Calif. Mar. Res. Comm., CalCOFI Rept., 12: 43–49, 1968

OCEAN-WIDE SURVEYS, BOTH METEOROLOGICAL AND OCEANOGRAPHIC

HARRIS B. STEWART, JR.
ESSA Institute for Oceanography, U.S. Department of Commerce
Washington, D.C.

Any ocean-scale survey activity would be less than efficient if it were purely oceanographic or purely meteorological. Oceanic and meteorological phenomena are too closely interrelated to attempt to understand one through ocean-wide surveys without considering the other at the same time.

To digress for a moment, this same philosophy has been extended to the administrative end of the scientific spectrum with the recent merger of the Weather Bureau, the Coast and Geodetic Survey, and the Central Radio Propagation Laboratory of the National Bureau of Standards to form a new group within the Department of Commerce which labors under the burdensome—but descriptive—title of the Environmental Science Services Administration. ESSA is a new concept—"lumping" versus the usual governmental operation of "splitting." So far it is working well, and we who are involved in it have great hopes for the future.

ESSA, to carry out the research required to provide adequate services in relation to the marine environment, is establishing the ESSA Institute for Oceanography. Its establishment will be formally announced on the 26th of December. Just a word about this might be in order, since institutes of and for oceanography are fairly close to a lot of our hearts out here. What we're doing is this: We hope to be providing to ESSA the research needed in order to carry out their missions in the field of marine products and services. It is not to be a purely basic research institute as such in competition even scientifically or financially with Scripps or Woods Hole and Lamont, rather we envision this as a research group that will be trying to bridge what some of us consider a considerable gap between basic research conducted elsewhere and the people who are banging on our doors for information on the ocean. This involves everyone from the Jerry Namiases in the long-range forecasting business screaming for sea-surface information, through the people concerned with putting up oil rigs who want to know the currents that they are going to be involved in as they work in the ocean, to the minerals people, the fisheries people, everyone concerned with the ocean as an environment. This will be the thing then that we will be working on in our Institute for Oceanography. It will be located, at least temporarily, in Washington, D.C. Eventually, of course, we hope for a coastal site somewhere, but that will be long in coming, I'm afraid.

Joe Reid had my talk this morning all scheduled and a name tied to it, and my first reaction was to change the name, but my second reaction was to become sufficiently informed myself so that I could speak to the same title Joe had planned. Therefore, what I would like to do is tell you something of ocean-wide surveys both from the meteorological point of view and the oceanographic point of view.

Jerry Namias alluded briefly to something called the World Weather Watch, and I think it's worth cluing you in briefly on the World Weather Watch as a concept. As I discuss this, please keep it within your oceanographic frame of reference. Think of this as perhaps an oceanographic possibility although being developed primarily for meteorological purposes. To commemorate the United Nations' 20th birthday, 1965 was designated as International Cooperation Year, and in speaking of this President Johnson said: "We will move ahead with plans to devise a world-wide weather system, using the satellite facilities of all industrialized countries. The space age has given us an unparalleled capacity to predict the course of the weather. By working together on a global basis we can take new strides toward coping with the historic enemies: storms, droughts and floods."

The World Weather Watch is an interesting idea. The rapidly evolving capabilities of modern weather instrumentation together with the very large advances which have been made in the understanding of the atmosphere have led people to plan a truly global observation network for meteorology. The motivating idea was that better weather service for all nations really offers the best hope for understanding the atmospheric environment in which we all live. Again keep the oceanographic framework in mind as I go through this meteorological approach.

The World Weather Watch is a system of observing, collecting, processing, and distributing weather information, using the latest developments in communications, data processing, instrumentation, and space technology. Its objective is to remedy age-old deficiencies in weather operations which have prevented meteorologists from providing weather predictions of longer range, greater accuracy, and more usefulness. The plan is being worked out through WMO (World Meteorological Organization). There are some 125 nations now involved in WMO. Already there is an international weather network, but it reflects the widely differing capabilities of the internal weather services of the various countries involved. In many instances several nations cooperate in joint efforts to collect vital weather information. The United States and some western European countries, for example, share the task of maintaining the ocean weather stations.

But the present weather observing and communication networks fall far short of providing the weather

services that are required today. The network of upper air observations, for example, is way below the minimum requirements for about 80% of the earth, for half the globe these observations are totally inadequate, so the meteorologists have considerable problems. But one thing they have done is to establish this World Weather Watch. No one nation could be expected to provide it all—it had to be done on an international basis. As Jerry Namias said, the perfection of mathematical models is coming along, but they need the information that is to be put into them, and I agree with him in that I think it quite probable that when we have good mathematical models and adequate input of global weather data to these models, we will be able to increase our ability for long-range forecasting. But again, this depends on global-scale data—it's nothing that can be done with one man and one lab somewhere—it requires a large network for obtaining meteorological data.

In 1961 after the first Tiros satellite, President Kennedy expressed the desire of the United States to cooperate with other nations in space technology for peaceful purposes, and, speaking to the United Nations, he said the United States "would propose cooperative efforts between all nations in weather predictions and eventually in weather control" (they keep talking about weather control, but this is a long, long way away). And United Nations Resolution 1721, which concerned international cooperation in the peaceful uses of outer space and embodied the idea of cooperative meteorological work, was approved unanimously by the General Assembly of the UN on December 20, 1961, just four years ago today. In the field of meteorology the resolution proposed that the World Meteorological Organizations study means of developing a global weather network to receive, process, and transmit information received from weather satellites.

Specifically, the resolution requested WMO in collaboration with UNESCO and ICSU (the International Council of Scientific Unions) to draw up a proposal for appropriate organizational and financial arrangements and get going with it. In the first report to the United Nations submitted in 1962 WMO recommended the creation of a World Weather Watch combining satellite information with an expanded network of continental information to bring better weather services to all nations of the world. And it is coming along. Plans are developing, and—as these things do—it requires committees and panels, and meteorologists, at least in the United States, are working closely with the National Academy of Sciences Committee on Atmospheric Sciences, and it is coming along—the plan is taking shape, funds for it are being planned—are being budgeted (no one knows how these will come out, it's always sort of a problem), but the point to be made is that the meteorologists are moving right along in this field of developing a global observational network for improving weather prediction and especially long-range weather forecasting throughout the world.

It would be very interesting to me to see the word "meteorological" replaced with "oceanographic" throughout the foregoing discussion. And there are trends in this direction. One of the aspects of the World Weather Watch is that over much of the ocean there are no means of obtaining meteorological data. The early plans for the World Weather Watch include a series of ocean buoys transmitting meteorological data. It is our intention that the buoys will also be able to obtain oceanographic information.

Again this creates something of a problem because I personally am convinced that right now we do not have a buoy that can sit out there and operate six–eight months with high reliability. It just isn't here yet. There are a lot of plans, ideas, lots of developmental work, particularly the work that ONR is doing, but to get the buoy that will sit in one place for as much as six months with the sensors operating effectively with no deterioration of the data right now is not possible. There are people working on it, but it seems to me that we have to stop talking about great global buoy networks without having the backup to go along with it, and we just don't have it yet. Good buoys are one thing that a lot of people are working on, some of you here are involved in it. It is primarily a technological problem rather than a scientific problem, and I'm a firm believer that if enough bucks are poured into it, it can be solved. Never underestimate the profit motive as a means for getting something done. I think this is also true for oceanography as a whole. People say, for example, that there are not enough oceanographers to justify adding funds to the program on a large scale. My answer is "horsefeathers." With enough money poured into it, oceanographers "will come out of the woodwork." There will be people from other disciplines who are currently working on problems unrelated to the ocean who can just as well translate their effort to similar problems in the ocean.

The same thing happened when we were first talking about a large effort in space. If you look back at some of the Congressional hearings, the standard question was "How can we possibly mount a large-scale space program, we have no space scientists in the United States." Yet when the dollars were placed on the line, "space scientists" came from everywhere. The same thing could happen in oceanography. But I get sidetracked. That then is a brief summary of the World Weather Watch as it now stands.

Now what about the ocean business? Certainly the problem of systematic surveys in the ocean is nothing new to the CalCOFI people. Your organization's program has been one of continuing systematic surveys for some 17 years. Within the Federal Government, where we have been trying to do this on an oceanic scale, we had some of the same problems that CalCOFI has had. Processing, working up, and publishing the data has been a real bugaboo for us. First, a few words as to how this effort got started.

The National Academy of Sciences Committee on Oceanography (NASCO) in their monumental 12-chapter report had a Chapter 9 called Ocean-wide Surveys. This was no brand-new concept. This had been proposed over and over again. It was proposed by the International Council for the Exploration of the

Seas at the end of the last century. It was either ICES or what later developed into ICES. It was proposed by the Navy in the early 1920's—something called the Matthew Fontaine Maury Oceanographic Research Expedition. I've seen a volume this thick of justification as to why the Navy should get into the oceanographic survey business and I have framed in my office a copy of the letter from the Bureau of the Budget saying that the President had looked at this program and found that submission of this program at this particular time was not consistent with the President's present budgetary ideas. This circumlocution means no bucks, so it died again. We still have the same trouble; but within the Federal Government in Washington, we've tried to see what could be done about implementing this latest recommendation to get going on taking a systematic look at the world's ocean.

The Interagency Committee on Oceanography, in trying to put things into categories so that you can label them and add them up to find out how much money is going into what, made an unfortunate split between surveys and research. I think it was a mistake—we have had to live with it ever since, and it has been darn difficult at times. In the Coast and Geodetic Survey, for example, we knew we couldn't get any money for research, we never got any money for research. Thus if we called our effort a research effort, we never would have gotten started. So we had to call it a survey effort. We are a survey organization, and by calling it a survey effort we were able to get it started. Other organizations doing exactly the same thing called it research. But when you start totalling this up to see how much money is going into one aspect of oceanography and how much money into another, you run into definitional problems. The way I like to sort it out is to say that the systematic survey effort is looking at the "what," the "where," and the "when," whereas research-motivated work is looking primarily at the "why" and the "how." I think it is a legitimate way to split them up. In other words, the survey effort is primarily a descriptive effort, looking at the "what's," the "where's," and the "when's," whereas the research effort is trying to understand why and how these things are as they are.

Now in order to find out about the "why's" and the "how's," you have to go back and do the descriptive work first, so these two approaches are inextricably related, and it is criminal that we had to try and make a split between them for budgetary purposes. The hydrographers, the nautical charting people, for years have been doing systematic surveys along the coasts of the world producing nautical charts. These guys are good at it—they have what I like to call a tolerance for tedium that most of us just don't share. If something exciting isn't happening or if we can't see some scientific problems that we want to attack, oceanographers feel it's pretty dull. But fortunately the hydrographers have this tolerance for tedium—this ability to do the same thing day in and day out over and over and over, and they're good at it. What we have done is try and utilize this capability of doing good, systematic, technical, accurate work and utilize this capability for oceanography. What we have tried to do is translate the recommendations of Chapter 9 of the NASCO report, Ocean-wide Surveys, into an operational reality. To say it is coming along well would be stretching the point a bit. It's limping, just barely limping, but we're beginning to get some interesting results out of it.

As to what the program is, we have, in the classic Washington tradition, given it a code name (you seem to do better getting funds for things when they have a code name) and we struggled to find one for this for a long time. There had been considerable confusion between the continuing historical missions of the agencies—that is, the nautical charting of the Geodetic Survey and of the Naval Oceanographic Office—and the attempt to get started on the ocean survey program. Both ended up as survey items in the budget presentation, so there was confusion as to what bucks were for what. So it became imperative to point out that the specific ocean survey program was different, that it was separate from the continuing historical mission of the agencies. So to point out this difference very strongly during the hearings before the Panel on Oceanography of the President's Science Advisory Committee (PSAC), we called it the "Federal Oceanic Exploration and Mapping Program" which came out "FOEMP" as an acronym, and actually FOEMP! wasn't a bad description of what we had been able to accomplish to date. It has been coming along really very slowly. A lot of work, a lot of good work, has been done but the support has not been there. So we have come up with a better name: it's called Project SEAMAP for Scientific Exploration and Mapping program, and we're going to stick with that title now, Project SEAMAP.

What SEAMAP involves is the systematic mapping of the bottom topography, gravity, and magnetics on underway surveys plus such meteorological observations and sea-surface observations that can be made underway. In this respect I'll be particularly interested this afternoon to listen to Lee Alverson, Ahlie Ahlstrom and Tim Parsons and the rest of the papers on your agenda.

For a long time we have been trying to instill in biologists a feel for the systematic approach to biological surveys, the point being that if we can get this survey rolling, there will be ships doing systematic survey work in the world oceans, ships that can be biologically useful. What is it that the biologists want that can be obtained on a systematic global basis? We are sure that there are such data. I was interested to hear from Maurice Blackburn just recently of developments on measuring pigment material well underway. In the early stages we talked with the Bureau of Commercial Fisheries people in Honolulu. They said, in effect, "Yes, we're very sympathetic; there are a lot of things we would like to learn on this basis, but we don't have the people to do the work. Our shelves now are just stocked with plankton samples that we can't work up—what good would it do to get another 500,000 plankton samples?" So there are some real problems on taking a biological look on a global basis. But the point I want to make is that we're still fighting to get this project SEAMAP going, and to me it would be

criminal to have the project going without a solidly based biological program. The meteorological part is coming along very well—why can't we get the biologists to cooperate?

The work done to date on this program has been in the North Pacific between the Hawaiian Islands and the Aleutian Islands starting at 153°W and working all the way over to 180°. We have done a series of north-south lines; generally they have been 10 nautical miles apart. This, of course, is meaningless unless you have accurate navigational control. I won't beat the navigational drum any more. It has been one of my pet ones for a number of years; but the point is that we had Loran-C control. We now on the *Pioneer* have TRANSIT—the Navy Navigational Satellite System, and hopefully we can hang on to it. We got ours through a little different route from that of the private institutions, and so far we have been able to hang on to it. It hasn't been pulled back by the Navy; we hope to hang on to this thing. The system works—it's a good system. The accuracy is classified, other aspects of the system are also classified, but the point is that it works and we can tell where we are on the surface of the ocean. This really is the fulcrum on which this whole ocean survey business depends—having good navigational control.

Question: What observations are planned for the SEAMAP program? The plan as proposed by the ICO covers the whole spectrum—it reads like a Montgomery-Ward catalog of oceanography, and it is meaningless as far as I'm concerned. It is ridiculous to try to do everything at once; we're under political pressure at this point of the game. But what is actually being observed now? There is one ship working on this —the *Pioneer* of the Coast and Geodetic Survey. The observations being made underway are continuous echo sounding, gravity, magnetics, BT's every two hours (hopefully next year some expendable BT's will be added to this), meteorological observations, regular radiosonde balloon releases, and surface weather observations. We are also using the logs of the Bureau of Commercial Fisheries for fish and bird sightings. We monitor sea-surface temperature, and sea-surface salinity is determined on all BT bucket samples. These make up the underway observations.

In addition each year we have hove-to or station operations which include a research input. For four years we had a series of stations—hydrographic stations—running from the Hawaiian Islands to the Aleutians. These data have been worked up, and they are now in the process of publication by the Seattle laboratory. Cores have been taken when there was a requirement for them. Our own feeling has been that the best place in the world to store cores, if nobody is going to look at them, is at the bottom of the ocean where they were in the first place. So when there are specific requirements, we will do coring.

We've cooperated with the University of Washington and the Geological Survey in doing some dredging on the rift zones seaward of the Hawaiian volcanoes. Dredge samples from these studies enabled the people from Hawaii, the geologists, to come up with some very interesting correlations between the size of vesicles in pillow lavas, lavas extruded under water, and other characteristics of the lavas as a function of the depth at which the lavas were originally emplaced. This is turning out to be a very interesting new tool for geologists to use to determine the depth at which pillow lavas were extruded on the ocean floor. In the early days of the SEAMAP program we also did some cesium 137 collections for Ted Folsom. We have done other specific projects like this. We collected water samples at depth in the North Pacific for NIO in England, and we have done some biological work for the Bureau of Commercial Fisheries, particularly for the Hawaiian group that wanted samples in specific places. We did work on magnetics with Vic Vacquier who was interested in the possibility of extending some of his crustal displacements. He wanted to see how far these things ran, so we ran some specific magnetic crosslines for him.

We have been concentrating, so far, primarily on the time-independent variables: gravity, magnetics, topography, and so on. The whole problem of the time-dependent variables, as Warren Wooster has pointed out over and over again, is a different problem. Joe Reid alluded to it this morning. We also include within the philosophy of project SEAMAP the systematic collection of information on the time-dependent variables. This problem is a real stinker as you all know. We are proceeding very slowly. Perhaps we are overly conservative, but I don't think so. I personally am tired of the grandiose schemes of loading our ocean with buoys (a) before we have the buoy that will do the job or (b) before we know what we really want to measure, or where. What we hope to do, following the suggestion of the new NASCO report now in the draft stages, is to carry out their suggestions that a small test buoy network be established, and so far the item has been able to remain in our 1967 budget (how long it will stay there is hard to say). We are requesting funds to plant on the east coast shelf an array of five buoys of which the prototype is being delivered to us this week. The system was developed within the Coast Survey and will measure current direction and speed, pressure, temperature, and salinity. These will be in sensors that can go on the cable. We plan to plant five, if we have funds for them, in a fairly tight network on the east coast shelf somewhere out of the Gulf Stream system. With these we will take a look at the whole spectrum of variations, the range of frequencies, and the scales of these variations. And when we have accumulated a volume of data, what we then hope to do is to make copies of these and farm them out to physical oceanographers in the United States and elsewhere. Hopefully we will then have a meeting to sit down, take a look at these data and see what people feel are the things to measure on the larger, more systematic scale.

Question: What sort of an array of buoys do you plan? It's not set yet, we don't know and are open to suggestions; probably they would be arranged in a square with one in the middle. How far apart, we are not yet sure. We would plan it to be close enough to shore so that we can intersperse the buoy measurements with ship observations so that we can fill in some of

the space holes. Question: What is the cost per copy? By the time you get your anchoring gear and the buoy itself we think it's going to run about $30,000 per buoy. It isn't terribly expensive as buoys go. Question: How do you get the data back? These are both telemetered and/or stored in the buoy on incremental magnetic tape. The man handling the whole project is Mark Goodhart of the Coast Survey. They have done considerable modification to the Geodyne current meter and the tests so far show it has worked very well not only in slow currents but also in currents of two to three knots. So we will continue to be working on buoys, for within this SEAMAP project is a requirement for the measurement of the time-dependent variables. But, this phase is going very slowly and conservatively, which I think is as it should be.

One thing that Jerry Namias mentioned this morning struck a very responsive chord. This was the requirement for long series of data so that you can take a look at time variations systematically. What this always brings to my mind is tidal data, for here in fact is one of the best—if not the best—long series of oceanographic data. They go back into the last century. Generally these are available, with some gaps in the record, on an hourly basis. This is an incredible time series of data. Some people have been well aware of this. Gunnar Roden, for example, has dug many times into our tidal data bank and has utilized these data to come up with new ideas. Walter Munk has done a lot with these long series of tidal data, things that couldn't be done before electronic computers were here. Bernie Zetler from the Institute of Oceanography has been working with Walter Munk on this and has come back from his work with Walter this summer with something which to me was very interesting. I'll pass it on as far as I understand it and suggest that you talk with Walter to get the details on it. To me it was very intriguing. They were using a very long series of hourly tidal height data at San Francisco. They were applying to it new analytical techniques using the BOMM program developed here at Scripps. They were taking a look at the whole range of spectrum of frequencies that occurred in this tremendously long series of hourly tidal heights running back 80 years or so.

Instead of looking for what they thought would be there, they looked at the whole thing to see what actually was there. They found some interesting things. For example, there was a 5-day cycle that appeared as a line on their frequency chart that no one ever suspected. You'd never think of a 5-day frequency in tide; but they also came up with another thing as they looked at these. They found what they are calling a "radiation term." What they feel is that this is a variation in sea level that is a function of the incoming solar radiation. Actually the sun warmed up the water column sufficiently during the day to put a measurable steric variation in sea level, and they are convinced that is what it is. To me what this meant is that all of a sudden we have a tool for going back historically and taking a look at the variations in what I would call the "effective incoming radiation." So here is a whole storage bin of air-sea interaction data that suddenly people tripped on, and it's all there in the records just waiting for someone to go ahead and take a look at long-term variations in this effective incoming radiation. This may tie in with some of the solar activity we were speaking of a minute ago. In other words, this is the sort of thing that can happen when you get long series of dependable data.

One other thing, while we're on this ocean-scale survey subject and talking on tides, is a program that is now in the thinking and planning stages, and funds have been budgeted here and there for. Hopefully it will come off. This is the IAPO-Walter Munk plan for an ocean-wide look at deep-sea tides. There has been a lot of interest generated in taking a look at deep-sea tides on a global basis. One nice thing, of course, is that this does not have to be done synoptically, so you are not going to have to have instruments all over the ocean at the same time. Rather the plan is to run a profile dropping the instruments, say, across the Pacific, then coming back and picking them up later on—hopefully. We now have, as you know, cotidal charts that are theoretical. They are based on coastal and island data. We don't really have much of a feel for what happens to a tidal wave as it comes up on to the Continental Shelf—what sort of modification takes place. The idea of going out with bottom-mounted tide gauges on a global scale and taking a look at the whole movement of tide in the ocean is a fascinating idea, and it can very probably be done. People have been working on deep-sea gauges. Aeries in France, Jim Snodgrass and Walter Munk here, Steacy Hicks of the Coast Survey, and many others have been working on deep-sea gauges, and they are beginning to get pretty good results. These things will work. So here is another look on a global scale—this one at the phenomenon on tides.

One other aspect of this large-scale business is one other look at the time-dependent variations which is going on even now. This is called Gulf Stream Studies—'65. I realize it isn't your ocean, and I apologize: but it's a lot like your Kuroshio, so what we Atlantic oceanographers can say is that we are looking at the Gulf Stream and maybe this will help with understanding your Kuroshio. This was a project dreamed up three years ago when air-sea interaction was an especially good budgetary word, and we thought that maybe by using that word which people were latching onto, we would get some additional funds to do something we had been wanting to do all along. This is the way you have to play it in Washington, as you know. So what we proposed was to take a long look at the Gulf Stream. We knew perfectly well that if we in the Weather Bureau and the Coast and Geodetic Survey said that we were going to go into a Gulf Stream program, that it probably would be shot down in flames before we ever got started. So what we did was this: we called in the Gulf Stream people, brought them to Washington for three full days of sessions. This was Henry Stommel, John Knauss, Fritz Fuglister, Tak Ichiye, Bill Richardson, and Ray Montgomery. All came in for three days, and all sat down in a conference room on

the top floor of the Department of Commerce. We said, "Let's be perfectly frank about it. We have the facilities—both meteorological and oceanographic. What we would like to do is take a look at the Gulf Stream, but we want your guidance. We want to know what are the major scientific problems that have to be solved; don't worry about the justifications, we'll tie it in with fish and weather and national defense in the national budget; all we want to know is the scientific problems involved." They were fairly good sessions. On the basis of those sessions we planned a Gulf Stream survey—Gulf Stream Studies 1965. It is going along pretty well. It started actually in August and it's going for one full year. Let me just briefly show you the way it's working, and then I'll get back to these survey studies.

This program is in three phases. For the first at Miami and at Bimini in the Bahamas we had continuously recording tide gauges. Originally we hoped to have the one at Bimini telemetered into Miami so that we could have these on a two-pen recorder. This way we could see immediately the variations and the difference in sea level across the straits. We ran into some telemetering problems with the Canaveral people who were a little touchy about what radio frequencies were used; and rather than get all the new equipment that would be required, we decided that it wasn't really that important to have these data in real time. Thus we waited until we could see the records that would now come in, and we could get hourly heights. Bill Richardson of Miami was working with these data, and we hoped to get some feel for variations in the volume flow through the straits as indicated by variations in sea level across the straits of Florida. Also as part of this program, Bill Richardson has been working with the pop-up current integrator, a very clever gadget. With accurate positioning, you drop it to the bottom and then wait until it comes up to the surface, and the difference between the point were it was dropped and the point where it is recovered is a measure of the net transport that was going on at the time.

The second phase of Gulf Stream Studies—'65 is a standard section running about 150 miles out from Charleston, S.C., done by the Coast Survey Ship *Pierce* with meteorologists aboard making regular upper air observations. The *Pierce* occupies 28 deep stations of which every other one goes to the bottom. This profile is run once every two weeks. This projection is not very accurate. There is no great directional change in the Gulf Stream at Cape Hatteras. If you look at it on the globe, it is one straight run all the way out.

The third aspect, and the one most interesting to me, is continuing the work that Fritz Fuglister was doing, that is, taking a look at the Gulf Stream meanders in the area northeast of Cape Hatteras. Using the Braincon vee-fin towed at 200 meters we pick up the 15° isotherm. Actually the ship is navigated as a function of the temperature at 200 meters. If the temperature gets warmer, we come to the left; if colder, we come to the right, and this way we are able to follow the left-hand (downstream) edge of the Gulf Stream. These meander trips are made once each month, with the first one made in August.

What we have found is that these large-scale meanders are the norm rather than an exception. When we first started, Henry Stommel became particularly interested in looking at an eddy if we found one. He was sure that these large circular eddies formed and broke away, but he was hoping we would find one so he could go out and look at it. It turned out that we found several of these. The first one we found south of the main stream in September. On the October trip we found that it was still about in the same place, but it had moved to the west, and we found another one over to the east. These large eddies do break away and maintain their integrity at least during periods on the order of three months. We also found very large changes in the position of these meanders. Where at one time we followed a meander like this (drawing on the blackboard), the next time a month later when the ship went out, the meander had moved some 50 miles to the east.

This, then, is another way of taking a look at some of these time-dependent variables. I think this program is going to work out pretty well—I think we will learn a good deal about the Gulf Stream. We held a meeting in November at which the Fuglisters and the Knausses, the Richardsons, and the Ichiyes were all there, and we had a delightful time hashing out what we found to date and what modifications should be made in the program as we go along.

But I want to get back to your ocean and what has been found in some of these systematic surveys in the North Pacific—the area covered through last June, primarily north-south lines with occasional cross lines. The cross lines have not been adequate to date, and this is being improved. We'll talk right now about the work underway. The 1961 data have been almost completely processed and are already being used in papers by George Peter on the geophysics of this area.

The results of the magnetic observations from the area across the Aleutian trench show the same general thing that the only previous systematic survey of this type had also shown. As you recall, the work of Mason, Raff, Vacquier, et al., showed the magnificent magnetic topography off the west coast of the United States. That was magnetic topography found as the result again of systematic surveys off the west coast done by the *Pioneer,* but done on a classified survey for the Navy. We still don't have the bathymetry from that survey in our own shop, but the magnetics were not classified, and Vacquier and company found very intriguing ridge and trough magnetic topography off the west coast. If we examine the Aleutian Trench area with the magnetic anomalies superimposed on top of the topography we find these long magnetic trends, the same sort of thing that Vacquier, Raff, and Mason found farther down off the west coast of the United States. In other words, what these are are magnetic trends that do not follow the pattern of the topography. Now if you took a single trackline of a research ship going through this area and plotted the magnetics, it would look the same

way it does in any other ocean—just a single trackline. If you tried putting two or three of these tracklines together, it would help some, but what I'm contending is that it is the systematic, back-and-forth, tedious survey job that turns up information like this.

I checked with George Peter before I left on Friday. He was quite excited. He has continued to work up this information farther to the South and has found that these lineations do not, as he at first suspected, continue down to join up with the magnetic trends found off the west coast, but these magnetic lineations peter out and become quite irregular in the general area of the Mendocino fracture zone. They then pick up below that, so that the Mendocino is having some reflection in the magnetic data. But this again is the sort of thing that can be discovered only by a systematic survey. We're looking from 45°N to 55°N and from 150°W to 159°W.

One other thing about how this ocean survey program is progressing. I'd like to be much more optimistic than I can—we just had budget sessions this past week and I'm anything but optimistic. A ship that we had in our '67 budget for doing this type of work was disallowed—we're not even sure where we are going to get the funds to repair the *Pioneer* which is badly in need of major overhaul before she can go back to sea. However, we do have two bright spots in the horizon with the delivery sometime this winter of the *Oceanographer* and the *Discoverer,* two large oceanographic survey ships. Each is 3,800 tons, 303 feet length over-all, with 4,200 square feet of lab space. Lots of versatility was designed into them. For example, the lab is of modular construction so you can switch it around to do what you wish. These ships have really good possibilities. One will be operating in the Pacific, one will be in the Atlantic, and both doing project SEAMAP, laced, we hope, with a good deal of research work going on at the same time. We've done a lot of homework for this program. A recent operations research study carried out at considerable expense has come up with mathematical planning models which we are already using. I can go into details later, perhaps, for those of you who are interested. It was very interesting, though, that after a very detailed research analysis of the whole thing, they came up with almost the identical number that the NASCO people had come up with for the number of ship-years operation required to survey the whole ocean. NASCO did it over a few drinks at the Cosmos Club one night, and these people to whom we paid X number of bucks came out with the same number, so it was legitimate. It was about 285 ship-years. Granted this would have to be done like the World Weather Watch, on an international basis. The oceans are just too big to try to do it by ourselves. However, we approach the international basis cautiously, for if you have to strike the median level of competence of all the countries involved, this would perhaps fall short of the achievement level that we have in mind. Probably what will be done internationally at first—again a recommendation of Warren Wooster and the NASCO group—is to have some of the larger maritime countries, perhaps the United States, Canada, and the United Kingdom, undertake a portion, say, of the North Atlantic. Then the others come along as they can meet our standards.

The only point that I really want to make is that be it meteorology and the World Weather Watch, or be it oceanography and project SEAMAP, over and above research activity, the systematic collection of meaningful data in both the atmosphere and the ocean can contribute tremendously to our knowledge of both of these environments. Both areas must be pursued with considerably more vigor than in the past if we are ever to realize any real benefits of new and needed knowledge.

DISCUSSION

Schaefer: Are the buoys being planned by ESSA as part of World Weather Watch designed to obtain sub-surface temperatures through the mixed layer? It would be important to do this both for oceanography and also for the weather-forecasting problem.

Stewart: They are being planned to have this capability. No bid proposals have been requested—the buoys are still being considered by ESSA. Not only NASCO and MASCAS, but also the oceanographic element within ESSA has insisted that oceanographic capabilities be included in any buoys for the World Weather Watch.