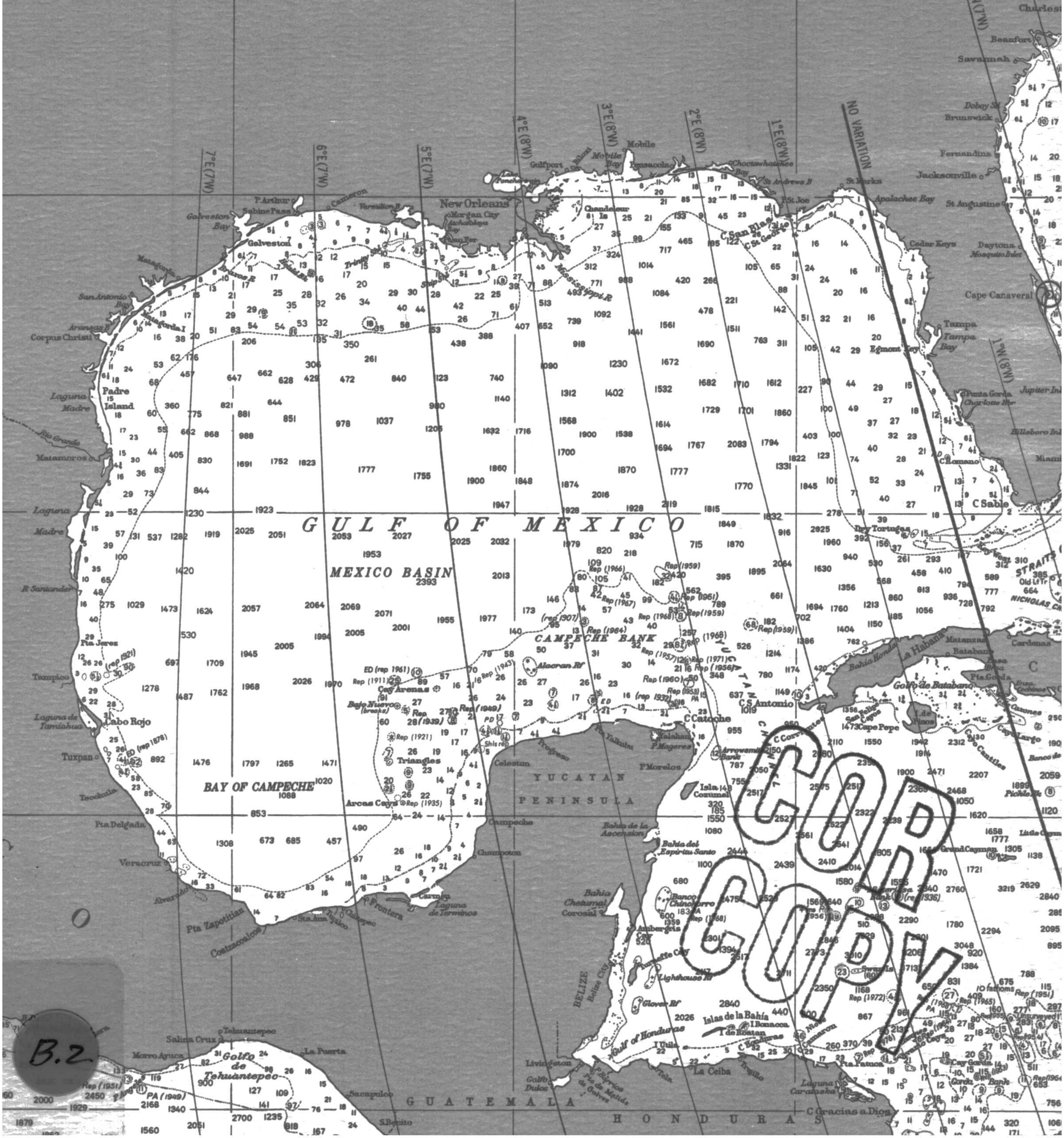
GULF CIRCULATION STUDIES WORKSHOP

14-15 May 1981, New Orleans, Louisiana



Proceedings of the

GULF
CIRCULATION STUDIES WORKSHOP

14-15 May 1981, New Orleans, Louisiana

Sponsored by the U.S. Bureau
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TABLE OF CONTENTS

TABLE OF CONTENTS - Cont.

PREFACE

Background. On-going and prospective energy-related uses have supported continued research on the physical processes governing Gulf of Mexico circulation. In particular, the Bureau of Land Management has funded a circulation modeling effort for the southwest Florida shelf, and the Department of Energy has sponsored a circulation model of the entire Gulf system. Additional circulation studies are planned by these and other federal agencies. It is evident that existing data are not adequate to define the governing circulation processes in the Gulf or to support present and future research work on Gulf circulation.

Accordingly, planning has now begun for a three-year research program to obtain physical oceanographic data in the Gulf. Because the Gulf Loop Current is the dominating circulation feature, a primary goal of this measurement program is to improve our understanding of the driving forces of the Loop Current, and the Loop Current's interaction with general Gulf-wide circulation.

In order to coordinate this data collection effort with the research goals of the many individuals and institutions, and several governments interested in the Gulf of Mexico circulation, a workshop was held at New Orleans, Louisiana on 14-15 May 1981. The workshop was organized by New England Coastal Engineers and documented by Tetra Tech, Inc., under Bureau of Land Management sponsorship.

Purpose. The purpose of the workshop was to provide a forum of scientists and engineers knowledgeable of the Gulf of Mexico to identify the major physical oceanographic processes of interest, to identify known data sources and deficiencies, and to outline a three-year data collection program for the Gulf. Major workshop goals were:

(a) To establish priorities for the collection of physical oceanographic data with the purpose of better understanding the major processes controlling circulation in the Gulf of Mexico.

(b) To stimulate discussion about Gulf circulation and data collection needs by interested professionals representing a variety of viewpoints.

(c) To document and disseminate ideas generated at the forum.

(d) To assist BLM in defining the Scope of Work for a contract to collect physical oceanographic data in the Gulf.

Workshop Structure. The workshop was structured around the work of three keynote speakers, representing different points of view, who prepared papers for presentation at the workshop. The three keynote speakers were Dr. Goerge Maul of AOML, Dr. J. Dana Thompson of NORDA, and co-keynote speakers Dr.'s Robert O. Reid and John D. Cochrane of Texas A&M University. The keynote speakers also chaired the meetings of three participant subgroups, each of which addressed the data collection program along the following lines:

Subgroup 1 Collection of velocity field data to describe the Loop Current. Dr. G. Maul

Subgroup 2 Collection of velocity field data to support numerical and analytical modeling of the general Gulf circulation. Dr. J.D. Thompson

Subgroup 3 Oceanographic data collection to supply Gulf-wide circulation information to the physical oceanographer. Dr.'s R.O. Reid and J.D. Cochrane

Abstracts of the prepared papers were sent to workshop participants prior to the meeting date, to encourage prepared response to the stimulus of the keynote speakers. During the subgroup meetings, the participants developed priorities for the collection of physical oceanographic data. Subgroup chairmen summarized the results of their discussions and presented their lists of priorities at a general assembly on the second day of the workshop. During the general assembly some common elements among the subgroup priorities were identified. Ensuing general assembly discussion then focused on molding a single data collection program around these common elements, while reaching a general consensus on the most important of the non-common elements from each subgroup to be included.

This proceedings of the workshop was prepared, leaving open a period of two weeks after adjournment for participants to provide additional written comments or dissensions from majority opinions. The workshop proceedings also include a preliminary program plan for data collection in the Gulf, synthesized from the subgroup reports and the major group consensus. The editor of the proceedings is Mr. James R. Pagenkopf of Tetra Tech, Inc.

OPENING SESSION

Welcoming Remarks and Workshop Purpose - B. Pearce, Workshop Chairman

B. Pearce - It gives me great pleasure to welcome all of you to this workshop, and I want to thank you for your participation. It is very encouraging to see an almost 100 percent attendance by the invited participants, and it appears that we have several additional attendees as well.

The overall purpose of this workshop can be defined by the following four goals to be achieved. The first goal is to establish priorities for the collection of physical oceanographic data with the intent of improving our understanding of the major processes controlling circulation in the Gulf. The second is to stimulate discussion about Gulf circulation processes and data collection needs by this group, which represent a variety of viewpoints. The third is to publish a proceedings of the workshop results, and the fourth is to assist BLM in defining a Scope of Work for a three-year data collection program in the Gulf of Mexico. Now I would like to introduce Ed Wood from the Bureau of Land Management, who will give you some background on BLM's program objectives.

Overview of BLM Program Needs and Objectives - E. Wood

E. Wood - Good morning and welcome to the Gulf Circulation Studies Workshop. As you know, the Bureau of Land Management (BLM) and its sister agency, the U.S. Geological Survey (USGS), have been charged with the task of managing the removal of oil and gas from the earth in an expeditious and environmentally safe manner while ensuring a fair return to the public. The New Orleans OCS Office is specifically responsible for initiating offshore petroleum resource development in the Gulf of Mexico through leasing in federal waters. Offshore oil and gas activities started in the north central Gulf and have now expanded into the western and the eastern Gulf, as well as moving into deeper central Gulf waters. In addition to U.S. activities, Mexican offshore petroleum development has increased substantially with the recent major find in the Campeche area. Because of the potential environmental impacts generated by these activities, we need to gain a good understanding of the general Gulf circulation, as well as specific processes occurring, such as Gulf circulation impingement on the shelf, shelf flushing, etc.

I have prepared a chart which gives you an idea of the broad spectrum of the various integrated studies and programs that BLM has underway. These include mapping of marine topographic features, documentation of endangered species, analysis of the southwest Florida shelf coastal and shelf ecosystem characteristics, Texas barrier island characteristics, and satellite oceanography, to name a few. More specific to the interests of this group is BLM's present program plan for strengthening our knowledge of the Gulf of Mexico circulation processes. This program plan consists of the following tasks: (1) problem definition, (2) a literature search (which has been accomplished several times over the years but most recently by AOML in 1978), (3) diagnostic model development and applications, (4) an oceanographic/meteorological data search, (5) the design of a data collection program (the subject of this workshop), (6) the data collection itself, and (7) prognostic model development and applications utilizing the boundary conditions supplied by field data. We envision a three-year data collection program which would start in FY 82 and extend through FY 84 with a synthesis in FY 85. Ultimately, the information gained from this effort will be used by BLM and USGS in the Department of Interior's oil spill trajectory analysis for a statistical analysis to develop long-term projections of probable environmental impacts.

T. Sturges - In reference to your flow chart listing the various tasks, have you outlined the problem definition and how this affects data collection requirements?

E. Wood - I would like all of you to feel free to suggest the problem definition, but in general I should say that the intent is to focus mainly on the deepwater, that is, the open Gulf circulation processes and the interaction between the open, central Gulf processes and the shelf processes. I feel, for the most part, that the shallow water nearshore areas are controlled by local winds, tides, and river outflows, which are more easily modeled. Our work should concentrate more on firming up our knowledge of the central Gulf circulation processes. For example, we have to relate the Gulf circulation in the area that determines the boundary conditions for the west Florida shelf numerical model. (That model is presently being developed.)

G. Csanady - In the end, is the ultimate goal to obtain inputs for models for predicting the trajectories of oil spills such as the recent major Mexican spill in the Campeche area?

E. Wood - That's right, or for prediction of contaminants involved from our own activities in the south Texas, central Gulf, and south Florida areas. More generally, however, we need to be able to better predict what the circulation will be not only at the surface but also at depth in the Gulf and at various times of the year. I think that some people feel that the Loop Current and the eastern Gulf exhibit the dominant circulation features. In short, there are certainly different opinions as to which areas need the most study and what processes are most dominant, but I do not intend to be a referee on that particular matter. I would like to emphasize, however, that there is certainly room for more input, and I won't discourage you from putting in your own definition of the problem.

D. Brooks - You mentioned earlier the possible involvement of a number of other nations, particularly Cuba and Mexico. Could you say anything about what the boundary conditions are and how the measurement programs will take this into account?

E. Wood - That is a good point, and I should have brought it out. About a year or so ago, I discussed with certain people involved, in particular G. Maul, the model that G. Mellor and his group were developing for DOE. We were concerned at that time about the inflow through the Yucatan and outflow through the Straits of Florida. It was my job to convince the people in my office that we should be venturing this far out to study the Gulf of Mexico. Since they went along with this approach, I would say that the Yucatan and Straits of Florida would be the limits that we could live with. Therefore, I don't see a problem sampling anywhere in the Gulf, and I hope that we can enter into cooperative arrangements with Mexico or perhaps even Cuba so that we can exchange information (and even scientists on cruises) and that we can all share in the data products. We have two representatives from the scientific community of Mexico with us today: Jose Altamirano and Rafain Rodriguez of the Petroleum Institute of Mexico. We are pleased to have them with us. I have discussed this with other people in Mexico, and we see that there is a good possibility for exchange of information and cooperation in the entire Gulf. I don't see the BLM funding cut off at any particular imaginary line; and although it may not be imaginary to politicians, it is imaginary to the ocean's circulation. It may be that someone will say that the Loop Current inflow is really being pulsed by something out in the north or central Atlantic. That's a little far-a-field even though it may be the real world, and it may be difficult for us to convince the managers that we should be running off to Barbados to study the Gulf system.

D. Grossman - Ed, following up on the T. Sturges' question about problem definition, I guess there are a couple of ways of looking at this. One is coming in and seeing what the problem is that you want solved and then we could propose a number of alternatives for solving it. The second is that for a given set of resources, we come up with the problems that should be solved and somehow prioritize them. You haven't really given a good definition of the type of resources that you are talking about in dollars and support for the data collection program, and I think that for any amount of resources that you want to throw out on the table, there are enough problems collectively in the room that could be defined to fill your requirements.

E. Wood - I can't tell you how many dollars are available, and I wouldn't if I knew, because of our contracting procedures. This work, or most of it, will be going out in a competitive procurement, and we tend to get a little tight lipped about total dollars and the specifics about a particular statement of work when it gets near contracting time. Now I've mentioned before that there seems to be a little crisis bell that starts ringing when physical oceanography starts eating up more than 30-35 percent of the entire budget.

P. Niiler - What is the Budget?

E. Wood - If we look at the past history, we see that the Gulf funding has been on the order of 3 to 5 million per year and in some cases more than that. Our high year was nearly 8 million dollars for the Gulf. We are now looking at a reduced budget, and expect the FY 83 budget to be something in excess of 3 million dollars for the Gulf of Mexico. Last year we had something like a 40 percent cut in our funds early in the year when we started to fund the projects. This is one of the reasons why I would like to remind you for a minute about priorities. We are often faced with crises requiring rapid responses where we have to come up with X amount of budget from a program. We have to make decisions as to which studies get cut and which tasks are deleted or altered. To avoid reducing a critical part of a study we need to develop priorities at the beginning of the program, such as which seasons and frequencies are most important, and minimum requirements. There comes a point, where if minimums cannot be met one might as well stay home. So we need to establish priorities even though we don't like it. One of the things I am hoping to achieve by this workshop is to coordinate with many groups and countries so that there will be cooperation in terms of funding of various studies from other sources where there are common needs and interests. In this way we can all benefit from the effort.

I would now like to introduce D-P Wang of Argonne National Lab, who will give you a brief summary of DOE's interests in the Gulf of Mexico.

U.S. Department of Energy Perspective - D-P Wang

Summary. The two major restraints on the use of floating OTEC plants in the Gulf of Mexico are: (1) they have to be located in U.S. territorial waters, and (2) the thermal resource necessary to allow adequate plant efficient with a 1000 meter intake as well as proximity to an acceptable shore demand area is confined to a relatively small zone off the southwest Florida shelf. As such, the priorities for physical oceanographic data for DOE's purposes are in the Florida Straits and on the southwest Florida continental shelf.

As for future DOE programs, the funding for the OTEC program is going to be substantially reduced, and tighter priorities are necessary under the limited funding levels. The OTEC program will be concentrating on island sites (e.g., Hawaii and Puerto Rico) and very possibly on shelf mounted OTEC plant designs rather than floating plants. A future OTEC pilot plant is possible for the Gulf but is presently rated as a low priority.

KEYNOTE ADDRESSES

A CURRENT DATA COLLECTION PROGRAM FOR THE GULF LOOP CURRENT

George A. Maul, NOAA/AOML

Between 1874 and 1883, temperature measurements at a depth of 250 fathoms in the Gulf of Mexico were observed by American hydrographers which showed a warm intrusion in the eastern basin. In the 1930's, oceanographers made salinity measurements and began to piece together the T-S properties that identify the dominant water masses: Subtropical Underwater, Antarctic Intermediate Water, Deep Gulf Basin Water, Continental Edge Water, and Resident Gulf Basin Water. It was not until the 1960's when it was realized that the distribution of water masses defined the Gulf Stream System in the Gulf of Mexico and that a highly variable current regime existed (Leipper, 1970). Today, the Gulf Loop Current is recognized as the dominant current system in the eastern Gulf (Caparro and Reid, 1972; Maul, 1977; Molinari, 1980), and through periodic shedding of mesoscale anticyclonic eddies which drift west, is probably more important than wind stress to the energetics of the western Gulf (Elliot, 1979).

Careful studies of historical data (Behringer et al., 1977) suggest that the Gulf Loop Current has a mean annual cycle of northward penetration of over 4° of latitude followed by the separation of a ~ 400 km diameter anticyclonic eddy, which is approximately in phase with the mean annual mass transport cycle of the Gulf Stream. Although a great deal of interannual variability is now recorded (Molinari et al., 1978), physical oceanographers have asserted that the Loop Current's mean annual cycle is forced by cycles of mass transport, current location and direction, and/or vorticity through the Yucatan Strait and outflow through the Straits of Florida. A recent numerical simulation of Gulf circulation (Hurlburt and Thompson, 1980) suggests that the mean annual cycle is a "natural" eddy-shedding period which does not require variability in mass transport through the Straits as a forcing function. Other models such as Wert and Reid's (1972) and Ichiye's (1962) suggest choice of the horizontal eddy coefficient and/or velocity and direction at the Yucatan Strait force the eddy-shedding period.

The notion of an annual mass transport cycle (Fuglister, 1951; Cochrane, 1965) has been supplemented in the last 30 years by data suggesting that the fortnightly variability is as large as the annual variability exclusive of tidal effects (Niiler and Richardson, 1973). A complex picture of spectral energy at 4-14 days (Brooks, 1979) in the Straits of Florida has been observed in a quasi-geostrophic channel flow of undercurrents, countercurrents, eddies, meanders, vortex streets, and horizontal waves (see also Düing, 1975; Düing et al., 1977). Simple arguments using

$$Kv^2 + fv = g\frac{\partial h}{\partial x}$$

where K is curvature, $f = 2\Omega\sin\phi$, g is gravity, v is velocity, and $\partial h/\partial x$ is the free surface height gradient, show that variation in curvature accounts for ageostrophic mass transport variability as large as the annual amplitude (Chew, personal communication).

Comparison of satellite imagery with concurrent in situ density observations shows ageostrophic variability in the surface temperature patterns, and further dispels any notion of linear steady-state dynamics in the Gulf Loop Current's frontal structure. Wind stress as an important forcing function is evidenced by the marked changes in satellite surface temperature patterns after passage of an atmospheric front and in the Somali Current-like behavior of the Mexican Current (Sturges and Blaha, 1976). Wind events with periods less than a week seem to dominate equal-period oceanic variability including spin-off eddies of 10-50 km diameter, some current front meanders, and intrusions of cold (fresher water) tongues from the northern bays and rivers (Vukovich et al., 1979).

Water masses at the surface (0-200 m) reflect the complex patterns observed in satellite data, but at temperatures less than 15°C, the T-S properties of Gulf water masses are indistinguishable. Rivers from five nations drain into the Gulf and account for the fresh water needed to modify the surface layer T-S properties of Loop Current eddies to match the juxtaposed T-S properties of resident Gulf Basin Water (Maul, 1979). The Mississippi River forms the source of fresh water lenses entrained along the current's cyclonic shear edge which have been traced to Georgia (Atkinson and Wallace, 1975). Water deeper than the 2000 m sill depth of the Yucatan Straight has a weak circulation pattern which appears detached from the Loop Current (Molinari et al., 1978). Carder et al. (1977) argue that the deep Gulf is in communication with Caribbean water which they demonstrate to flow into the Gulf and sink to over 3500 m, thus renewing the deepest waters. Current meter data from just above the Yucatan sill (Hansen and Molinari, 1979) show a persistent SSW flow which may be forced by Loop Current displacement of surface waters and partially fed by returning Caribbean water.

While knowledge of the Loop Current seems extensive, it is equally important to stress what is not known and is necessary to further understanding. Almost all knowledge of current velocities are based on geostrophic calculations, and direct measurements are not available as a function of space and time along the Loop Current's path or in defining the decay of mesoscale eddies. Effect on the spatial distribution of absolute velocities by the tides, by wind events, of seasonality, and due to position in the Gulf basin is unknown. Interaction of the current with bottom topography is not well investigated, and little is known about spin-off eddies on the continental shelf edges. Upwelling (both in the deep basin and along the shelf edge), tidal current influences, and interaction of the quasi-annual mesoscale eddies with coastal currents is poorly known. Other unanswered questions center on: What forces the Loop Current? What is the effect of wind stress? What is the effect of river runoff? Does the Loop Current establish a secondary circulation in other parts of the basin?

Satellite sensed surface thermal patterns in the eastern Gulf during winter are operationally interpreted as defining the continental edge of the Loop

Current, mesoscale eddies, and cold tongue intrusions. Proper interpretation of small area features and loss of thermal contrast in the summer limits this technique, although low-level winds from satellite imagery is an operational year-round product. Satellite measurement programs by their nature require constant in situ data for verification as would any operational numerical model. Maul (1980) gives an overview of the modern in situ and in vaccuo current measuring techniques which should be considered, including Lagrangian drifters, profiling current meters, satellite altimeters, and image analysis.

From the overview presented thus far, it is apparent that a data collection program for the Gulf Loop Current cannot be divorced from collection programs for the entire basin or from programs specifically suited to numerical modelling. The information required about the Loop Current are its three-dimensional extent, its forcing, and its interaction with the less energetic Gulf waters. Such a requirement is immediately open to questions of spatial and temporal scales, duration, accuracy, cost, and the ultimate objective of the measurements. Assuming that the need in this instance is pollutant trajectories such as from an oil spill or a marine cargo accident, a three-dimensional answer is necessary with sufficient accuracy to direct a containment or clean-up operation. This suggests two levels of data collection effort: one, a low resolution, low frequency effort so that prediction at 50 km x 50 km x 100 m grid points can be made; secondly, a real time, high resolution (~ 5 km x 5 km x 10 m) prediction for operations. The requirements are quite different.

Based on contemporary technology and plans for the next five years, the following measurements are offered as a discussion vehicle for the low resolution monitoring of the Gulf Loop Current:

- Continued operational satellite surveillance and development of nonthermal monitoring techniques.
- Significant increase in ship-of-opportunity XBT and weather observations with data reporting to a diagnostic/prognostic model.
- Moored buoys especially in areas outside of marine transportation routes which measure current velocity, temperature, salinity, and surface meteorological variables.
- Velocity, vorticity, temperature and pressure differential across the two Straits measured so as to account for Kv^2 at a spatial resolution less than $\sqrt{g'h}/f$, the baroclinic radius of deformation.
- A program of satellite tracked surface drifters and acoustically tracked floats at several depths.

- Quarterly surveys of the basin to measure absolute velocity fields and standard water column properties for at least three years.
- Process oriented measurements to study specific features and/or questions as they arise.

Measurements for the 5 km x 5 km x 10 m requirements associated with a specific event should not interrupt the multiyear systematic measurements described above, but should supplement them. Specific event measurements are probably best conducted from aircraft, land based radar, and high speed surface vessel, and are more appropriately designated as nowcasting measurements. Spatial and temporal spacing of nowcasting variables depends on the target area's proximity to the coast and/or major currents, on the time of year, and the potential hazard involved. The important variables which need to be measured are surface wind stress, mixed layer depth and velocity, areal extent of pollutant, surface wave spectra, and deeper current and thermal regimes along the projected trajectory.

In conclusion, it should be emphasized that any data collection program for the Gulf Loop Current should be a three-year minimum continuous effort, and be coordinated as much as possible with other programs such as NOAA's Subtropical Atlantic Climate Study (STACS), any CICAR activities especially associated with Caribbean fisheries initiatives, appropriate programs of university research, and efforts by state or local governments. Further, both the scientific and political necessity of entraining Mexican and Cuban interest needs to be recognized and acted upon at the outset. Finally, nonphysical aspects of the Gulf circulation problem have to be considered in any sampling scheme, while keeping in mind the primary objective of the research effort.

REFERENCES

Atkinson, L.P. and D. Wallace (1975). Deep Sea Res., 23, 913-916.
Behringer, D.W., R.L. Molinar, and J.F. Festa (1977). J. Geophys. Res., 82, 5469-5476.
Brooks, T.U. (1979). J. Phys. Ocn., 9, 1048-1053.
Capurro, L.R.A. and J.R. Reid, eds. (1972). Contributions on the Physical Oceanography of the Gulf of Mexico. Gulf Publ., Houston, 288 pp.
Carder, K.L., K.A. Fanning, P.R. Betzer, and V. Maynard (1977). Deep Sea Res., 24, 1149-1160.
Cochrane, J.E. (1965). In: Annual Report, TA&MU Ref. 65-171, 20-27.
Duing, W. (1975). J. Mar. Res., 33, 53-73.
Duing, W., C.N.K. Moores, and T.N. Lee (1977). J. Mar. Res., 35, 129-161.
Elliot, B.A. (1979). Ph. D. Dissertation, TA&MU, 18 pp.
Fuglister, F.C. (1951). J. Mar. Res., 10, 119-127.
Hansen, D.V. and R.L. Molinari (1979). Geophys. Res. Ltrs., 84, 359-362.

Hurlburt, H.G. and J.D. Thompson (1980). J. Phys. Ocn., 10, 1611-1651.
Ichiye, T. (1962). Geofisica Int'l., 2, 47-76.
Leipper, D.F. (1970). J. Geophys. Res., 75, 637-657.
Maul, G.A. (1977). J. Mar. Res., 35, 29-47.
Maul, G.A. (1979). In: FAO Fisheries Report No. 200, 597-619.
Maul, G.A. (1980). Mar. Geodesy, 4, 1979-196.
Molinari, R.L., J.F. Festa, and D.W. Behringer (1978). J. Phys. Ocn., 8 987-996.
Molinari, R.L. (1980). Mar. Geodesy, 3, 409-436.
Niiler, P.P. and W.S. Richardson (1973). J. Mar. Res., 31, 144-167.
Sturges, W. and J.P. Blaha (1976). Science, 192, 367-369.
Vukovich, F.M., B.W. Crissman, M. Bushnell, and W.J. King (1979). Gulfstream, 9, 3, 6-7.
Wert, R.T. and R.O. Reid (1972). In: Contributions on the Physical Oceanography of the Gulf of Mexico, Gulf Publ., Houston, 177-209.

DATA REQUIREMENTS FOR THE GULF OF MEXICO: RECOMMENDATIONS BASED ON NUMERICAL EXPERIMENTS

J. Dana Thompson, NORDA

The traditional picture of a static, sluggish ocean is nowhere more incorrect than in the Gulf of Mexico. The circulation, particularly in the eastern Gulf,is remarkably variable and intense. However, the space/time observational data base for the Gulf is in general sparse and aliased. One means of "filling-in" this data gap is through ocean models. Here an ocean model is defined as a mathematical statement of the conservation laws for momentum, heat, salt, and mass and the equation of state.

This set of partial differential equations, coupled with well-posed initial and boundary conditions, describes the three-dimensional time evolution of velocity, temperature, and salinity fields. A model is valid to the extent that (1) the governing equations accurately describe the physical system, (2) the initial and boundary conditions are correctly specified, and (3) the system of differential equations is accurately integrated. In reality there is no ocean model which fully satisfies these requirements. The governing equations are simplified and parameterized, initial and boundary conditions are inadequately known, and integration techniques are limited for practical applications.

Two different model types must be considered when assessing data requirements for the Gulf: (1) Diagnostic or inverse models in which the observed density field is prescribed and the velocity field calculated to satisfy a specified set of dynamical constraints. (2) Prognostic models in which initial and boundary conditions are specified and the model is marched forward in time. Our focus is on the latter model type, particularly the low vertical-resolution, high horizontal-resolution, hydrodynamic models described by Hurlburt and Thompson (1980). These models have contributed to our understanding of Loop Current dynamics and have aided our interpretation of the existing observations. They have also revealed several crucial observational requirements for monitoring the Gulf.

Because the initial conditions over the Gulf at any instant are poorly known, these models were driven from rest to statistical equilibrium over a period of three to five years by specified inflow transport through the Yucatan Strait and compensated outflow through the Florida Straits. Over 150 numerical experiments were performed in order to determine the sensitivity of the models and to explore the parameter space appropriate for the Gulf. Important results from our study indicate that:

(1) The Loop Current can penetrate into the Gulf, bend westward, and shed anticyclonic eddies with almost an annual period with <u>no</u> time variations in the inflow through the Yucatan Straits.

(2) The Loop Current described by a single baroclinic mode can exhibit at least three stability regimes: a steady source-sink regime with little northward penetration of the Loop Current, a steady regime in which the Loop Current spreads far westward, and the familiar unsteady, eddy-shedding regime. When vertical model interactions are allowed, baroclinic instability can become important, leading to break-up of large anticyclonic eddies and efficient transmission of energy to the deep water. The process is less likely over steeply sloping topography.

(3) Significant deep-water inflow transport through the Yucatan Straits can prevent Loop Current penetration and the shedding of anticyclonic eddies. Loop Current behavior is very sensitive to the deep water transport but is rather insensitive to the details of the cross-stream velocity profile in the upper ocean.

(4) To obtain stable mean and eddy statistics, especially for cases with a time-varying inflow transport, long sampling periods (ten years or more) are required in some experiments.

Based on the results of our modeling studies of the Gulf, the following data collection efforts are recommended:

(1) Initiate continuous monitoring of the transport through the Yucatan and Florida Straits, particularly in the deep water for a period of no less than three years.

(2) Initiate a hydrographic data collection program (ships, aircraft and buoys) to describe the position and intensity of the Loop Current and its shed eddies on a monthly basis for the same three-year period. A comprehensive satellite observing program utilizing all available sensors (IR, CZCS, altimetry, etc.) should augment in-situ measurements during the period.

(3) Establish a network of deep-water current meter moorings to provide information on the rate of energy transmission to the deep water from the Loop Current and shed eddies and to determine how the Loop Current and shed eddies interact with the continental shelf and slope.

(4) Determine the feasibility of adequately calculating heat fluxes and wind stresses over the Gulf from the present observing system. Wind stress curl on space scales of 100 km and time scales of days to seasons may be particularly important.

(5) To complement this central data collection effort, limited-area, focused process studies involving individual investigators, institutions, and industry should also be funded during the three-year period.

Although the proposed program is ambitious, it will by no means give us a complete description of the physical oceanography of the Gulf. It will, however, be a drastic improvement over the present situation.

REFERENCES

Hurlburt, H.E. and J. Dana Thompson, 1980: A Numerical Study of Loop Current Intrusions and Eddy Shedding. J. Phys. Oceanogr., 10, 1611-1651.

AN OCEANOGRAPHIC DATA COLLECTION PROGRAM FOR THE GULF OF MEXICO

J.D. Cochrane and R.O. Reid, Texas A&M University

The Loop Current is surely the strongest circulation feature in the Gulf of Mexico and the one which brings energy in from other ocean areas. Because of its obvious physical importance it has received the greatest attention. How the rest of the open Gulf receives the greater part of its energy is still unclear. Is it in the form of the anticyclonic rings that break away from the Loop, or is it from action of local winds? The abyssal circulation and particularly its possible barotropic component are virtually unknown. The shelf regions which constitute a large portion of the Gulf have been avoided by many oceanographers in the past because of their evident complexity and in spite of their economic importance.

The Gulf has the advantage of small size and a small number of circulation features. Its openings to exterior oceanic energy sources and sinks are small and rather readily monitored. However, the Gulf's small size leads to some disadvantages: the features are so interrelated that isolated consideration of any one is difficult, and so much of the region is near boundaries that some standard simplifications of open-ocean dynamics are of doubtful validity.

To decide which problems are most important seems to us to depend on the criteria to be developed by the Workshop. At this point therefore, we have chosen to list most of the problems we perceive except those peculiar to the Loop which are covered by another speaker, and sketch some of the observations which would contribute to their solution. This is done also partly because of the close interaction among Gulf features. We do however give a tentative selection of "most important" circulation problems at the end.

To save space, we use a tabular form. Since many observation tools are common to many problems, we use the following abbreviations:

CM/T	current meter arrays with temp. sensors
HS	hydrograhic surveys
IES	inverted echo sounders
IR	satellite sea surface temperature
RF	Richardson-Schmitz floats
SD	satellite-tracked drifters
SF	Swallow floats
TG	tide gauges
VC	satellite cloud photos
WB	weather buoys
XBT	rapid XBT surveys by ship or airplane

GULF CIRCULATION FEATURE	OBSERVATION METHOD
LOOP CURRENT IN RELATION TO OTHER CIRCULATIONS	
Seasonal variation of strength and intrusion Modal configurations (east and west modes) Instability Yucatan Current Meanders, precursors of detachment (?) West Florida Current meanders and associated upwelling Ring detachment	IR, CM/T, IES XBT for special events, HS to bottom, infrequent RF
Interaction with Campeche Bank Interaction with W. Florida Bank	CM/T, XBT near shelf break
Small Scale meanders and rings such as appear in IR imagery (> 100 km)	IR, CM/T
DETACHED ANTICYCLONIC RINGS (> 100 km)	
Detachment Migration Interactions with shelves Spin-down	IR, CM/T, IES for approximate detection, in path of feature, (possibly even TG), XBT, SD, SF for close tracking
Water modifications by rings	HS, probably not deep
Modification by wind	IR, WB, VC
ANTICYCLONES GENERATED IN GULF (> 100 km)	
Wind stress curl Buoyancy flux	IR, XBT, IES, WB, VC Timely HS

GULF CIRCULATION FEATURE	OBSERVATION METHOD
CYCLONIC FEATURES	
NE Gulf (between Bank & Miss Delta) NW Gulf (north of western anticyclone)	IR, XBT, HS
Campeche Bay (local generation ?)	VC, IR, XBT, HS, CM/T
ABYSSAL CIRCULATION	
Baroclinic aspects	HS to bottom, CM/T
Spreading of Caribbean Water	HS to bottom in SE Gulf
Barotropic recirculation	CM/T deep, widely spaced near boundaries
Absolute velocity	Inverse & vorticity methods, CM/T, RF at Yucatan and Florida Straits
COMMON FEATURES OF SHELF CIRCULATIONS	
Tidal motions	TG
Shelf waves	CM/T on outer shelf
Bottom friction	CM as described by Scott and Csanady
CAMPECHE BANK CIRCULATION	
Influence of Yucatan Current Small meanders and eddies Cold bottom water intrusions Wind upwelling along north coast of Yucatan Cyclonic circulation on eastern shelf Wind-driven circulations on western shelf Influence of strong wind events Annual variation	IR, VC, SD Coastal and buoy wind observations CM/T along coast, near shelf edge and in few cross-shelf lines Bimonthly and Special event HS TG

GULF CIRCULATION FEATURE	OBSERVATION METHOD
WEST FLORIDA SHELF CIRCULATION	
Influence of W. Florida Current	IR, VC, SC
Eddies and cold intrusions	Coastal and buoy wind observations
Upwelling near shelf break	CM/T along coast, near shelf edge and in few cross-shelf lines
Influence of northers and hurricanes	Bimonthly and special event HS
	TG
TEXAS-LOUISIANA SHELF CIRCULATION	
Wind-induced up- and down-welling	IR, VC, SD
Coastal orientation influencing above	Coastal and buoy wind observations
Circulations due to up- and down-welling	CM/T along coast, near shelf edge and in few cross-shelf lines
Coastal fresh (Miss.) band, associated front and current system	Bimonthly and special event HS
Shelf-scale cyclonic circulation	TG
Convergence along coast	
Anticyclone SW of Miss. Delta	
Annual variation	
Influence of offshelf circulations	
Influence of northers and hurricanes	

Water characteristics provide an important tool for studying circulation. Sometimes this tool seems the only one available, as in distinguishing migrating from indigenous anticyclonic rings in the western Gulf. Studies of water modification by winter storms, water circulation features, and evaporation minus precipitation and runoff, therefore, appear to us to be an indispensable part of an observational program aimed at circulation problems of the entire Gulf.

Our tentative selections for greatest emphasis on the basis of least present knowledge, American economic (as well as scientific) interest, and present promise of solution are: Loop Current, Life History of a Detached Anticyclone, Indigenous Anticyclones, W. Florida and Texas-Louisiana Shelf Circulations. Observational strategies for particular problems are to be discussed.

It seems worthwhile to mention that there are existing observation programs with which cooperation ought to be actively sought, e.g., current meters near Flower Gardens. Hydrographic surveys which cover any region approaching a quarter of the area of the Gulf ought to be done by more than one vessel in order to cover the region quickly. The importance of cooperation with Mexico in all possible ways is evident.

SUBGROUP DISCUSSIONS

GULF LOOP CURRENT GROUP

G. Maul - Chairman
C. Cooper - Recorder
W. Merrel
P. Niiler
D. Pillsbury
T. Sturges
F. Vukovich

Discussion. The general first day's discussion of the Gulf Loop Current Group was guided by the list of suggested measurement programs given in G. Maul's keynote address. The following is a summary of this discussion.

(1) Continued operational satellite surveillance and development of non-thermal monitoring techniques.

- All group members agreed that continued high resolution satellite IR is valuable and should be continued.
- A ground-truth field program is needed in order to interpret satellite data, otherwise it is worthless.
- Three satellites with IR will be in operation by 1982 (GOES, NOAA-6, and NOAA-7). No satellites will be measuring surface height.

(2) Significant increase in ship-of-opportunity XBT and weather observations with data reporting to a diagnostic/prognostic model.

- Group members agreed that ship-of-opportunity XBT observations should be increased.
- The program should be well planned rather than random, using an array design.
- Need to know frequency of ship traffic and routes before the sampling program can be designed. The Port Authorities at Corpus Christi, Galveston, New Orleans, and Tampa should be contacted.

(3) Moored buoys especially in areas outside of marine transportation routes which measure current velocity, temperature, salinity, and surface meteorological variables.

- Group members were generally against moored buoys because of the high costs involved.
- However, wind data are important to obtain, especially for the shelf regions.

(4) Velocity, vorticity, temperature and pressure differential across the two Straits measured as to account for KV^2 at a spatial resolution less than $\sqrt{g'h}/f$, the baroclinic radius of deformation.

- If tide gauges are used, they should be deep, i.e., 500 - 2500 m.

- Investigators have looked at 2 years of tide gauge data and could not get any correlation between the Yucatan and Florida Straits.

- Group members generally felt that it would not be reasonable to measure differences in mass fluxes through the Straits.

- It was the general belief that it would be possible to look in more detail at existing data in the Straits (e.g., P. Niiler's data), and that additional data in the Straits would not be useful unless access to Cuban waters was possible.

(5) A program of satellite tracked surface drifters and acoustically tracked floats at several depths.

- The group members generally supported acoustic float tracking, but felt it should be tied into a particular process oriented study.

- It was agreed that there is no major need for additional surface drifters, since these are only useful when they behave as one would expect.

- Also, satellite tracked surface drifters are interesting for special process studies such as large scale flow on the west Florida shelf, but one must be careful about the quality of the data.

- A group concensus on the depths of the acoustic floats was 700 m and 1200 m.

- The noted cost of a bottom ALS for such a system is more than $1 million.

- Current meter arrays might be more cost effective. It was suggested to place 4 moorings in the Yucatan Channel for about $400K/year if acoustic drifters are used.

(6) Quarterly surveys of the basin to measure absolute velocity fields and standard water column properties for at least three years.

- Ships-of-opportunity will give some information depending on the frequency of observations. These may need to be augmented with AXBT data.

- The possible need for an airplane or high speed boat was identified for this type of survey.

Summary (G. Maul). Two different, but interrelated problems were discussed and ultimately presented to the plenary session on Friday: (1) Loop Current growth, eddy break-off, movement, and dissipation; and, (2) wind driven west Florida shelf circulation. The interrelation is centered on the question of whether or not the west Florida shelf is causal to separation of an anticyclone current ring, or if the separation causes a circulation event on the shelf. A summary of the discussions for each problem is given below. Appendix III presents the corresponding equipment needs.

(1) Loop Current Growth, Eddy Break-off, Movement and Dissipation

The numerical circulation models of Gulf waters beyond the continental shelf break require verification measurements in order to calibrate large scale predictions. Satellite infrared measurements show general agreement with model predictions but careful data interpretation is required in order to understand details between the two. Tracking of eddies after separation is poorly documented and details of their movement and dissipation is unknown. Similarly, transport of deep water through the Yucatan Strait is poorly documented and its effect on the overall circulation or model results can only be inferred from continuity arguments. Although there are many other interesting questions, within the expected financial constraints, only the above seem addressable as follows:

- Continuation and improvement of the satellite IR time series of frontal movements over the entire Gulf basin including the shelf regions.

- An optimum ship-of-opportunity XBT and meteorological sampling program using technology developed by NORPAX in consideration of existing marine transportation routes.

- Programs of AXBT surveys of significant Loop Current events such as eddy shedding, cold tongue intrusions, or shelf/current interactions.

- Five current moorings (initially), one each at about 24°N, 86°W and 26°N, 89°W, and three across the Yucatan Strait designed to quantify the flow below ~ 250 m. (see Figure 1)

- A program of satellite tracked drifters deployed so as to detail the motion and fate of detached eddies.

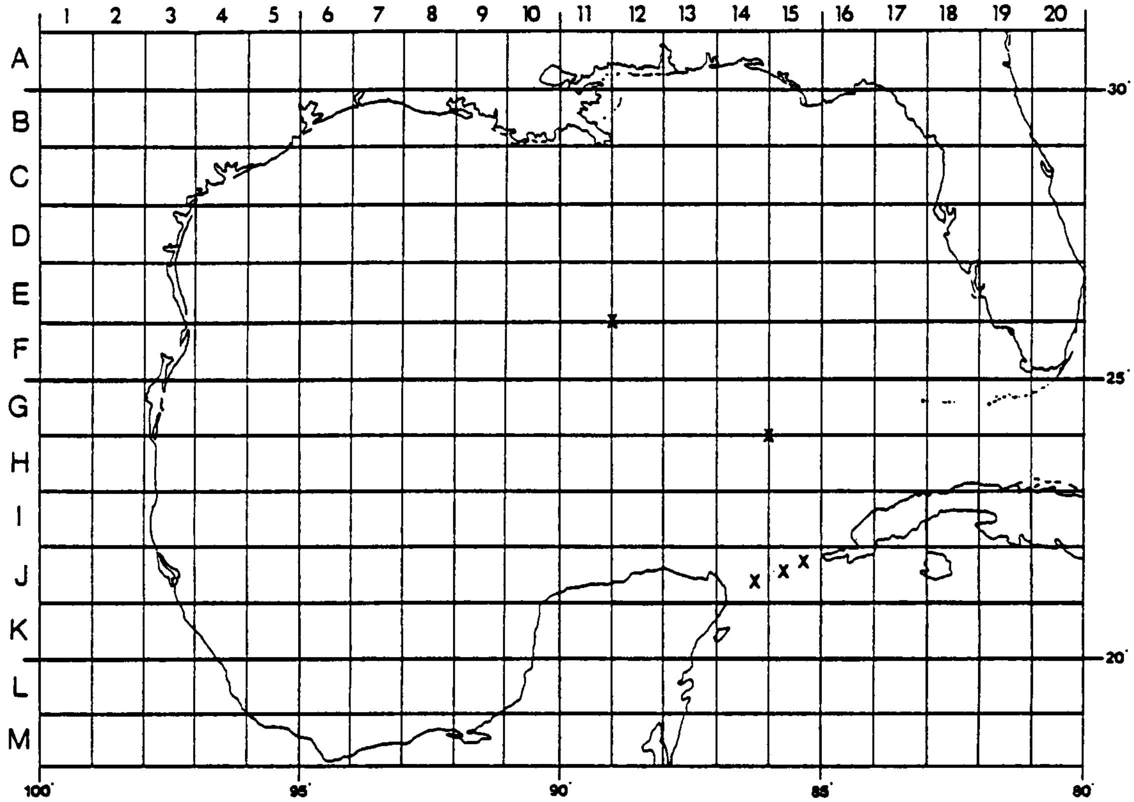

FIGURE 1: PROPOSED CURRENT METERS FOR LOOP CURRENT INTRUSION STUDY
(LOOP CURRENT GROUP)

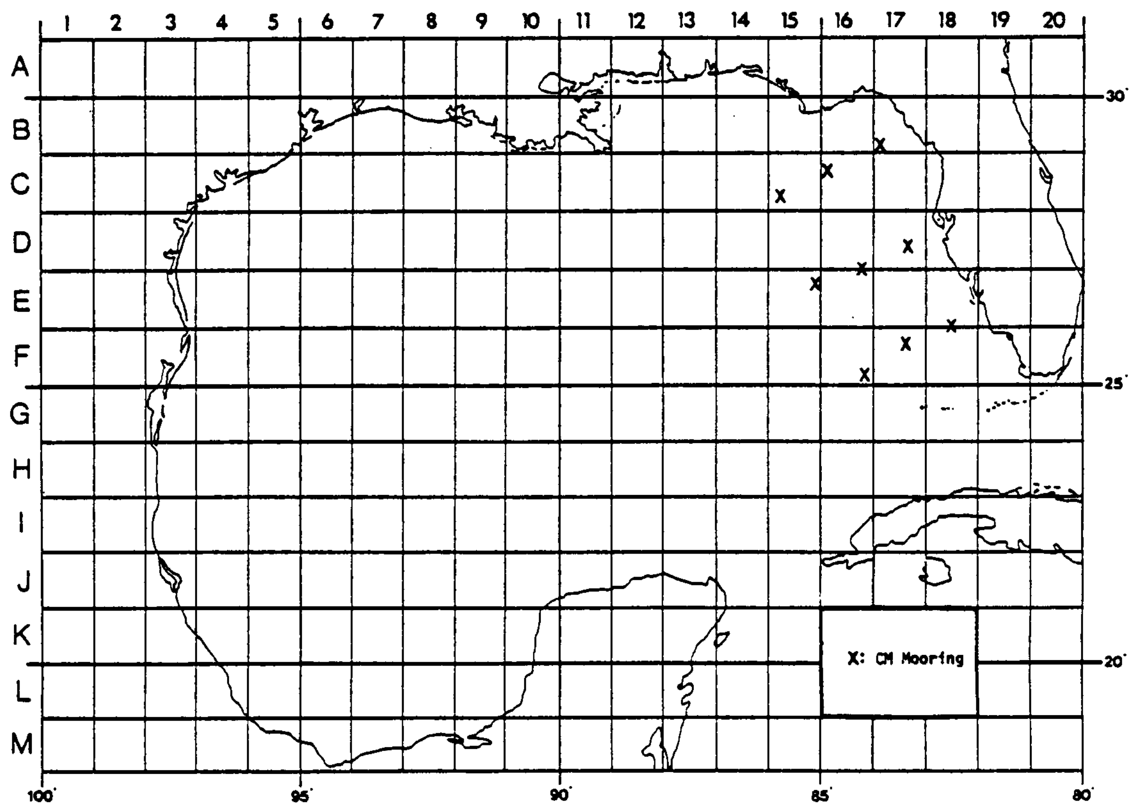

FIGURE 2: PROPOSED CURRENT METERS FOR WEST FLORIDA SHELF WIND STUDY
(LOOP CURRENT GROUP)

These suggested programs are in concert with recommendations from the two other groups except that in addition they endorse programs of hydrographic surveys particularly in the western Gulf, more definitive studies of wind stress over the whole basin, and arrays of IES and CM's along 90°W and in the western basin near 26°N.

(2) Wind-Driven Shelf Circulation

The west Florida shelf probably has a wind driven regime in waters less than 50 m deep, and a mixed circulation between 50 and 200 m driven by wind events <u>and</u> Loop Current events. To calibrate numerical models of large scale shelf circulation and interaction with the flow in waters of the open Gulf, the following measurement programs should be initiated:

- A high resolution meteorology study to detail the wind stress with a space and time scale matched to the shelf numerical circulation models.
- AXBT/XBT surveys of the west Florida shelf at scales compatible with the models and the current meter arrays (below).
- Three triads of CM arrays across the shelf designed to investigate (in part) the eddy/shelf interaction. (see Figure 2)
- Shallow water satellite tracked drifters set and reset for west Florida shelf studies.
- Special model development for winter circulation patterns so as to optimize the use of existing remote sensing technology in shelf/basin interaction.

In concert with the two other panels, the Texas shelf requires a similar effort including AXBT/XBT studies and a better understanding of the driving by wind stress, particularly with respect to the fate of separated Gulf Loop Current eddies.

While the above discussions are somewhat prioritized, no hard and fast concensus was reached. Being charged with the Gulf Loop Current <u>per se</u> as an observation program did not blind us to the overall objective of predicting the surface flow or the central role of numerical modelling to the effort. While we all conceded some personal special interest in our delibrations and recognized that certain interesting problems have been neglected (notably the deeper-than sill depth currents, western boundary spin up/down, and Texas shelf circulation), we at least agreed that the conference was worthwhile and that we will continue to agree to disagree.

MODELER GROUP

J.D. Thompson - Chairman
J. Pagenkopf - Recorder
B. Pearce
H. Hulburt
D. Brooks
Y. Hsueh
G. Mellor
G. Csanady

Discussion. The following presents the highlights of the general first day's discussion of the Modeler Group, organized by major topics of discussion (not necessarily in order of priority).

(1) Monitoring of flows through the Yucatan and Florida Straits.

- The total transport through the straits is required for model boundary conditions but is only weakly known.

- However, the models are fairly insensitive to total transport at the straits (which is known to within 10-15 percent), so this requirement deserves lower priority.

- It was the general consensus that knowing the transport off the southwest Florida shelf would be more valuable to the models than knowing the transport through the Yucatan Straits.

(2) Tracking the life-cycle of an anticyclone eddy from its origin in the Loop Current to its eventual dissipation on the western Gulf shelf.

- The production and decay of an anticyclone is a major feature of western Gulf circulation, and to a large extent determines surface currents, which is a prime concern of BLM.

- It was noted that G. Mellor's model did not simulate Loop Current eddy shedding, probably because the horizontal viscosity is too high by a factor of 4. Improvement is needed in our understanding of horizontal viscosity effects.

- D. Brooks suggested a program to track anticyclones using drifting buoys or IR. IR would be used say from September or October through April or May. The rest of the year must be filled in by drifting buoys, but need to know where to put them (must be inside anticyclone). Also should use AXBT's since these are very cost-effective for information received.

- It was noted that the approximate cost of an AXBT was $200.

- It was recommended to do monthly 10 x 10 AXBT drops at about $20K per drop plus aircraft costs.

(3) Monitoring the interaction between waters of the Loop Current and waters on the west Florida shelf.

- It was generally agreed that determination of the cause of eddy production and meanders of the Loop Current on the west Florida shelf deserves high priority.

- Knowing the deep flow off the Florida shelf would be more valuable to the models than knowing flow through the Yucatan Straits.

- Data which reveals the interaction (dissipation) of the Loop Current on the west Florida shelf is also required to provide boundary conditions for the west Florida shelf model under development by NECE.

- Y. Hsueh stated that the flow through the Yucatan Strait follows the f/H contours, so it doesn't matter exactly where one measures. Penetration of the Loop Current depends on deep flow (few hundred - 1500 m) off the west Florida shelf. NSF may install 4 or 5 CM moorings perpendicular to the Florida coast (also measure bottom pressure). Approximate depths would be at the abyssal plain, 1000, 200, 100 and 50 m.

- B. Pearce recommended that additional CM's be placed along the shelf break and parallel to the coast.

- D. Brooks recommended that if the IR indicated a significant Loop Current event, that hydrographic data or an AXBT survey be done in the Loop Current to augment the current meters on the Florida shelf. It was recommended that about 100 AXBT's deployed in one day would be adequate and cost about $50K.

- It was also recommended to place drifters in the Loop Current with thermistor strings to obtain cross current data which would allow estimates of Loop Current vorticity.

(4) Synoptic monitoring of wind stress for the entire Gulf.

- It was generally agreed that wind stress was the dominate driving force in the western Gulf basin.

- G. Mellor stated that, for model purposes, need synoptic wind data every 12 hours over a year. Also, for accuracy requirements, need measurements in the middle of the Gulf, not just along the shore.

- All agreed that the wind field should be known at a resolution of at least 100 km and especially from Mexico.

- It was noted that NDBO has 3 or 4 buoys that could be used, however, should also have one down in the Bay of Campeche in Mexican waters. The data from these buoys would be correlated to coastal stations.

- Data to allow calculation of heat fluxes (evaporation) are also important to obtain.

(5) A special focus study to correlate North Atlantic winds to Gulf boundary forcing.

- Y. Hsueh recommended that an analysis of the existing North Atlantic wind/sea level data be done to determine if the low level frequency phenomenon in the Gulf is pulsed by the North Atlantic activity.

- D. Brooks mentioned that the amplitude of transport fluctuations at the straits is known to within 10-15 percent, which won't significantly improve model development. However, this analysis may reveal part of the variation in the transport.

Second Day Summary. Four problems were identified during the first day's discussion of the Modeler Group and were presented at Friday's summary session: (1) Synoptic Gulf-wide wind and heat-flux measurements; (2) Interaction of the Loop Current with the west Florida shelf; (3) Production and decay of anticyclones in the western Gulf; and, (4) North Atlantic winds/sea level correlation to Gulf processes. A summary of the dicussions for each problem is given below, in order or priority.

(1) Synoptic Gulf-Wide Wind and Heat Flux Measurements

It is strongly recommended that the present observing system for surface winds and heat fluxes over the Gulf should be improved. Data from the southwestern Gulf is especially inadequate. Operational output from the National Meteorological Center's limited fine-mesh model may be useful for providing wind and heat flux data in the northern half of the Gulf. A procedure for free exchange of wind data from coastal stations surrounding the Gulf should be instituted.

(2) Interaction of the Loop Current with the West Florida Shelf

Satellite data indicate that meanders and possibly the initiation of the pinched-off eddies may be a function of the interaction between the Loop Current water and water on the west Florida shelf. Also, existing model exercises indicate that the deep flow along the f/H contour (thus along the slope off the west Florida shelf) is of controlling importance to the baroclinic response of the Loop Current. Finally, there is a need in general to understand the exchange processes for salt, heat, momentum and energy. Specifications of the recommended program plan are as follows:

- A minimum of one CM transect across the west Florida shelf from Ft. Meyers to the abyssal plain (see Figure 3).
- A minimum of 4 moorings at 2000 m, 700 m, 200 m, and 50 m.
- A minimum of 4 CM's in deep water to define the total transport.
- A minimum of 1 year continuous measurement.
- Of lower priority would be additional CM moorings along the shelf break and parallel to the coast.
- An auxiliary program is to perform hydrographic surveys at suitably frequent intervals to provide details of the salinity/temperature distribution, as well as AXBT surveys for mapping the near-shelf portion of the Loop Current during the time when satellite images indicate the presence of large meanders. Ten sections of 10 drops are envisioned for each survey (2 surveys per year).
- The approximate minimum costs of such a program (one year) are:

11 CM's	$ 88K
8 Acoustic Rel	80K
Deck Unit	10K
Mooring Gear	40K
AXBT's (2 times/yr)	
Probes (200)	40K
Aircraft	20K
Shiptime (12 days)	
w/6 month recycle	150K
TOTAL	$428K
	+ overhead
	+ data analysis
	$1 million

(3) Production and Decay of Anticyclones in the Western Gulf

Past modeling work and data analysis have revealed that the principal large-scale circulation of the western Gulf is dominated by large anticyclonic eddies separating from the Loop Current and travelling westward. Better understanding of this feature is hindered by the absence of experimental evidence on the reflection/dissipation process that takes place at the western boundary of the deep Gulf basin, as anticyclonic eddies impinge on the continental slope. Measurements of the evolution

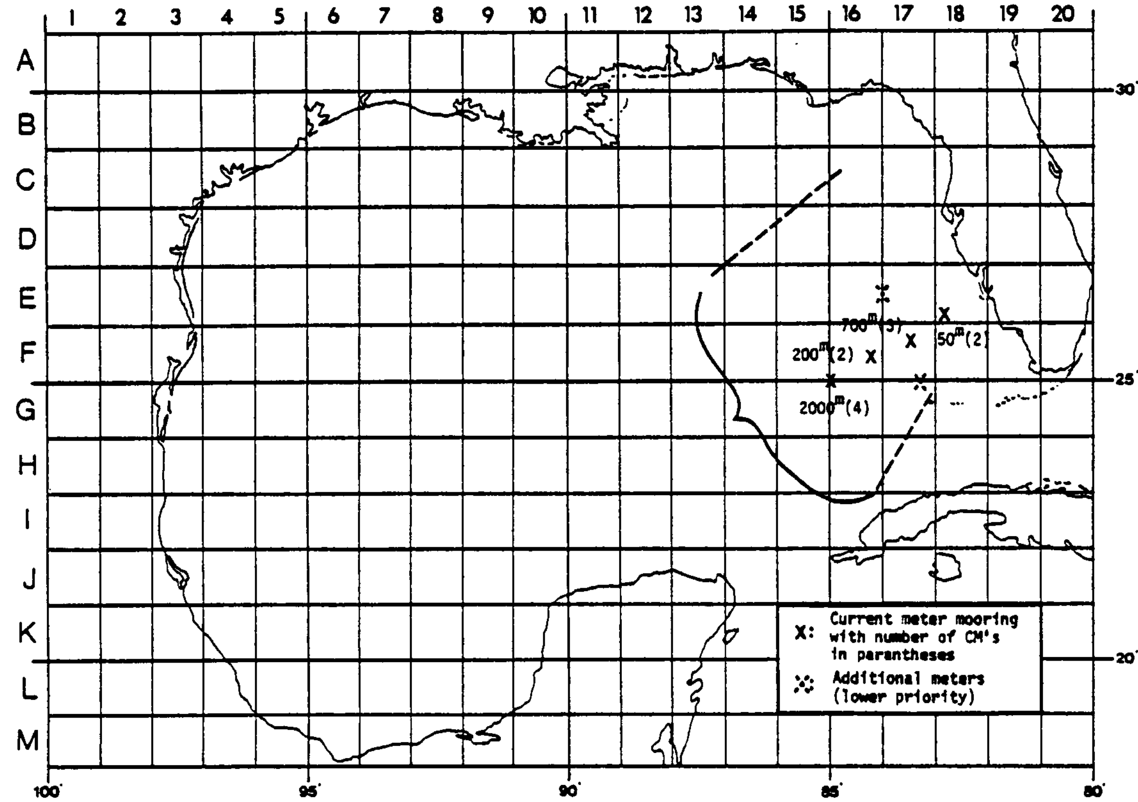

FIGURE 3: PROPOSED WEST FLORIDA SHELF STUDY
(MODELER GROUP)

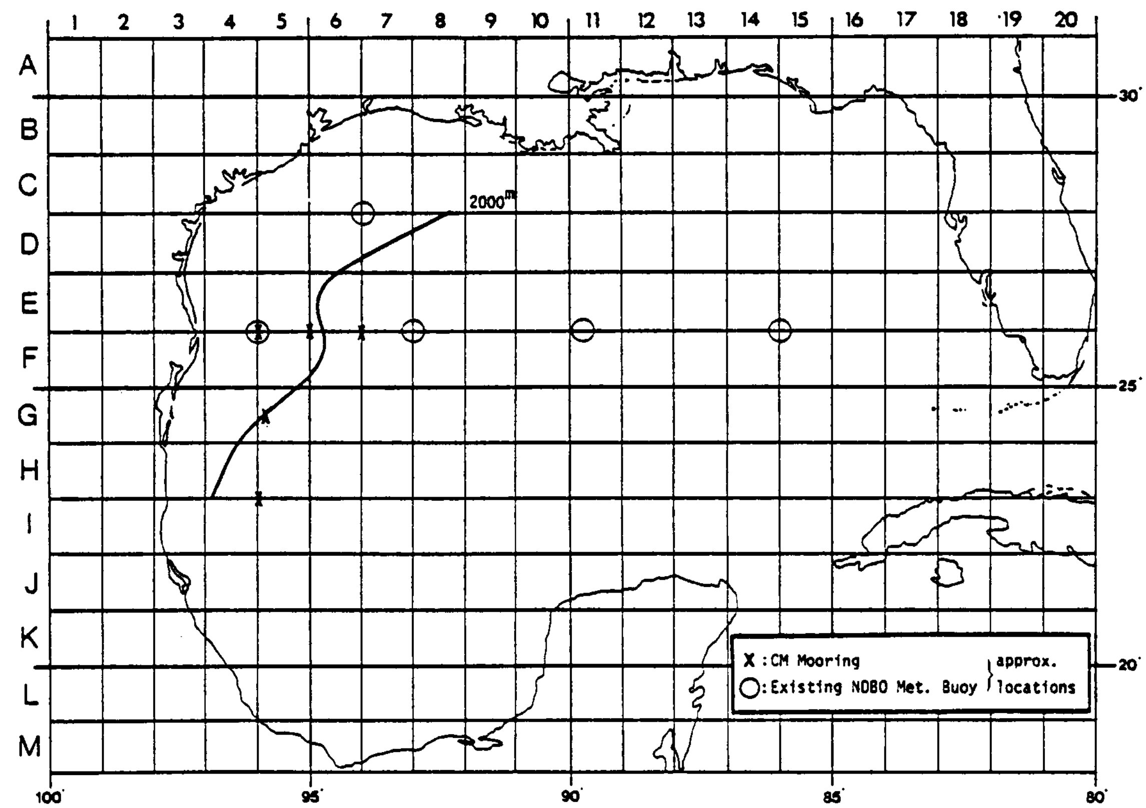

FIGURE 4: PROPOSED WEST GULF STUDY
(MODELER GROUP)

of the current, hydrographic, nutrient and biologic fields associated with the eddy are desirable as it interacts with the shelf. The physical processes of short wave radiation, continental shelf waves, and momentum, salt and heat fluxes are expected to be important and should be resolved. Major elements of a field program to accomplish the physical portion of the above are as follows:

- CM mooring arrays (~ 5 moorings with ~ 5 CM's each), with a suggested array plan shown on Figure 4 . This array is needed to provide a resolution of about 200 km in the N-S scale and about 150 km in the E-W scale. Also, this array should be "dynamically positioned" to intercept an arriving eddy.

- Satellite IR imagery is required to identify and track (winter only) the creation and movement of a candidate eddy. This approach would not be useful from about May to September. Arrangements should be made for the processing and retention of the maximum possible number of satellite images for the period of study.

- Satellite-tracked drifters should be used to track the eddy during summer, and also to record the evolution of the temperature structure in the upper 200 m.

- AXBT surveys should augment the data collection to determine near-synoptic surface and subsurface temperature structure evolution of the eddy as it interacts with the shelf slope.

- Ship hydrographic data is desirable to provide basic temperature and salinity (nutrient and biological) data during the periods of AXBT surveys.

- Existing NDBO buoys (see Figure 4) and coastal stations can be used to obtain adequate wind stress and wind stress curl time series in the array area.

- Expected major logistical/political difficulties include: (1) Mexican clearances (minimum 6 month - maximum 1 year lead time); (2) acceptable ship and aircraft scheduling flexibility; and, (3) development of means for real-time transmission of satellite IR images to ships and/or aircraft to guide surveys.

- The <u>approximate</u> costs for such a program (one year) are:

25 RCM-4's @ $8K	$ 200K
10 EG&G releases @ $10K	100K
Mooring Gear	50K
AXBT's (~ 3 surveys)	
Probes (150 @ $200)	30K
Aircraft (P-3 Orion)	30K
Platforms	
Ship Time (mooring deployment and recovery and 2 cruises for hydrographics - 4 weeks @ $6K/day)	170K
Personnel (PI, 2 students, technician, full year each)	75K
TOTAL	$ 655K
	+ overhead and travel
	+ data analysis
	> $ 1 million

(4) Correlation of North Atlantic Winds to Transport in Gulf Straits.

Y. Hsueh recommends a very simple analysis, which requires no new data collection, to look at variations in the transport through the Yucatan and Florida Straits which are in response to the very large scale circulation over the whole North Atlantic. This involves a statistical analysis of wind stress and sea level data over the whole North Atlantic and correlation to Loop Current growth and transport through the Straits.

The above proposed programs were judged by the Modeler Group to hold the highest priority in terms of refining our knowledge of the most important controlling processes in the Gulf for a realistic cost. Other agencies should be encouraged to fund concurrent studies, such as outer shelf circulation on the broad Texas shelf, and inner shelf circulation off both Florida and Texas.

OCEANOGRAPHER GROUP

R.O. Reid - Co-Chairman
J.D. Cochrane - Co-Chairman
A. Humphreys - Recorder
F. Chew
M.A. Estoque
J. Van Leer
B. Taylor
F. Everdale
J. Altamirano
R. Rodriguez

Discussion. The general first day's discussion of the Oceanographer Group was guided by the list of problems presented in the keynote address. The object of the first day's discussion was not to define the data collection program, but to identify the most significant data collection needs and the most significant physical processes in the Gulf. The following is a summary of the discussion.

A. Data Collection Requirements

(1) Monitor currents in the Yucatan and Florida Straits using CM strings, inverted echo sounders, aircraft AXBT probes, acoustic measurements, and hydrographic profiles.

(2) Sea level measurements across and downstream at both Straits, or measure bottom pressure across and downstream. Should have sufficient redundancy of instruments.

(3) Continue IR imagery with XBT ground truth for whole Gulf.

(4) XBT measurements by ship and aircraft. Plan strategic event related surveys at space and time scales sufficient to resolve migrating pressure systems.

(5) Optimization of ships of opportunity for:

- Towed thermistors
- XBT's
- Meteorological measurements - barometric pressure, temperature, humidity, wind
- Doppler current profiles
- Investigate use of commercial shipping to and from Tampico

- Surface thermo salinograph

- Aircraft of opportunity, i.e., military, fishing co-op's, Hurricane Center

- Ensure proper advanced coordination of data collection system.

(6) Perform Gulf-wide inverted echo sounder measurements. Locate a meridional string at 90°W in deep water and at location of of anticyclone eddy separation from Loop Current.

(7) Deploy satellite tracked drifters with drogues at fixed depths with thermistor strings. Coordinate with detailed meteorological measurements.

(8) Install permanent current meter arrays with temperature and pressure at the following locations:

- Along the west Florida shelf/slope break

- Along a line from the Mississippi Delta to the Yucatan Strait

- Along a line from the Campeche Bank to Key West

(9) Utilize Oil Platforms to obtain meteorological, currents, temperature/salinity and tide data.

(10) Install bottom-mounted pressure gauges at shelf edge.

(11) Additional measurements to be considered include SOFAR floats, swallow floats, satellite altimetry, and satellite scatterometer for measuring winds and mixed layer depths.

B. Important Physical Processes

(1) Basin/shelf interaction (transfer of energy).

(2) Migration of cyclones/anticyclones (transfer of vorticity).

(3) Convergence/divergence zones along edge of Loop Current and vicinity of eddies (transfer of mass).

(4) Slope upwelling/downwelling (coastal).

(5) Spindown/dissipation of rings in western Gulf.

(6) Separation of warm rings from Loop Current.

(7) Local generation of eddies (anticyclones in western Gulf by local winds).

(8) Generation of cold rings (cyclonic).

(9) Modification of water characteristics in migrating rings.

(10) Topographic interaction of rings in western Gulf.

(11) Influence of intense meteorological events on circulation and thermal structure (winter storms and hurricanes).

(12) Influence of fresh water discharge on shelf circulation.

(13) Wind effects on shelf circulation.

(14) Surface and bottom boundary layers.

Second Day Summary. The outcome of the second day's discussion of the Oceanographer Group was an outline of a three-year measurement program which concentrated on the eastern Gulf in year one, the western Gulf in year two, and the entire Gulf in year three. A summary of the recommendations for each year's program are presented below, arranged in order of priority.

EASTERN GULF - YEAR ONE

(1) Interaction of the Loop Current with the West Florida Shelf.

Measurements required to investigate Loop meanders, upwelling and convergence phenomenon involve the following specifications (number in parenthesis indicates priority):

- CM/T and TG moorings located across shelf from shallow to deep water at about 26°N (pick standard level for current meter moorings - 100 m). (I)
- AXBT's and IR. (I)
- Bottom mounted pressure gauge at shelf edge. (I)
- Bottom boundary micro-scale current measurements at selected times to study the bottom shear dissipation process. (II)

(2) Loop Current Intrusion and Breakoff

Measurements required to study the behavior of Loop growth and production of eddies involves the following specifications (order of priority):

- Ships of opportunity - XBT's and salinograph. (I)
- IR imagery. (I)
- AXBT surveys at strategic times as indicated by the IR. (II)
- Extend CM/T moorings from edge of west Florida shelf to edge of Campeche Bank (3 moorings). (III)
- Install inverted echo sounders. (III)
- Perform single ship surveys for XBT's and hydrographics. (III)

(3) Perform a Study on "How to Monitor a Strait" using Florida Straits as an Example

Measurements recommended to study the inflow/outflow characteristics of the Straits include deep CM/T moorings, cyclesonde, and bottom mounted pressure gauges.

WESTERN GULF - YEAR TWO

(1) Migration of Detached Anticlones and Interaction with the Western Shelf

Measurements recommended to study the migration and fate of detached anticyclones in the western Gulf include (in order of priority):

- Satellite tracked drifters strategically placed by analysis of IR imagery. (I)
- IR imagery. (I)
- Strategically planned ships of opportunity - XBT's, towed thermistors, meteorological data. (I)
- CM/T arrays. (II)
- Limited number of single ship surveys to deploy XBT's and collect deep hydrographic and biological data - T, S, O_2 and nutrients. (II)
- IES - inverted echo sounders. (III)

(2) Texas/Louisiana Shelf Circulation

The existing programs off Freeport, Sabine and Calcasieu should be supported and tied in with the Flower Gardens at the shelf edge. It is of interest to examine the shelf response to norther events and tropical storms as well as normal regimes. Measurements recommended to study the Texas/Louisiana shelf circulation include (in order of priority):

- Maintain and supplement the cross-shelf Freeport-to-Flower Gardens (93°-40'W, 27°-55'N) line of CM/T's for at least one year (could also sample on a line from Calcasieu Pass to Flower Gardens). (I)
- Bottom mounted pressure gauge at the outer edge of shelf. (I)
- Utilize ships of opportunity and oil platforms. (I)
- Employ satellite tracked drifters. (II)

SYNOPTIC SURVEY OF ENTIRE GULF - YEAR THREE

The purpose is to capture a near-synoptic picture of the entire Gulf to investigate the interaction of the various processes, i.e., Strait dynamics, Loop Current growth, anticyclone shedding, and shelf interactions. This involves very intense (two week) monitoring events described by the following:

- Multiship (3-4) and aircraft (2) to survey whole Gulf during at least two different Loop intrusion states (twice/year), covered in approximately two weeks. Measurements include deep hydrographics, XBT's, IR, 100 m thermistor tows, surface salinographs, and meteorological data. (I)
- Monitor the inflow/outflow at Yucatan and Florida Straits one month prior to and during the above surveys, using cyclesonde and deep moored CM/T's. (I)
- Utilize ships of opportunity for XBT's, salinograph and towed thermistors. (I)
- Supplement with continuation of the Florida shelf slope CM/T array measurements. (I)

In general, the Oceanographer Group recommends better coverage of meteorological information throughout the Gulf. One possibility would be to convince the National Weather Service to extend their analyses down at least to 18°N. Another possibility is to make maximum use of meteorological measurements taken at oil platforms.

SUMMARY SESSION

The workshop summary session began with brief presentations by the respective subgroup charimen: G. Maul, J.D. Thompson, and R.O. Reid. A written summary of each presentation is given under the previous section on Subgroup Discussions. Highlights from the general open discussion which followed these presentations are given below.

B. Pearce - I think we can now open the floor for questioning. I think it's interesting that the measurements in the Yucatan and Florida Straits have been dropped to a lower priority than it would have appeared from the beginning. Also, everyone seems to agree more or less with the measurements in the eastern and western Gulf.

R.O. Reid - There is one point that I failed to mention and this is that NOAA plans to do some monitoring in the Florida Straits.

F. Chew - That's correct. As part of our national climate study, we plan to monitor the heat transport through the Florida Straits off Miami. Once we can get started, it will continue for several years. This is part of a larger program that will be looking at a section extending from Florida to Africa at about 24°N.

D. Brooks - With regard to a synoptic survey of the whole Gulf, I think that even with four ships it would be hard to get the truly synoptic picture in two weeks, if you are interested in resolving the 100 km scale features that you see in the IR images of the western Gulf. For example, I've seen changes within the time scale of a week to ten days that are significant.

R.O. Reid - Well, we are talking about perhaps four ships and two aircraft primarily over the deep Gulf.

D. Brooks - If you concentrated the aircraft in the areas where you knew the smaller scale phenomena would be maybe that would work out.

Anonymous - I want to point out that our drifting buoys have the capability of measuring wind speed and direction besides positioning and all the other variables.

J. McCall - I assume that NDBO will be active in this program in the future and I have two questions that will help me in supporting what you plan to do. One is the accuracy of the cost estimates mentioned, although I don't need an answer right now on this. I'm guessing that the quoted cost estimates could be off several million dollars. The second question is probably more important, as to what is the output to the U.S. taxpayer and where does he benefit from knowing more about the Gulf processes? This is very critical in terms of favorable political support and obtaining the necessary funding requirements, which may be quite substantial.

J.D. Thompson - If you're talking about trajectories for an oil spill, and you're trying to drive a model of the area with surface boundary conditions, the wind field is a very important part of that. If you take the example of the IXTOC-1 blowout, we really didn't have very much information on the detailed wind field, and where this oil spill trajectory was going. Also, for example, consider the western Gulf measurements. The fate of a particular pollutant depends very much on how the circulation pattern works not only at the surface but also over depth. When there's an eddy in this area, things circulate around and around in a circle all the while dispersing.

J. McCall - I understand the oil spill trajectory aspects, but are there any others?

D. Brooks - You can see, for example, that one practical benefit would be the influence on hurricanes, and whether there was an eddy under it when it went across the Gulf. People who worry about hurricane tracks would probably be very interested in knowing where an eddy was.

G. Csanady - Another point is the assimilative capacity of the continental shelf for wastes which depends very much on the exchange processes between the shelf and the deep water. This is a very important aspect of the mooring area experiments in both the eastern and western Gulf.

F. Everdale - Fisheries also. If you have upwelling along the west Florida shelf one of the things I found is that the sports fisheries become very intense where there is an upwelling of nutrients.

P. Niiler - It's really interesting that the modelers designed the current meter arrays, and they are not observationalists, so I hope that when you go home you will continue this interaction in finding people who can advise you on the RFP. I would hate to see that array on the RFP. I would hate to see anything that we have produced here today specifically on the RFP, because they are very specific suggestions. I don't think that we have had the time to do a proper design, but I think that we have had the time to identify two or three central problems of the Gulf and write down the rationale and the kind of tools you might be able to use. I think there is a time now for people who may want to disqualify themselves and those of us who might want to spend some more time actually designing the problem more carefully. The design of an oceanographic measurement program over a long period of time is very crucial and it takes another two days of work or another week of work, or another month or a year of work. So I would hate to see the BLM and the coastal engineers leave this meeting with those things that have been drawn by the modelers, or those things that we've drawn, and on the basis of this put out an RFP.

D. Brooks - Just for the record the current meter arrays you mentioned were also designed in part by myself and G. Csanady.

P. Niiler - Well, I would hope that there will be another opportunity to take the recommendations of this workshop and get together with a much smaller group of people, with people who know about observations in the Gulf, and focus in with BLM's advice on where the priorities lay and then design something before the RFP goes out.

J. McCall - Let me comment on that. I support what you say completely. A solution to that is to break up this RFP wherein you retain the flexibility by going to an agency which does not have to be specific. For example, we build and deploy buoys, and we need to know in general where they might be or how many are needed for your purposes, but not being a contractor and not negotiating for profit and these various things, it's relatively easy to change them and suitably later after you've had time to properly design the program.

P. Niiler - Yes, and I've heard some horror stories, like "you shall take a CTD every hour you're out there", but you can't take a CTD every hour when you're trying to put moorings out and do other things, it's impossible.

D. Brooks - I would like to make one comment here. One of the things we were asked to do was to have some specific recommendations for the measurement programs in the Gulf. I agree with you Peter, that a great deal more careful thought has to go into planning arrays or anything approaching the scale that we are talking about, but given the few hours we had to put together a program here based on some of our own knowledge we didn't expect to come up with a final detailed plan.

P. Niiler - I think that's wonderful, but I'm just cautioning the people who are going to walk off with this document to please not set it in concrete and please ask us again for our ideas. I'm saying that you should not make specifications of what we are going to use, how we are going to use it, and where to put it on the basis of this workshop.

D. Brooks - I don't think anyone suggested that this would be done.

J.D. Thompson - Peter, I think you've taken us far too seriously on this BLM meeting. What we were charged to do, and what I think our (Modeler) group did, was to put up some proposals for ways of measuring things that we know we need to measure. For example, the 700 m depth was not chosen arbitrarily, it was chosen because it is the particular contour which the models say we need to see what the flow is there. That contour goes out through the Florida Straits. If someone comes along later and knocks that down to 300 m, then that's not what we are asking for as modelers. We are asking for something that has a contour above the sill depth of the Florida Straits, and that's very important. If that particular message gets lost, between here and when it's actually done, as far as the modeling we will have missed that particular opportunity to do something. I don't think we were completely blind and having fantasies in doing these. We asked D. Brooks some particular things about how to measure processes, and we didn't know a lot about the details.

G. Csanady - Well, we sat together and discussed this whole problem, and we thrashed it out, and we came to terms with M. Brown that we just had to be more specific or else the whole thing isn't useful. That is the facts of life.

Y. Hsueh - Those moorings do have aspects that are likeable.

B. Pearce - I have a question. It seems there is general agreement for the current arrays off Florida and the one in the western Gulf, but there seems to be a major dissension here on wind-driven shelf circulation. I'd like to hear a few comments on that.

P. Niiler - I would like to make a comment on that. Firstly, if you look at the shelf break array and we see that, right in here we have a history of measurements of currents between 50 meters and 200 meters for two years. We know that it is a very complicated regime, and I know you can't talk about the modeling of the deep circulation, but at least the first order shelf exchange process can be looked at already with the existing data if you are interested in doing that. Secondly, the problem is that what you measure here won't have any relationship with what you measure 100 kilometers away or 50 kilometers away. It is a very incoherent kind of picture as to what's happening. It is really difficult to make sense of an onshore and an offshore array and learn more than we already know in a year's time. With the exception of course of one deep meter which Dana Thompson's model seems to need. Now, there is one aspect or hint from the kind of data which comes from Oregon, from New England, and which comes from this data as well (the historical set) and it's based on 9 months of record here and 9 months of record there. There is a real hypothesis that says there is a general winter circulation of the Gulf, and we see that the fluctuations on the shelf are really directly related to them. The only thing that is coherent with anything on this shelf edge is when you get to shallow water less than 100 meters deep in the winter time and you begin to see something which you can relate to something which somebody else is computing. G. Marmarino, I am told has a model of the west Florida shelf. We have experience in Atlantic Bight, shelf circulation modeling. We have experience in the fact that the New England Coastal Engineers are looking at a west Florida shelf model and so we felt that the shelf circulation problem is one of the predictable aspects in terms of: (1) the tidal dissipated currents, (2) the wind-driven currents, and (3) the sea level set up that's associated with this entire Bight.

Y. Hsueh - I was going to say all you said. But what I am concerned about is that I still think that even though you have two years of data and we need it, but that two years indicated that these eddies are very interesting. I think that from looking at the satellite pictures over the last day, I feel there is a lot to be learned. I guess there is always a choice of problems, but we are really looking for predictability in an area that is very interesting in terms of things like that (eddies). Eventually we have to face the Loop Current problem, and we see the interaction right there in the satellite picture. I just feel that this is the problem to be looked at.

J.D. Thompson - One of the things that these models do is to keep you from kidding yourself and you are kidding yourself if you try to do a limited area model of the west Florida shelf without offshore boundary conditions, particularly for long time scales like for years. Now we are not addressing the offshore boundary condition problems in any of these proposals and there is no one that says that. But what we are trying to do is to look at one testable hypothesis and that is that the deep flows tend to follow the f/H contours in the deep water from the Gulf through the Straits.

G. Csanady - I would like to say that what Peter is saying is certainly very worthwhile, that the west Florida shelf is ripe for the picking to try to explain it now that we have developed the ideas that weren't around 10 years ago. It is certainly going to be possible to do something worthwhile with it. In this very meeting at this time, however, I think that we ought to address the deep water circulation, and we have what I consider a testable hypothesis with Dana's model and some of the ideas that group around the large scale Loop and the eddies that impinge on the western boundary. That is certainly a very interesting, worthwhile problem and it's relevant to the large scale circulation problems that perhaps BLM is concerned with in the western Gulf. So it is a choice between two nice scientific problems and there is no way in the world that you can fund a good shelf circulation project and a good deep water circulation project on something like a million dollars a year, so we just trimmed our sails to fit the project. In fact we were talking about the types of measurements for these two observation enterprises for the west Florida shelf and the western Gulf and clearly it is not going to be possible to do it simultaneously on the BLM budget unless somebody else comes in with an equivalent amount of money. So they would be sequenced according to our recommendations,but again this is up to E. Wood and BLM and everybody else as well. There is another equally good recommendation we could make on shelf circulation not only on the west Florida shelf but on the Texas-Louisiana shelf and the Mississippi shelf as well. They are very interesting and very important problems. The shelf circulation is in some sense a more direct and more important problem as far as the shore impact is concerned, if anything. So while I endorse what you are saying basically, I can also say we have really been charged to look at the deep water circulation because this is what they are interested in funding next. And that is what we were doing.

J.D. Thompson - I have to agree with Gabe. Somehow during the meeting this morning Peter went off onto the Florida shelf, and I didn't really say anything about it because I wasn't sure we were going to leave, but I really think you have nailed it down. I think that aspect is truly an interesting problem but that we have gone astray from what our basic mission has been here. I really think we ought to regroup our minds back to the deep water problems and stop flopping around quite so much about it.

P. Niiler - I hear deep water on one side and predictability on the other with respect to oil spills and I can't hook the two together. Someone has told somebody you've got to understand the deep water circulation in the Gulf if you are going to understand something about the oil spills.

C. Cooper - One of the points you had made Peter, was the interaction of the west Florida shelf with the spinoff of the eddies, and that was one reason for focusing in on that particular shelf area. So it is tied, or at least that was an argument that was made that it is tied to the deep water circulation patterns.

P. Niiler - We do see an interaction in the winter, and it is the wind and the big eddy that have an obvious large scale pattern of flow, and we also see that in the satellite information as we see that cold tongue that shoots across the bottom of the Loop Current.

E. Wood - Peter, I would like to make a clarification here. I am not sure I was the one who used "deep water". I used "open Gulf" and by that I mean circulation from top to bottom but in the open Gulf versus on the shelf. So I think maybe it's a matter of semantics.

P. Niiler - I can't separate usually the deep from the shallow. I don't know where to draw the edge. Someone says here is the shelf break. I've always been wondering where the shelf break is because it depends on what dynamics you're looking at. The tide goes right across and it doesn't know it's a shelf break. The wind-driven circulation depends on what season you are in. So I don't know where to put the edge of the shelf.

G. Csanady - You can see it on the satellite pictures. In the winter you have a nice line. Actually the dynamics of a 100 m deep column is much different from the dynamics of a 5 km deep water column. There is certainly a fairly rapid transition, although it is not a sharp boundary, but it's a boundary layer.

J. McCall - I would like to ask Ed one question. Are we talking in general about a million dollar realm per year or are we talking about 5 million dollars per year. We may be able to put some money into this thing ourselves, but I would like to know what ballgame we're playing.

E. Wood - We went through this yesterday, and I tried to give people some idea of what ball park we're working in, but I really can't say how much money because it's a competitive procedure.

J. McCall - The point I'm trying to make is that we really have to get back to reality, because we can spend a million dollars just like that.

G. Maul - One thing that Tony touched upon yesterday which is very important is that we would really like to hear something from our Mexican scientists, as to their perspective of what they see going on, and what their role might be in this. We really need their help, and we need to know what they think.

E. Wood - Maybe I can shed a little light on what's happened here. We have tried now for about 6 months to make contacts with Cuba and Mexico and there was a series of letters that went out through the State Department, and we didn't get too much response. Then suddenly we did get some response and some of it was that we are not too sure or yes, we are interested but we'll have to see how things progress. We got a response from a physical oceanographer in Mexico, Alberto Vasquez, and he was interested in what we were doing and sent us some of his data but unfortunately he has been tied up with other activities. We then received word from Jose Altamirano that they would be glad to come up and sit in with us. We realize they are more interested in the hydrocarbon problem but they are going to be faced with the same types of problems we are faced with in showing that the environment is protected from the industrialization that is taking place in their waters as it is in ours. So they have concerns about Loop transport as well but they have to be looking at it from the analytical point of hydrocarbons. So we are very pleased to have them with us. They know some of our concerns even though its from a discipline that they are not familiar with, and I am sure that they will carry the word back on our concerns. Mexico's scientists and others in physical oceanography in particular are going to be interested in what we are doing, and contacts that you people have with them are going to be very important. So we welcome their comments and participation.

P. Niiler - Picking up on what Gabe was saying, I think that the deep water eddy problem and the continental shelf problems on the west Florida shelf are two problems that work together. Also on the western part of the Gulf there are three problems that work together. I think it's a matter of sequencing more than its a matter of saying one or the other. But I think these are the problems which all of us seem to agree we have a good chance for. We have enough background data so we don't have to have a research program, and that's an important aspect for BLM in that they would like to use instrumentation to do a measurement program based on some good background ideas. I think over a three year period, one could put together a sequence of studies which really understand more about the wind-driven field and more about the motion and development of the eddy in the deep water and its interaction with the shelf perhaps in the winter time especially, and with two shelfs for that matter - the western shelf and the eastern shelf. So I think its a matter of balance and sequencing but if you are going to take something with you from this meeting, these are the two big things that people see a good bet on. It's amazing to me how all three groups mentioned both of them.

B. Pearce - I tend to agree. You can also make an argument for the shelf circulation on the basis of marginal costs, in addition to the deep moorings.

J.D. Thompson - Since the observationalists asked the modelers how they could design experiments, I am going to ask Peter how his group decided that we had the best bet of predicting the breakoff of the Loop Current. What do you mean by that?

P. Niiler - I didn't say the breakoff of the Loop Current. We have the best bet of following the Loop Current eddy. We have to study the breakoff process which we don't know very well. But once it's broken, I think the idea of following the Loop Current eddy for three years, very carefully, and then seeing how your model follows the Loop Current eddy would make a very interesting prediction problem, and I think it's the kind of thing that you have a good bet on not predicting its cutoff because that depends on the flow into the Straits and out of the Straits. But once it is isolated, I think that is a good bet, Dana.

J.D. Thompson - Well, I misunderstood, I read the recommendation as "prediction best bet Loop breakoff."

G. Mellor - This is beginning to penetrate into the far future where we will have ocean weather prediction models because in this sense obviously a model has to be injected or updated at some particular time to create an eddy and watch it. So it's the beginnings of perhaps ocean weather predictions.

T. Sturges - One of the things that has come out is the fact that there is a lot of hash on the boundary between the Loop Current and the inner frictionally dominated shelf flow, but we have seen a lot of pictures of that so we have a fairly good idea from the satellite photographs of what to expect. One of the things that I thought numerical models are supposed to do is be able to handle that, if you have a reasonably decent non-linear model. If you have an eddy resolving model that resolves the right sized eddy, I was wondering whether or not Peter could suggest what the minimum scale is that he thinks is important to run the numerical models at.

P. Niiler - From observations? I think on the shelf break at 200 meters there is no relationship to the low frequency flow at 50 meters below the surface and at the bottom. The vertical scale is incoherent at 150 meters. The second point is that we are talking about a frequency band of from a 2-day period to about a 40-day period, which includes the little eddies that have a vertical scale less than 150 meters, with a lot of stratification in between. The other point is that the little eddies on the shelf have a horizontal resolution which depends somewhat on frequency. I don't quite understand it yet, but I can see on and off the shelf the scale is somewhere around 10 kilometers or less, and along the shelf it is about 25 kilometers or 20 kilometers. You really start to lose coherence very rapidly beyond that. There is a lot of energy in very small scales and there is also some coherent energy in some longer scales. Sometimes you get on the west Florida shelf a wave train that is really coherent over 150 kilometers and other times you don't see that. So there is a very complex horizontal/vertical problem. For example, the temperature and the currents are not related at all in the high frequencies.

C. Cooper - From BLM's standpoint are those high frequency oscillations important? Are they going to add to the advection, for example, of an oil spill?

P. Niiler - It turns out that the 40-day time scale phenomena, if you look at the transport of heat by eddies off of the shelf ($\overline{v't'}$), you can compute those vectors from all the current meter data, and you can also compute the co-spectrum, which means you can find out where the variance comes from in the frequency band, and it mostly comes from the low frequency bands by 40 days. So there is a real transport, and we can look at what the transport across the shelf break is. We have made those computations and they really do depend on the 40-day low frequency motions. The high frequency is not coherent as I have told you. There is no $\overline{v't'}$ correlation on a higher frequency band of 20 days and 2 days. You have a temperature spectrum which looks very different than the velocity spectrum. The temperature spectrum is very rare and the velocity spectrum falls off the frequency spectrum too. The temperature cascade is very different than the velocity cascade. It's very weird.

T. Sturges - All that hash on the west Florida shelf also probably means there is a great deal of dissipation going on there.

CLOSING SESSION

Closing Remarks and Summary of BLM Objectives - E. Wood

E. Wood - I sat in on portions of all three of the workshops, and all of you really jumped in there and got a hold of this thing. Although there was a little bouncing off the walls for awhile, I think you really got around to the issue, and I want to thank you all for your participation, your comments and your planning. I think what we have done here is very important, and that if nothing happens beyond this meeting, it was still worth the effort. But we do have approval for FY 82 funding for physical oceanography, and the FY 83 physical oceanography package is high enough on the list that we are pretty well assured that it will get funding if there is money available to do it. Although the Reagan Administration is prodding to see where the lower level is, I don't think they will be rash enough to cut off the OCS marine environmental program altogether at this point.

I would like to tell you now about what to expect from here. New England Coastal Engineers is developing a model for us on the west Florida shelf, and we tucked in this little effort of holding the workshop because it was convenient to contract, and it basically fit into what they are doing. They have done a very good job here, and I am pleased how things have progressed. I thank them, and I especially thank you all for your input. Their subcontractor, Tetra Tech, is going to produce a report of what went on here. Although it may not cover all of your points exactly the way you wanted them to get through, I think it is important that they turn around this document as soon as possible so that we can get it out to you. We will circulate it to as many people as we feel appropriate, and it will be available to anyone else who wants it. So those who didn't attend this meeting, and yet who have an interest in it, will certainly have access to what went on here. We will take your collection of ideas and try to work them out and pick those that we feel we can get the biggest bang for the buck. I hope that what we produce will be a contribution to the scientific community and to those people who are paying the bill.

In the past, BLM has been accused of being overly specific and too inflexible in our contracts. We have made changes, however, and I think we are flexible and sensitive to the needs for change. There still are a few people (scientists), however, who have to learn the difference between a grant and a contract. We have specific products that we have to come up with in a certain time frame, so we are locked in from that aspect. If you can come up with good rationale for changes, however, we will make them. Presently we have concerned contracting officers to work with. They are sensitive to the needs of scientists, ship schedules, etc., so we can expect cooperation from the Branch of Contract Operations. I appreciate the comment that P. Niiler made to me about proper planning before initiating a sampling program, so that we don't come out with a set of specifications that say "If you are going to do it at all, you are going to do it our (BLM) way." We may suggest a way that you do it, but we don't expect you to treat the Statement of Work as though it were set in concrete.

For those of you who are interested in responding to an RFP, we will have a separate section of instructions to give guidance on submitting alternate ideas or proposals. In order for us to evaluate and compare all proposals with some rationale, however, you may end up having to respond to something that you feel is incorrect, but there is nothing wrong with saying in your proposal that there is a better way to do it and to give us your rationale. Later on in the negotiation process, which may take one or more iterations of secondary proposals, an approach can be worked out that is more valid than what we had initially proposed.

G. Csanady - In your Statement of Work could you define some basic objectives, for example, defining circulation on the west Florida shelf, or to find the total transport of the Gulf? That is really what the experimental design was about. If that is stated it makes it much easier for everyone.

E. Wood - There is a Background and Purpose and Objectives section in the Statement of Work which will hopefully articulate our needs well enough to give you some guidance on how to respond to the RFP. This is a good point, and we will try hard to clearly define the objectives.

I would be surprised if we didn't see some of you responding to the RFP's in some way or another. It may be as principal investigator, as a manager, or as an advisor. We expect this and as long as we don't go into too many specifics here, then there is really no conflict of interest or prior knowledge problems.

We will be putting out a Statement of Work, which will get some review outside of BLM. If it is a competitive procurement we necessarily cannot go to a unversity type or someone who may want to bid on this. We can go to another federal agency, such as AOML or some other NOAA lab, or the Corps of Engineers, and try to select people with expertise who can give us some assistance in rewording certain portions. The Statement of Work with our standard boilerplate will then go to Washington, and they will add some more boilerplate and it will eventually come out on the street as a Request for Proposal.

I would like to give you a little information on BLM types of RFP's and more or less what we look for in a response. We don't have enough people to do the management of all the details. So we necessarily have to depend on a contractor to provide some management to take care of the nitty-gritty details, such as scheduling ships and keeping track of products and due dates. We expect, therefore, the proposal to include a lean but efficient management system. We don't want all the money going into administration either by us or by the contractor, but we do expect a tight management.

We have the schedules that are specified and agreed upon through the negotiation process, and we expect them to be adhered to. This doesn't mean we are inflexible, but we do look unfavorably upon delays.

We expect an efficient data management system. We demand that all the data collected be submitted to NODC in a reasonable time frame. We want to make sure that there is quality control, that the data submitted are in good shape, and are ready for use by the general scientific community. (Our first obligations are to us (the government) and to the Principal Investigators.) We also look favorably upon local talent. This is not entirely a political concern, but we like to see people who have knowledge of the area so that they are not wandering into something totally unknown. There is usually a role for advisors or a scientific oversite group, for quality control and quality assurance, as long as it doesn't get out of balance. This should not be an elaborate effort, but a certain amount of time by people of some professional stature, who can share their expertise and help guide the program, is applicable here. We also look favorably upon a program which shows that people are coordinating with other projects, and that they know what else is going on around them. If they have contacts with other federal agencies, with other universities, or privately funded industrial projects, this shows they are really aware of what's going on.

For this project, it would be also desirable to have contacts with the country of Mexico, because it is important that there be maximum international cooperation. I think that the more parties involved in this project, the more pieces of the puzzle we'll be able to put together, and the greater benefit for everyone. We expect that proposals have a realistic approach to logistics and to a sample plan. That plan should include an efficient use of platforms, be they ships, aircraft, drilling rigs or whatever. We also expect an effective plan for dissemination of information and reports.

In summing up, there is one other practical consideration. This is the difference between basic science or processes versus an applied or a descriptive type of approach. BLM by its mission must be more concerned with the effects than with what causes them. That may not be the way you would like to look at it, but the manager doesn't necessarily care why something happens. He is interested in what transpires and how it affects the resources that he is trying to manage. The other point that I really can't emphasize enough is that you've got to be able to relate what you are proposing to do to the layman. Finally, I want to emphasize that we (BLM) cannot do it all, and that is quite apparent. So if there is any piece of work that you can see being coordinated and funded through ONR, NSF, or any other agencies, take advantage of it, and let's see if we can't bring this whole effort together soon so that it benefits everybody.

I would like to give Dave Amstutz a chance now to express the views of the Washington office of BLM and the overview that he has of the physical oceanographic programs.

D. Amstutz - The following is a summary of the major points discussed by D. Amstutz.

1. In the beginning I sensed disorganization but I am very pleased with the outcome of the workshop.

2. BLM serves many concerns, including various Publics: affected states, special or limited interest groups, the general public and the scientific community. As a result, there is always going to be a group that thinks we've done the wrong thing.

3. The justification for this program lies with Congress and the Outer Continental Shelf Lands Act which gives us the authority to lease the public resources, in an environmentally safe and organized way which returns maximum benefit to the public. We are charged with using the "best available knowledge" in managing the leasing of these resources.

4. One of the most important issues that receives a great deal of attention and is of interest to the public is oil spills. BLM deals with oil spills in a probabilistic sense, and not in the "real time" sense. They are oil spills which we believe have a likelihood of occurring during the next thirty years from the time the lease is sold. It is our job to predict the occurrance of oil spills and the consequences from them over that thirty year time frame. We have an accuracy requirement for predicting trajectories that is much less stringent than you would need for doing real-time predictions. For example, the basis of our first oil spill trajectory analysis in the Atlantic off the southeast U.S. was the work done by Bumpus with drift bottles, along with a statistical representation of winds from shore stations. We recognized, however that we needed a more reliable method for predicting surface velocities. The second study done in this area was based on satellite altimetry from which we obtained a monthly portrayal of the surface circulation for a three year period, which was used in our oil spill model. We now have some more advanced methods, such as G. Mellor's model which is now used in the diagnostic mode. We have also done detailed correlations of onshore and offshore (buoys) winds.

5. BLM's studies have both temporal and spatial natures. We have already had several separate sales of tracts in the Gulf which are in various stages of development (since the early 1950's). The spatial nature of the problem stems from the fact that our offers of sales for tracts have to address oil spills even though the tracts may never be developed for oil. The transportation of oil, by pipelines and/or tankers, is a further complication of the problem.

6. BLM recognizes that success in properly developing the offshore resources requires very close coordination between technology and applied science. Dependence upon applied science has certainly been responsible for solving problems of navigation and fishing; and we believe it will aid in the development of offshore oil and gas. This is what I hope we are doing in our present program. We (all of us) recognize the need to care for the offshore environment; it is important to us for transportation, food, energy, recreation, etc. Thus we must be concerned with the cumulative impacts of the various contamination sources, not just those from oil and gas activities.

7. BLM is responsible for several other programs (e.g., Alaska and Georges Bank) under OCS, and we have to recognize budget priorities. It is my belief that we have a better overall knowledge of some areas, such as the South Atlantic and the Bering Sea, than we do of many areas in the Gulf of Mexico, and the area off California. We have funded circulation models and field measurements in the Bering Sea, and we now know we made a serious mistake that should not be repeated in the Gulf of Mexico. The mistake was that we broke down the modeling and measurement efforts on the basis of the lease sale areas, which were spread out around the Bering Sea, when we should have studied and modeled the entire Bering Sea. This is because transportation of oil by pipeline or tanker between the leased areas and their associated impact potentials could not be fully addressed. We are correcting this problem now, and we must be careful to plan correctly for the Gulf.

PRELIMINARY THREE YEAR GULF DATA COLLECTION PROGRAM

The purpose of this section is to outline a preliminary three-year data collection program for the Gulf of Mexico that will guide BLM's preparation of a Request for Proposals for their FY 82 through FY 84 program for the Gulf. The three-year program is a synthesis of the ideas developed during the workshop taking into account the priorities assigned by the participants.

Table 1 presents a summary of the recommendations of each workshop group organized by major Gulf processes. Approximate priorities of the major process studies, as well as subpriorities for instrumentation and surveys, are shown. Evident during the Summary Session discussions was a major concensus on studying three Gulf processes, including (1) the Interaction of the Loop Current with the West Florida Shelf; (2) Loop Current Intrusion and Eddy Break-off; and (3) Migration and Fate of Anticyclone Eddies in the Western Gulf. The priorities assigned to these three processes were approximately the same. Table 1 also indicates a moderate concensus on performing basin-wide semi-synoptic hydrographic surveys of the Gulf. This recommendation was set at a slightly lower priority. Additional "minority" proposals included a study on North Atlantic winds (Y. Hsueh) and measurements on the Texas/Louisiana shelf (R.O. Reid). A general recommendation made specifically by the Modeler Group and supported by all was the development of a synoptic Gulf-wide meteorological measurement program particularly for wind and heat flux calculations.

Based on the information given in Table 1 and from the workshop discussions, a preliminary three-year program has been outlined eliminating the overlap between the four major programs, thus increasing the cost effectiveness of the instrumentation and surveys. No attempt has been made to define detailed specifications of the number and types of instruments, locations, or frequencies of sampling. A general description of the three-year program is given below with a preliminary schedule shown in Table 2.

Interaction of the Loop Current with the West Florida Shelf

Justification and Reasoning:

- Satellite data indicate that meanders and possibly the initiation of pinched-off eddies may be a function of the interaction between the Loop Current water and water on the west Florida shelf.

- Calibration of numerical models of large scale shelf circulation require data to define the forcing functions at the boundary, which is probably a mix of wind events, tides and Loop Current events.

TABLE 1 - SUMMARY OF WORKSHOP SUBGROUP RECOMMENDATIONS

	LOOP CURRENT GROUP	MODELER GROUP	OCEANOGRAPHER GROUP
West Florida Shelf	(2)* Wind-Driven West Florida Shelf Circulation and Interaction with Loop Current (3 years) (a)** • Satellite IR and cloud photos • Met. buoys (b) • 9 CM/T moorings across shelf • AXBT's over Loop and shelf • SD - shallow satellite tracked drifters	(1) Interaction of the Loop Current with the West Florida Shelf (1 - 1.5 years) (a) • Satellite IR • 4 CM/T moorings across shelf at 25-26°N • AXBT's over Loop and shelf (2/year) • HS-hydrographic surveys (2/year) (b) • 2 additional CM/T moorings parallel to shelf	EASTERN GULF - (Year One) (1) Interaction of the Loop Current with the West Florida Shelf. (a) • Satellite IR • CM/T and TG moorings across shelf at 25-26°N • AXBT's • PG-bottom mounted pressure gauge at shelf edge (b) • Bottom boundary micro-scale current measurements
Loop Current	overlap (1) Loop Current Growth, Eddy Break-off, Movement and Dissipation (3 years) (a) • Satellite IR over whole Gulf • SOOP+ XBT's and Met. • 2 deep CM/T moorings in Loop Current (b) • 3 deep CM/T moorings across Yucatan Channel • AXBT's over whole Gulf • SD - satellite tracked drifters	overlap overlap	overlap (2) Loop Current Intrusion and Break-off of Eddies (a) • Satellite IR • SOOP XBT's and salinograph (b) • AXBT's (c) • Add 3 CM/T moorings from WFS to Campeche • 2 IES - inverted echo sounders • HS - hydrographic surveys and XBT's (3) Monitor Inflow and Outflow at Yucatan & Florida Straits (a) • Deep CM/T moorings, PG and cyclesonde
Migration of Anticyclones	overlap	(1) Production and Decay of Anticyclones in the Western Gulf (1 - 1.5 years) (a) • Satellite IR - October to April • 5 CM/T moorings in Western Gulf • SD - satellite tracked drifters - May to Sept. • AXBT's (3/year) in eddy • HS - hydrographic surveys (2/year) • Use existing NOBO met buoys	overlap WESTERN GULF - (Year Two) (1) Migration of Detached Anticyclones and Interaction with the Western Shelf (a) • Satellite IR • SD - satellite tracked drifters • SOOP XBT's, towed thermistors, Met. (b) • CM/T moorings in Western Gulf • HS - hydrographic surveys and XBT's (c) • IES - inverted echo sounders
Whole Basin Surveys	(3) Quarterly Basin Surveys (3 years) (a) • HS - hydrographic surveys (4/year) • SOOP XBT's and Met. • AXBT's	No Recommendation	SYNOPTIC SURVEY OF ENTIRE GULF - (Year Three) (1) Synoptic Survey two weeks twice/year (a) • IR • Multiship (3-4) HS with XBT's, 100 m thermistor tows, salinographs and Met. • AXBT's (2 aircraft) • SOOP XBT's, salinograph, towed thermistors • Deep moored CM/T's and cyclesond in Yucatan and Florida Straits • Continue West Florida Shelf CM/T's
Minority Proposals		(2) Correlation of North Atlantic Winds to Transport in Gulf Straits	WESTERN GULF - (Year Two) (2) Texas/Louisiana Shelf Circulation (a) • Supplement CM/T arrays • Bottom mounted PG at shelf edge • SOOP's and Oil Platform measurements (b) • SD - satellite tracked drifters
Other		(1) Synoptic Gulf-Wide Wind and Heat Flux Measurements	

* Gulf Process Priority

** Instrumentation and Survey Priority

\+ Ships of Opportunity

TABLE 2 - PRELIMINARY SCHEDULE

	FY 82 Apr.–Oct.	Oct.–FY 83 Apr.	FY 83 Apr.–Oct.	Oct.–FY 84 Apr.	FY 84 Apr.–Oct.	Oct.–FY 85 Apr.
1. West Florida Shelf/Loop						
(a)* • IR (whole gulf - see #2,4)		<——>				
• CM/T's at 2000, 200, 50 m	<———	————	————	———>		
• CM/T's at 700 m	<———	————	————	————	- - - - -	- - - - ->
• AXBT's (WFS & Loop - see #2,4)	<-->	<-->	<-->			
(b) • HS (WFS & Loop - see #2,4)	<-->	<-->	<-->			
• Bottom PG at shelf edge	<———	————	————	———>		
(c) • SD's with thermistor strings (WFS & Loop - see #2)	<——>		<——>			
• micro-scale bottom currents	<- - - -	- - - - -	- - - - -	- - - ->		
• 2-5 add'nl CM/T moorings on shelf	<———	————	———>			
• Met. buoys	<———	————	————	———>		
2. Loop Current Behavior						
(a) • IR (see #1,3,4)		<——>		<——>		<——>
• SOOP's (see #3,4)	<-->	<-->	<-->	<-->	<-->	<-->
(b) • 2 CM/T moorings in Loop			<———	————	- - - - -	- - - - ->
• AXBT's (see #1,3,4)	<-->	<-->	<-->	<-->	<-->	<-->
• HS (see #1,3,4)	<-->	<-->	<-->	<-->	<-->	<-->
• SD's with thermistor strings (see #1,3)	<——>		<——>		<——>	
(c) • CM/T moorings in Yucatan			<———	———>		
3. Migration of Anticyclones						
(a) • IR (whole Gulf - see #2,4)				<——>		<——>
• SOOP's (Loop & W. Gulf - see #2,4)				<-->	<-->	<-->
• 5 CM/T moorings in W. Gulf				<———	————	———>
• SD's with thermistor strings (see #2)					<——>	
(b) • AXBT's (Loop & W. Gulf - see #2,4)				<-->	<-->	<-->
• HS (Loop & W. Gulf - see #2,4)				<-->	<-->	<-->
(c) • IES				<-->	<-->	<-->
4. Whole Basin Surveys						
(a) • IR (whole Gulf)		<——>		<——>		<——>
• SOOP's for XBT's, Met., salinograph, thermistor tows	<-->	<-->	<-->	<-->	<-->	<-->
• HS - XBT's, Met., salinograph thermistor tows	<-->	<-->	<-->	<-->	<-->	<-->
(b) • AXBT's	<-->	<-->	<-->	<-->	<-->	<-->
(c) • Deep CM/T's in Straits	<- - - -	- - - - -	- - - - -	- - - - -	- - - - -	- - - - ->

* Measurement Priority

<——> Continuous Measurement

<- - -> Measurement Occurring During Indicated Period

- Model experiments indicate that the deep flow along the f/H contour (thus along the slope off the south west Florida shelf) is of controlling importance to the baroclinic response of the Loop Current.

- Penetration of the Loop Current depends on the deep flow (few hundred - 1500 m) off the southwest Florida shelf. Knowing the deep flow off the Florida shelf would be more valuable to the models than knowing the flow through the Yucatan Straits.

General Specifications (see also Table 2):

(a)
- Satellite IR over whole Gulf (Oct. to May).
- Minimum of 4 CM/T moorings across shelf at about 26°N from deep (200 m) to shallow (50 m) for at least one year. Note - NSF may contribute funding for this effort.
- AXBT surveys of the near-shelf portion of the Loop Current during periods of significant meanders (2 surveys/year)

(b)
- Hydrographic surveys for XBT's, meteorological, salinograph, and towed thermistors during periods of significant meanders (2 surveys/year)
- Bottom mounted pressure gauge at shelf edge for at least one year.

(c)
- Satellite tracked drifters with thermistor strings in summer in Loop Current to track meanders and to obtain cross current data which would allow estimates of Loop Current vorticity.
- Bottom boundary micro-scale current measurements at selected times to study the bottom shear dissipation process.
- 2-5 additional CM/T moorings on shelf north and south of 26°N for at least one year.
- Met. buoys for high resolution of wind stress. Note - NDBO is a possible source of funding for this.

In addition to the above measurements it would be very desirable to continue operation of a CM/T mooring at about 700 m depth off the west Florida shelf to augment the measurement requirements of both the Loop Current study and the western Gulf study, in lieu of CM/T moorings in the Straits (see Table 2).

Loop Current Intrusion and Break-off of Eddies

Justification and Reasoning:

- The Loop Current is the strongest circulation feature in the Gulf and the one which brings energy in from other ocean areas.
- It is relatively unknown how the Loop Current transfers energy to other regions in the Gulf, such as the west Florida shelf.
- No direct measurements of Loop Current velocities are available along its path.
- Effect on the spatial distribution of absolute velocities by the tides, by wind events, of seasonality, and due to position in the Gulf basin is unknown.
- Analysis of historical tide data has failed to reveal a correlation between the Straits. Any attempt to measure differences in mass fluxes through the Straits is felt to be an unreasonable proposition.
- A good handle on Loop Current flow and penetration could be obtained by measuring the deep flow (few hundred - 1500 m) off the southwest Florida shelf.

It is emphasized that the Loop Current study is directly related to both the west Florida shelf/Loop interaction and western Gulf anticyclone studies. For example, during the first 1.5 years of the program during which the west Florida shelf measurements are proposed to occur, measurements of the Loop Current are required in the form of AXBT's, hydrographic surveys, and satellite tracked drifters. During the last 1.5 years of the program during which the western Gulf measurements are proposed to occur, continued measurements of the Loop Current are required in the form of ships of opportunity, XBT's, AXBT's, hydrographic surveys, and satellite tracked drifters. Thus, there is a significant amount of overlap between measurement requirements for the Loop Current and requirements for the eastern and western Gulf programs.

General Specifications (see also Table 2):

(a)
- Satellite IR over whole Gulf (Oct. to May).
- Strategic ships of opportunity for XBT's, meteorological, salinograph and thermistor tows in the Loop Current during periods of significant meanders (2 surveys/year)

(b) • Approximately 2 deep CM/T moorings in the Loop Current between Campeche Bank and the west Florida shelf for at least one year, augmented by continuation of the ~ 700 m CM/T mooring off the west Florida shelf.

• AXBT surveys over the Loop Current during periods of significant meanders (2 surveys/year).

• Hydrographic surveys for XBT's, meteorological, salinograph and thermistor tows in the Loop Current during periods of significant meanders (2 surveys/year).

• Satellite tracked drifters with thermistor strings in summer in the Loop Current.

(c) • Deep CM/T moorings in Yucatan Channel for one year.

<u>Migration of Detached Anticyclones and Interaction with the Western Gulf Shelf</u>

Justification and Reasoning:

- Past modeling work and data analysis have revealed that the principal large-scale circulation of the western Gulf is dominated by large anticyclonic eddies separating from the Loop Current and travelling westward.
- Tracking of the anticyclonic eddies after separation is poorly documented and details of their movement and reflection/dissipation on the western Shelf is unknown.

General Specifications (see also Table 2):

(a) • Satellite IR over whole Gulf (Oct. to May).

• An array of approximately 5 CM/T moorings in the western Gulf for at least one year to provide a resolution of about 200 km in the N-S scale and about 150 km in the E-W scale, dynamically positioned to intercept an arriving eddy.

• Strategic ships of opportunity for XBT's, meteorological, salinograph and thermistor tows during significant anticyclone eddy events (2 surveys/year).

• Satellite tracked drifters with thermistor strings to track the eddy during summer when IR is ineffective, and record the upper 200 m temperature structure.

(b) • AXBT surveys to determine near-synoptic surface and subsurface temperature structure evolution of the eddy as it interacts with the shelf slope (2 surveys/year).

• Hydrographic surveys for XBT's, meteorological, salinograph and thermistor tows during the AXBT surveys.

(c) • Inverted echo sounder string along 90°W in deep water near location of anticyclone eddy separation from Loop Current.

Maximum use of the existing NDBO buoys should also be made during this study. It is noted that NDBO may provide assistance for this effort.

Semi-synoptic Gulf-wide Surveys

Justification and Reasoning:

- Basin-wide hydrographic surveys are desirable to obtain a near-synoptic picture of the Gulf in order to determine relationships between various processes, i.e., Loop Current intrusion, anticyclone eddy production and migration, and shelf circulation (east and west).

- This type of survey is generally considered very cost and labor intensive, and thus was recommended at a lower priority level. However, proper coordination of ships of opportunity and coordination with other survey requirements for the west Florida shelf, Loop Current, and western Gulf programs may prove very cost effective from a marginal cost standpoint.

General Specifications (see also Table 2):

(a) • Satellite IR over whole Gulf (Oct. to May).

• Ships of opportunity for XBT's, 100 m thermistor tows, salinograph and meteorology (2 surveys/year).

• Multiship (3-4) hydrographic surveys for XBT's, 100 m thermistor tows, salinograph and meteorology (2 surveys/year).

(b) • AXBT surveys (2 aircraft) - use to survey rapidly changing smaller scale 100 km features (anticyclones).

(c) • Deep CM/T moorings in the Straits (three years). Note - possible multi-year measurements in Florida Straits planned by NOAA.

APPENDIX I

GULF CIRCULATION STUDIES WORKSHOP AGENDA AND LIST OF PARTICIPANTS

GULF CIRCULATION STUDIES WORKSHOP AGENDA

14-15 May 1981

1. Opening Session

1.1	Welcoming Remarks and Workshop Purpose	* B. Pearce, NECE
1.2	Overview of BLM Program Needs and Objectives	E. Wood, BLM
1.3	U.S. Department of Energy Perspective	D-P Wang, DOE-ANL

2. Keynote Addresses

2.1	A Current Data Collection Program for the Gulf Loop Current	G. Maul, AOML
2.2	Data Requirements for the Gulf of Mexico: Recommendations Based on Numerical Experiments	J.D. Thompson, NORDA
2.3	An Oceanographic Data Collection Program for the Gulf of Mexico	R.O. Reid, TAMU J.D. Cochrane, TAMU

3. Subgroup Discussions

3.1	Gulf Loop Current Group	** G. Maul, AOML C. Cooper, NECE W. Merrel, TAMU P.O. Niiler, OSU D. Pillsbury, OSU T. Sturges, FSU F. Vukovich, RTI

3.2 Modeler Group	** J.D. Thompson, NORDA
	J. Pagenkopf, Tetra Tech
	B. Pearce, NECE
	H. Hulburt, NORDA
	D. Brooks, TAMU
	Y. Hsueh, NSF
	G. Mellor, Princeton
	G.T. Csanady, WHOI
3.3 Oceanographer Group	** R.O. Reid, TAMU
	** J.D. Cochrane, TAMU
	A. Humphreys, NECE
	F. Chew, AOML
	M.A. Estoque, U. of Miami
	J. VanLeer, NPGS
	B. Taylor, Tetra Tech
	F. Everdale, NOAA/EDIS
	J. Altamirano, IMDP
	R. Rodriguez, IMDP
4. <u>Summary Session</u>	* B. Pearce, NECE
5. <u>Closing Session</u>	E. Wood, BLM
	D. Amstutz, BLM

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* Workshop Chairman

** Subgroup Chairman

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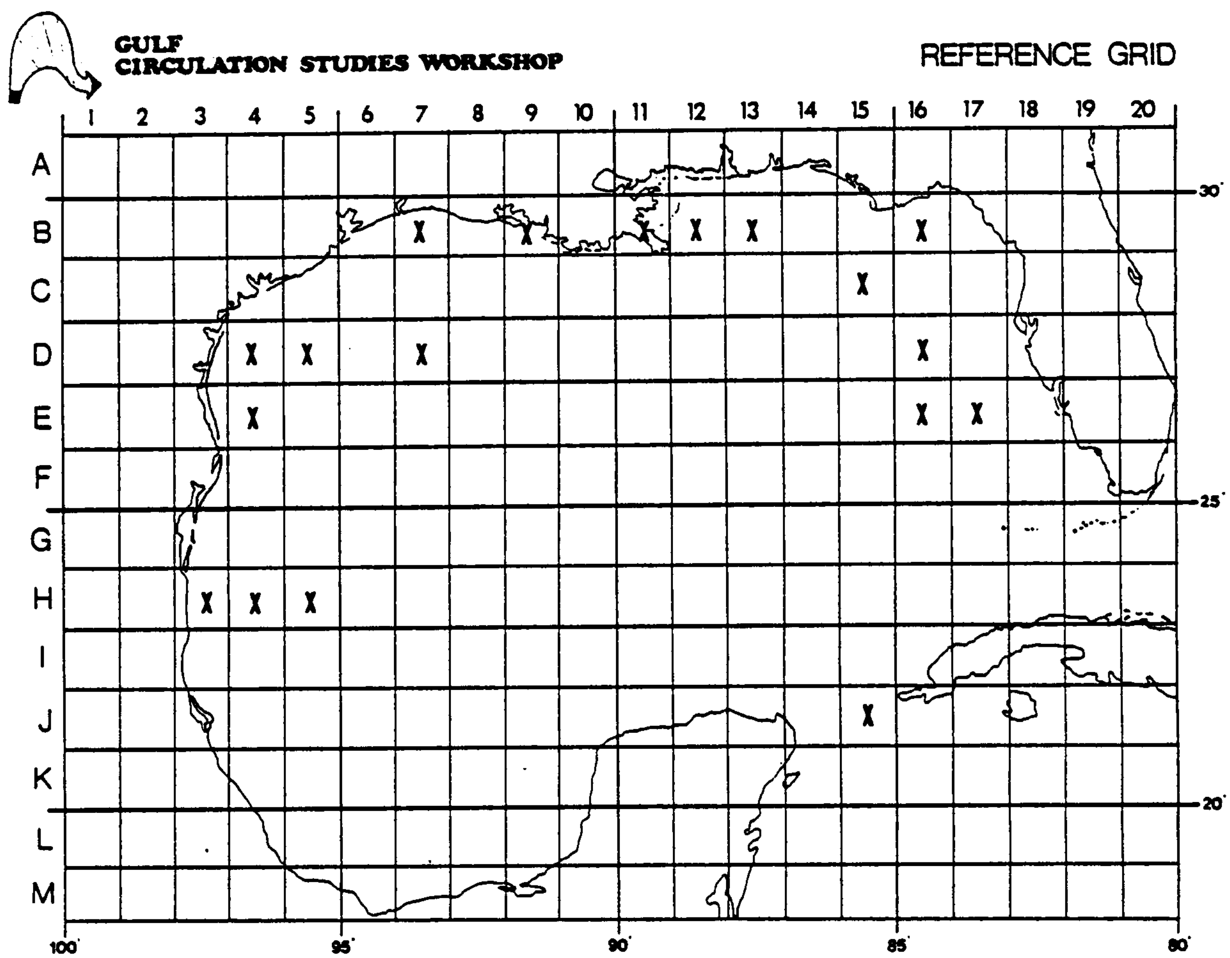
APPENDIX II

SUMMARY OF EXISTING CURRENT METER DATA

SUMMARY OF EXISTING CURRENT METER DATA

During the course of the Gulf Circulation Studies Workshop several inquiries were made as to the availability of existing current meter data throughout the Gulf of Mexico. The workshop chairman requested that each participant submit a list of known data including sampling location, instrumentation, sampling depths, sampling period, sampling interval and location of the data. The following pages summarize the known available current meter data for the Gulf of Mexico. The map on the following page can be used to determine the approximate location of the current measurements.



APPROXIMATE LOCATION OF EXISTING CURRENT METER MEASUREMENTS

GULF CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
B-7,9		CM MET Package			Contin-uous 1977-1978	½ hour to 1 hour		DOE-SPR PROJECT SAI, NOS, DAMES & MOORE (In NODC Archive)

National Ocean Survey (NOS) Current Meter Mooring Site

West Hackberry Stations		
#11	29°40'00"N	93°28'00"W
#12	29°41'59"N	93°28'08"W
#13	29°38'00"N	93°27'53"W
#14	29°40'20"N	93°22'17"W
#15	29°39'39"N	93°33'42"W
Weeks Island Stations		
#21	29°05'42"N	91°47'36"W
#22	29°07'29"N	91°46'33"W
#23	29°03'56"N	91°48'38"W
#24	29°03'26"N	91°42'34"W
#25	29°07'57"N	91°57'37"W

Science Applications Inc. (SAI) and Dames and Moore Current Meter Mooring Sites

Chacahoula	28°52'00"N	91°02'03"W
Big Hill Secondary	29°33'42"N	94°08'18"W
Chacahoula Site 1	28°57'06"N	91°22'45"W
Weeks Island Site A	29°04'57"N	91°42'15"W
Big Hill	29°33'54"N	94°00'00"W
Calcasieu Pass	29°41'48"N	93°23'54"W
West Hackberry Replacement	29°42'12"N	93°29'54"W
Black Bayou	29°38'54"N	93°35'30"W
Weeks Island Site B	29°03'06"N	91°46'12"W
Weeks Island Site Al	29°19'30"N	91°48'12"W

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

GULF CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
B-7		CM	?	bottom	1 yr.			E. Waddell - SAI M. Frey - NOAA
B-11		CM	1	7 m	1 mo. winter 1 mo. spring			S. Murray - LSU
B-12		CM pres-sure						U.S. Army Engineers "Missippi Sound Project" Contact Brown - NO-OCS

LEGEND:

- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

GULF
CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
B-13		CM	5-6	to 400 or 600 m				L. Shay - NAVOCEANO
B-13		CM	1	100,200, 800,1,000m	1 yr.	Cont.		Maul - AOML
B-16		CM	1	20 m	Aug.- Oct. 1978	Burst Sample ~ 5 min.		W. Sturges - FSU

LEGEND:

CM/T	Current meter array with temperature sensors
HS	Hydrographic Surveys
IES	Inverted Echo sounders
IR	Satellite SST
RF	Richardson-Schmitz Floats
SD	Satellite-tracked drifters
SF	Swallow floats
TG	Tide gauges
VC	Satellite cloud photos
WB	Weather Buoys
XBT	Expendable bathy-thermograph

GULF
CIRCULATION STUDIES WORKSHOP SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous).	SAMPLING PRECISION (specify units)	GROUP
C-15		CM-TC HS MET Package	2-10 CM-TC	Surface Mid-Depth Bottom	Contin-uous since Feb.'78	½ hour to 1 hour		DOE-SPR PROJECT NDBO/TAMU (In NODC Archive)

Texas A&M University Current Meter Mooring Sites

NRS	28°46'57"N	95°18'47"W
RA	28°47'03"N	95°18'47"W
RB	28°41'58"N	95°25'42"W
RC	28°43'54"N	95°14'34"W

NDBO Current Meter Mooring Site

NDBO	28°47'24"N	95°19'12"W

LEGEND:

CM/T	Current meter array with temperature sensors	SD	Satellite-tracked drifters
HS	Hydrographic Surveys	SF	Swallow floats
IES	Inverted Echo sounders	TG	Tide gauges
IR	Satellite SST	VC	Satellite cloud photos
RF	Richardson-Schmitz Floats	WB	Weather Buoys
		XBT	Expendable bathy-thermograph

GULF
CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
C-15		CM-TC HS MET	2-10	surface mid-depth bottom	since Feb. 1978	½ hour to 1 hour		DOE-SPR Project NDBO - TAMU (in NODC archives)
D-4								Ned Smith
D-5,7		CM	4 moorings		since Jan. 1979			D. McGrail - TAMY/BLM (713-845-3928)

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

GULF CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
D-16		CM	4	100,200,800 1,000 m	June '78 - June '80	Cont.		Molinari/Maul - AOML
E-4		CM	10	200-700 m	6 months	30 min.	~2 cms^{-1}	D. Brooks - TAMU/NSF
E-16 E-17		CM			various			Shelf Dynamics Experiment 1973-1974 Mooers, Price, Niiler

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

GULF
CIRCULATION STUDIES WORKSHOP

SUMMARY OF EXISTING CURRENT METER DATA

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	GROUP
H-3,4,5	~ 24°N 95°W to Coast	CM T	10	300-900 m	3 mos. 20 mos.	Burst Sampl ~ 5 min		W. Sturges - FSU
J-15		CM	2	1,800 m	Oct. '77 - Oct. '80	Cont.		Maul - AOML

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

APPENDIX III

SUBGROUP WORKSHEETS SUMMARIZING FIELD EQUIPMENT SPECIFICATIONS

GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Loop Current

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous).	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
All		IR	2	GOES-VISSR NOAA-AVHRR	3 yrs		0.25K	1	Gulf Wide ocean fronts study including non-IR techniques
All		XBT	1	T-7	3 yrs	30 km	0.1°C	1	Ship of Opportunity Program
15G		CM	5	To be determined	3 yrs	1 hr		1	Deep Loop Current Intrusion

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

PROGRAM PRIORITIES:
1. Crucial, must be included in any program.
2. Important, but may be omitted if funding limited.
3. Useful, but should be cut from program before priorities 1 and 2

GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Loop Current

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous).	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
12F		CM	5	To be determined	3 yrs	1 hr		1	Deep Loop Current Intrusion
14-15J		CM	15	3 arrays	3 yrs	1 hr		1	Measure deep water in Yucatan Strait
All		SD	5-10	Australian	3 yrs	daily	1 km	2	Concentrate on Western Gulf and Eddies

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

PROGRAM PRIORITIES:
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GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Loop Current

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
15-17 B-F		VC WB	3		3 yrs	1 hr	1 ms^{-1} 5^{o}	2	West Florida Shelf wind study
All		AXBT	1		3 yrs	TBD	0.25^{o}	2	Process oriented studies as they occur
15-17 B-F		CM	27	9 arrays	3 yrs			2	West Florida Shelf/Loop Current Interaction

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

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GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP: Loop Current

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
15-17 B-F		SD	3		3 yrs	12 hrs	1 km	2	West Florida Shelf Circulation
All		SF	21	700 m 1200 m	3 yrs	daily	1 km	3	Deep Gulf Circulation
All		HS	4	Niel Brown CSTD	3 yrs	90 days	0.05° 0.02°/oo	3	Quarterly multiship surveys

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

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GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Modelers

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous)	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
16F 17F 18E		CM/T	11	4 moorings 2000, 700, 200, 50 m	1 yr	cont.		1	Interaction of Loop Current with West Florida Shelf
see note*		AXBT	200		1 yr	2/yr	0.25^{o}	1	Interaction of Loop Current with West Florida Shelf
* Ten sections of ten drops along eastern edge of Loop Current and West Florida Shelf edge.									
see note**		HS	1	CSTD	12 days	2/yr	0.05^{o} 0.02^{o}/oo	1	Interaction of Loop Current with West Florida Shelf
** Wide coverage of eastern edge of Loop Current and West Florida Shelf edge.									

LEGEND:

- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

PROGRAM PRIORITIES:

1. Crucial, must be included in any program.
2. Important, but may be omitted if funding limited.
3. Useful, but should be cut from program before priorities 1 and 2

GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Modelers

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous).	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
4E-H 5E 6E		CM/T	25	5 moorings with 5 CM's each	1 yr	cont.		1	Western Gulf Eddy Movement and Decay
All		IR	2	GOES-VISSR NOAA-AVHRR	3 yrs	Oct.-April	0.25 K	1	Eastern and Western Gulf Studies
see note*		AXBT	150		1 yr	3/yr.	0.25°	1	Western Gulf Eddy Movement and Decay

* to be determined by IR

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

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2. Important, but may be omitted if funding limited.
3. Useful, but should be cut from program before priorities 1 and 2

GULF
CIRCULATION STUDIES WORKSHOP

PROGRAM WORKSHEET

GROUP Modelers

LOCATION (Square)	LATITUDE & LONGITUDE (optional)	MEASUREMENT TECHNIQUES (see legend)	NUMBER OF INSTRUMENTS	INSTRUMENT DEPTHS (metres)	SAMPLING PERIOD (days)	SAMPLING INTERVAL (if not continous).	SAMPLING PRECISION (specify units)	PROGRAM PRIORITY	
see note*		HS	1	CSTD	12 days	2/yr.	0.05° 0.02°/oo	1	Western Gulf Eddy Movement and Decay
* to be determined by IR									
see note**		SD	?	Australian	6 mos.	May - Sept.	1 km	2	Western Gulf Eddy Movement and Decay
** area to be determined by IR indication of eddy location									

LEGEND:
- CM/T Current meter array with temperature sensors
- HS Hydrographic Surveys
- IES Inverted Echo sounders
- IR Satellite SST
- RF Richardson-Schmitz Floats
- SD Satellite-tracked drifters
- SF Swallow floats
- TG Tide gauges
- VC Satellite cloud photos
- WB Weather Buoys
- XBT Expendable bathy-thermograph

PROGRAM PRIORITIES:
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2. Important, but may be omitted if funding limited.
3. Useful, but should be cut from program before priorities 1 and 2

APPENDIX IV

GULF SHIPPING LANES

GULF SHIPPING LANES

A number of participants suggested that shipping lane charts would be useful to data collection program managers planning ship-of-opportunity efforts.

The following three charts are taken from working maps of the commercial shipping traffic for the base year 1979, developed by the Office of Ocean Resources Coordination and Assessment of Coastal Zone Management (ORCA/CZM). This information was supplied by Fred Everdale of NOAA. The working assumption of these maps are that ships leaving a given port travel the shortest distance to its destination.

The three charts are:

(1) Intra Gulf of Mexico traffic

(2) Traffic leaving the Gulf of Mexico via the Straits of Florida

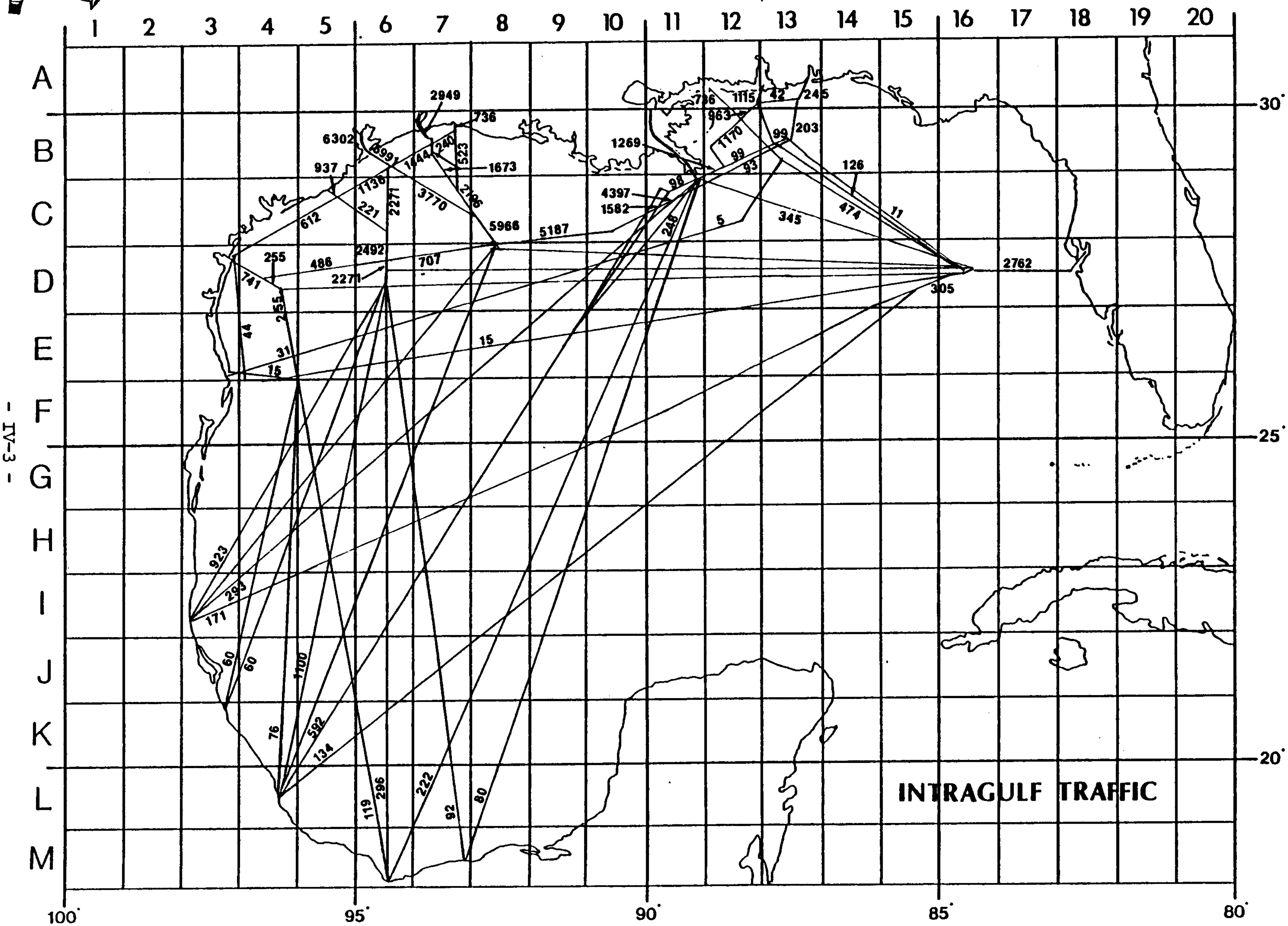
(3) Traffic leaving the Gulf of Mexico via the Yucatan Straits.

The numbers on the various shipping routes designate the number of ships transversing that route for the base year 1979. For additional information concerning these maps, please contact:

Daniel Basta
ORCA/CZM/NOAA
Washington, DC 20235
202-634-4120

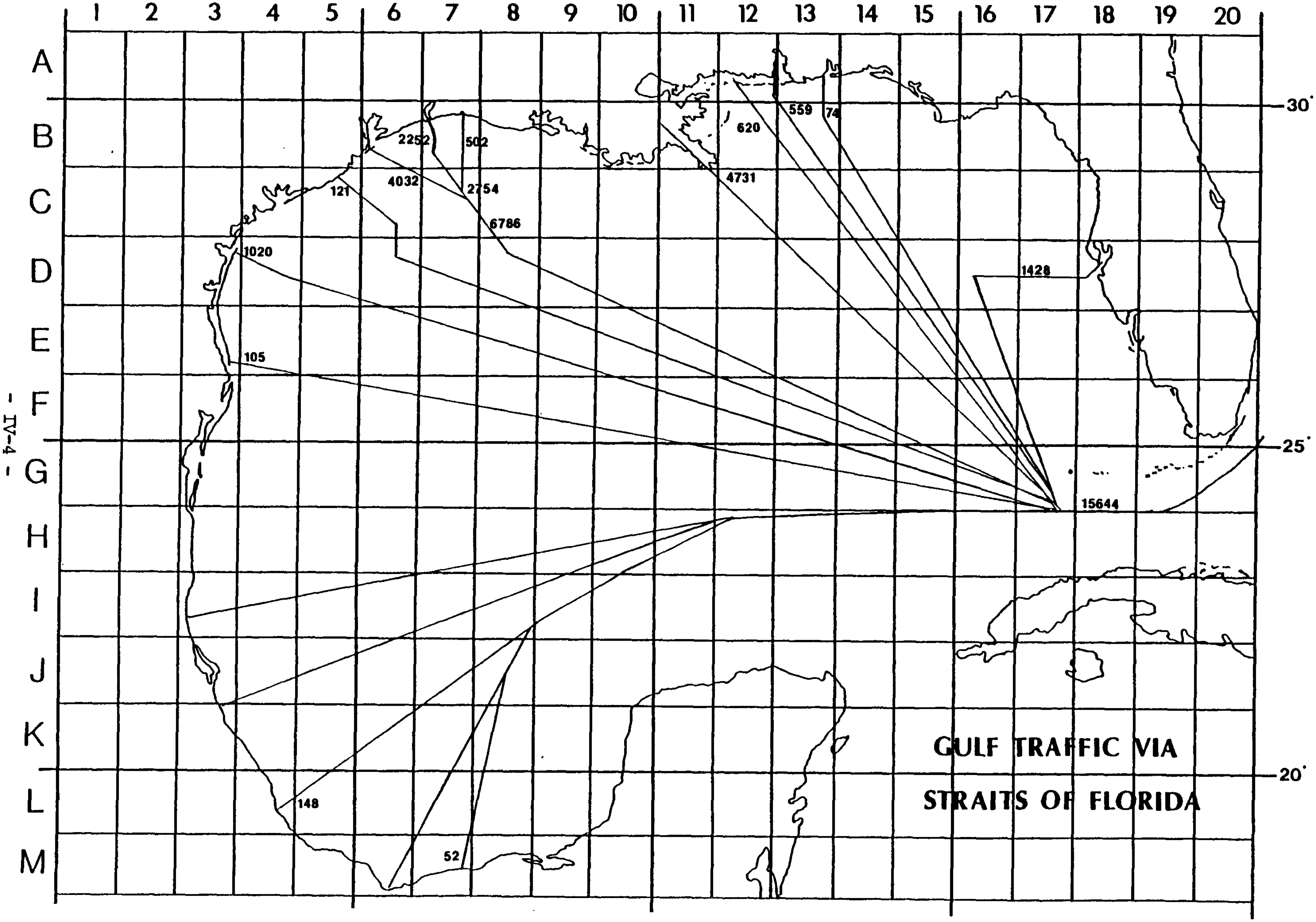
GULF CIRCULATION STUDIES WORKSHOP

REFERENCE GRID



GULF CIRCULATION STUDIES WORKSHOP

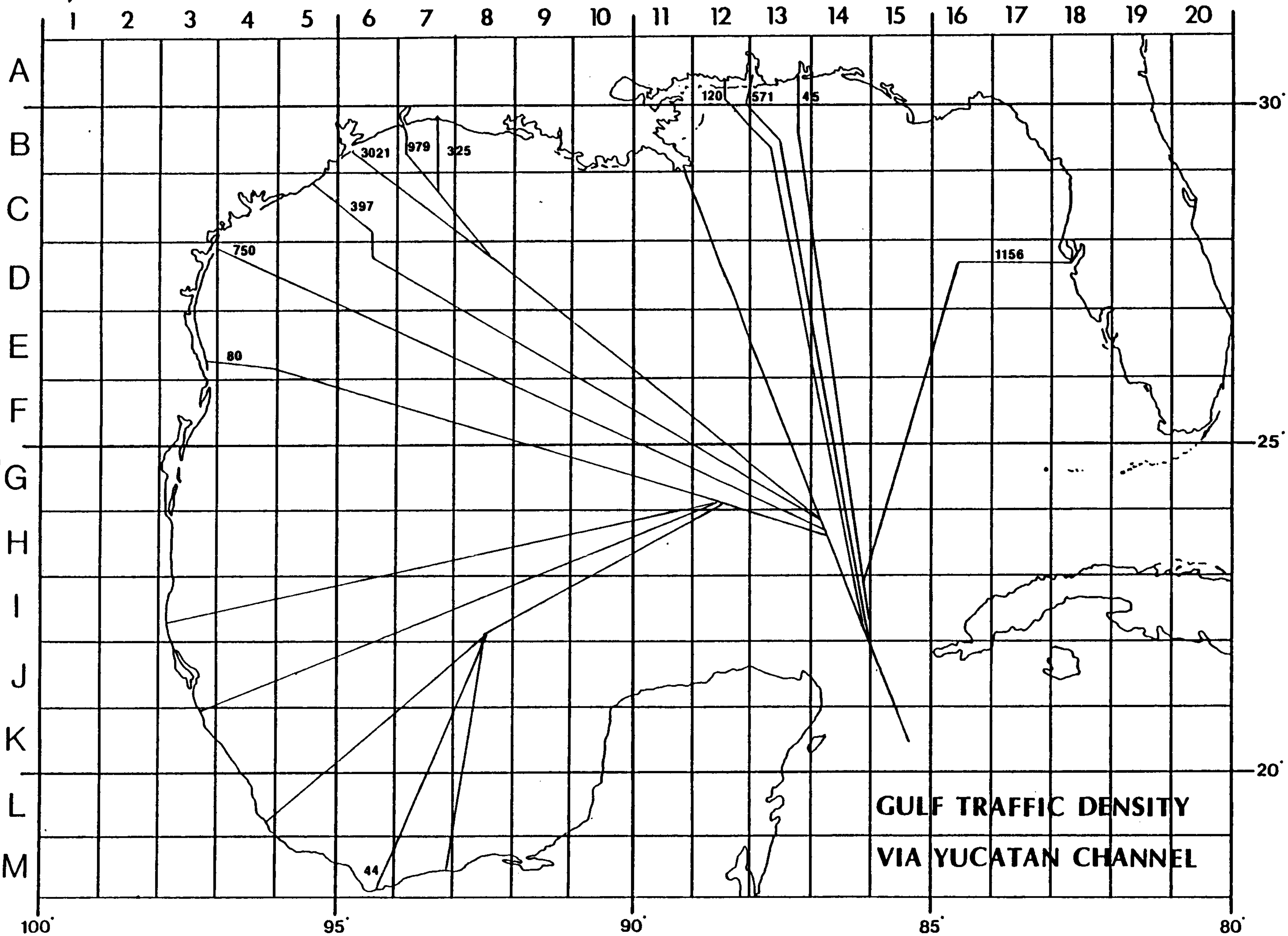
REFERENCE GRID



GULF TRAFFIC VIA STRAITS OF FLORIDA

GULF
CIRCULATION STUDIES WORKSHOP

REFERENCE GRID



APPENDIX V

SYMBOLS AND ABBREVIATIONS

SYMBOLS AND ABBREVIATIONS

AXBT	expendable bathy-thermograph by airplane
CM/T	current meter arrays with temperature sensors
HS	hydrographic surveys
IES	inverted echo sounders
IR	satellite sea surface temperature
Met.	meteorological
PG	pressure gauges
RF	Richardson - Schmitz floats
SD	satellite-tracked drifters
SF	Swallow floats
SOOP	ships of opportunity
TG	tide gauges
VC	satellite cloud photos
WB	weather buoys
XBT	expendable bathy-thermograph by ship

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.