UNIVERSITY OF CALIFORNIA

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Marine Life Research Program

ORGANIZATION AND WORK OF PHYSICAL OCEANOGRAPHY

DIVISION III, MARINE LIFE RESEARCH

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Physical Oceanography

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Objectives of the Program

The objectives of Division III, Physical Oceanography, may be stated as follows:

1. To observe the time and space distribution of quantities which are suspected of being significant in the study of marine life off the west coast of North America.

2. To correlate the various quantities, with the help of the other divisions of Scripps Institution of Oceanography, in order to determine which are the most significant.

3. To study the variations of these physical quantities in an effort to determine the reasons for the variations.

4. To develop methods for forecasting the variations.

Observations and General Office Procedures

The program of observations includes 122 hydrographic stations per month during eight months of the year and an estimated 80 stations per month during the remainder of the year. For each of these stations it is planned to prepare temperature-depth, salinity-depth, and T-S diagrams; to compute dynamic height; to list meteorological data; and to determine geographical position. The 122 stations will be distributed over an area of 670,000 square miles. For this area isolines of temperature, salinity, oxygen, dynamic height, and density will be prepared for the surface and various constant depth levels. Also the bathymetry of surfaces having certain constant properties will be shown.

For each hydrographic station there will be thirteen Nansen bottle observations. Thus, there will be 1,560 such observations per month. For each of these it will be necessary to determine the true water temperature, the salinity, the depth, and the density. In spite of the large number of bottle observations, each represents the only monthly sample from a volume of some 250 cubic miles of water. Thus, considerable extrapolation and interpolation will be necessary to describe space and time distributions.

There will be three reversing thermometers attached to each deeper Nansen bottle, one for the determination of depth and two for temperature determination. This makes a total of about 4,000 temperature readings monthly, each of which must be corrected because the temperature at which the thermometer is read is different from the temperature at which it was reversed.

There will be approximately 500 bathythermograph observations per month. One will be obtained at each hydrographic station by fastening the bathythermograph on the wire with the Nansen bottles. Three other observations will be made between each pair of hydrographic stations.

In addition to the above, other types of observations are either necessary or desired. For example, some satisfactory means of measuring the transparency of sea water should be developed and used.

Once a set of observational data are complete, correlation of the various quantities may be initiated. Each of the divisions in the Marine Life Research Program may be able to point out which of the particular physical factors are significant in the work of that division. At the present time there appears to be no question but that temperature, salinity, pressure, light intensity, current direction, and current speed are important. Therefore, the Division of Physical Oceanography is beginning a study of the variations of these quantities.

Organization of the Division

The staff of the Division consists of two oceanographers and one assistant oceanographer. Each of these has had professional training and practical experience in meteorology as well as in oceanography. Their task is to administer the program, to divise methods of obtaining the scientific objectives; to supervise the nonprofessional employees in the routine work of the Division, to keep abreast of developments in the field of oceanography and other pertinent subjects, and to carry out special investigations.

There are at present four full-time nonacademic office personnel:

1. A senior engineering aid whose work is to supervise and to maintain a high standard of accuracy and efficiency in all computational work and in plotting. He assists in the development of forms and procedures, and he investigates scientific material in the German language concerning each topic which becomes important to the Division.

2. A statistician whose main job is to assist in the statistical work which arises in the special investigations. She also carried out computations associated with the routine part of the program. In addition, she

sets up and maintains the technical files of the Division, devises methods of presenting data in reports, and supervises the typing and reproduction of technical material as carried out by clerical personnel.

3. A meteorologist whose main assignment is to analyze the charts which are plotted under the supervision of the senior engineering aid, i.e., to draw isolines of temperature, salinity, oxygen, density, etc., on horizontal and vertical sections; to assist in computations of a non-routine nature involving the use of advanced mathematics; and to assist in typing technical material.

4. A draftsman whose duties are to prepare illustrations, maps, charts, and graphs for reproduction; to enter the scales and headings; and to design efficient layout methods. She also assists with computation of the data to be used in the illustrations and with reproduction of the data to be used in the illustrations and with reproduction of reports.

In addition to the full-time nonprofessional personnel there are twelve marine technicians who will work approximately half time with the Division of Physical Oceanography to carry out the necessary computations in preparing observational data for distribution.

The routine typing and secretarial work is to be done by a special group outside the Division. If the data desired by other agencies interested in the Program are to be made available to them, the typing each month will involve reproduction of tables having over 10,000 numerical entries.

Training Program

Between the time that the personnel were hired for the respective positions described above and the time that routine survey work at sea was initiated, a training program was carried out. The purposes of this training program were threefold:

1. To improve the quality of observational data. This was done by giving the marine technicians, who are sea-going observers, a thorough training in the interpretation, recording, and analysis of the quantities to be observed so that they will understand the degree of accuracy required in the observational data.

2. To prepare an organization which can efficiently work up the first set of data as soon as it becomes available. This involved working up data which were already available, learning the methods which were employed, and becoming skillful in their application.

3. To carry out special studies based on data which are now available in order to obtain results which may be immediately useful.

The training program included:

a. Correcting protected and unprotected thermometer readings to obtain true water temperature and depth.

b. Computing of densities and dynamic heights.

c. Reading and plotting bathythermograph data.

d. Learning the classifications of oceanographic and meteorological phenomena and the codes by which they are described.

e. Preparing and using graphs involved in the various computations.

f. Learning methods for determining ship's position.

g. Plotting various kinds of data.

Work at Sea

The organization of the Division's work at sea depends upon availability of ships and upon the plans of the other divisions engaged in the Marine Life Research Program. This work will not be discussed further in the present report.

Office Forms, Materials, and Methods

Various forms for use on shipboard and in the office have been designed and printed on transparent paper so that copies of the original data may be obtained readily by ozalid or photographic reproduction. Thus, the data will be available to any division; it will be unnecessary to spend large amounts of time copying information; errors in copying of forms will be eliminated; and the original records may be stored in a fireproof vault for safe keeping, all the work being done from copies of these originals.

Wherever possible, forms have been designed on standard 8½ by 11 sheets so that they may be entered in regular files or in loose-leaf notebooks. Forms have been adapted to the methods of computation which are to be used. Samples of Forms 1 through 5, which have been completed for a typical station, are attached.

The materials which will be needed by the Division in carrying out its work, and which include drafting supplies, books, office equipment, base maps and charts, computing forms, a Sund slide rule for computation of dynamic heights, reproduction supplies and miscellaneous materials have been ordered.

Arrangements were made for the calibration of reversing thermometers. Mr. Reid visited Woods Hole Oceanographic Institution where he calibrated fifty-one thermometers, studied the calibration system, and discussed pertinent problems with members of the Woods Hole staff.

Two technicians carried out thermometer calibrations in the Oceanographic Branch, U. S. Navy Electronics Laboratory. It is expected that NEL will cooperate with SIO in devising calibration equipment which is more satisfactory than that now in use at NEL.

For protected thermometer correction a modification by Klein of a graph designed by Hilert Theisen[1], Bergen, Norway, has been adopted. A graph has been prepared for each thermometer. To use these graphs, it is necessary to find only the point where the proper curve of a family of curves for t^2 intersects the straight line having the proper value of T and to measure by means of a sliding T scale the distance from this point to a line showing the thermometer index correction. When the index correction is larger than 0.1, it may be necessary to enter the graph with T + I rather than with T alone. Whether or not this actually is necessary can be quickly determined by reference to a small graph showing the effect of I upon T.

The station plan for the initial cruises, which is included in the appendix of this report, was designed on the basis of biological as well as physical considerations. Its purpose is to cover as large an area as possible in a uniform manner. The size of the area is determined by the time that the ships may be at sea. The stations have been laid off at intervals of approximately forty miles along lines spaced 120 miles apart. On the basis of observations carried out at these positions certain regions may turn out to be critical and others to be of little interest. The pattern of stations may then be revised to give an improved observational network in the critical regions.

It has been decided to place observations at depths 0, 10, 20, 30, 50, 75, 100, 150, 200, 300, 400, 600, 900, and 1,200 meters. Data will be tabulated at depths recommended by the International Association of Physical Oceanography[3] using only levels up to 1,000 meters.

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[1] Theisen, Hilert, "Correction of temperatures and a handy way of making correction charts for reversing thermometers," Fiskeridirektoratets Skrifter (Report on Norwegian Fishery and Marine Investigations), VIII, 9, A.s John Griegs Boktrykkeri, Bergen, 1947.

[2] Sverdrup, H. U., "Note on the correction of reversing thermometers," Scars Foundation Journal of Marine Research, VI, 2, 1947.

[3] Sverdrup, H. U., M. W. Johnson, and R. H. Fleming, The Oceans, Their Physics, Chemistry, and General Biology, Prentice-Hall, Inc., New York, 1942, p. 357.

Of the available methods for determining specific volume anomaly and dynamic heights one similar to that described by Oscar Sund[4] seems to be most satisfactory. The Division has organized data for plotting such a graph on rectangular coordinates showing isopleths of temperature and having linear scales for salinity as ordinate and also for 10^5 $_{s,T}$ as abscissa. The abscissa is marked also with a nonlinear scale of sigma-t. For the range of salinity with which the present study is chiefly concerned (32.70 to 34.70°/oo), the graph is particularly simple to construct and to use. Mr. Reid has shown analytically that straight lines may be substituted for the isopleths of temperature without a loss in accuracy of more than ± 3 units in the seventh decimal place of specific volume.

The linearized transformation of the original Knudsen equations has been used to determine the position of each isotherm. The computed values for use in constructing future graphs have been tabulated since the original graph will not be readily adaptable to photographic or other reproduction. Col. P. H. Ottosen offered a suggestion which was adopted for computing the pressure correction to specific volume anomaly.

The Sund slide rule[5] is possibly an improvement over the graph just described. Both the graph and the slide rule were designed by Sund, and it was his conclusion that the slide rule was the more practical of the two. However, delivery on the rule cannot be made in less than six months, and therefore the Division proceeded with the construction of the graph.

The decision to use the methods described here was based upon a thorough study of the literature and upon comparative tests using the various methods available. The factors affecting the decision were degree of accuracy, speed of computation, and suitability to long-continued application with minimum fatigue to the computer.

Analysis of Available Data

A large observational program has been planned for Marine Life Research. Also there are considerable data already available which will contribute to this program. These data have been used in the

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[4] Sund, Oscar, "Graphical calculation of specific volume and dynamic height," Journal du Conseil, I, 1, Copenhagen, 1926, pp. 235-241.

[5] Sund, Oscar, "An oceanographical slide rule. A new apparatus for calculating oceanographical data." Journal du Conseil, IV, 4, 1929, pp. 93-98.

development of methods for handling the new observational material. They serve to build up a climatology which will make the subsequent observations more meaningful. They provide information which will aid in determining the nature of the program which should be carried out in the future, and their organization and analysis will provide valuable training and practice to the Division.

During cruises of the E. W. SCRIPPS and other vessels in 1937 through 1941, data quite similar to those which will be obtained on the Marine Life Research Program were collected. These data, however, represent a considerably smaller area, and the time coverage was not as complete as that planned for the new program. Although several studies have been made based on these data, their potentialities have been by no means exhausted.

In 1937 Sverdrup and Fleming studied the relationship between the winds in the region off San Francisco and the ocean currents. They computed the amount of upwelling. Similar studies should be carried out for the other years represented by the observational material. Mr. Herrer and Miss McLatchie have initiated such a study.

It is desirable to summarize the results of cruises made during the 1937-41 period so that the predominant and semi-permanent features of the circulation can be easily shown. For the case of dynamic topography this has been done by making use of oceanographic coordinates. This is a method of averaging which retains the significant features of a shifting pattern of isolines. All available cruises have been included in the averages, and the final result is a set of five charts representing the dynamic topography in different parts of the year.

The five years of data available may be used to determine averages and variations of the different physical quantities, to study the effect of wind stress at the ocean's surface, to provide material for determining the amount of upwelling which occurs, and possibly to indicate the effect of bottom friction upon the current system.

For many years daily observations have been made at certain fixed points near shore under the supervision of Dr. G. F. McEwen. These observations are available. Because of their continuity in time, when used together with the hydrographic cruises which were made at intervals of approximately six weeks, the daily shore observations provide available information as to the time when certain changes occurred. Shore observations are available for the following stations:

Scripps Pier, 1916-48
Balboa Pier (Newport Beach), 1925-46
Point Hueneme, 1919-48
Pacific Grove, 1919-48
North Farallon Island, 1926-42
Blunt's Reef Lightship, 1923-41

The stations which are now in operation and are regularly submitting data to the Scripps Institution are:

Scripps Pier
Balboa Pier
Point Hueneme
Pacific Grove
San Nicolas Island
Point Mugu

It is hoped that arrangements may be made so that observations will be available from the Farallon Islands, Blunt's Reef Lightship, and possibly Santa Catalina Island and Anacopa Island. In order to provide the most complete picture of the region under consideration, these stations should be in operation, if at all feasible, during the time that regular hydrographic cruises are being made. This would make it possible to interpret the shore-station observations in terms of the oceanographic changes offshore. It might then be possible at times, using the shore-station observations when there are no hydrographic surveys, to make inferences concerning the nature of the changes which are taking place offshore.

Shore-station observations may be analyzed to determine the nature of the variations which occur. Due to the complicating effects of irregular bottom topography in shallow water, the variations are more complex than those further at sea. However, they have biological significance.

For each of the shore stations which are now submitting daily observations base charts have been prepared showing for each day of the year the mean value of sea-surface temperature, the value which occurred in that month having the lowest monthly average. These base charts then indicate the means, the ranges, and the nature of the day-to-day variations which occur at the various stations. As new observations are reported, they are plotted upon these base charts so that the present trends may be compared to the climatology.

Diagrams have been prepared for the warmest and coldest months of the year for each station showing the frequency with which various temperature values were observed. These diagrams were prepared for each month of the year at the Scripps pier. The standard deviations, the peakedness, and the skewness of the frequency distribution have been computed. These values change in a systematic fashion throughout the year. The study may thus aid in predicting the variability of temperature which will occur in a given month.

Special Projects

In order to answer requests from other divisions and to provide results required for efficiently carrying out the routine work of the Division of Physical Oceanography, certain special projects have been initiated. Some have been brought to completion. Those which have been carried as far as available data permit are:

1. A study of the ranges of temperature and salinity in the area to be surveyed.

2. A transformation of the Knudsen equations into a linear equation giving sigma-t in terms of temperature and salinity.

3. A study of the daily observations at fixed shore stations.

4. Calculation of the change of vertical pressure gradient with depth.

5. Review of literature on upwelling along the California coast.

6. A study of bucket temperatures obtained near shore.

7. An attempt to estimate the amount of upwelled water in certain regions.

8. A study of bucket temperatures obtained near shore.

9. A distribution of average temperature at 30 meters depth.

10. A distribution of average temperature throughout the layer 0 to 50 meters.

11. Calibration of reversing thermometers for index error and correction parameters.

12. Determination of pressure factors for unprotected thermometers and study of their reliability.

13. Design and development of methods for determining dynamic height and for thermometer correction.

Other special studies which have been initiated are:

1. Determination of methods for ascertaining light intensity and for finding its relationship to cloud cover.

2. Analysis of wind stress off the California coast as related to the ocean-current pattern.

3. Maintenance and generation of anti-cyclonic eddies.

4. The use of bathythermograph observations as a supplement to Nansen bottle data.

5. Determination of wire lengths needed to obtain desired Nansen bottle depths.

6. Examination of the three-dimensional structure of wind-driven currents in a baroclinic ocean.

7. Adaptation of IBM methods to dynamic height computations.

8. The design of practical reports to be made available regularly to the fishing industry.

9. Determination of the depth to which observations should be made.

10. Computation of currents in shallow water.

11. Design of calibration tank for reversing thermometers.

12. Investigation of accuracy of the numerical method of integration of dynamic heights now employed.

13. Study of the accuracy of the correction formula used to adjust reversing thermometer readings.

14. Study of the thermal response of protected and unprotected reversing thermometers and the significance of thermometric depths at the thermocline level.

It cannot be expected that all of these special projects may be brought to completion. Many of them involve problems which are extremely complicated and it can only be hoped that some progress can be made.

Summary and Conclusion

It can be seen from the above that the Division of Physical Oceanography has been set up in such a manner as to handle the routine computational work and also to provide some personnel for investigation of special problems. This is desirable. As Sverdrup[6] has stated,

> "The development (of oceanography toward an exact science) has suffered and still suffers from the same conditions which admittedly have existed and still exist in meteorology and which were described by Angot who about seventy years ago said that too many persons take observations and too few do the thinking. . . Work at sea is expensive. It is poor economy to spend large sums on expeditions without providing funds for discussion and publication. And it is poor economy to maintain a staff so small that its time must all be spent on its own problems, leaving little opportunity to become acquainted with work that is being carried on elsewhere and little possibility for travel to other stations and participation in congresses. . . I wish to urge that governments . . . do not embark upon a program of observations without providing staffs which in reasonably short periods can extract the results of the field work and at the same time keep informed as to all development in the field."

The present organization of the Division is such that once work procedures have been developed and put into operation, it should be possible to carry out some of the recommendations as stated by Sverdrup.

Comment and Discussion

Dr. Roger Revelle: An eventual objective of the Marine Life Research Program is to develop methods and theories which will permit a reduction in the number of observations required to understand the subsequent oceanographic variations. We are interested in not only the climatology of the ocean area but also in the deviations from average values.

Dr. Carl Hubbs: I should like to emphasize that coordination of the various divisions from the time of initial planning and throughout all the phases of the work is extremely important.

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[6] Sverdrup, H. U., "New International Aspects of Oceanography," Proceedings of the American Philosophical Society, 91, 1. February, 1947.

Dr. Martin Johnson: Are there any facilities for carrying out mathematical and statistical computations which arise in the other divisions? (It is hoped that some of this work may be done in the Division of Physical Oceanography. This may be possible since the personnel are trained in many types of computation and have facilities for carrying them out.)

Dr. George McEwen: The general survey consisting of observations at regular intervals may show that certain regions are critical. It may then be desirable to conduct more intensive investigations in these regions.

Dr. Russell Raitt: How is it possible to determine which of the physical factors are significant in the Marine Life Research Program? (It is assumed that the factors mentioned earlier--temperature, salinity, pressure, light intensity, and current direction and speed--are significant. This assumption was not questioned. It is expected that other significant factors will be discovered during the research work in the various divisions.)

Mr. Robert Arthur: The broad coverage of the observations planned will not permit a detailed study of any region. For certain purposes, such as the study of upwelling, it may be necessary to make more detailed observations in certain specific areas.

Dale F. Leipper

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