is governed by pressure gradients, inertia, surface tension, and turbulence. The first three factors have been modelled by Fay (1969) and supported by Hoult (1972). The results are shown in the Figure below.



ℓ = slick size

g = gravity

V = volume

t = time

ν = kinematic viscosity of water

σ = surface tension

ρ = density

Figure 1 *The size ℓ of an oil slick as a function of time t for a 9.08 x 10^6 kilogram spill (from Fay[6]). Reproduced by permission from Plenum Press, New York, © 1969 and the author.*

Three different regimes are defined depending upon the principal pair of forces involved. Initially the pressure gradient and inertia terms dominate. Viscous forces then supercede the inertia terms and finally, the pressure gradient gives way to surface tension. Spreading ceases in this formulation when the sign of the surface tension reverses or the oil no longer "wets" the sea surface.

Turbulent diffusion, neglected in the Fay-Hoult formulation was found to be very important in the field observations of Murray (1972). A comparison between the observed slick behavior, that predicted by the Fay-Hoult formulation, and that modelled via turbulent diffusion is shown on figure 2 (taken from Murray, 1972).

This figure demonstrates the difficulty in modelling oil slick spreading. The deterministic approach of Fay and Hoult appears to be inadequate for field applications.

The modelling of oil slick advection has generally followed the equation shown below:

$$\frac{d\underline{x}}{dt} = \underline{V}_c + \underline{V}_w + \underline{V}_t$$

where $\underline{x}$ is the position vector of the slick which changes in response to the vector addition of $\underline{V}_c$, the mean current or circulation; $\underline{V}_w$, the wind induced drift; and $\underline{V}_t$, the tidal current. Tidal excursions are generally of order 1-2 km. They tend to further spread the slick rather than causing significant net advection. Consequently some model, such as the USGS one, neglect it. The wind drift is generally modelled using a wind speed and a deflection angle of some 20^0 to the right of the wind direction. The 3% rule has an empirical basis and crudely follows theoretically from continuity of stress across the air-sea interface. Letting the stress be proportional to density times a friction speed squared, it follows that

$$V_w = (\rho a/\rho w)^{\frac{1}{2}} V_a \approx 0.03 V_a$$

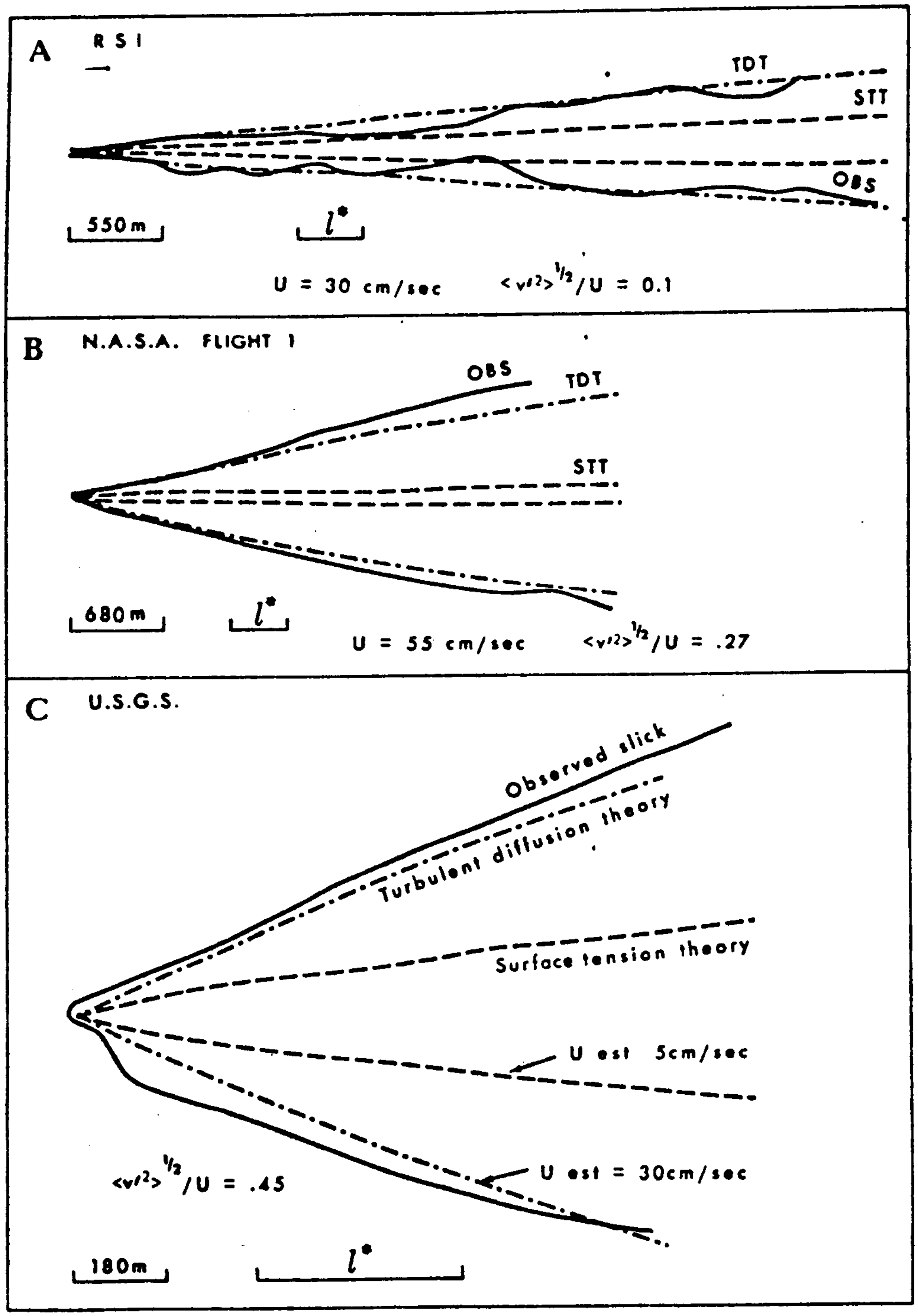


Figure 2 Comparison between observed slicks and slick outline predicted by both Taylor diffusion theory and surface tension theory of Fay (1969). In (A) and (B) the current speed was observed on site; in (C) the current speed is estimated at the average value for the incident (29 cm/sec) for the turbulence theory, and estimated at 5 cm/sec for the surface tension theory to maximize possible agreement between Fay's theory and the observation.

where V_w (V_a) is the water (air) speed and $\rho w(\rho a)$ is water (air) density. Finally $\underline{V}_c$ is obtained from whatever data source is available e. g. drift bottles, dynamic height, etc.

As an example of an application of the proceeding advection model, three figures are now shown for the South Atlantic Outer Continental Shelf lease area. These are taken from the USGS risk analysis model for that area (Slack and Smith, 1976). Several coastal sites appear to be vulnerable to oil spill damage which demonstrates the importance of improved slick behavior modelling for this region and others.

C. MODEL LIMITATIONS

The principal limitations to oil spill trajectory modelling at present are the treatments of advection. Specifically, the mean current data are woefully inadequate and the wind water coupling is poorly understood and crudely modelled.

The mean current data limitation is exemplified by the USGS modelling effort for the mid-Atlantic OCS region (Slack and Wyant, 1978). Depending upon which data set they used, the trajectories were either on-shore or off-shore. In this region (as with the SAOS region), the Gulf Stream results in a very large to variable circulation gradient. Thus, depending upon initial conditions, the oil spill trajectory may be diametrically opposite. Improved capabilities for modelling the low frequency (quasi-mean) circulation of the OCS regions along with improved data bases are essential for oil trajectory modelling.

Our ability to predict wind induced drift over synoptic scales is equally crude. Empirical wind factors and deflection angles vary by factors of 2 or more; the relative roles of wave and current in the air-sea momentum exchange is unknown; and the at-sea meteorological data base is virtually non-existent.

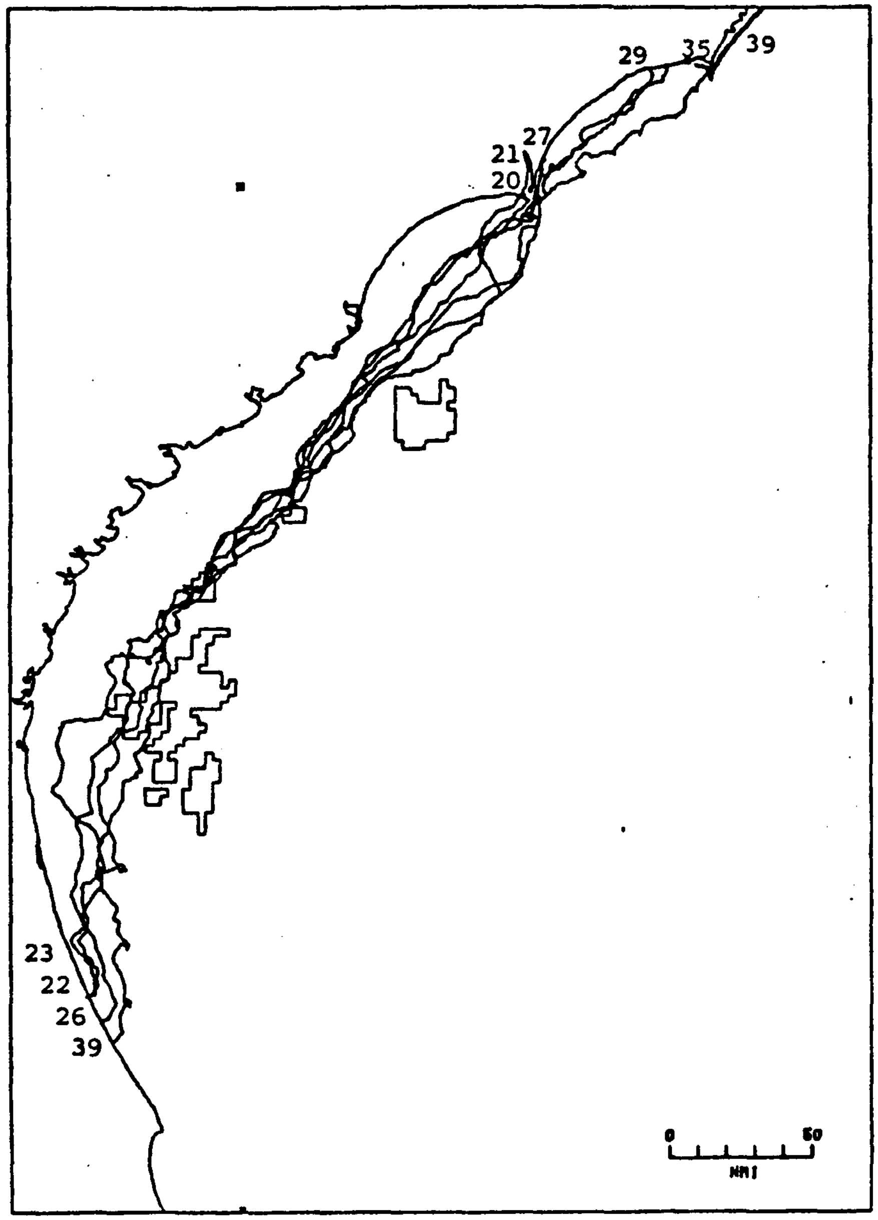


Figure 3 --Example oilspill trajectory results for a spill site near the center of the proposed lease area: summer conditions. Number on trajectory reaching the coast gives time to land in days.

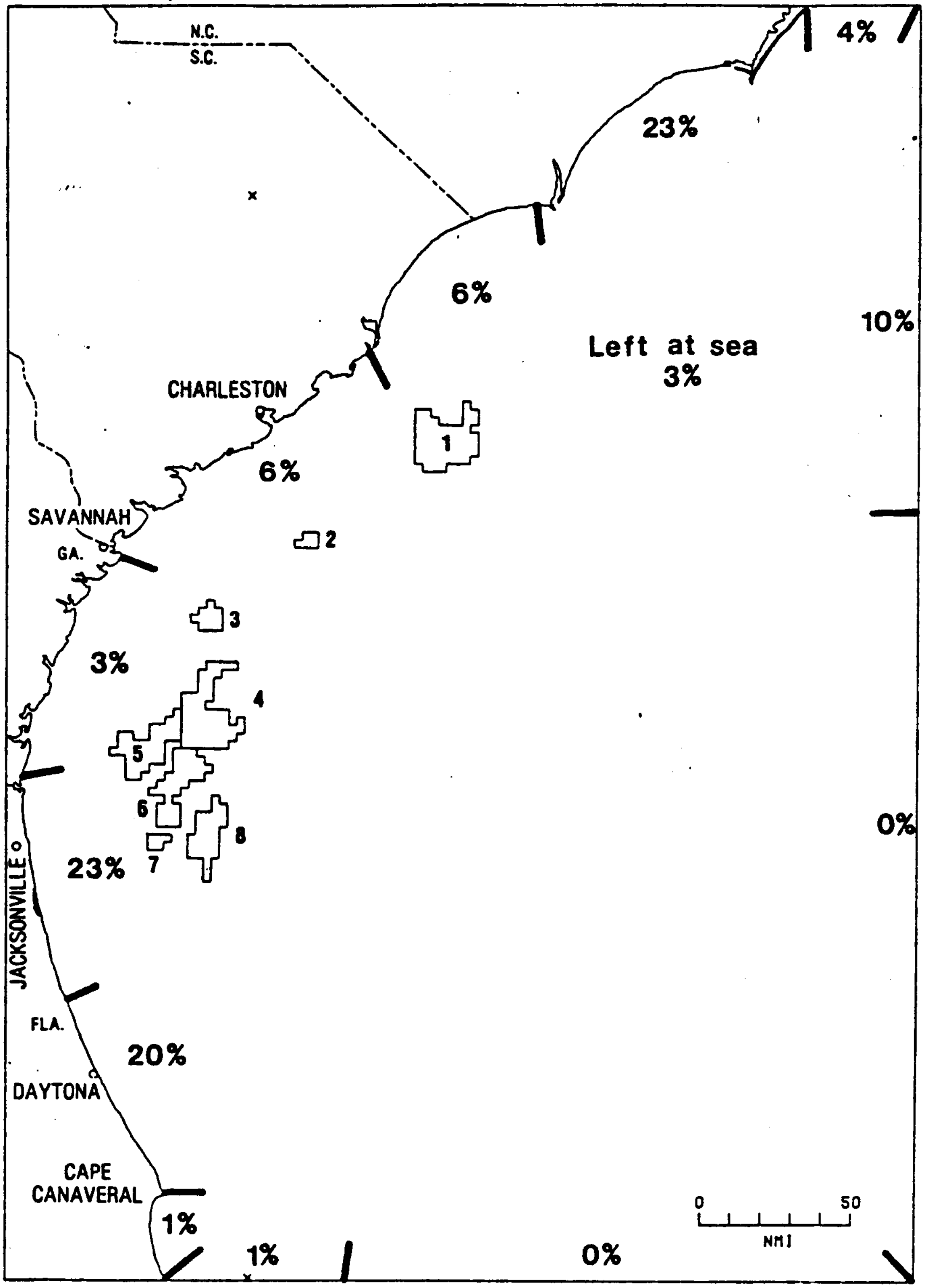


Figure 4--Probability that if an oilspill occurs in the South Atlantic lease area, it will reach a particular geographic location.

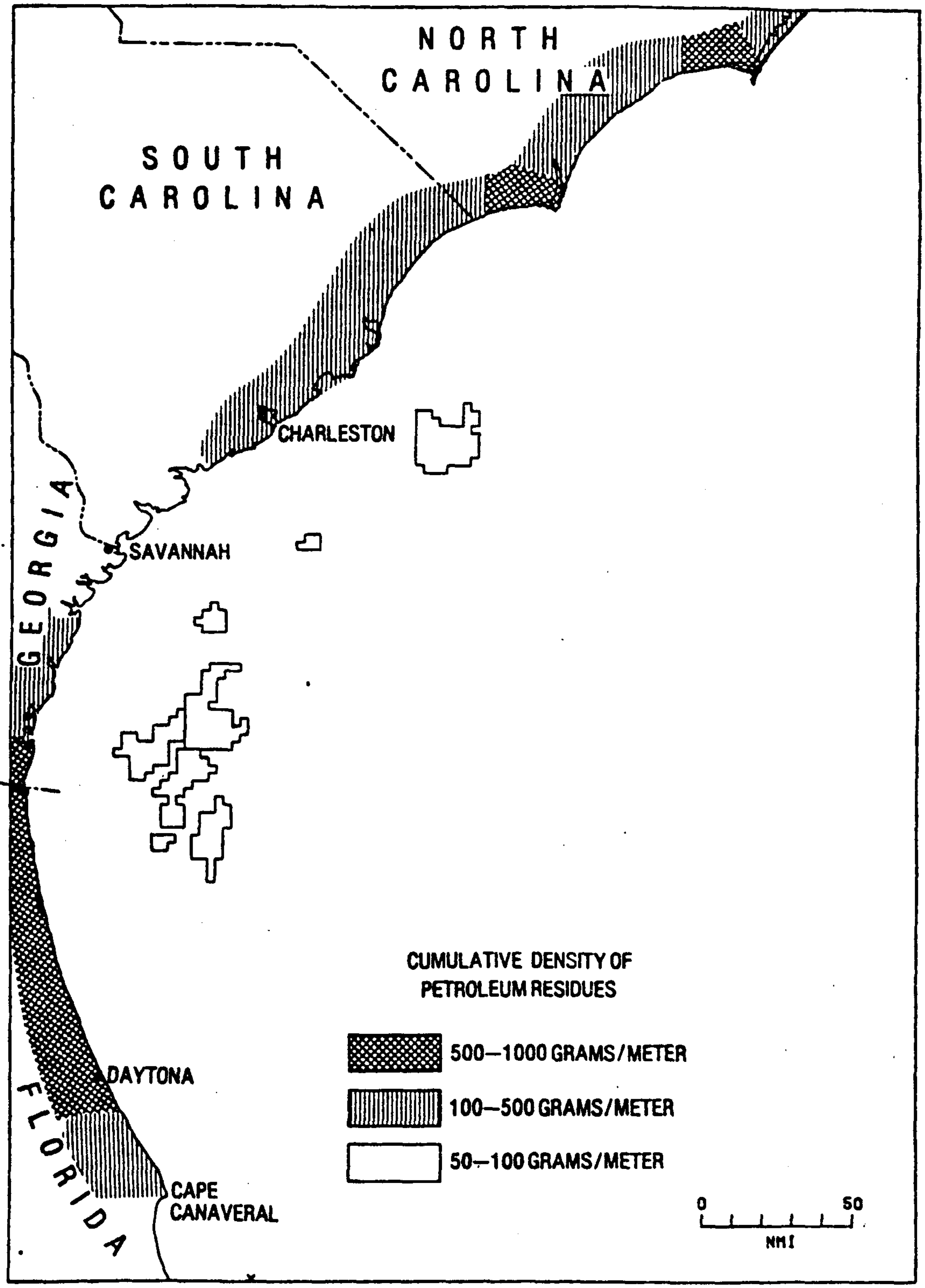


Figure 5 --Projected cumulative distribution of petroleum residues on South Atlantic beaches resulting from small scale, chronic spillage during the production life of the lease area. Estimated densities do not include existing background levels resulting from tanker washings and natural seeps.

D. SOME SUGGESTIONS

TWO LEVELS OF MODELS SHOULD BE PURSUED:

1) Long range risk assessments similar to those presently performed by the USGS, &

2) Short-term interactive prediction models for implementation during an actual spill to assist with cleanup operations.

Models of the type 1 require more accurate specifications of the mean and wind driven current systems. Coupling with numerical models would be fruitful. Several attempts at this (at least 3) have been tried.

Models of the type 2 would benefit greatly from Wiener filtering/prediction techniques using the full memory of the physical system rather than just one or two previous steps as in first and second order Markov processes. This approach result is transfer functions between the wind and the water velocities. If the transfer functions are found to be stationary or slowly varying, then they can be used for predictive purposes. An example of the utility of this approach is given in the figure below (taken from Weisberg, 1976). The solid line represents an observed velocity component and the dotted line is by linear mean square estimate based upon the wind velocity.

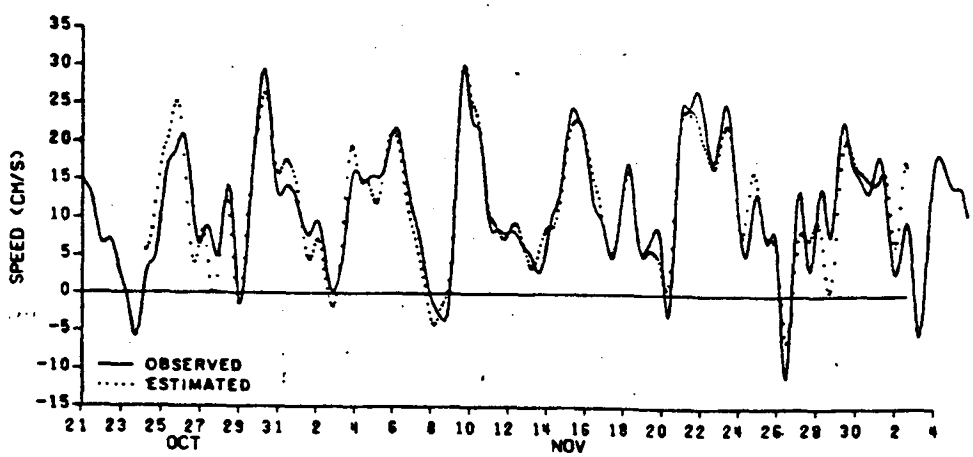


Figure 6 The observed nontidal axial current (solid line) compared with its estimate (dotted line) based upon the 335° wind velocity component.

E. OTHER IMPORTANT PROCESSES

- Channeling and preferential advection and sinking due to Langmuir cells
- Blocking and sinking at fronts
- Seasonally varying coastal trapping scales
- Effects of Gulf Stream intrusions and warm core eddies.

F. SUMMARY

The intent of this introductory overview has been to stimulate discussion for trajectory model improvements. Most of the models reviewed were formulated in a similar manner, i.e. the vector summation of mean wind induced and tidal currents. Whether the treatments of these components were deterministic or probabilistic, they all suffered to varying degree from the constraints of poorly understood or inadequately modelled dynamics coupled with scant or non-synthesized data bases.

QUESTIONS AND COMMENTS ON PRESENTATION BY PLENARY SESSION PARTICIPANTS

Dr. Robert Weisberg

Comment 1: One thing that is apparent from the oil spill review articles is that oil disappears more quickly than models predict and change in consistency with time (more than half evaporates in twenty-four hours).

Comment 2: One tentative conclusion that can be drawn from your presentation is that Murray turbulent diffusion theory is closer to reality than the best spreading model prediction.

Comment 3: Advection conclusions cannot be based on the dichotomy in direction of drifters between Bumpus data and Coast Guard data. The question could be posed: How many of the total drifters were found (the insinuation being that only those going to shore were, for the most part, the ones found)? How did time scales compare?

Comment 4: Autocorrelation bothers one because of the lack of skill of the data base; for example, are you measuring consistently three meters from the surface in a time series?

Comment 5: Stationarity of one's statistics is vital.

Comment 6: Oil spill modeling is difficult to correlate with actual trajectory at night? Why not tag it radioactively?

OCEAN-STRUCTURE INTERACTION MODEL ASSESSMENT

Dr. C. C. Tung

The design of offshore structures requires knowledge of the environmental forces to which they are subjected. Due to the exorbitant cost of construction of these structures the need for accurate assessment of these forces cannot be overemphasized. The envorinmental forces that offshore structures must be designed to resist are primarily those due to waves, currents, earthquakes and ice. I shall address only wave and current forces in this analysis.

Waves

Waves in the ocean often present a semblance of disorder particularly in the case of waves generated in severe storms which are highly non-linear, directional and random. Confused as they may appear, however, these motions must satisfy basic laws of hydrodynamics. As has been the case with the history of all branches of science, the development of wave theory began with linear, unidirectional and deterministic models beginning with the work of Airy*. The theory assumes that the fluid is incompressible, inviscid and the motion irrotational, and the amplitude of the wave is small. To relax the assumption of small amplitude, Stokes extended the theory to waves of finite amplitude. In recent years, the stream function wave theory, developed by Dean and Monkmeyer has been introduced to the profession. The theory is similar to Stoke's theory, but offers a better solution to the equations. There have been many other nonlinear unidirectional deterministic wave theories developed in recent years but they are either computationally more difficult or are more suited for regions other than offshore.

Classical random wave theories have led to an understanding of the principal kinematical and kinetic relations of simple water waves the appearances of which in nature, nevertheless, is found only in rare circum-

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*All references can be found in the List of Models in Appendix C.

stances. Realistic description of the sea surface must be based on methods of statistics, time series analysis and probability theory. The applications of these methods in areas of water waves were first pioneered by Darbyshire, Longuet-Higgins, Neumann, Pierson and Putz. In its simplest form, the statistical approach assumes that the sea is steady and spatially homogeneous. A concise exposition of this statistical model is given in Phillips and Borgman. Attempts to take into account the nonlinearities of the sea surface was carried out by Longuet-Higgins. Consideration of time and space changes have been made by Brown and Rosenblatt.

For the purpose of ocean wave forecasting, it is advantageous, though not necessary, to relate waves with wind. Although the causal relation between wind and waves is apparent, the physical mechanism underlying wind wave generation is difficult to construct primarily due to the complexity of the wind structure close to the surface of the sea in motion and the lack of accurately executed laboratory test and field measurements. The first step toward an explanation of wind wave generation was taken a century ago by Helmholtz who suggested a mechanism based on surface instability. His theory was later extended by Kelvin to include surface tension. The influence of viscosity was considered in the same physical model by Wuest and Lock. The first distinct approach was that of Jeffrey's, often referred to as the sheltering mechanism. The mechanism of wind wave generation was not adequately addressed, however, until the introduction of two new complementary hypotheses: the resonance hypothesis of Phillips and the shear flow hypothesis of Miles. Although these two models complement each other, they are not mutually exclusive since both are linear. Miles combined the two theories in a classic paper in 1960, resulting in a basic prediction model that was subsequently shown to be highly reliable through field verification of predictions. The only constraint to routine application of this model is that it requires specific over-the-water wind field data which is not routinely available. Because of this, actual engineering practice is limited to simpler approximation techniques based on certain assumptions of sea state equilibrium (see, for instance, Pierson-Moskowitz, 1964). There are a number of empirical models that are used in the areas where extensive data bases are available; the most famous of these is the Sverdrup-Munk-Bretschneider method. The most recent improvement of wind wave spectra has been made in connection with extensive wave-growth studies under well defined wind conditions during the Joint North Sea Wave Project (JONSWAP).

When one is designing a structure to withstand wave action, it is important to forecast the most severe sea state to which the structure may be exposed. The ordinary statistics dealing with the properties of random data dispersed about a central value are not very helpful when one is essentially concerned with the behavior of values distantly located from the mean, as happens when seeking to predict the characteristics of extreme probability distributions of the extreme value of a variate have been studied by various mathematicians notably Gumble, who made the first compilation of the technique. Numerous improvements have been made on that initial work.

Wave-Current Interaction

If the site of a structure may come under the influence of current, the design of the structure must take into consideration the effects of current. Furthermore, if the current is externally generated, then wave and current interact and wave characteristics undergo changes. For example, if current is in the direction of wave propagation then the wave amplitude decreases and its length increases, but if the current opposes the wave then the wave steepens and shortens. An appreciation of the importance of current and wave-current interactions on the design of offshore structures can be gained from Hogben (1974) and Wu and Tung (1975).

Currents occur in a varied physical circumstances some of them are obviously not relevant to structural design. For example, the effects of current on capillary wave and small scale currents are of no concern in structural design. The type of currents that are considered are mainly those which are externally generated such as the Gulf Stream and those generated by wind waves. It is noted that in both cases the current speed and wave particle velocity may be of the same order of magnitude. Since fluid forces are proportional to the square of fluid velocity, an error of 50% under high wind conditions can easily occur if current is neglected.

In all water wave problems, approximations must be made to find mathematical solutions in order to gain physical understanding. Almost always, the water is assumed to be inviscid and the flow irrotational. The first assumption is justified in most cases, but the second assumption may or may not hold depending on whether the current is uniformly distributed with depth.

The influence of wave-current interactions (where the current is uniform with depth) on random wave forces, and the response of structures has been investigated by Tung and Huang, Tung, and Tung and Wu. The problem of interactions where the current varies with depth is extremely difficult even in the two-dimensional case. Numerous attempts have been made at analytical solutions to this problem, but are limited by unrealistic assumptions (eg. expanding the free surface boundary condition using a Taylor Series while assuming waves of finite amplitude). Ultimately numerical methods must be employed.

Wave-Current Forces

From the standpoint of design of offshore facilities, the ultimate purpose of studies of waves and currents is to enable one to compute wave and current forces on these structures. The manner in which fluid forces on objects are computed depends on whether the object is "small" or "large" compared with "dimensions" of the wave. Thus, piles and members of an offshore tower are considered small objects and oil storage tanks and deep water docks are large bodies in the literature of fluid force studies. The reason that such distinction is made can be seen if one recognizes that when the body dimension is small compared with wave amplitude, flow separation and energy dissipation in eddy formation become important. Furthermore, when the lateral dimension of the body is much less than the wave length, the wave field is not greatly disturbed. However, as the lateral dimension of the body increases to become comparable to the wave length, the presence of the body begins to alter the wave field. When such interference is appreciable, wave scattering or diffraction must be considered.

In spite of the excellent results obtained in laboratory experiments it is noted that the usually large dissimilarity between the key parameters in the laboratory and in nature, makes direct application of laboratory results to the field questionable and field experiments must be carried out. The numbers of field programs that have been conducted to examine the forces on small bodies, and the results obtained, is fairly limited. Two of the most extensive field programs to measure waves and wave forces are the so-called "Wave Project I" and "Wave Project II". In these projects, water particle velocities were not measured. In order to determine the drag and internal coefficients, wave kinematics must be inferred from wave profile as predicted by selected wave theories. The scatter in the resulting coefficients is substantial and it is clear that a significant but somewhat unquantified portion of this scatter is due to the fact that there are considerable differences in the kinematics predicted by various theories.

Within the last decade, field measurement of water particle kinematics has become possible largely through the development of the electromagnetic current meters and high-response duct current meters. Recently, a group of petroleum companies launched the "Ocean Test Structure" project, a jointly sponsored large-scale engineering experiment designed to help establish the actual values of wave forces. The structure was fabricated, calibrated and installed in 1976 in the Gulf of Mexico. In addition to the extensive wave force data collected, wave profile and wave kinematics were simultaneously obtained. This enables verification of various wave theories making evaluation of the force coefficient more meaningful. However, due to proprietary reasons, the results of such efforts will not be made public until sometime in the future.

Probabilistic description of wave forces in a random sea was first studied by Pierson and Holmes (1965) and later by Borgman (1967-1972). Methods for the estimation of force coefficients were pursued by Brown and Borgman (1967) as summarized by Borgman (1972) and, later, by Dean (1976).

For the cases in which current is uniformly distributed with depth and waves are random, probabilistic framework for wave-current force computation has been developed for both the cases in which free surface fluctuations are ignored and included.

When ocean structures whose lateral dimensions are large compared with wave length, separation is negligible but scattering becomes important. Such a problem is mathematically well posed and lends itself well to mathematical treatment. Nevertheless, theories have only been developed for small amplitude waves and most of the studies have been restricted to linearized potential theory. As such, for stationary bodies, the effects of steady current is static in nature and can be treated separately and superposed on the solution due to waves. Exact solutions of the linearized boundary value problems have been achieved only in a few instances. For bodies of simple geometry such as rectangular cylinders in the free surface or horizontal submerged cylinders and docks or storage tanks which have circular symmetry about a vertical axis, semi-analytical theory has been developed, however, these structures must have vertical side walls and horizontal bottoms.

For more general geometries in two and three dimensions, there are two powerful numerical methods: (a) the internal-equation method and (b) the hybrid-element method.

The method of internal equation begins with a singular solution such as a Green's function that satisifies the governing equations and nearly all the boundary conditions except that on the body surface. Applying the boundary condition on the body, are internal equation can be obtained. Only in a few exceptional cases can the internal equation be solved exactly. The advent of large computers now makes it possible to discretize the surface of the body so as to replace the internal equation by a definite number of algebraic equations. The application of the internal-equation method to wave final computations has been made by C. J. Garrison and Seethorama Rao, Bai and Yueng, Yueng, and Black.

The second major class of methods that has been rapidly developing into a powerful alternative to the internal-equation method is the finite element method, which has scored spectacular successes in structural mechanics. A succinct survey of the application of the finite element method to fluid mechanics problems is given by Shen.

In conclusion, it should be emphasized that although these general methods are now available for the solution of water wave problems, many wave problems remain to be studied. For example, in reality, the sea surface in a severe storm is random and of large amplitude. These two factors alone pose severe difficulties in the solution of the boundary value problem and development of methods of solution to the nonlinear random boundary value problem is essential to advancing the state-of-the-art in ocean-structure interaction theory.

QUESTIONS AND COMMENTS ON PRESENTATION BY PLENARY SESSION PARTICIPANTS

Dr. Dave Tung

Question: What is the relative weight of the wind and wave force on a structure?

Answer: The wind force is usually of the order of 5 to 10 percent.

Comment: Bottom scour is a problem for some types of structures.

Comment: An unresolved question is how to get at the wave distribution across the OCS.

Comment: RMS measurements do not properly treat the low end (25-10 cm/sec).

Comment: Takano has a treatment for in-line case; Morison's formula is the standard, though.

Comment: Large body data is tractable. We have a lot of data (theoretical and experimental) on wave-ship interaction; for example, contact the USN David Taylor Model Basin at Carderock, Maryland.

Comment: One can't rely on pure numerical solution for large bodies; however, wave-current-model tests in wave tanks can help.

Comment: Structures are diverse and require different treatment; i.e., pipelines and large fixed structures are obviously totally different.

QUANTITATIVE MODEL EVALUATION

Dr. Phil Hsueh

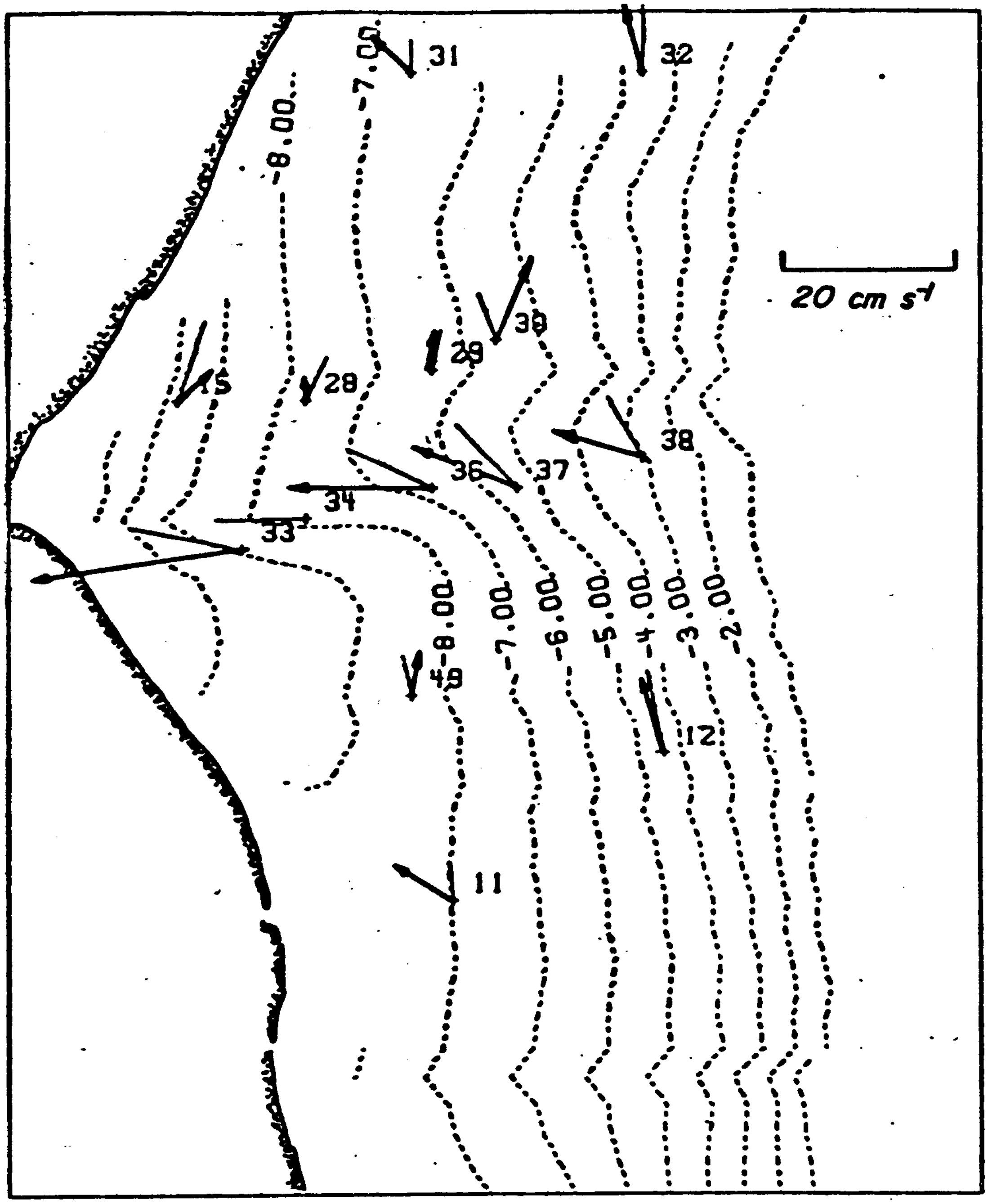
Experience from developing both steady-state and time-dependent models for bottom currents in New York Bight indicates that steady-state models used in an episode-oriented mode are capable of producing mean current patterns that are qualitatively similar to that observed and averaged over the duration of the episode that lasts typically for a week or more (see Figure 1). Since the mean current on the open continental shelf is generally an order of magnitude smaller than the fluctuations, it is far more significant to note that observed currents at subtidal frequencies are quite readily simulated also by long wave models (see Figure 2). Forward scattering of long waves incident upon topographic features such as Hudson Valley in New York Bight does not seem to have much ramification except perhaps immediately downstream from these features.

In terms of model verification, the use of linear regression techniques, skill computation, absolute error estimation, and the standard coherency analyses appears to provide an adequate objective assessment, the results of which can be used to determine suitability of models for the purposes intended by BLM. These techniques will be applied in the final stages of the BLM model evaluation project to those models that are deemed most likely to provide the desired predictive capability based on the adequacy of the physics.

1. Relative Error (R_o), determined by,

$$R_o = \left[\frac{(R_{obs} - R_{comp})}{R_{obs}}\right] \times 100$$

$$= \frac{\int (v_2' - v_1')^2_{obs}\, dt - \int (v'_{2obs} - v'_{2comp})^2 dt}{\int (v_2' - v_1')^2_{obs} dt} \times 100$$



Near-bottom, mean current vectors for episode Julian day 90-95 (March 31-April 5). Observed vector shown as heavy line with arrowhead; model results as light line. Also shown are isopleths of bottom pressure, in units of sea-surface elevation (cm). (In the model, pressure is fixed at zero along the offshore boundary; the velocity vector is assumed not to veer in a bottom boundary layer of 5-m thickness; and the observed alongshore flow at moorings P31 and P32 is used as the upstream boundary condition.)

Figure 1. Comparison of calculated and measured mean current vectors.

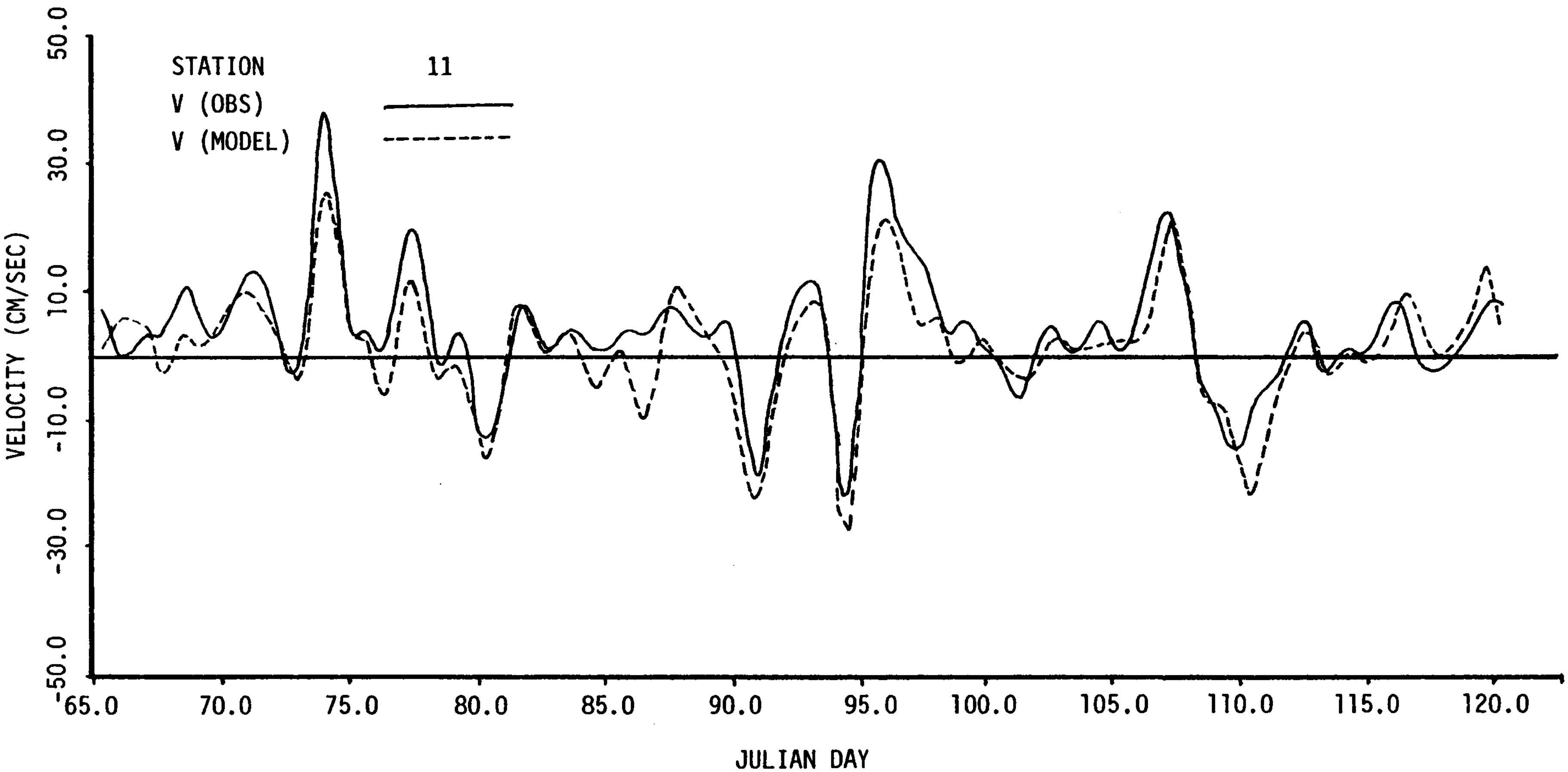


Figure 2. Comparison of time-series of bottom currents derived by model and actually observed.

where R_o = percentage variance of the model,

R_{obs} = squared difference between observed velocities at two different points

R_{comp} = squared difference between computed and observed velocities at a point where model prediction is made.

R_o will vary from zero to negative infinity with zero representing a total agreement between the observations and model computations and negative infinity representing no fit of the data. This criterion utilizes phase information as well as amplitude.

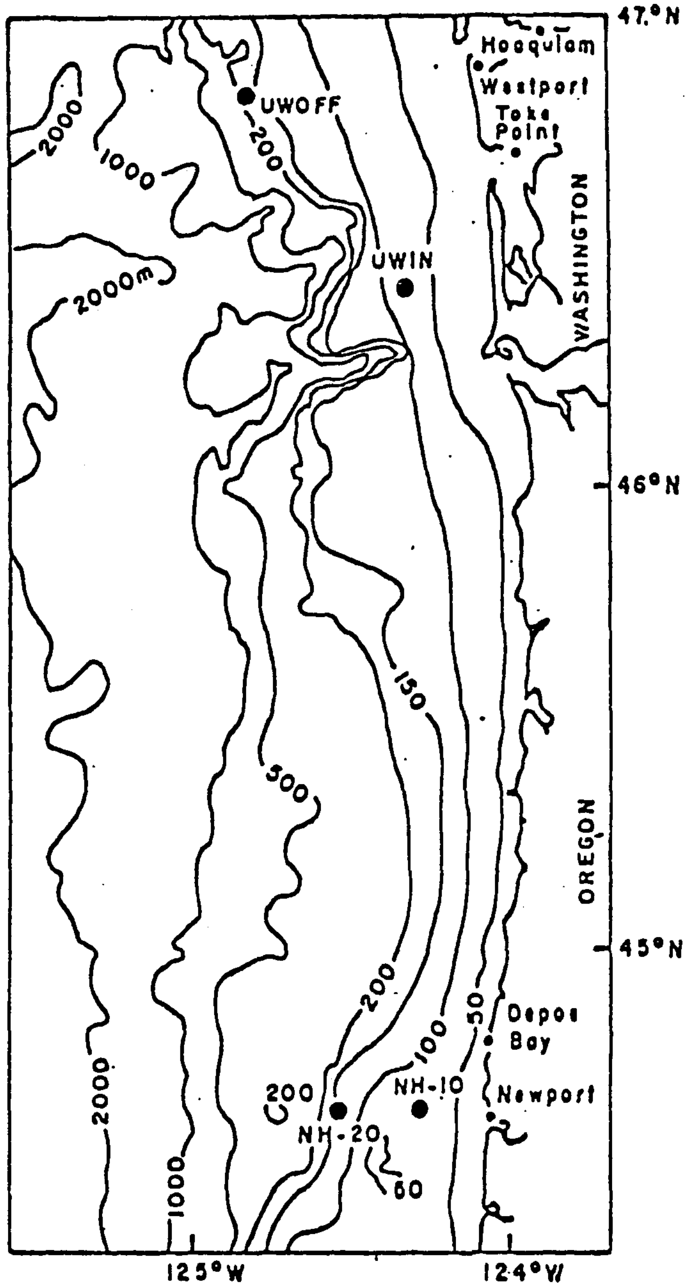
2. Absolute Error (R_A)

It is important to complement the R_o computation with an estimate of the absolute error of the model velocity field. For a measure of the absolute error, we compute the ratio of R_{comp} to the square of the observed velocities and name the ratio R_A. So, the smaller the value of R_A the better are the model results in the absolute sense.

$$R_A = \frac{R_{comp}}{V_{obs}^2} = \frac{\int (v'_{2obs} - v'_{2comp})^2 dt}{\int v'^2_{obs} dt}$$

where R_A represents the root mean square error expressed in the units of the computed variable, e.g., cm/s for velocity. Examples of absolute error values are shown in Figure 3 (numbers in parentheses) for a case study involving comparison of current velocities obtained from two moorings along the Oregon-Washington continental shelf (see map).

Diagnostic/predictive models have discernible frequency distributions of both coherency and phase, as illustrated in Figure 4.



		Inviscid Model	Viscous Models δ=10m	δ=20m	δ=30m
DB-7	u	-83(32)	40(3)	80(1)	80(1)
	v	-63(*)	82(49)	97(6)	99(0)
POL	u	0(18)	58(12)	58(12)	75(4)
	v	81(*)	95(*)	97(*)	99(11)

*over 400%

NOTE: Percentage of explained variance along the 100 m isobath (R_A) values in parentheses.

Figure 3. Example of Absolute Error

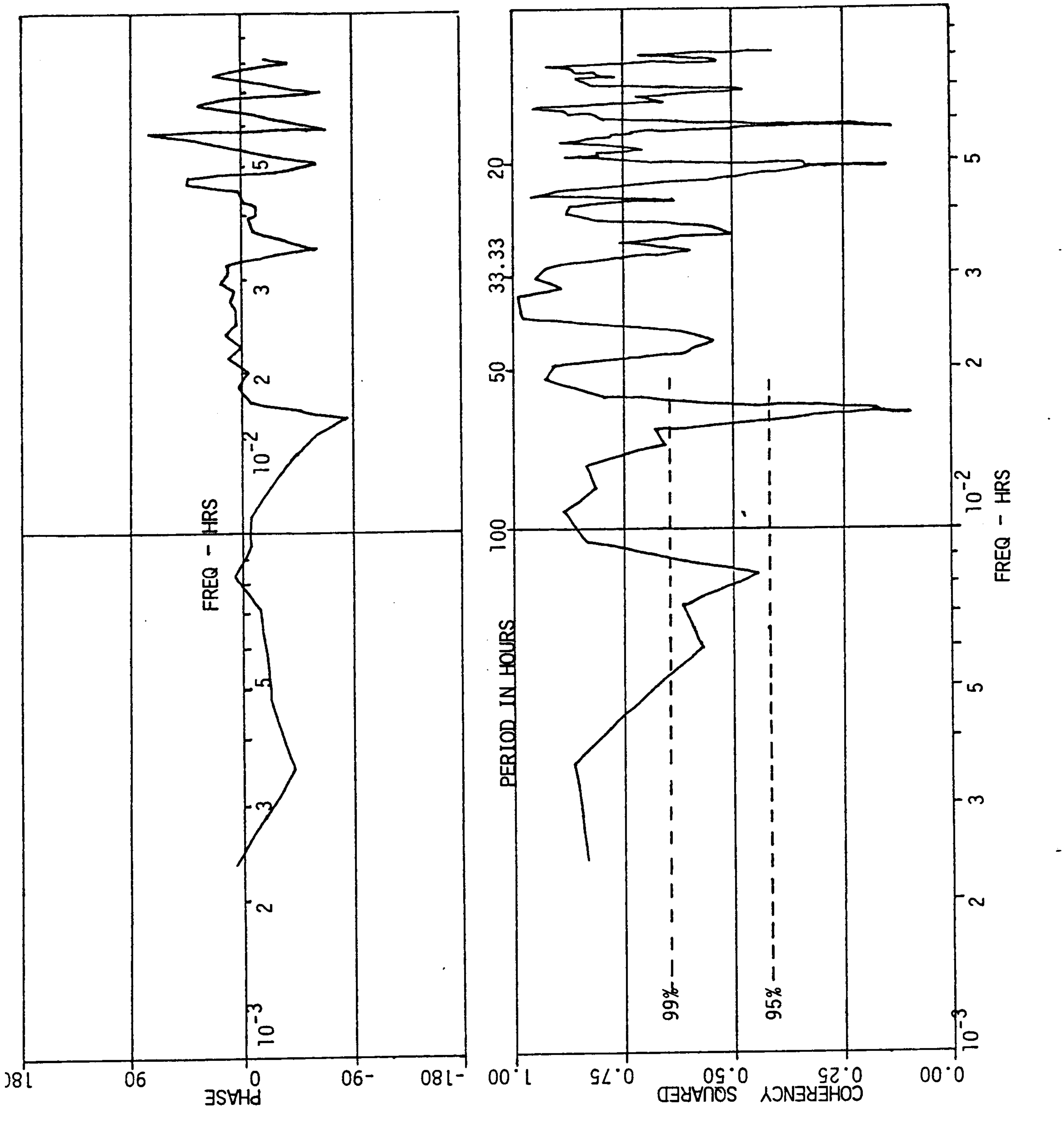


Figure 4. Example of Frequency Distributions of Diagnostic/Predictive Models in Phase and Coherency.

Phenomena over certain frequency ranges will be modeled better than those over other frequency bands — this being related directly to the extraneous noise of the natural system, numerical noise, the degree of nonlinearity of the system, and the applicability of the model to the physical processes which themselves have distinct frequency distributions. Coupling the coherency/phase estimates with the frequency distribution of variance will determine the processes which can be adequately modeled and the relative/absolute error in modeling these processes. By employing a transfer function analysis, the time series resulting from the model calculation can be compared directly to: a) the observed time series, and b) the linear least square error time series obtained from the model input data and the observed variables. This will provide the clearest visual display of just how well the observations and the model results are related to the system inputs.

The distribution of errors criterion addresses the reliability of models in terms of temporal and spatial scales. The effectiveness with which it may be applied depends on the extensiveness of the relevant data base and the extent of detectable variance in the distribution of properties. Worthy models must yield results that are reasonably coherent with observations at the scales of importance. For example, in oil/toxicity distribution prediction, since it is the first three or four days after an oil spill that are really important on the basis of the fact that surface water moves with 3 percent of the wind, models must yield concentrations that are reasonably coherent with observations at, say, spatial scales of 3 km or less for a wind speed of 30 knots or so.

QUESTIONS AND COMMENTS ON PRESENTATION BY PLENARY SESSION PARTICIPANTS

Dr. Phil Hsueh

Comment 1: This is an interesting and important case in specifying model skill.

Comment 2: Our community needs a common definition, or at least a common understanding, of what we mean by "model skill."

Comment 3: Stewart at PMEL is looking at the skill of oil trajectory models.

REPORT OF THE BOTTOM AND SEDIMENT TRANSPORT WORKING GROUP

I. OMISSION OF SIGNIFICANT MODELS OR INTRODUCTION OF NEW MODELS

The Bottom and Sediment Transport working group agreed that the list of models that had been reviewed in their area of expertise was fairly complete, with the following exception:

Grant, W. D., and O. S. Madsen, 1979, Combined wave and current interaction with a rough bottom, Journal of Geophysical Research (in press).

After a brief discussion of the content and capabilities of this model, it was decided by the group not to do a formal evaluation of it at the time, but such an evaluation will be included in the final JAYCOR report. It was the consensus of the group that the models by Grant and Madsen (1978), Madsen and Grant (1977), Smith and McLean (1977), Weatherly and Martin (1978), and Weatherly and van Leer (1977), along with the Taylor and Dyer (1977) model (see Appendix C), represent the state-of-the-art in sediment transport modeling.

With regard to their applicability to the South Atlantic Bight, it was felt that they could be used in the SAOS region if the input data were available for certain critical terms, such as shear stress, perhaps even broken down further to obtain a skin friction value (see Section II of this working group's report).

The models that are available can predict the movement of oil and sediment if certain assumptions regarding the behavior of oil droplets are made; namely, that the droplets will behave as sediment particles once the two have joined and that even if they do not, the oil particles once they sink will not become neutrally bouyant at some level in the water column. There are a number of significant problems related to these assumptions. First, it is not certain that oil droplets do not, at some point in the weathering process, become neutrally buoyant and cease sinking even if they are associated with sediment particles. The existing sediment transport models could accommodate the variability in density, but there is insufficient information regarding the actual behavior of such droplets. Second, the model would have to account for the variability in type of oil (or products) that was spilled along with certain environmental factors affecting the weathering characteristics of the oil. There is an additional problem of not knowing how oil affects the threshold for initiation of sediment movement once the oil has been deposited on the bottom. The group agreed that these were important items that should be addressed in the future in order to better understand the role of sediment in dispersion of oil.

There are a limited number of models available to deal with bedform movement and effects of bedform movement on structures. In fact, there are no predictive models available, and the physics of such processes are known only in a qualitative sense. Investigators at WHOI have been able to describe, again in a qualitative way, the movement of small-scale bedforms (on the order of one meter in height) in areas of high tidal currents (two to three knots) but, to the knowledge of the group, there are no models available for describing the movement of bedforms on the continental shelf. Quite a bit of work has been done on the fluid flow over slowly varying topography, particularly in flume studies, but little has been applied to actual continental shelf situations. There was some discussion in this working group of the availability of engineering models to deal with sediment scour and bedform movement as it relates to structures, but the bulk of that topic was covered in the Ocean-Structure Interaction Group.

II. JAYCOR MODEL EVALUATION

The Sediment and Mass Transport Group felt that the list of models that had been reviewed was fairly complete, except as noted in Section I of this report.

There was a brief discussion of the BLM needs for sediment and bottom transport models in their environmental assessments. It was stated that there were basically three applications of such models:

1) In predicting the distribution of sediment particles that could come into contact with spilled oil from any source (the role of suspended sediment in fate of oil)

2) In describing the bedform movement and scour as it related to hazards to man-made structures on the continental shelf

3) In predicting the distribution of potentially harmful material, e.g., drilling muds, emanating from a point source.

The generic problem of parameterization of the bottom boundary layer is inherent in all three types of models noted above (e.g., what are the effects of various roughness elements on drag coefficient?). Other factors that should be parameterized if sediment transport models are to be made usable for prediction in OCS environments include thickness of the viscous sublayer, frictional velocity (u^*), concentration of sediments at the bottom of the sediment transport layer, and thickness of the Ekman turbulent layer. There was, however, some concern among the group participants regarding the efficacy of BLM tackling this problem. What may be the most viable approach for BLM, given their time frame and the applied nature of the investigations, is to utilize a wave hindcasting model such as the one being done by the Waterways Experiment Station (Corps of Engineers, Vicksburg, Mississippi) to provide data on waves (high frequency component) and to couple that with mean current data (low frequency component) to determine a crude transport picture. The group felt that to go much beyond this type of effort, one would be getting involved in a long-term, expensive research effort such as the SANDS program currently under consideration by the National Science Foundation. It was emphasized that one model could not do the job; it was more likely that elements from two or more would have to be combined to make an effective tool.

It was stated that models must be sufficiently general and reasonably parameterized so that as advances are made, the old models do not need to be discarded completely, but merely updated. The sediment transport problem has a definite feedback to the establishment of a bottom boundary condition for water column models, but subsequent discussions with the water column modelers indicated that the type of model they were recommending as being most applicable to the BLM needs would not be able to effectively use such sophisticated input.

III. DATA TO DRIVE MODELS

The preponderance of the discussion focused on the adequacy of the available data to verify existing theory. Although there has been considerable data collected on the concentration of suspended sediment on the continental shelves of the United States (particularly on the Eastern U. S. continental shelf), much of the data are of limited value to the calibration of sediment transport models because:

- The instruments used have inherent measurement weaknesses (e.g., the transmissometer), especially in their inability to determine quantitative values for suspended sediments. There is also a problem resulting from the level at which suspended sediment measurements are made. The height commonly used for placement of the transmissometer is one meter, which may be above the level attained by resuspended sediment.

- It is difficult to differentiate between locally suspended and advected sediments, thereby raising significant uncertainties in the mechanisms of sediment transport.

- There is a lack of simultaneous measurements of high frequency (time scales directly relevant to sediment resuspension) and low frequency (current) components in the system.

It should be pointed out that the data collected in the SAOS region by Butman and other USGS personnel do have applicability at the zero-th level in the prediction of sediment transport. That is:

- Trends in sediment transport can be discerned;
- Significant events affecting the threshold of sediment movement can be identified;
- Length scales of events can be determined, which is useful in determining sampling grid size; and,
- A sense of the relative importance of various sediment transport mechanisms can be obtained.

It was the consensus of the group that at the present time theory is advanced beyond our capabilities to make field measurements of critical parameters. It is, for instance, unclear how to separate skin friction from total stress at the present time; therefore, it is difficult to verify the applicability of laboratory criteria for sediment movement (e.g., Shield's parameter). In order to really get a sound data base for sediment transport in the benthic boundary layer, it will be necessary to obtain time series of total shear stress at the appropriate scale. In addition, it will be necessary to get more definitive information on the vertical structure of turbulence in the water column in order to upgrade existing models.

There are really three sets of scales of interest in sediment and bottom transport modeling:

- For initiation of sediment movement, on the order of sediment grain size;
- For the transport of sediments, on the order of size of bedforms and over the scale of wave fields; and

- For the purpose of modeling, spatial averages of skin friction and average sediment size over a distance commensurate with the model of interest.

Sophisticated measurements of the shear stress in a special case (i.e., a viscous sublayer over a smooth bed) in the benthic boundary layer have been made by Caldwell, of Oregon State University, using a hot film technique; his measurements are reliable at the 95 percent level, but are of limited direct interest to sediment transport. These measurements show, however, that some of the concepts developed in the laboratory are applicable in the field. The major question is how accurately does one need to know bottom stress in order to make useful predictions for the problems of concern to BLM.

There are computer models available (see, for example, Weatherly and Martin, 1978) that utilize existing wave climate, currents, and grain size distribution data to describe sediment transport. These are limited by the reliability of the benthic boundary layer stress values that are used and the input data. Therefore, while the solutions are quantitatively correct, there is no way to verify the agreement of the results with natural conditions.

IV. MODEL HIERARCHIES

As discussed previously, the benthic boundary layer models can provide input to the water column models in the form of a "bottom" boundary condition. However, in the face of the type model being recommended by the Water Column Group, it seems to be not worth pursuing in the BLM program.

The input of water column models to benthic boundary layer models has been shown to be feasible by a number of investigators, including Smith and McLean, Madsen and Grant, and Taylor and Dyer. There are no real problems with the computer interface either, since the output from one model used as input to another is generally in the form of one or two terms easily inserted in the benthic boundary layer model.

Coupling threshold models to bed load models to suspended sediment models to wave-current models to determine ultimate dispersal is technically feasible. It would be practically impossible, however, to obtain field verification of such a hierarchy of models.

AFTERNOON PLENARY SESSION CONTINUED
DR. LEONARD PIETRAFESA
WORKING GROUP REPORT

Comment 1: A number of participants affirmed the working group comments on the absence of any "oil/sediments" transport models, and the lack of verification of the many "effects" models for spills due to the paucity of field data.

Comment 2: Array technology and new data processing algorithms developed by the Naval sonic array community and the multistatic radar community could perhaps be used in the area of oil-sediment transport to provide much data. They could, for instance, resolve local from area originated sediments, similarly, they could resolve low frequency and high frequency sources. Combined in a hybrid array with transmissometers to yield sediment concentration, and other conventional sensors to measure salinity, pressure, etc., conceivably the entire dynamics of sediment transport could be captured.

Comment 3: A small network of Brad Butman's type of stations might economically demonstrate the value of such an approach and permit development of the data handling algorithms.

Comment 4: Theory is advanced far beyond experiment in the area of oil-sediment interaction. In fact, the processes are complicated by the fact that different types of oil behave differently under varying physical condition. Cline at Pacific Marine Environmental Laboratory is studying how, and when, oil agglomerates which should be a major step forward in our understanding of the sedimentation principles that should be applied.

REPORT OF THE WATER COLUMN MODEL WORKING GROUP

I. Omission of Significant Models or Introduction of New Models

After having reviewed the extensive list of models that had been examined, the working group pointed out a few recent efforts that merited review as part of the final report preparation. These were:

Hsueh, Y. and Lee, C. Y. 1978, A Hindcast of Barotropic Response over the Oregon-Washington Continental Shelf During the Summer of 1972. Jour. Phys. Ocn. 8(5).

Holland, W. 1978, The Role of Mesoscale Eddies in the General Circulation of the Ocean-Numerical Experiments Using a Wind-Driven Quasi-Geostrophic Model. Jou. Phys. Ocn. 8(3).

Garvine, R. W. 1979, An Integral Hydrodynamic Model of Ocean Frontal Dynamics; Pt 1. Development and Analysis, Jour. Phys. Ocn. 9(1).

Flierl, G. R. 1978, Models of Vertical Structure and Calibration of two Layer Models, Dynamics of Atm. & Oceans 2(4).

Hamilton, P. and Rattray, M., 1978, A Numerical Model of the Depth-Dependent, Wind-Driven Upwelling Circulation on a Continental Shelf, Jour. Phys. Ocn. 8(3).

Bennett, J. R. & Magnell, B. A. 1979, A Dynamical Analysis of Currents Near the New Jersey Coast, Jour. Geophys. Res. 84(3).

It was decided by the group that no formal evaluations should be done at that time, but that the aforementioned models contained significant, new information and should be evaluated.

II. JAYCOR Model Evaluation

The working group participants were in general agreement with the comments presented by Dr. Janowitz in the morning session. Several additional problems associated with two layer models, namely lack of density mixing and difficulties associated with shallow slopes were discussed.

The difficulties associated with treatment of open boundary conditions were discussed, and it was concluded that this seriously limited the utility of the more sophisticated models at the present time.

Recommendations of this group are constrained by the 1 to 2 year lead time and budgetary limitations of BLM. They do not advocate that BLM use the most complete hydrodynamic models, which require additional research, i.e., the "Cadillac" of models, but rather they suggest use of a cost effective state-of-the-art procedure. Subject to these qualifications this group recommends that two procedures be adopted. The first approach utilizes a time dependent diagnostic model in which random events such as filament occurrence and effect will be treated stochastically. A second approach involving objective mapping of the rather extensive existing data base subject to reasonable dynamic constraints should be adopted. It is recognized that these procedures will not completely reproduce the complicated physics of the South Atlantic Bight region, but rather represent a state-of-the-art type of calculation describing what are considered to be the dominant processes. The grid spacing will be determined by topographic constraints. Those topographic features which BLM (with the advice of oceanographers) determines influence the flow most, should be well resolved; a process which will necessitate a variable horizontal grid.

III. Data to Drive Models

As indicated by Dr. Pietrafesa in his morning presentation, there is an extensive oceanographic and meteorological data base for the SAOS region. This has been developed through funding from BLM, NASA,DOE , and others and covers the full range of key measurements from remotely sensed data to in situ surface and subsurface current measurements. Much of this data has been summarized by BLM and others; however, a good deal of data is in NODC and is virtually irretrievable at the present time.

Data inputs for the diagnostic model suggested here are most critical at the northern and southern boundaries particularly the northern. The north-south extent will be determined by BLM requirements. This should include a minimum of three moorings at each boundary with three current meters and bottom pressure sensors at each mooring. Current meter data from the interior will be necessary for model verification. In addition, hydrographic cruise data for each seasonal period will be necessary to determine the baroclinic structure of the entire study area including the Gulf Stream. Data from the DOE effort off of Savannah may be appropriate for the verification of the model. The use of this data set would minimize the data collection effort. The climatology of filaments and intrusion processes will be obtained from ongoing studies.

The sensitivity of the model to various inputs, e.g., parameters, eddy viscosities, veering angles as well as grid scale, should be performed to determine the worth of the model. It was generally agreed that while models should be tested with respect to the sensitivity of results to input parameters, in practice this was seldom done. Analytical models are particularly useful in this regard.

IV. Model Hierarchies

No hierarchical formulations were discussed by the group.

AFTERNOON PLENARY SESSION CONTINUED
DR. GERALD JANOWITZ
WORKING GROUP REPORT

1. *Comment:* One thing we don't need to focus on is a lot more stationary seasonal mean data - at least for BLM purposes.

2. *Question:* What would it take to develop a tailored optimum model for the region or say any given region.

   Answer: It's not a one or two year job - that's for sure - and probably well beyond the resources BLM could justify. That is why the warning; the group has recommended a compromise solution to BLM for its purposes. Just to give you an idea of what it would take to go the other route. At a similar level of rigor, Mellor has worked three or four years with a staff of three or four full-time people and virtually unlimited computer resources to develop his model.

   Comment: This is further complicated and in fact limiting as to where or how to do this kind of work when one thinks that on a normal computer a fine resolution computation can take a half a day as opposed to about 400 seconds on one of the few extra large computers.

3. *Comment:* So we are back to Jerry's (Janowitz) recommendation at the start of the meeting for a diagnostic model, the form of which is not overly constrained by the data base - either its initialization or variation - and which accomodates interpolation of the temperature field so as to permit its linear extrapolation at the boundary.

   Comment: The modeling for a 3-D stochastic temperature field to be effective would require kinds of data beyond present equipment - most would drop out. For one thing there are no calibrations for most over one or two seasonal

seasonal variations - just a few long term moorings and how well are they calibrated seasonally. This is just one more justification for the simpler modeling approach, like, one that data resources can reasonably be expected to validate and feed.

Question: What do you mean by this simpler approach in action scale effort?

Answer: (from working group chairman) We visualize a program of about two years of $150-200 K per year (2½ to 3 man years per year) to build the model and, talking to the people who obtain and analyze the data like Len (Pietrafesa) and Tom (Curtin) probably about the same resources and time scale to get the field data needed in addition to the present BLM data base, to check out the model. Here the point is that the modeling and field data developments could proceed in parallel with the major difference that this time the modelers would be able to suggest to the field people what data is needed most for model tests particularly and perhaps, for other BLM purposes as well.

Comment: I (session chairman) think that is an important point.

REPORT OF THE SURFACE TRAJECTORY MODELING WORKING GROUP

I. Omission of Significant Models or Introduction of New Models

Drift

Norden Huang (unpublished manuscript) presented a new model for estimating surface drift based upon the Eulerian mean wave momentum. The model suggests an approximate 3% of the wind speed drift magnitude in the direction of the wind velocity. Its utility is that it depends upon the average significant wave slope which can be measured rather than upon wind velocity or stress. The model can also be expanded upon to give the velocity distribution and effective eddy viscosity for the mixed layer.

Recent papers by Madsen (1978) and Lange and Hufnerfuss (1978) may be relevant as well as results by Milgram (1978). Additions to the current bibliography include works by Dore (1976), who has written a variety of papers on mass transport in waves and Faller (1970) who developed the theory of time dependent Ekman layers.

Circulation

Galt (manuscript in preparation) has applied a diagnostic hydrodynamical model in the Gulf of Alaska to calculate oil movement using observed winds.

II. JAYCOR Model Evaluation

The group was generally in agreement with the JAYCOR evaluation. The "state-of-the-art" of oil spill trajectory modelling consists of a vector summation of the advection due to winds, tides, and circulation. Superimposed upon these effects is spreading by pressure gradients, inertia, surface tension, and turbulence; and the various non-conservative chemical-biological processes. None of these factors, however, are adequately understood, or field tested, and improvement are required in all areas.

Suggestions were discussed for further analyses and improvements. It was generally agreed that the concept of modelling individual aspects of the surface displacement followed by vectorial summation is a valid and operationally feasible one.

Spreading

Slicks are poorly understood in the ocean environment and further theoretical, lab, and field studies are required to:

1. Determine the initial differential spreading of the oil constituents,
2. Determine the mechanisms of tar ball formation,
3. Determine the role of mechanical mixing upon dissolution and the distribution of the oil throughout the mixed layer.

It was pointed out that the cleanup of an oil spill in the presence of typical deep ocean swell and large current is nearly impossible with present technology.

Surface Drift

An attempt at validating or intercomposing existing similar models seems fruitless with the data at hand. A better understanding of the physics governing air-sea momentum exchange is required to improve our modelling capability. Well thought out field experiments with inclusion of sea state data are necessary to differentiate between the momentum going into currents, waves, mean wave momentum, langmuir cells, etc.

Drifter experiments are recommended. These experiments would involve an ensemble of releases from one or several stations with each member (a collection of drifters) of the ensemble (the sum total of repeated drifter releases) tracked for a period of 10 days to several weeks. This would allow for a statistical treatment of drift data at time scales similar to landfall estimates and synoptic weather systems. The data could be used for eventual model verification studies. Seasonal variability would be expected therefore and an experiment should be performed accordingly over the course of at least one year.

The above Lagrangrian experiment could be compared with results from Eulerian transfer functions derived directly from data or indirectly from sophisticated numerical models. The intercomparison of the two results (Eulerian & Lagrangian) would provide a realistic indicator of predictive capabilities.

Circulation

Hydrodynamical models should be utilized to address the circulation. This would offer a significant improvement upon the crude estimates based upon inadequate data.

Tides

Enough data appears to be available at this time for synthesis into a tidal circulation model for the SAOS region.

Trajectory model improvements can be made at the present time by the addition of dynamics as suggested in the discussion under Circulation (see above). Ultimately, these improved (or existing) models will (or have been) used by governmental bodies for decision-making in regard to lease sales. Realistic input to this decision making process is perhaps the single most important end result.

III. Data to Drive Models

Velocity field modelling has been broken into three categories: 1) the slowing varying mean circulation, 2) the tidal circulation, and 3) the synoptic scale wind-induced circulation. The data requirement for modelling each of these differ somewhat. Mean circulation modelling requires a knowledge of the density field and its seasonal or shorter term variability. Data coverage for this purpose should be uniform over the region. Surface wind field measurement or extrapolations are necessary inputs for wind-induced circulation modelling.

The data available for the SAOS region are not fully adequate for these modelling purposes, however, a considerable amount of data has been collected in recent years and their synthesis into a workable data set will vastly improve the situation.

Tidal circulation modelling is particularly attractive at the present time since adequate data to model this principally deterministic phenomena exists for the SAOS.

The implementation of models and subsequent sensitivity analysis will no doubt point out deficiencies and offer guidance for field data collection efforts.

The deployment of meteorological bouys in the SAOS region will be highly beneficial in extrapolating surface winds from the combined wasted and at-sea array. Analysis is on-going and some indication of adequacy will be available in the near future.

Sea state data may be obtained via satellite and aircraft measurement. Directional spectra measurement, however, need further refinement.

Frontal processes are important in surface transport. The SAOS contains fronts associated with the Gulf Stream and coastal river runoff. Their positions, persistence, etc. should be examined in further detail.

One approach to focus the operational modeling capabilities would be the creation of a regional catalog of synoptic scenarios characteristic of the observed typical episodes in the SAOS.

IV. Model Hierarchies

Trajectory models are hierachial in nature since they depend upon different processes. Improved modelling of each of these processes is the most important step in formulating a combined model. The simple vector addition concept presently seems to be the most feasible one for the combined model. Due regard must also be given to the chemical-biological aspects of oil dispersion. These effects tend to dissipate spills; however, they are not a panacea. Applications of dispersants may be as toxic as the oil and further understanding and modelling of the various non-conservative factors affecting oil spills are important.

AFTERNOON PLENARY SESSION CONTINUED
DR. ROBERT WEISBERG
WORKING GROUP REPORT

Comment: Advective motions may far outweigh other motion modes in importance for oil transport modeling.

Comment: Back to the earlier discussion we had about stationary means and the water column - This is probably not quite the same for the surface, except that stationary means never exist in the real world in any regime for even with surface trajectories if you use statistical mean values in a trajectory analysis and go there the particles or markers may, or may not, be in that location.

Comment: Certainly for the surface regime oil spill trajectories are the focus.

Comment: U. S. Navy Fleet Numerical Weather Center has a real time program for some aspects of the meteorological parameters - the ones they use in Pierson's model - for their forecasting; it covers much of the Pacific, the Atlantic, and the Mediterranean and from it one can obtain significant wave heights that aren't too bad. Perhaps they can some day be intercompared with Norden's (Huang) GEOS-3 and SEASAT sea state data and provide needed data for real-time OCS oil spill trajectory mapping.

Comment: Although we clearly get the message BLM's primary objectives are more long term than real time, near real time verification of model skills on spills of opportunity gives them assurance that the models are probably physically meaningful when used with longer term mean statistical or extremum data.

Comment: It also lets the BLM help out, or at least contirubte indirectly, to those who have the near-term or spill management and clean-up responsibility. The emphasis today - at our state of the art -

has to be on model verification and not just model use. Here remote sensing can make a major contribution as can laboratory simulations (eg. experiments in wave tanks), albeit more limited but useful sometimes because of ones ability to control the parameter variations.

Question: Do your statements (question addressed to mean Bob Weisberg) really mean that the statistical mean is a meaningful quantity?

Answer: You might say so, yes (Weisberg).

REPORT OF THE OCEAN-STRUCTURE INTERACTION WORKING GROUP

I. OMISSION OF SIGNIFICANT MODELS OR INTRODUCTION OF NEW MODELS

Two categories of omissions from the project report covering this area were discussed by the working group:

- Topical areas omitted as being beyond the scope of this effort
- Previous work within the included scope of topics which were omitted in the project report.

Each of these areas is discussed separately.

Topical Omissions

The following topical areas were agreed by the working group to be beyond the scope of the present effort but because of potential future concern warrant their enumeration in this report.

a) Pipelines represent a structure with unique characteristics related to OCS oil spill scenarios. Their entire structural design and location makes them relevant to the dynamics of the seabed and perhaps more so than to the dynamics of wave-current interactions which is the focus of the research paper reviewed by this working group. A similar assessment of this type of structure could well be warranted in the future.

b) Seafloor (soil) stability represents a whole area of problems, some of which have already been encountered by the BLM in its OCS decision making. Scour problems are not appreciable with pile-type structures. However, North Sea has gravity-type structures with respect to which scour problems have proved to be of significance (see related papers in Offshore Technology Conference Proceedings and Behavior of Offshore Structures Conference Proceedings (OSS of Norway). Other problems related to seafloor stability occur where compliant bottom (soil behaves visco-elastically) conditions are found; certain drilling areas in the Gulf of Mexico have been found to have such conditions.

c) The broad topic of wind-driven currents during storms is not well understood and was only treated in the research paper in a cursory manner. It is the view of the working group that this area deserves recognition as a topic for future research with respect to:

- How do storm-generated currents arise?
- How do they propagate?
- How should they be treated in calculations?
- How should they be included for use in structural design work?

d) The overall risk assessment of offshore platform development requires treatment of a variety of reliability-type questions that were omitted in the research report. Specifically, such questions include uncertainties in force versus structure resistance and the probability of structural failure (see, for example, summary paper of Bob Bea in the Proceedings of the Offshore Technology Conference of 1978).

e) In addition to the types of fixed structures considered in the report, future research may well entail consideration of moored structures derived from a variety of naval architectural type. Such vessels are used today for exploration.

References of Relevance

A number of references of relevance to the topics discussed in the report are recommended for inclusion.

a) There are a number of summary publications by Ken Nolte of Amoco related to extreme distributions.

b) Another summary publication concerning distribution of extremes is that of Battjes published in the Proceedings of the North Sea Conference of 1977.

c) The classical paper by Longuet-Higgins on the statistical distribution of wave heights in a storm, and the related work of working group member G. Z. Forristall of Shell Oil (JGR Vol. 83, No. C5, p. 2353, May 20, 1978).

d) Perhaps the most critical aspect not included is the work of Ward and Evans, published in the Proceedings of the Offshore Technology Conference 1977, which presents a first-cut solution to the hindcasting of waves on the East Coast (complements Reference 47, which lists other earlier references to hindcasting data and methodology which are actually used by the oil companies). Waves are agreed to be the most important forcing element in offshore platform dynamics.

- There is insufficient wave data base for high confidence statistics extrapolations
- A hindcast model of waves can be constructed given the use of available wind data.

One hindcast technique evolved from the following steps:

- Pierson and Cardone developed the hindcast model
- Offshore data gathering project (ODGP) data were used to refine the model
- Directional spectra were verified by field work
- Analysis phase was undertaken to develop statistical capability for estimating extremum waves.

Some changes have evolved from more recent hurricane work. Other related models have been developed in England and on the Continent. These are summarized in the Proceedings of the NATO Symposium on Turbulent Fluxes Through the Sea Surface, published by Plenum (1978).

e) Don Resio of the Corps of Engineers Waterways Experimental Station is developing hindcast models. This current work should be applicable to the South Atlantic for offshore structures and therefore should be noted in the report.

II. JAYCOR MODEL EVALUATION

A. Thoroughness of Coverage

The section on Extremes Statistics is a topic that has received a great deal of attention and much work has been performed. The presentation in the present report is very brief. The subject merits thorough and separate review.

B. Further Analyses/Evaluations Required

In addition to those areas cited in I. above (topics omitted in the report), a number of areas are recommended for further analyses/evaluations concerning topics which fall within the scope of research reviewed by the working group.

a) Wind-driven currents require further research.

b) Refinements in wave spectra are needed for improving the means of hindcasting and predicting.

c) Wave-bottom interactions on a compliant bottom require further research.

d) Long and slender structures in deep water produce dynamic stress amplification which, although included in today's designs, use calculations that are quite questionable and require more work. For example, how does Morison's equation work when the structure is moving? Force evaluation on large bodies seems to be more tractable than on small bodies.

e) What are the coefficients in Morison's equation for force on small bodies? These require more research.

f) There are two schools of thought with regard to how extreme storms should be handled in model calculations: the approach espoused by Gumbel and that based on hindcasting. These require further evaluation.

III. DATA TO DRIVE MODELS

A. Discussion of Data Coverage, Adequacy, and Collection Requirements

a) More directional spectra are needed for wave environments since wave energy is basically a function of direction and frequency. Their availability would open the possibility of predictive and more accurate use of force functions derived from waves.

b) Although the general data base is statistically insufficient, appropriate data taking must be selectively approached because of its expense. The ocean current measuring program (OCMP) of Shell Oil took data for five years on the northern Gulf of Mexico, which was recorded on magnetic tape. Only the severe storm data have so far been reduced, analyzed, and distributed. This data base, nevertheless, is an example of a resource that could be economically used to the benefit of the entire community. Glen Williams, of Texas A&M, is looking for funding and could reduce and distribute these data to the community for about $100K, a real bargain for millions of dollars worth of valuable wave and current data pertaining to a vital U. S. OCS resource area. These data include currents from three platforms taken over five years at three or four depths.

c) Wind data for hindcasting is derived today from Weather Bureau isobaric pressure data and National Hurricane Center data. The Corps of Engineers at Vicksburg has planned hurricane modeling work.

d) The use and application of background currents in structure design require some additional research. Generally speaking, platform design requirements do not include consideration of steady currents which might well be of concern for a structure in, say, the Gulf Stream environment. In this regard, an interesting question is: Where does the Gulf Stream go when a hurricane crosses its axis?

B. Discussion of Model Sensitivity

Some comparative work on selected wave hindcast models was done by Vince Cardone and Duncan Ross at Marshall Earle's Dulles Airport Meeting (Ocean Wave Climate, Marshall Earle (Ed.), Marine Science Series, Vol. 8, 1979, Plenum Press).

C. Boundary Conditions

a) It is easy to get caught up with attempting to satisfy the Bernoulli equation; this is not always worthwhile for large turbulent hurricane waves. In this regard, further work is needed on the condition of the boundary, not on the boundary conditions.

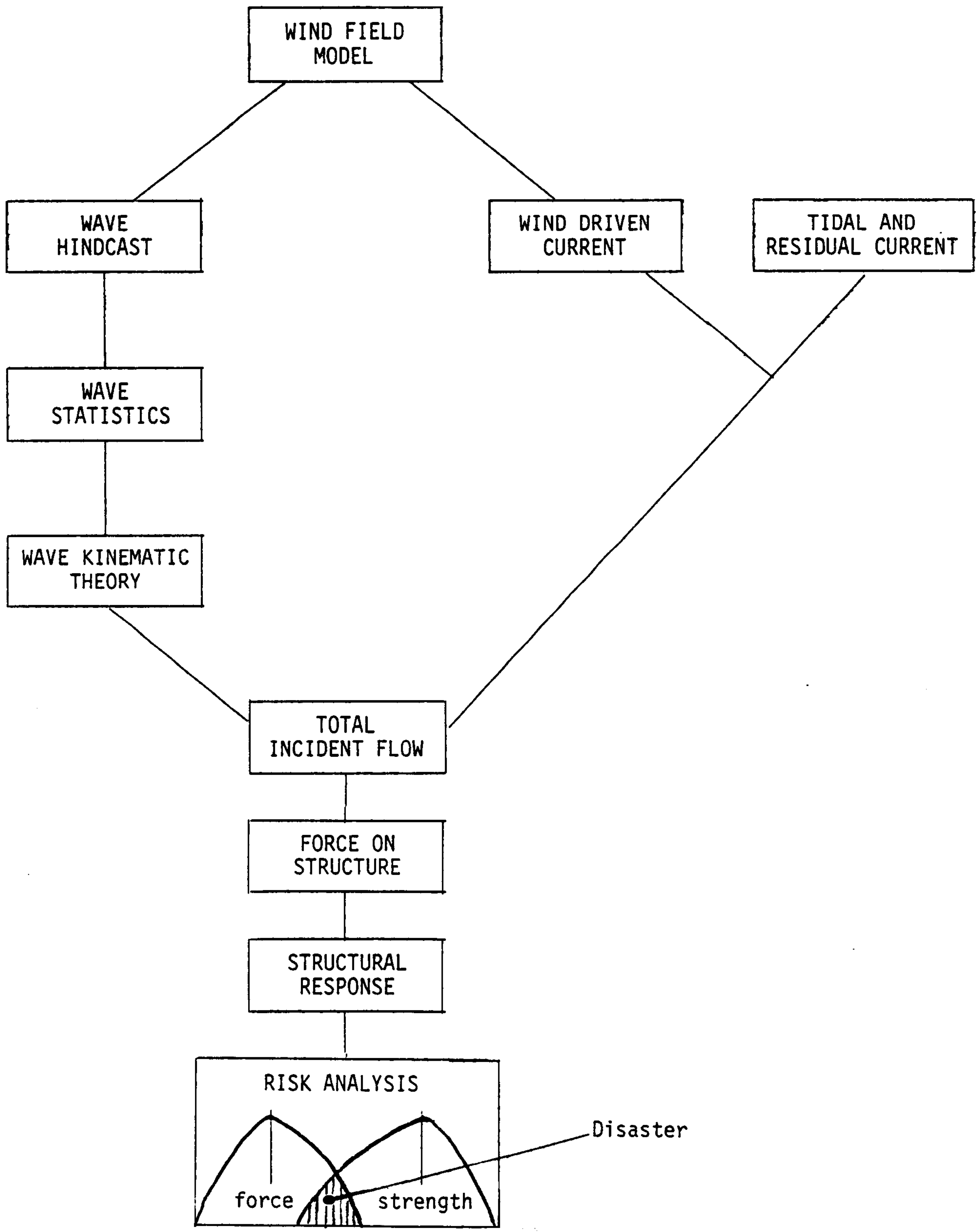
b) When nonlinear wave theory is used to calculate subsurface velocity, it yields little difference from the linear theory with regard to wave kinemetrics and structure forcing. The random and directionally spread nature of storm waves is more important in practice.

c) The standard tools for handling random seas are either a time series simulation of a random sea of going directly from random sea to the statistics of the forces. Morison's equation, which is non-linear, makes transformation of the random sea to wave force and attending structural analysis difficult. Statistical simulations are therefore often more handy as a way to express random wave theory in a quick and practical form for engineering applications.

IV. MODEL HIERARCHIES

Suggestions for Establishment of Model Hierarchies to Meet BLM Needs

A conceptual hierarchy for oceanographic input to structural design and failure probability relevant to oil spill (the bottom line for BLM applications at present) is indicated in the appended sketch.


WIND FIELD MODEL
WAVE HINDCAST
WIND DRIVEN CURRENT
TIDAL AND RESIDUAL CURRENT
WAVE STATISTICS
WAVE KINEMATIC THEORY
TOTAL INCIDENT FLOW
FORCE ON STRUCTURE
STRUCTURAL RESPONSE
RISK ANALYSIS
force
strength
Disaster

AFTERNOON PLENARY SESSION CONTINUES
DR. C. C. TUNG
WORKING GROUP REPORT

Comment: The Shell Oil data is an excellent example of the fact that the oil companies really do want to make their rather extensive data resources available to the community.

Question: That certainly wasn't the impression a couple of years ago with the big joint venture by three or four companies in the Gulf of Mexico and Shell was one of them. Why were they holding back then?

Answer: That data - the tapes as we had calibrated - has been turned over to the NOAA Oceanographic Data Center people for everyone's use for some time. When anyone takes data sets they will probably want to do some initial calibration and editing and possibly some level of use themselves of the data in analysis before releasing it. Usually without calibration and editing it is either useless or misleading or both. In this regard the oil companies may have been in this initial massaging stage during the period you sought the data. I do know we turned it over to the data center very early.

Comment: And now nobody knows where to find it or how to use it !

Comment: That is why Shell is suggesting a deliberate data reduction program of the present data five year data set for the community-data which cost literally millions on the Gulf OCS could be available for about $100,000 in useful form. The oil companies have reduced only the storm data in it.

Question: Do we know where the Gulf Stream goes if a hurricane crosses it?

Comment: We know that in 1965, Betsy had no appreciable effect on the Loop Current in the Gulf of Mexico when she crossed it.

Comment: We do have one good experience with a hurricane crossing the Gulf Stream: Belle in August of 1976, the effects were so dramatic we are still looking at them, the Gulf Stream moved off onto the coastal shelf with marked effects. In Onslow Bay the temperature dropped on the order of 9^{o} or $10^{o}C$ just after passage. The whole area will take some more study.

FINAL PLENARY AFTERNOON SESSION

Dr. Phil Hsueh

Dr. Phil Hsueh, Session Chairman convened the final plenary session and summarized what the workshop was to have achieved to that point and plans for the afternoon. He also cautioned the speakers about being overly verbose since there was a lot to discuss and inflexible airplane schedules at the end of the session. The following is a textual summary of that plenary session.

DISCUSSION OF THE FEASIBILITY AND REASONABILITY OF ESTABLISHING A MODEL HIERARCHY FOR THE SOUTH ATLANTIC OCS AREA

Discussion Leader: Dr. Leonard Pietrafesa

This topic is one which to my mind at least is a few years early so far as establishment of a grand overall model, within each regime we are beginning to understand the hierarchies as we heard in the comments on the individual working group reports by the various working group chairman. Even here some are much further along than others.

Our present state as I see it, and I'm probably overly generalizing here, is one in which we are working on and beginning to develop suitably parameterized boundary conditions between regimes. Norden Huang among others here and elsewhere are presently making contributions on wind-wave energy partition that allow us to start to model more accurately the air-sea interface. The surface current and water column interface and sediment-water column boundary conditions seem to be adequate for many circulation analysis purposes, on the other hand we have little work on response of structures to variations in the circulation parameters of the water column.

One of the most pertinent aspects of any hierarchy is, of course, what are the specific questions that the model array is intended to address. For some questions that state of the art will allow an arraying of models suitable to get answers to the desired adequacy. If one has the questions and the route to get the answers, the next problem is to obtain the verification data. Then for the model hierarchy to truly be useful, we have to assure the adequacy of data resources to feed the production runs of the model with data of the amount and accuracy needed to answer the questions at hand.

If I were to attempt to summarize where I feel we are today in this chain, I would in the light of my discussion, have to respond with a serial type of answer:

- We of the modeling and data taking community had previously been asked the pertinent questions about specific phenomena by the BLM; here in the course of this workshop, we have developed a better feel of, not simply what the BLM needs are, but how they are intended to be used. These needs are primarily inputs for our community to respond appropriately in terms of model rigor and accuracy, both of which translate ultimately into how the job is done and the amount it costs to do it. We can now start to conceptualize the hierarchies needed to answer BLM's questions.

- No gereralized hierarchy of models for the South Atlantic OCS, or for that matter, any other OCS region is practically attainable at the present time. Even if this were an attainable goal there is no data base suitable to verify or use such a hierarchy. We can now develop models in each of the four regimes covered in this workshop that will address BLM's requirements which were pointed out in the presentations of the deliberations of the individual working groups so I won't go into it further here. By so doing, we will also be be in a position for the first time, for the theoreticians to tell the data takers just what data is needed so that the models can be verified and later used to meet BLM objectives.

I'm afraid this is not very specific but it is about the level of specificity with which I am comfortable on this subject and so with these brief comments, invite your further discussion.

Question 1: In other fields one can at least define the phenomenonological linkages and boundary conditions, as in the case for instance of an electron beam into the atmosphere and again to a specific experiment, say, for controlled fusion. Models here allow source tailoring, experiment design and sensitivity studies. Can't a similar overall model with modules and boundary conditions be constructed for interaction of ocean circulation under experimental conditions with a structure (one model) or a pipeline (another model).

Answer: As Dr. Piertafesa indicated, we are not ready for a generalized hierarchy to do that yet. We are at a stage of building the models that can address questions concerning specific phenomena and regimes and the boundary conditions between regimes. Deterministic answers are simply beyond the state of the art both for OCS models and the data base to support them.

Comment 1: This has hurt us (BLM) in the past; it has contributed to our all too limited knowledge of properties at a specific lease site; at the risk of being repetitive, it is why our program is structured to get the most important and pertinent elements answered first while developing in parallel an overall, but manageable, rationale that will make the progress needed.
I (Dr. Amstutz) feel this need to go for answers now has been the cause of most of the criticism of our (BLM) program in the past. Your inputs today are a help towards better organizing to more effectively get these inputs quickly, while enhancing the overall systematic progress of the program.
An example is the oil spill trajectory model we use. Maybe it is not the best, but we needed something to use, and we keep improving. Before we had a handle on interleaving/extraleaving we simple had to treat it as though the oil spill trajectory followed the center of mass. This could, of course, theoretically sit still while the oil spill moved. We are beyond that now and have considered including many other processes such as weathering, diffusion, etc. Some other factors, such as tide probably don't warrant inclusion and they are in.

Comment 2: These are management questions and the answer for each is different for each question or at least type of question; it really reaffirms what Len (Pietrafesa) said about knowing the question, then we can take the best boundary conditions and theory and determine the important phenomena to address that class of questions. A lot of fallicies, so far as real world results go, can get hidden in the theory if the question is not asked just right. If you run a transport model, the residual current term (v_r) could have significant influence on trajectories. Depending on the means employed for deriving that value, spilled oil could easily go other than where it is predicted to go. At the present time drift bottle data is used to get at v_r; if, however, you couple the surface trajectory model with Norden's (Huang) formulation you will get a more sophisticated prediction. In spite of the added sophistication, our lack of understanding regarding surface transport may still not predict a black beach when it occurs.

Comment 3: I (J. Galt) feel you get some statistical improvement in assessment capability by running verified models to build up your statistical data base. Relating models to boundary conditions of different forcing functions (winds, wind-drift, etc.) gives you a feel for model sensitivity on the one hand and the importance of various phenomena on the other.

Comment 4: (facetious comment) The most fruitful way to build an ocean circulation model hierarchy on the basis of this discussion is

$$\frac{dx}{d\tau} = \sum_i \sum_j v_i \ ?_j$$

Comment 5: We really do make progress, despite our joking, We learned a lot from the AMOCO CADIZ incident, for instance. Surprises occurred like the oil did not go to shore on a rising tide. The oil only came in when a wind component held the slick on the shore during the receding tide leaving the slick on the beach face. We understand these things now and didn't before. We still have a lot to learn though.

Comment 6: The BLM staff are the integrators for management decisions. They need different models to use the data base for different uses. Hindcast generally vary completely from forecast uses, for instance.

DISCUSSION OF DATA ADEQUACY TO DRIVE MODELS AND MODEL SENSITIVITY

Dr. Tom Curtin

The introduction to this discussion will be rather short, since most of the pertinent points were raised during our discussion in the previous hour.

Without belaboring the same points again, there are two levels of data requirements of concern here today:

- that needed to verify the models;
- that needed to use the models.

The inadequacies of both are understood where BLM is concerned. Our previous orientation was towards data of quantity and quality to answer scientific questions of interest rather than BLM's most important management questions, the kind of data to address those questions may be just as useful for scientific purposes. We just don't know, since if the models are now conceptualized to do those specific jobs we can then look at the data requirements. That is not to say the data base we've built won't be useful to BLM's objectives. It's just that when we have the data needs identified we can see where we are and prioritize what data is needed for verifying and running the models that give BLM its answers.

In a general sense, we have to consider two categories of data:

- bands which include slowly varying mean in time or in its circulation parameters (monthly or seasonly);
- data which varies continuously, for all practical purposes (eg., wind or wave driven) and which must have a specific short term resolution associated with the model used and accuracy needed.

We have joked about the significance of mean data. It can of course be a useful quantity, depending on its stationarity and otherwise how well behaved it is. Stationarity over long periods will of course improve its utility. It certainly is not very useful in an observational sense. With that preface let me invite your discussion of the topic.

Discussion of the Topic by Plenary Session Participants

Comment 1: I, (J. O'Brien) agree with Tom (Curtin) that the best mean data on the OCS is not really zero. When one partitions in time it is a reasonable and useful quantity; also different means with respect to same other quantity may suggest a different kind of partition.

Comment 2: Not only is the adequacy of data questionable but also the adequacy of the way existing data is managed is perhaps even more of a problem. NODC does not archive the data usefully for the modelling community (a number of participants verbally affirmed this comment).

Comment 3: Were it properly archived, one could say some kinds of data (eg, wind field, surface wave field, hydrographic) are marginally adequate.

Comment 4: The synoptic atmospheric events are of course not equally likely. Some acquire less of a data base than others. Some appropriate prioritization and sorting here would help make the data problem more tractable.

Comment 5: What is right for treating oil will always depend to some extent on seasonal or monthly means. The same is true for pollutant trajectories like Dong Ping (Wang) models in the Chesapeake.

Comment 6: Trajectories aren't necessarily instantaneously varying whereas a source may be continuous for weeks.

Comment 7: Again (Curtin speaking) as Jim (O'Brien) said in our discussion of hierarchies, we must get back to the objectives.

Comment 8: I (D. P. Wang) see a real need for peak events and extreme data and only for risk work; good time series data (properly calibrated and well documented) is another type of data we should call out again; good judgment in mapping where data is taken is needed to assure systematic acquisition and its greatest utility.

Comment 9: I (L. Pietrafesa) feel we are particularly fortune in the South Atlantic in the institutional way our data base has been acquired, largely by N. C. State University, Skidaway University of Miami. We who are the principals all know each other and freely exchange our data. We all have a good knowledge of what data there is, where it came from, when and how it was obtained and what quality it is. This is perhaps more the picture for the short term data than it is for the long term statistical data.

SUMMARY STATEMENT OF THE RESULTS OF THE ENTIRE WORKSHOP

Dr. Phil Hsueh

My view of this workshop is that what we have attempted to do is to focus on rather specific BLM objectives to be capable of looking at the potential problems posed by oil spills and oil and other mineral resource developments (with their attendant structures) on the OCS and to try to develop the capability to reduce the uncertainties in the various kinds of related environmental assessments. The way we have been looking at doing this is by providing them with appropriate modeling tools and the data to drive them.

Because of its immediate and obvious priority, we have tended to focus mostly on the oil trajectory problem. Here our discussion has been at times about the forest and at times about the trees. Facts that stand out in my mind from these discussions are of such variety as:

- that immediately after an oil spill we need winds from the preceding days, current time and predictions;
- three percent of the wind speed coupled into surface energy (probably in waves);
- that currents in the water column, particularly the mixed layer, are important;
- that a problem is the time dependency of the mean field;
- that one defines and matches boundary conditions differently to address different overruns or problems;
- that model can itself generate useful statistics;

- that a 3-D time dependent model is not needed to address BLM questions;

- that Norden's (Huang) surface layer model represents a progress point of significance to BLM;

- that all models need both verification and sensitivity homework before being turned over for management use.

Such a random sampling of my impressions is intended only to serve to give my sense of the flavor of our feelings as I perceive them.

I feel as the true summary, the reports of the working groups speak far better for themselves.

CONCLUDING REMARKS OF DR. MIKE DOWE

It has truly been a privilege for JAYCOR to have had the opportunity to host this meeting. I hope each of you will visit us here from time to time for discussion of various ocean research. If you happen to be in Del Mar, you might visit our Fluid Dynamics Group there; this group is comprised of oceanographers none of you know (J. Stuhmiller, D. Deitrich, R. K.-C. Chan) now pioneering in Numerical Modelling of Fluid Fields in Advanced Energy Processes and Nuclear Reactor Cooling, (using ocean modeling techniques) - real technology transfer from the ocean theoretical modeling community to the energy community.

Again, I thank you for your participation and hope that the results you have generated prove as useful to BLM as they have been educational to me.

Ed Wood also has a few closing remarks (I won't forget him this time).

CONCLUDING REMARKS OF DR. ED WOOD

On behalf of BLM, Dave Amstutz and myself, I want to extend to all of you our gratitude for your participation. My only regret is that we didn't do it two years before. We will certainly try to work out a regular format for an interchange such as this of some sort with the ocean modeling community on a regular basis in the future. I also want to thank Mike (Dowe), Frank (Monastero) and the JAYCOR staff for the most pleasant and effective way they organized and managed the workshop.

I would be remiss if I let so many leaders in the Education of Physical Oceanographers go without an add for BLM. We have two positions in our New Orleans office: one for a physical oceanographer and one for an ocean scientist (not limited to physical oceanography). One is at the PhD and the other at the MS or BS level. We would be most receptive to your recommendations or suitable candidates for those positions. Again, thank you all.

Mike Dowe then declared the workshop adjourned.

APPENDIX A

BLM-JAYCOR MODEL EVALUATION WORKSHOP AGENDA

<u>April 25, 1979 — Morning Session</u>

8:30 - 9:00	Welcoming, Opening Remarks, Materials Distribution, Administrative Matters, *Dr. R. Michael Dowe*
9:00 - 9:25	BLM-COAR — Environmental Studies Program Objectives and Their Relationship to the JAYCOR Model Evaluation Study, *Dr. E. D. Wood* and *Dr. David Amstutz*
9:25 - 9:50	JAYCOR — Statement of Workshop Objectives, Review of Contract Effort to Date, Program Participants, *Dr. R. Michael Dowe*
9:50 - 10:05	Coffee Break
10:05 - 12:10	JAYCOR — Presentations of Results and Preliminary Conclusions • Geospecific Aspects of the South Atlantic OCS, *Dr. Leonard Pietrafesa* • Bottom and Sediment Transport Phenomena, *Dr. Leonard Pietrafesa* • Water Column Processes, *Dr. Gerald Janowitz* • Surface Phenomena, *Dr. Robert Weisberg* • Ocean-Structure Interaction, *Dr. Dave Tung* • Quantitative Model Evaluation, *Dr. Phil Hsueh*
12:10 - 12:30	Open Question Session, *Dr. Leonard Pietrafesa*
12:30 - 1:30	Lunch

April 25, 1979 — Afternoon Session

1:30 - 5:30 Group Sessions I: Review, Discussion, and Comment on Findings and Conclusions of Model Evaluation Study

- Bottom and Sediment Transport
  Small Conference Room, Suite 2
  Dr. Leonard Pietrafesa, Group Leader
  Dr. Frank Monastero, Group Coordinator

- Water Column Processes
  Main Conference Room, Suite 2
  Dr. Gerald Janowitz, Group Leader
  Dr. Yates Fletcher, Group Coordinator

- Surface Phenomena
  Conference Room, Suite 6
  Dr. Robert Weisberg, Group Leader
  Dr. Thomas Curtin, Group Coordinator

- Ocean-Structure Interaction
  Conference Room, 20 Park Plaza
  Dr. Dave Tung, Group Leader
  Dr. Michael Dowe, Group Coordinator

April 25, 1979 — Evening

6:30 - 7:30 Social Hour, Governor's Inn

7:30 - 9:00 Dinner, Governor's Inn

April 26, 1979 — Morning Session

8:30 - 12:30	Group Session II: Review of Preceding Day's Efforts, Preparation of Final Version of Recommendations and Group Report (same locations, same Group Leaders and Group Coordinators)
12:30 - 1:30	Lunch

April 26, 1979 — Afternoon Session

1:30 - 5:30	Plenary Session, *Dr. Phil Hsueh*
	Presentation of Individual Group Findings:
1:30 - 1:50	Bottom and Sediment Transport, *Dr. Leonard Pietrafesa*
1:50 - 2:10	Water Column Processes, *Dr. Gerald Janowitz*
2:10 - 2:30	Surface Phenomena, *Dr. Robert Weisberg*
2:30 - 2:50	Ocean Structure Interaction, *Dr. Dave Tung*
2:50 - 3:05	Coffee Break
3:05 - 4:00	Discussion of the feasibility and Reasonability of Establishing a Model Hierarchy for the South Atlantic OCS Area, *Dr. Leonard Pietrafesa*
4:00 - 4:45	Discussion of Data Adequacy to Drive Models and Model Sensitivity, *Dr. Thomas Curtin*
4:45 - 5:15	Summary Statement of Results for Entire Workshop, *Dr. Phil Hsueh*
5:15 - 5:30	Closing Remarks, *Dr. Michael Dowe*

APPENDIX B

FINAL LIST OF PARTICIPANTS

MODEL EVALUATION WORKSHOP

Research Triangle Park, North Carolina

April 25 and 26, 1979

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MODEL EVALUATION WORKSHOP
Research Triangle Park, North Carolina
April 25 and 26, 1979

Surface Phenomena

Robert Weisberg	JAYCOR
Norden Huang	NASA, Wallops Island
Robert Stewart	NOAA-PMEL
Christopher Mooers	University of Delaware

Sub-Surface Phenomena

Gerald Janowitz	JAYCOR
Jerry Galt	NOAA-PMEL
Dong Ping Wang	The Johns Hopkins University
James O'Brien	Florida State University
Peter Hamilton	Science Applications, Inc.
Robert Reid	Texas A & M University

Bottom and Sediment Transport

Leonard Pietrafesa	JAYCOR (Principal Investigator)
Charles Nittrouer	North Carolina State University
Georges Weatherly	Florida State University
William Grant	WHOI

Ocean-Structure Interaction

C. C. (Dave) Tung	North Carolina State University
Leon Borgman	University of Delaware
George Forristal	Shell Development Company

BLM Key Personnel

E. D. Wood	New Orleans OCS Office
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