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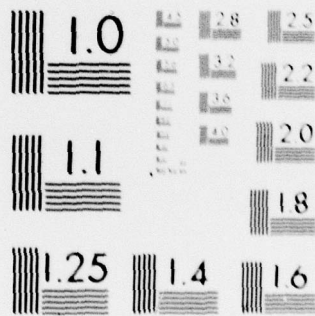
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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

14 WHOI-REF-53-41

Reference No. 53-41

6 NORTH ATLANTIC OCEANOGRAPHY  
under Task Order I

conducted during the period

October 1, 1952 - December 31, 1952

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15 N6onr-277(41)

9 Periodic Status Report No. 26, 1 Oct - 31 Dec 52.  
Submitted to Geophysics Branch, Office of Naval Research  
Under Contract N6onr-27701 (NR-083-004)

11 May 1953

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Director

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According to the terms of Contract N6onr-27701 (NR-083-004), the work to be performed by the Contractor shall consist of the following:

1. The Contractor shall furnish the necessary personnel and facilities for and, in accordance with any instructions issued by the Scientific Officer or his authorized representative, shall

- (a) conduct research, analyze, and compile data and technical information, prepare material for charts, manuals, and reports, and foster the training of military and civilian personnel in the following fields of oceanography:
  - (i) permanent currents;
  - (ii) interaction of the sea and atmosphere (including wind waves, swell, and surf);
  - (iii) the distribution of physical properties;
  - (iv) the distribution of chemical properties;
  - (v) the distribution of organisms;
  - (vi) the characteristics of the sea bottom and beaches;
  - (vii) tides, tidal currents, and destructive sea waves; and
  - (viii) the physics and distribution of sea and terrigenous ice.

The research shall include, but not necessarily be limited to, the following:

- (1) studies of North Atlantic oceanography;
- (2) wave observations and analysis;
- (3) current measurements;
- (4) studies of Arctic oceanography;
- (5) development of unattended instruments;
- (6) thermocline studies; and
- (7) studies on inshore oceanography.

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## INTRODUCTION

During recent years it has become clearer that in many different ways waves can exert an important influence on the success of naval operations. During World War II it was thought that the most important applications of wave research were in connection with amphibious operations, but it is now evident that in a future war nearly all kinds of activities at sea can be adversely affected by waves, not only by storm waves but also in some cases by waves only a few feet high. If this is true, then it is highly desirable to improve means of predicting open ocean wave conditions.

A renewed attack on wave theory has recently been made at New York University which at the very least gives promise of having broad application in naval architecture. These new studies by Dr. Willard J. Pierson, as well as other aspects of present-day wave research, require a reliable open ocean wave meter that will provide a continuous record during at least a period of 20 minutes from which the power spectrum can be conveniently derived.

For these reasons during the autumn considerable thought was given as to how best this Institution could contribute to a renewed attack on wave problems. Although no member of our staff considers himself a specialist in wave research, in the course of the present field program much useful information could easily be collected, provided suitable instrumentation were available. It was decided that the necessary instrumental development would be carried out under our contract with the Bureau of Ships, but, since several investigators whose work is reported on below have made valuable suggestions and have taken part in frequent discussion concerning waves, it seems worth while summarizing the basic considerations here.

In the first place, it was obvious that to design into a single instrument the ability to record over a wide range of sea conditions would be most difficult. We did hope, however, to develop an instrument that could deal with waves of, say, less than 10 feet in height and that perhaps some quite different method would be effective under storm conditions. It was decided that the first objective would be to strive for precision, even though considerable complexity might be involved, so as to have available at least one measuring system against which other, more approximate methods could be evaluated.

Many possible systems were studied and for one reason or another laid aside. For example, it was decided to avoid systems employing accelerometers, either as the primary sensing element or as a correction, as in the ship-borne systems under development in England and at our Hydrographic Office, even though these may well turn out to be the only practical way to measure storm

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waves. In both cases the output of an accelerometer on the bow of the ship, after double integration, is subtracted from a record that is essentially the rise and fall of the water on the stern.

Of the air-borne systems, one studied by Mr. von Arx was by far the most attractive. This would require two planes so as to secure an adequate base line for a pair of synchronized cameras. For all but quite small waves the resolving power of this system appears to be adequate. However, even if a pair of long range planes could be made available, not only would the labor of reducing the photographs to the power spectrum of the waves be considerable, but also it seemed improbable that the conditions for photography in a generating area would often be favorable.

Methods employing an upside-down echo sounder at first also appeared promising. Even if a submarine were seldom available as a stable platform, the double catenary system suggested by Dr. W. V. R. Malkus for turbulence measurements could be used to tow the transducer at a steady depth below the surface. However, as the autumn progressed so that tests could be made in strong winds in local waters it became evident that for winds stronger than about 30 miles per hour too many air bubbles are present down to depths of 50 feet or more to permit continuous echoes off the sea surface and for small waves this method lacks resolving power.

As the study progressed it was decided that if a wave pole and damping disk method could be made to provide a stable platform, by far the most flexible system would be to use the change in capacitance of an insulated wire, culling the sea surface and held perpendicularly by a wave pole, to vary the frequency of a radio signal. Several standard systems for recording a variable frequency signal and of analyzing by acoustical instruments for the power spectrum would then be available. The question here was: could a wave pole and damping disk be designed that would perform reasonably well in wind waves approaching 10 feet in height? A number of variations of a damping disk were tried out in the hope of overcoming the difficulty that the front side of a wind wave is so much steeper than the back side. The resulting uneven tug of the wave pole causes a simple damping disk to rise with each wave passage a little more than it descends, so that the wave pole gradually climbs higher and higher in the water until the float broaches. The result is that after a time the system begins to record square-topped waves. To date all efforts to overcome this difficulty under a variety of sea conditions have failed, although we do now have an excellent instrument for use where the water is sufficiently shallow to float the wave pole up from a bottom mooring.

Although the initial results of this work were somewhat discouraging, there is no lack of ideas involving somewhat more complex systems.

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#### NORTH ATLANTIC OCEANOGRAPHY

Second Trade-Wind Cruise. The ATLANTIS Cruise 181 started at Rio de Janeiro where Mr. Fuglister took over from the Columbia University group. A total distance of 7200 nautical miles was covered during this cruise. A study was made of the Brazil Current between Rio de Janeiro and Recife. Fourteen sections were made across the Guiana Current on the leg from Recife, Brazil, to Port of Spain, Trinidad. One section was made across the eastern end of the Antilles Current and four stations were occupied in the deep western basin of the North Atlantic south of Bermuda.

Bathythermograph observations were made hourly, generally to a depth of about 800 feet. These data fill in an important gap in our over-all distribution of observations in the North Atlantic. The instruments used were in poor shape, so that a careful check of the data and recalibration of the instruments will be necessary before the bathythermograms are processed.

The data showed that in the area off the coast of South America between Rio and Recife there are no major temperature changes such as are found in the Gulf Stream System in comparable northern latitudes. Insofar as such data can be used to indicate the current pattern they did show numerous relatively weak currents and countercurrents in this region.

In the Guiana Current area along the northeastern coast of South America the most striking feature of the bathythermograph data was the stratification within the thermocline layer as indicated by step-like traces. This same phenomena was observed during the trade-wind cruise of last spring.

After the bathythermograms from this cruise are processed a chart of the temperatures at a depth of 200 meters in the North Atlantic will be produced.

Sixty-eight stations were occupied on the cruise where temperature, salinity, oxygen and phosphate samples were obtained by the Nansen bottle method. On eighteen of the stations total phosphate and total nitrate samples were taken. Where the depth of the sea permitted all stations went to more than 2,000 meters. Nineteen stations were to depths over 3,000 meters, the deepest cast made went to 5,460 meters. One bottle and two thermometers were lost when they struck bottom. In general the gear worked well though some difficulty was caused by the mercury sticking in several unprotected thermometers. These station data fill in a gap in our knowledge of the density and chemical structure of the Atlantic especially in the Guiana Current area. Since this current crosses from the southern to the northern hemisphere,

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variations in the density pattern along its course should be of particular interest. The outstanding feature of the thermal structure in this area is an isothermal layer averaging about 200 meters thick lying beneath the thermocline at depths between 1,000 and 1,500 meters. Occasionally a slight temperature inversion occurred within this layer.

Some fifty observations were made with the geomagnetic electrokinetograph on the first leg of the cruise. Sponge rubber floats were attached along the cable in order to keep both electrodes at the surface of the water. The action of the floats appeared satisfactory but where a float was situated within a few inches of the after electrode the bending action was too abrupt and broke the cable. On several occasions pieces were torn out of the floats by fish. Attempts to repair the cables and electrodes were unsuccessful and after two observations north of Recife the instrument was secured. The observations obtained south of Recife showed a series of relatively weak currents and countercurrents.

Unfortunately the new pitometer which was shipped to Rio was not tested and put into working order until after the GEK was secured. Navigational evidence was used to determine the direction of the surface currents and then the pitometer was towed upstream. The wire angle which developed, in the horizontal plane, frequently indicated a change in current direction with depth. At one station the direction of the surface current was extremely doubtful so the pitometer was towed in a large circle, the ship changing course 15° every five minutes. All these observations were made in the Guiana Current area. The results are not satisfactory but time did not permit more extensive work with the instrument.

Because of failure of the trawl winch only one bottom core was obtained on the first leg of the cruise. The winch was repaired in Recife and nine cores were obtained during the remainder of the cruise, six in the Guiana Current area and three in the deep basin south of Bermuda. Except for the one failure of the winch the equipment worked well. Some difficulty was experienced in determining when the bottom was reached on those occasions when the tension change was damped by the Carbon 14 sampling can.

Three samples of bottom water, for Carbon 14 analysis, were brought to the surface. In each case the sampling can was leaking. Twice the clamp at the bottom of the can was torn loose. On two other occasions the can failed to close.

Throughout the cruise the ENM echo-sounder with the hull-mounted sounder and the EDO with the towed sounder were in operation. On numerous occasions there appeared to be more than a fifty fathom difference in the records obtained by the two

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instruments. On various occasions one or the other instrument was undergoing repairs. These data have been turned over to the Lamont Geological Observatory which will in turn pass them to the U. S. Navy Hydrographic Office. The only unusual feature noted on the cruise was a 45 fathom bank discovered at 22°25' south, 37°35' west. The charts used aboard ship indicated depths of 2,000 fathoms at this place. The ATLANTIS made two traverses of the bank and a bottom sample of coral was obtained.

After Recife SOFAR bombs were dropped at regular intervals until the ship reached Bermuda.

Note: For the sake of continuity and in order to round out the more general picture of North Atlantic oceanography, readers are informed that this work is reviewed also in the periodic status report for Contract Nonr-769(00) which contract supported the work during this quarter.

Current Measurements by G.E.K. Observations made on the most recent cruise of ATLANTIS from Rio de Janeiro to Woods Hole have been received as well as a report on the behavior of the buoyed cable, necessary in low magnetic latitudes. Generally speaking, the float system worked satisfactorily, but it was found that the cable flexed and finally parted between the more distant electrode and the float immediately ahead. During the preliminary trials this float had been moved closer to the electrode case than a strictly parabolic spacing required in order to improve the towing attitude of the float. This was obviously a mistake.

The general catalogue of electric potential measurements at sea begun by Mr. Lansing P. Wagner is now more than half completed. Few of all the known GEK measurements have yet to be received. The response of laboratories far and wide to our request for data has been both wholehearted and gratifyingly prompt. It is hoped that the catalogue may be made available before the latter part of next year.

The Appearance of the Sea Surface from the Air. Two flights in the PBV have been made during the past quarter from Elizabeth City, N. C., eastward along the edge of the Gulf Stream to 70°W. On the later flight made on 25 November, Mr. von Arx reports it was possible to follow the visible outcrop of the front for approximately one third of the flight along the continental edge of the Gulf Stream and to detect a change in the surface temperature at regular intervals throughout the entire distance. Study of the thermal and visual records obtained on this flight reveal a finer pattern of frontal waves superimposed on the long wave lengths similar to those recorded from shipboard during multiple ship survey of 1950, and at other times. The fine pattern may be only superficial.

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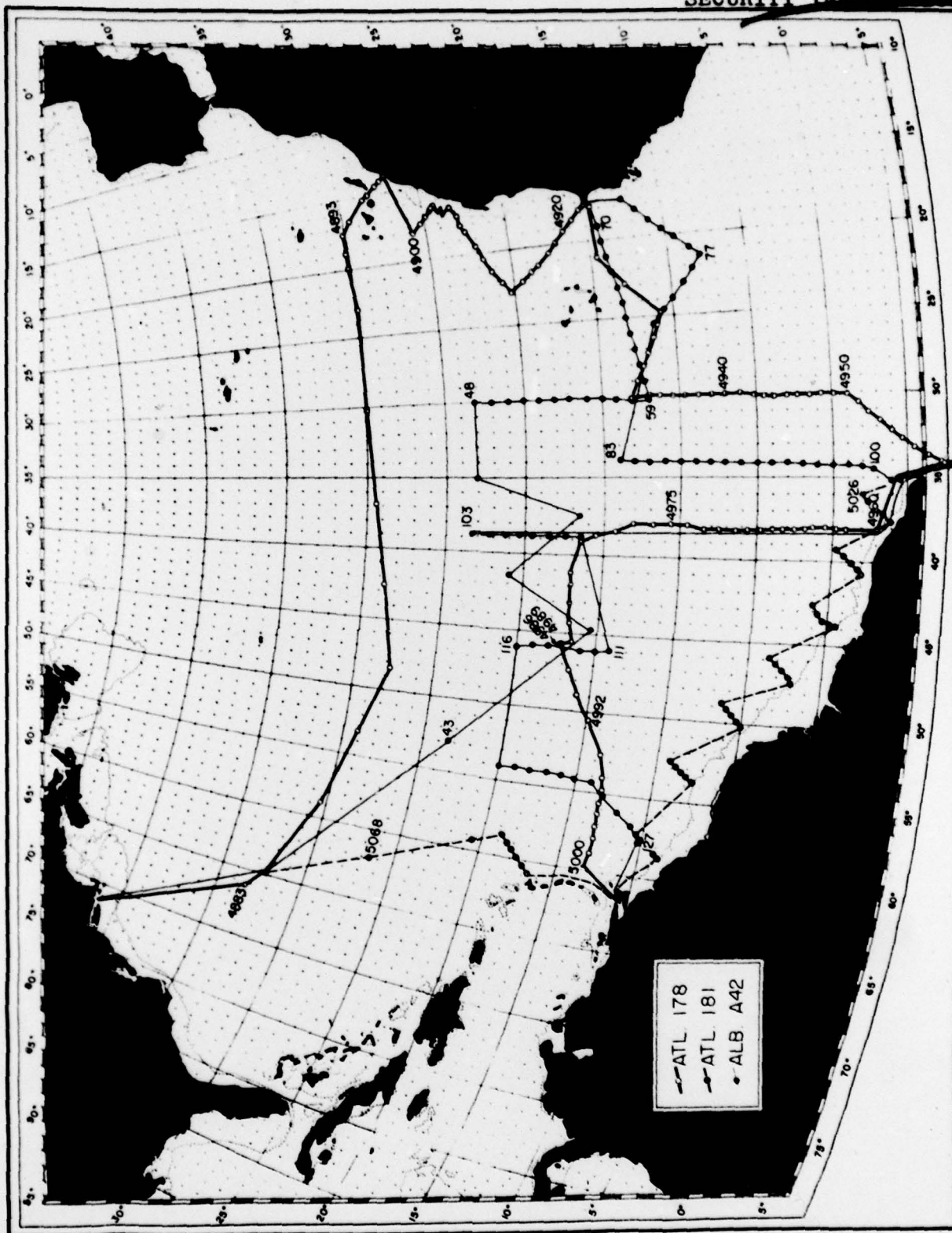


Fig. 1 Track chart, showing cruises made during 1952 in the Equatorial region by research vessels ATLANTIS and ALBATROSS III. Dots and numbers refer to hydrographic stations.

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Recently, the field of view of the nose camera has been increased from 65° to 80° without increasing distortion. The equipment has also been made semi-automatic so that it will run without mechanical attention for as long as thirty-three minutes, the life of one film magazine, at a time-lapse interval of one frame per second. Atmospheric haze has proven to be a considerable barrier to the maintenance of uniformly high quality color photographs. When haze filters are used, too much of the blue light of the sea is deleted to permit the subtle color differences between slope water and Gulf Stream water to be recorded regularly. As an alternative there may be advantages to using infra-red film and an 89A filter to penetrate the haze or to employ Type A Kodachrome with a modified daylight correction filter to admit more blue light from the sea and less of the longer wave lengths scattered in the air. The nose camera equipment for the PBY has also been used by Mr. Bunker and Dr. Joanne Malkus for meteorological studies of cumulus clouds. The problems of plane to cloud photography have not been troublesome.

Work from aircraft over the open ocean offers navigational problems for when course changes are made at frequent intervals it is difficult to determine the route traversed between successive Loran fixes. It would be very helpful were the plane equipped with a dead-reckoning tracer. To facilitate reduction of data it is contemplated that the indications of several standard instruments such as the magnetic compass, clock, and altimeter be recorded simultaneously on the nose camera films. Arrangements are also being considered for adding to this film record an indication of the radiation thermometer reading.

#### ARCTIC OCEANOGRAPHY

Arctic Field Observations. A technical report on Project Skijump II has been completed and is at present in press. Mr. Worthington returned from the ice island T-3 on January 15 and is at work on a report on his activities there. Before any observations could be taken, it was necessary to construct a heated laboratory on the "beach" of the island. The laboratory was built with snow blocks, roofed over, and insulated. Three hydrographic stations were made before the laboratory was destroyed by a pressure ridge on December 9.

A new laboratory was completed toward the end of December and two more stations occupied and a mud core obtained. Titration of the salinity samples has shown much pollution. The pollution apparently occurred in storage since the samples taken on the last station average only about 0.10 ‰ too fresh, against

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as much as 3 °/oo too fresh for the first station. The sample bottles were waxed and kept frozen while in storage. Experiments are under way to determine if the polyethylene plastic sample bottles are in any way responsible for this.

Relations between North Atlantic Ice and Arctic weather.  
To what extent the variations in the Atlantic-Arctic ice are related to the general storminess of the northern North Atlantic was examined by Mr. Schell. He also checked a theory, proposed independently by Zubov and Schell, to the effect that when the ice retreats from the Atlantic side of the Arctic it extends farther south on the Pacific side and vice versa.

To test the possible existence of a relation between the southerly limit of the ice and the storminess of the northern North Atlantic, the average annual frequency of storms by decade was examined for the area 0°W. 70°W. and 40°N. 70°N. This was done for the area as a whole and for each five degree zone of latitude and ten degree zone of longitude. The period examined was that from 1901 to 1938.

A decrease in the over-all storm frequency was found from the first decade (1901 to 1910) to successive decades with the lowest value of the average annual frequency for the 1921-1938 period. It appears that this diminution in storm frequency is generally in line with the more northerly position of the Atlantic-Arctic ice in recent decades.

A comparison of the annual (mean April-August) southerly ice limit in the Atlantic-Arctic with that in the Pacific-Arctic showed a tendency for the ice to retreat on the one side of the Arctic while extending farther south on the other side and vice versa. The amount of interrelation, though apparently real, is quite small and would explain only about a fifth of the annual variation in the ice on either side of the Arctic.

Over a period of years the relation should be very considerable. For example, the average ice limit in the Atlantic-Arctic has decreased by 18% from the 1901-1920 period to the following 1921-1939 period. During the same two periods the average ice limit has increased by roughly the same amount; i.e., 22% on the Pacific side of the Arctic.

#### DEVELOPMENT OF INSTRUMENTS

Unattended Instruments. Efforts have been concentrated almost entirely during this quarter on the problem of getting an explosive-actuated release for unattended instruments into the water.

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Progress has been slow, largely because of an underestimation of the manpower requirements, but individual components have tested satisfactorily and a comprehensive deep-sea test program is planned during January. It is hoped that two or three release mechanisms may be set in very deep water during the March CARYN cruise to the Bermuda area.

A deep-sea pressure recorder for the detection of small pressure fluctuations on the bottom is at a stage of development which indicates that it can be used as a cable-lowered device on the forthcoming cruise and possibly completely unattended for a relatively short period of time.

Four sets of Gifford grapnels have been manufactured, but their use in dragging for the Klebba temperature recorders, currently placed on the continental shelf, has been deferred until better weather in the spring.

Submarine Cable Connected Electrodes. The program of potential measurement across the Florida Straits is still in progress, and has been going more or less continuously since August 1, 1952 with the very generous cooperation of the Western Union Company.

Plans for measurements on the all-British cable from Halifax to Bermuda and Bermuda to Turks Island are well under way and measurements will begin at Bermuda in February. The British Cable and Wireless Company is making their cable available for these measurements.

#### MODEL STUDIES OF OCEANS

Active experimental work on ocean circulation was suspended during the past quarter to permit the rotating basin apparatus to be used by Mr. Stommel and Mr. Farmer for studies of the effects of rotation on flow through transitions in flumes. Plans were made during the interval for study of the wind-driven circulation of southern hemisphere oceans and for quantitative restudy of the earliest experiments of the wind-driven circulations within rectilinear boundaries. Dr. Kierstead's analysis of wind-driven systems (W.H.O.I. Tech. Rept., Ref. No. 52-87, Oct. 1952) suggests means for quantitative experiments and a recent paper by Corkan and Doodson (Proc. Roy. Soc. A (1121) 215, 147-162) offers a theoretical basis for studies of tidal motions in a rotating reference frame. A paper by Mr. von Arx describing the qualitative experiments he has done on the northern hemisphere circulations is being published in the next issue of Tellus under the title "A Laboratory Study of the Wind-Driven Ocean Circulation".

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#### MODEL STUDIES OF ESTUARIES

During the past quarter estuary studies have consisted primarily of two field trips to the Kennebec River and the study and interpretation of the data. The objective of these trips was to make measurements of the horizontal and vertical velocity fluctuations, and of temperature and conductivity at selected times during the tidal cycle and at various stations in order that the vertical flux of momentum and salinity could be determined. For these measurements an instrument was developed by Mr. Donald Parson consisting of a von Arx current meter, conductivity cell, thermistor and a vane sensitive to the vertical fluctuations of velocity.

Results indicate a turbulent stress or flux of momentum of as much as 15 dynes/cm<sup>2</sup> and a heat flux up to 0.1°F. cals/cm<sup>2</sup> at mid-depths. The ratio of the heat to momentum Austausch was determined in two instances at 0.20 and 0.13. These ratios are larger by at least an order of magnitude from those of Jacobsen for Randersfjord and Schultz's Grund who used long time averages to eliminate the tides. Using this method of Jacobsen for the Kennebec data this ratio is 1.0.

Mr. J. R. D. Francis who is on leave from the Imperial College in London on a fellowship with the Woods Hole Oceanographic Institution has contributed greatly to this work. Mr. Stommel and Mr. Farmer also took part.

#### MISCELLANEOUS

Salinity Titrations. The following groups of salinity samples have been titrated:

|                           |       |
|---------------------------|-------|
| ATLANTIS, Cruise #178     | 440   |
| Great South Bay           | 59    |
| CARYN                     | 120   |
| BEAR, Cruise #36          | 240   |
| ASTERIAS, Cruise B-2      | 242   |
| ALBATROSS III, Cruise #42 | 895   |
| ALBATROSS III, Cruise #43 | 120   |
| Total                     | 2,116 |

Ten carboys of sea water in various dilutions were prepared for Wallace and Tiernan.

A technician was engaged at the end of September and trained during the following month. The department now consists of three persons.

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Thermometer Calibrations. No thermometer calibrations were made during this quarter. Mr. Whitney completed all calibrations during the third quarter and only record work was left to be done.

As of December 31 a considerable number of thermometers are on hand for calibration, and a much larger number are scheduled to arrive in the next few months. The total number of instruments now in prospect for calibration during the coming year is 174, with the probability of still more to come.

This Institution has ordered a substantial number of reversing thermometers, which, when received, should provide a suitable number of instruments to equip all our vessels and special field projects.

During 1952, eight reversing thermometers were lost at sea or broken beyond repair in the course of normal use. A number of others suffered minor damage and have been repaired and returned to service.

Mr. Bumpus continued to supervise this department.

#### BIBLIOGRAPHY

Papers Submitted for Publication. The following papers were submitted for publication:

Farmer, H. G., and G. W. Morgan: The salt wedge. Proc. Third Conf. on Coastal Eng.

Francis, J. R. D.: A note on the velocity distribution and bottom stress in a wind-driven water current system. J. Mar. Res.

Redfield, A. C.: Interference phenomena in the tides of the Woods Hole region. J. Mar. Res.

Stommel, H., and H. G. Farmer: Control of salinity in an estuary by a transition. J. Mar. Res.

Stommel, H., and W. S. von Arx, D. Parson, and W. S. Richardson: Rapid aerial survey of Gulf Stream with camera and radiation thermometer. Science.

Published Papers. The following papers were published during the quarter:

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Iselin, C. O'D.: The Gulf Stream system. Proc. Amer. Phil. Soc., 96(6):660-662.

Malkus, W. V. R., and M. E. Stern: Determination of ocean transports and velocities by electromagnetic effects. J. Mar. Res., 11(2):97-105, 2 text figs.

Stommel, H., and H. G. Farmer: Abrupt change in width in two-layer open channel flow. J. Mar. Res., 11(2):205-214, 3 text figs.

von Arx, W. S.: Notes on the surface velocity profile and horizontal shear across the width of the Gulf Stream. Tellus, 4(3):211-214, 3 text figs.

\_\_\_\_\_: A laboratory study of the wind-driven ocean circulation. Tellus, 4(4):311-318, 4 text figs.

Technical Reports. The following technical reports were distributed during the quarter:

Ref. No. 52-79. A comparison of certain wind, tide gauge and current data. By J. Chase. September 1952.

Ref. No. 52-87. The wind-driven ocean on a rotating basin. By Henry Kierstead. October 1952.

Ref. No. 52-88. On the nature of estuarine circulation, Part I (Chapters 3 and 4). By Henry Stommel and Harlow G. Farmer. October 1952.

Ref. No. 52-95. Report of the combined BEAR-CARYN cruise of July 20 to 26, 1952. By W. Malkus, Henry Stommel, H. G. Farmer. September 1952.

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PERSONNEL

The following personnel were engaged in either full- or part-time activity under this contract. Not included in this list but contributing to the work were shop workers, maintenance personnel, crews of vessels, and the administrative staff of the Business Office.

| <u>Assignment</u>                            | <u>Name</u>        | <u>Title</u>                 |
|----------------------------------------------|--------------------|------------------------------|
| DIRECTION AND<br>ADMINISTRATION              | Ed. H. Smith       | Director                     |
|                                              | C. O'D. Iselin     | Sr. Physical Oceanographer   |
|                                              | A. C. Redfield     | Associate Director           |
|                                              | R. A. Veeder       | Assist. to the Director      |
|                                              | Jeanne M. Backus   | Secretary                    |
| HYDROGRAPHIC<br>OBSERVATIONS<br>AND ANALYSES | Nellie Andersen    | Senior Technician            |
|                                              | D. F. Bumpus       | Oceanographer                |
|                                              | A. Cangiamila      | Res. Assist. in Engineering  |
|                                              | J. Chase           | Res. Assoc. in Oceanography  |
|                                              | H. G. Farmer, Jr.  | Res. Assoc. in Engineering   |
|                                              | D. H. Frantz, Jr.  | Res. Assoc. in Engineering   |
|                                              | F. C. Fuglister    | Oceanographer                |
|                                              | C. R. Hayes        | Res. Assist. in Oceanography |
|                                              | S. F. Hodgson      | Res. Assist. in Engineering  |
|                                              | J. F. Holmes       | Res. Assoc. in Oceanography  |
|                                              | W. V. R. Malkus    | Physicist                    |
|                                              | W. G. Metcalf      | Res. Assist. in Oceanography |
|                                              | I. I. Schell       | Meteorologist                |
|                                              | H. M. Stommel      | Oceanographer                |
|                                              | L. A. Thayer       | Research Engineer            |
|                                              | Evangeline Tollios | Senior Technician            |
|                                              | W. S. von Arx      | Oceanographer                |
|                                              | G. K. Wertheim     | Res. Assoc. in Physics       |
|                                              | L. V. Worthington  | Res. Assoc. in Oceanography  |
| PHOTOGRAPHY,<br>DRAFTING AND<br>TITRATING    | F. A. Bailey       | Draftsman                    |
|                                              | Gloria Gallagher   | Multilith Operator           |
|                                              | Mary Manning       | Technical Assistant          |
|                                              | Dona Nelson        | Technical Assistant          |
|                                              | D. M. Owen         | Res. Assoc. in Oceanography  |
|                                              | F. C. Ronne        | Photographer                 |
|                                              | J. W. Stimpson     | Draftsman                    |
|                                              | Phyllis Vail       | Technical Assistant          |
|                                              | G. G. Whitney, Jr. | Senior Technician            |
|                                              | Nancy H. Williams  | Technical Assistant          |

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