ASSOCIATION INTERNATIONAL DES SCIENCES PHYSIQUES DE L'OCEAN
International Association for the Physical Sciences of the Ocean

Union Géodésique et Géophysique Internationale
International Union of Geodesy and Geophysics

PROCES-VERBAUX No. 10

XIV GENERAL ASSEMBLY
At
BERNE

September - October 1967
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FOREWORD

The Association resolved 4 October 1967 to change its former name "The International Association of Physical Oceanography" to "The International Association for the Physical Sciences of the Ocean". The reasons for this change are given in the paragraph 48 of the minutes and in the Resolution No. 1.

When preparing the manuscript of these Procès-Verbaux 1967 it was found confusing to use in the same text both the old name IAPSO and the new name IAPSO. For this reason, the new name of the Association is being used in these minutes and even in the attached reports irrespective of the datum of the original documents.

Ilmo Hela
Secretary
PAST AND PRESENT IAMPO OFFICERS

EXECUTIVE COMMITTEE (1961-1967)

PRESIDENT:
Prof. R. Revelle, Director of Center for Population Studies, Harvard University, Cambridge, Massachusetts, U.S.A.

VICE-PRESIDENTS:
Dr. B. Kullenberg, Oceanografiska Institutet, Stigbergstorg 8, Goteborg, Sweden.
Dr. Koji Hidaka, Ocean Research Institute, University of Tokyo, Hongo, Tokyo.

SECRETARY:
Prof. Dr. Tjaco Hula, Director of Institute of Marine Research, Tahttorninkatu 2, Helsinki.

DEPUTY SECRETARY:

MEMBERS:
Prof. L.M. Brekhovskikh, U.S.S.R.
Capt. L.R.A. Capurro, Argentina
Prof. Dr. Günter Dietrich, F.R.G.
Dr. D.J. Rodford, Australia

EXECUTIVE COMMITTEE APPOINTED AT BERNE (1967—)

PRESIDENT:
Prof. Dr. Günter Dietrich, Institut für Meereskunde, Kiel, Germany.

VICE-PRESIDENTS:
Prof. A.S. Manin, Director of Institute of Oceanology, Moscow, U.S.S.R.
Prof. M. Uda, Tokyo University of Fisheries, Tokyo, Japan.

SECRETARY:
Dr. Arthur K. Macmillan, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

DEPUTY SECRETARY:

MEMBERS:
Capt. L.R.A. Capurro, Argentina
Dr. D. Lal, India
Mr. D.J. Rodford, Australia
Dr. J.R. Rossiter, United Kingdom

UNITY AND FISSION IN OCEANOGRAPHY
PRESIDENTIAL ADDRESS TO THE
INTERNATIONAL ASSOCIATION OF PHYSICAL OCEANOGRAPHY
Roger Revelle

It is fitting that Professor Mosby should introduce me this morning. In terms of service he is the oldest living ex-President of the Association of Physical Oceanography, but in many ways he is the youngest man in this room, because he is always concerned about the future. Yet he is in his own person a strong link to the great traditions of the past.

The United Nations, on the 6th of December 1966 adopted a resolution on the resources of the sea. This resolution called for a comprehensive survey of activities in marine science and technology, to be carried out by various organizations, including member States, universities, and scientific and technical institutions. In addition, it requested the Secretary General of the United Nations to formulate proposals for expanding international cooperative activities directed toward scientific understanding of the marine environment, exploiting and developing marine resources, and strengthening marine education and training programs.

The United Nations' resolution reflects the enormous growth of interest in using and exploiting the ocean among many governments, both in the rich countries of Europe and North America, the Soviet Union, and Japan, and in some of the poor countries, including India, Peru, and the Philippines. In the United States, the 89th Congress of 1965-66 enacted several important bills concerning ocean science and technology, among them being the Marine Resources and Engineering Development Act, which established a Federal Council on Marine Resources and Engineering Development, the Chairman of which is the Vice-President of the United States. The members include the Secretaries of State; Navy; Interior; Commerce; Treasury; and Health, Education and Welfare; the Chairman of the Atomic Energy Commission; and the Director of the National Science Foundation. This bill also provided for the appointment of a Presidential Commission on Marine Science, Engineering, and Resources to consist of 15 private citizens and government officials and four members of Congress. At the same time, the Congress passed an act establishing sea-grant colleges, somewhat similar to the land-grant colleges which have strengthened agriculture in the United States, and it authorized construction of pilot plants for the production of fish protein concentrate.

Also in 1966, a Panel of President Johnson's Science Advisory Committee, after a year-long study, issued a report entitled, "Effective Use of the Sea", which began by giving a definition of oceanography even broader than the one I have often used: That oceanography is the scientific study of the part of the earth that is covered by sea water. The President's Panel said that oceanography can be defined as those "...activities within the ocean that have significant scientific or technological content." This is a very broad definition, indeed. They stated that the ultimate objectives of the national ocean program of the United States should be "...effective use of the sea for all purposes currently considered for the terrestrial environment: commerce, industry, recreation, and settlement; as well as for knowledge and understanding." And they mentioned shipping, food, minerals, and recreation as simply part of the potential economic interests in the ocean.
What do these developments mean for oceanographers? It seems to me we are somewhat in the position of the generals referred to by the great German military thinker, von Clausewitz, when he said, "War is too important to be left to the generals." Our fellow men are now saying the ocean is too important to be left to the oceanographers. We must get over the notion that we somehow have a prior claim on the oceans, that not only those who too hold a captain's warrant as certified oceanographers can work on the scientific problems of the sea.

At the same time, the explosive growth of interest in the ocean is causing society to demand a great deal more of the marine scientists than ever before. We are being asked to provide answers to some questions we would just as soon not think about at all, and others we have no idea how to solve.

In this burgeoning growth, special emphasis will probably be laid on the most complex and difficult part of the ocean to understand—the continental shelf and slopes and the estuaries and semi-enclosed waters, where the richest resources of oil, minerals, and living creatures exist, where the problems of pipelines, pollution, and underwater structures are pressing, and where the principal recreational opportunities lie.

In many cases, we can expect that the engineers, who want limited but precise answers as soon as possible, will simply bypass the oceanographers by making their own measurements, often with considerable detail and accuracy, and not just quick and dirty ones. Primarily, the engineers will seek quantitative values for particular parameters, the extreme of these values, their statistical distribution in time and space, and predictions for different future times.

Facing this "threat," if you will, from the outside world, where do we stand in oceanography? To lay the groundwork for an answer, it is profitable to consider the history of our science.

During the past 100 years, there have been three great periods of oceanic progress, each of which was determined by the development of new instrumental capacities for studying the ocean. In the transition from one period to the next, the torch of progress in oceanography has passed from one branch to another. The classical epoch began with the CHALLENGER Expedition and lasted for about 20 years, from the 1870's to the 1890's. It depended on the development of the biologist's dredge for collecting animals from the deep sea floor, and on the invention of devices for taking bottom soundings in great depths. These led to a remarkable, but, in the long run, disappointing, catalogue of the fauna of the deep sea. It turned out that almost everywhere one dredged up, everybody on board gathered around to see what marvelous creatures had been discovered. Later, not even the scientists came to look at what the dredge contained, because its contents were always so monotonously similar.

The second period of rapid advance, from about 1910 to 1930, is associated with the names of some great Scandinavians and Germans: Nansen, Bjerknes, Heiland-Honsberg, Sandstrom, Ekman, Sverdrup, Merz, Defant, Schott, and West. This time of exploration and discovery depended critically on the invention of three relatively simple devices: the Nansen bottle; the reversing thermometer; the method of chlorinity titration. It revealed the structure of the deep ocean, the variation of temperature and salinity, the stratification of the sea—the fact that the waters at great depths off Hawaii are as distant in kinship to the waters above them near the surface as they can be, because they have traveled around the earth since they were last at the surface.

The third climatic period of oceanography is just now drawing to a close. This was the world-wide exploration of the deep sea floor during the past two decades. It will probably be looked upon by two generations as one of the great ages of exploration of the earth. And, like all such ages, it was very short. Just as only twenty-five years elapsed between the discovery of America by Columbus and the conquest of Mexico by Cortez, so this period of exploration of the earth beneath the sea, which has given us a new perspective on the nature of our planet, began and reached its zenith with two decades. It showed us the unique and majestic topography of the sea floor; the overall texture of the mid-ocean ridges, one of the primary features of the earth; the ancient drowned islands and submarine mountain ranges a hundred million years old; the existence of cracks in the floor of the ocean along which differential movement of the crust has taken place over hundreds, and perhaps thousands, of kilometers; the fact that those remarkable boundary features, the deep trenches, are actually gashes in the crust of the earth, some of them hundreds or thousands of kilometers long, very narrow, V-shaped, almost bare of sediment, probably great grinding mills for the destruction of the sea floor; the thin, rocky crust over the mantle and the even thinner blanket of sediments over the crust—a very young blanket of sediments mainly deposited during the last epoch of geologic time. These and other observations have demonstrated the geologic "youth" of the actual ocean bed in the presence of a probably continuous existence of oceans and continents for thousands of millions of years, the virtual certainty that the continents have drifted for long distances over the face of the earth, and the probability that the sea floor is continually being renewed by eruptions of basaltic rock from the interior of the earth, perhaps along the crests of the mid-ocean ridges, the spreading of these rocks across the ocean bed and their final submergence again into the mantle under the trenches.

This great age of exploration sprang from the development of a series of geological and geophysical instruments: towed magnetometers; probes for measuring heat flow; seismic refraction and reflection methods using artificial earthquakes; measurements of gravity at sea from surface ships; piston coring of physical properties of sediments; bottom photography; and a continual, broadening echo sounding. The geochemists, with their mass spectrometers and low-level radioactivity counters, contributed fundamentally by establishing the time scale for geologic events on the sea floor and determining the amounts of heat-generating radioactivity in the rocks.

What about the future? There is a host of new instruments and new methods now coming into use on or on the horizon which could lead to an equally explosive growth during the next twenty-five years in our understanding of the waters—a renaissance of physical oceanography in its restricted sense of the study of the ocean as a fluid—water as a continuous, interconnecting, non-separable, and inseparable body of water. Most of you are familiar with one or more of these new instruments and techniques: the use of computers to investigate complex hydrodynamic problems; the handling of large quantities of data using onboard computer or land-based computer; the employment of underwater vehicles of various kinds; the so-called man-in-the-sea programs, started by the French and now being vigorously continued in the United States, which look forward to men living in the ocean for extended periods—going down even to great depths in the sea and staying there for weeks or months on end; the possibility of anchoring instrumented buoys in mid-ocean which will make continuous observations over extended periods; the use of satellites to study the variations of the sea floor for many other purposes, for example, the determination of free-floating and of bottom-mounted instruments; the many scientific uses of underwater sound; and, most exciting of all to a geological oceanographer, the possibility of flying over the ocean and sampling the entire column of sea floor sediments and the underlying rocks.
The development of small submarines for recreational, scientific, and engineering purposes, and the man-in-the-sea programs are to change our very attitude toward the ocean. We human beings are land animals, even though the salt in our blood tells us that our remote ancestors were sea creatures. The sea surface has always been an impenetrable barrier for us, whether we were on a ship at sea or looking at the watery surface of the ocean from the beach. The new capacity to move and live under water will give us new insights and new interests—a feeling of being at home in the great volume of the ocean and a capacity for thinking about the interior of the sea as a place that is like home. Just as Mao Tse-Tung’s army had to be like a fish immersed in the ocean of the people, so we will be immersed in the midst of the fishes and other creatures of the sea.

Unlike space exploration, which can be indulged in only by a few men with enormous resources at their disposal, the voyage to inner space may turn out to be comparatively inexpensive. John Krauss has suggested that it may be possible for a man with about $5,000 to have his own submarine, which will go down to depths of the order of 6,000 meters. This means that there may be scores of moderately well-to-do amateurs—perhaps getting in the way of the scientific submarines; perhaps making new discoveries on their own; certainly getting into trouble at various times; in any case requiring many new developments of undersea technology to take care of them.

The large computers, with their ability to do something with literally millions of numbers, are revolutionizing physical oceanography. But they will be really valuable only to the extent that they can communicate with human beings—capacities of human beings to comprehend much at any one time is extremely limited. We need to be sure that our computers don’t simply talk to each other, and this means we must be able not only to talk to them, but to understand what they are saying. We are faced here with the basic dilemma of our study: we are studying a single ocean. A complete description of ocean circulation would fill so many rolls of magnetic tape that it would be larger than the ocean itself, and hence useless for human comprehension. The dilemma is that when we are dealing with something like a tree, the understanding of it is constantly changing. An understandable description of the ocean must almost always be an abstract model of some kind. But this requires more than description; it requires simplification. Some simplifications come from understanding relationships; to summarize many data in a way we can understand, we can employ a set of generalizations or so-called scientific laws, the purpose of these laws being simply to state those underlying relationships between phenomena that make it possible to describe a great mass of data in relatively few words.

I am particularly concerned with the tendency to say that we must measure and describe the entire spectrum of motions in the sea. Certainly we must learn enough to be able to make generalizations about this spectrum, but, at least from the point of view of understanding air-sea interactions, the portion of the ocean spectrum we are primarily interested in are those that have a good correspondence with phenomena in the atmosphere, and these will probably turn out to be either rather small or quite large-scale features of the ocean.

One of the peculiar aspects of computers is their lack of interest in elegance. Consequently, we can expect that in summarizing large quantities of data for our comprehension, they will produce a new type of scientific ‘law’—one that is necessarily useful and leads to verifiable predictions but does not necessarily conform to Ocean’s rector or the principle of parsimony, is not easily derivable from first principles, and does not depend on ingenious manipulations of applied mathematics.

Besides exploiting the tools that are now coming into our hands, we need to think of the new instruments that will be needed in the future. We should be stretching our imagination about what we want to observe and measure, and what the ocean has to offer us, not next year or next century, but fifty or twenty years from now. Because, if my thesis, that advances in oceanography are dependent on new kinds of instrumentation, is correct, the future of our science will be sterile unless we can continually find new things to observe and new ways to measure them.

Over a shorter time horizon, what capacities will be given us by new technology? For example, what can be done with the potentialities of precise navigation? Navigation is an order of magnitude more precise than has ever existed before. Now allows us to make integrated measurements of instantaneous transport between any two depths, as has already been demonstrated. But it may be possible to do many other things. One of these is another kind of integrated measurement, referred to the other day by Professor von Arx, the determination of the slope of the sea surface, utilizing new developments in the use of satellites and gyroscopes that allow the position of the center of the earth to be fixed from a ship at sea.

But we need to think about more than observation and measurement, or theory and understanding, or even forecasting and prediction. What can be done to control or change the ocean? Let me mention three possibilities for illustration:

Off my own State of California, most of the water is too cold to swim in, but what are the possibilities of warming it up, particularly in the nearshore zone, by using waste heat from large nuclear power plants—plants that would generate thousands of megawatts of power? If a way could be found to keep a two hundred meter-wide ribbon of water near the beach, the new recreational areas that could be developed might be worth a good many millions of dollars.

A first-order change might be brought about by spreading thin particles of reflecting materials near the sea surface in the areas of generation of tropical storms or hurricanes, in such a way as to prevent overheating, during the summer time, of the waters near the surface in these areas. There might be two consequences, one favorable and one unfavorable: (a) hurricanes might be prevented from forming and (b) there might be a sharp decrease in precipitation over large land areas.

Another possibility of the same kind, in reverse, would be to decrease the albedo of the earth by spreading a thin powder of non-reflecting materials over large areas. Neither of these is a new idea, but the potentialities for spreading small amounts of light-reflecting or absorbing materials over large areas are greater now than they have ever been before.

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In oyster farming, they have managed to increase the productivity of a hectare of mariculture land by a factor of 25 to 50, from around 600 kg to 16,000 to 32,000 kg. One of the keys to this success has been the practice of attaching the oysters to long ropes hanging from buoys, both to avoid predators and to use the entire volume of the ocean and not just the bottom.

These Japanese successes suggest that we need to think of agriculture in quite a different way than agriculture. In modern farming on land large quantities of chemical fertilizers are added to the soil, and plant crops consume these nutrients. In the case of marine farming, it may be that we want to start with the animals and let the ocean provide not chemical fertilizer for plants but for animals, that is, the plankton the animals feed upon. And this means that the areas most useful for agriculture are those where this plankton can be enclosed or fished in and fertilized with chemicals, but rather those in which there is a continual through-pact of plankton carried by currents past the locality where the crop is being grown. This is a problem that calls for the expertise of the physical oceanographers.

To a large extent, in the development of the living resources of the sea, we are probably not as concerned with something like conventional agriculture as with pasture or pasture management, of somewhat the same kind that is now practiced over many land areas in raising cattle and sheep. In the pastures of the sea, we should harvest a balanced catch of different fish species at the same ecological level and control of populations of usable species, just as the manager of a live-stock range tries to make sure that the cattle graze on both wanted and unwanted plants and controls the population of other animals that compete with the cattle for food. Control of predators is desirable in such self-corolling fisheries salmon and other salmon. Both kinds of pastures may be made more productive by spraying them with relatively small quantities of nutrient substances such as cobalt-containing compounds. In the ocean they may be able eventually to increase plankton production and, hence, the fish's food supply, by changing circulation patterns or speeding up the vertical interchange of surface waters and deep nutrient-containing water.

In the above paragraphs I have been able to simply touch on a few future possibilities for exploring, understanding, and controlling the oceans. There are many more.

These are exciting and challenging possibilities, but they also contribute to a disturbing problem: the centrifugal tendencies in oceanography. Our science is, indeed, flying apart, exploding in the face of needs and demands, and fragmenting in terms of people. There are many causes of this science and enhance the centrifugal tendency: first is the growth in the numbers of oceanographers, and the sheer physical impossibility of their all meeting together at the same time and place. Professor Bjerknes and Professor Mosby and I first met in 1938 at the General Assembly of this Association in Edinburgh. All the physical oceanographers who were able to come to that meeting could sit in two rows of a small lecture hall. Now we are crowded together in an auditorium which is so big that you can't hear the speaker, and there are so many of us that one can talk seriously only to a small minority. It is difficult to engage in a real exchange of ideas and knowledge in such a large group. This Congress is an example of another physical problem, that very few cities in the world are big enough to hold an assembly of all the scientists who are concerned to a greater or lesser degree with the ocean, people with whom the oceanographers can and should communicate.

The second centrifugal tendency is the requirement for increased specialization. The science is becoming so complex and far-reaching that one can't know very much about more than a part of it.

Third is the development of local interests. Because we are becoming more and more involved with the problems of estuarine, bays, semi-enclosed water bodies, littoral zones, and the continental shelf, the need for oceanographers to exchange knowledge and to work together on the unifying problems of the world ocean is becoming less obvious.

Fourth is the growing tendency to relate aspects of marine research to particular basic sciences. The increasingly close relationships between applied mathematicians and theoretical fluid dynamicists, physicists and marine physicists, and astronomers and chemists, biologists and ecologists is occurring to some extent at the expense of the relationships among different kinds of marine scientists. A somewhat similar difficulty arises from the fact that there is often a conflict between scientists and biologists who don't think of themselves as all as oceanographers are nevertheless very much interested in certain scientific studies of that part of the earth that is covered with sea water. All the International Associations of the Union of Geodesy and Geophysics which are meeting here in various parts of Switzerland, plus the geobiologists and the Upper Mantle Committee, claim some cognizance over the ocean, and most of them are holding symposia that deal at least in part with oceanic problems. Biochemists, geologists, geophysicists, and pharmacologists use marine plants and animals as experimental tools and would be shocked at the idea of attending a meeting of marine scientists. And the geologists have organized their own separate commission on marine geology.

Fifth is the increased tendency to relate marine research to application. Hence, there are close working relationships between physical oceanographers and marine ecologists, biological oceanographers and fisheries scientists, physical oceanographers and meteorologists, all at the expense, again, of the relationship among different kinds of marine scientists in the narrower sense of that term.

There are some centripetal tendencies which work in the opposite direction to bring different kinds of marine scientists together. Some of these scientists come from different countries. Among these are the growth, in the last twenty years, of marine science laboratories and institutions, and of international marine science organizations. But the most important centripetal tendencies are the two overriding realities that the oceans are indivisible --events in any part of the sea eventually have profound effects at great distances--and that they belong to no man and no nation, yet are used by many men and many nations.

If you agree that we should think seriously about ways to combat the centrifugal tendencies in our science and enhance the centripetal ones, then we need to attempt to answer several questions. What are the proper functions and the future roles of different kinds of institutions in oceanography--university laboratories and departments, governmental institutions, oceanographic institutions and government agencies, international scientific bodies, inter-governmental organizations, new kinds of aggregations of persons concerned with the sea such as the new sea-grant colleges in the United States? What is the future of international cooperation in oceanography? And what is the best and most effective role for this Association of ours, the International Association of Physical Oceanography, in keeping the marine sciences together so that they should be and can be kept together?

Because applied research and development of new ocean vehicles and large instrumental systems are both very expensive and require large sums of money, persons who possess a variety of specialties, many of which are not related to marine science, it should be carried out by industrial organizations and government
agencies. Work of this kind is usually best supported financially when it is directly related to application in some specific ‘practical’ objective or ‘interest’ such as national security, increase in the harvest of fishes, or recovery of mineral resources. We have already seen a considerable expansion of expenditures and effort in these areas by government and industry, and we can hope for a further expansion in the future.

But for the fundamental research on which technological developments are based, we should continue to look to the universities and the oceanographic laboratories, which nowadays, of course, are also mainly supported by government. Beside their responsibilities for research, these institutions have two other central functions: the education of a new generation of marine scientists and the bringing together of scientists with a variety of disciplines and interests who can stimulate and help each other in marine scientific studies. Thus, they represent strong centripetal forces for oceanography. To recruit and effectively educate students and to ensure that some scientists in the fundamental disciplines of physics, chemistry, mathematics, and biology become and remain interested in marine studies, these institutions need to be more closely integrated with universities than in the past. My being integral parts of universities, some of them should also be able to expand the scope of their activities to encompass social, economic, political, and humanitarian aspects of oceanic problems.

Many nations are too small or too poor to be able to afford a sufficiently broad and strong oceanographic institution, and yet have problems involving ocean science and technology, and scientists who would like to do oceanic research. Here the oceanographic institutions of the rich countries may find both an opportunity and an obligation by providing facilities and intellectual back-up to the scientists in the poor countries and working with them on their national problems.

This and other kinds of international scientific cooperation in the marine sciences would be greatly strengthened by the creation of more effective international oceanographic organizations on a world-wide scale. (I do not believe that establishment of additional regional organizations should be given equally high priority. Such regional organizations as the International Council for the Exploration of the Sea and the Northwest Atlantic Commission are clearly very effective, but their members consist of rich countries. Similar organizations elsewhere in the world would be made up primarily of poor countries, the sum of whose research facilities and scientific personnel would still be inadequate for the tasks at hand.)

Because ocean science and technology, like agricultural research, must be mainly supported by governments, the basic international oceanographic organization should be intergovernmental. The Intergovernmental Oceanographic Commission has made a good start, and it has been given a good deal of help by the dedicated staffs of UNESCO and FAO, but it suffers from the fundamental deficiency that it has no budget of its own. The funds available to both UNESCO and FAO are subject to many competing demands and are controlled by government representatives who have little understanding of the needs in ocean science and technology. I am convinced, therefore, that an Intergovernmental World Oceanographic Organization is needed, with a separate budget contributed by its member countries, and with broad responsibilities for ocean forecasting, development of marine resources, and stimulation of marine science. I do not urge that this proposed organization undertake major research programs apart from its member countries, or that it be given jurisdiction over marine resources (though I am personally convinced that a U.N. agency should have such jurisdiction), but it should have responsibility for giving advice and planning international cooperative research on marine resource problems.
11. The President of the Association appointed the following Nominating Committee: Dr. Swallow (U.K.) as Chairman, and Adm. Gougoulin (France), Dr. Joseph (Monaco), Capt. Aragno (Argentina), Dr. Miyake (Japan), Dr. Belousov (U.S.S.R.) and Dr. Knuss (U.S.A.) as members.

12. The Association decided that the Nominating Committee shall, first of all, present to the Association a candidate for each position in the Executive Committee and, moreover, assist the present Executive Committee in the preparation of a proposal for a new committee structure of the Association.

13. The Secretary presented his proposal for a new procedure for nomination of members of the scientific committees of the Association (document 9.1). The task of preparing a proposal for the three core members in each commission, scientific advisory committee and working group to be reestablished or created was given to the Nominating Committee.

14. The President of the Association proposed that the Association should establish scientific committees for one inter-assembly period only. Further consideration of this proposal and of the whole question of the committee structure of the Association was referred to a joint meeting of the Executive Committee and the Nominating Committee.

15. The Secretary presented a proposal for creation of a joint UNESCO/INCO/ISSC/IAPSO/WG Group of Experts on the Statistical Data on Winds and Waves (document 9.4). Mr. Nadelsnik, representing INCO, gave additional information. The Association adopted the Resolution No. 7 and appointed Dr. Dorrestein to be the representative of IAPSO in the Group of Experts.

16. Dr. Cooper informed the Association of some recent trends in the study of problems relevant to the increasing marine pollution. He urged the Association to consider whether certain basic aspects of marine pollution should be studied also by the Association.

17. Mr. Nadelsnik and Dr. Dexion gave to the Association interesting information on the recent developments in the prevention of pollution of seas by oil.

18. The U.S.S.R. delegation presented a proposal (document 10) to consider the role of IAPSO in relation to the ISSC International Committee on Geophysics, to be transformed eventually into ISSC Commission on Data Exchange. It was decided to ask an ad hoc group, consisting of Dr. Deacon, Dr. Wooster, Dr. Schell, Dr. Lacombe, Mr. Monin, Dr. Charney and of others interested in the problem to consider the matter and to prepare a final proposal to the Association.

19. The U.S.S.R. delegation presented a proposal (document 9.3.1) for creation of a new IAPSO Scientific Committee on (Theory and) Computers in Oceanography. In consequence of a proposal of the President of the Association, it was decided to ask the Executive Committee, jointly with the Nominating Committee, to consider the proposal.

20. The President of the Association reviewed the motion, tabled in the XIII General Assembly, to change the name of the Association to cover better than the present name the actual interests of the Association. An ad hoc group, consisting of Dr. Maxwell, Dr. Cooper, Capt. Capurro and Prof. Mosby, was asked to consider the problem and to present a detailed proposal to the Association.

21. The Secretary presented a Draft Resolution (document 14.1.4) arising from the resolution passed by the First Marine Geodesy Symposium. An ad hoc group, consisting of Dr. von Arx, Capt. Capurro, Mr. Eyring, Dr. Roosier, and of the...
representatives of the British Admiralty and of the U.S. Office of Naval Research, was asked to consider the Draft Resolution and to report to the Association.

22. Following the proposal of the delegation of the United Kingdom, the Association decided to make available, at future general assemblies, more time than hitherto for the presentation of individual papers to facilitate general discussion of both the presented scientific contributions and of other scientific problems that may be raised.

23. Following the proposal of the delegation of the United Kingdom, the Association, considering that the Association includes chemical oceanography in its field of interest, decided to devote, at future general assemblies, more time than at the XIV General Assembly to problems in chemical oceanography.

24. The proposals by the SCAR/SCOR/IAPSO/IOC Symposium on Antarctic Oceanography, held in Santiago de Chile in September 1966, were tabled.

25. The Association decided to have another business meeting on Wednesday, 4 October, at 6 p.m.

SECOND GENERAL MEETING OF THE ASSOCIATION
4 October 1967, at 6 p.m.


27. Dr. Rossiter presented the Report of the Committee for Mean Sea Level and its Variations (document 4.2).

28. The Chairman of the Committee on Oceanographical Observations from Weather Ships had informed the General Assembly that, for various reasons, it had not been possible to devote time and energy to this work which it deserves.

29. Dr. Otto presented the Report of the Committee on Bibliographical Classification (document 4.9) and also the Report of the Committee on Bibliography on Physical Oceanography (document 4.7); with a list of Titles of Journals, with Abbreviations, both of them being submitted by Dr. Model. Moreover, Dr. Otto also presented a new Report of the Committee on Bibliographical Classification (document 4.4.a) in which, among others, the creation of a working group on bibliography and classification was suggested.

30. L'admiral Gougenheim presents the Rapport sur l'activité du Comité GICOR (document 4.5).

31. The Committee on Chemical Oceanography had not prepared a report.

32. Prof. Jarlov presented the Report of the Committee on Radiant Energy in the Sea (document 4.8).

33. The Report of the Committee on Near-Shore Oceanography, as prepared by Prof. L'Fouad, was tabled (document 4.9; with a number of enclosures).

34. Dr. Charnock presented the Report of the Joint IASHE-IAPSO Scientific Committee on the Interaction between Atmosphere and Oceans (document 5.1). The Association agreed to the proposal to enlarge the Committee with two members to be nominated by SCOR.

35. Mr. Lennon presented the Report of the IASH-IAPSO Working Group on a Global Survey of the Fluctuations of Glaciers (document 5.2). The Association decided that the new Committee on Tides and Mean Sea Level should act as an advisory body also to the Permanent Service on the Global Survey of the Fluctuations of Glaciers, to be created by IASH.

36. Capt. Capurro reported on the oceanographic activities of the ICESU Scientific Committee on Antarctic Research, especially on the proposals made during the SCAR/SCOR/IAPSO/IOC Symposium, held in Santiago de Chile in September 1966, concerning the cooperative study of the Antarctic Convergence.

37. The President of the Association presented a report on the activities of the ICESU Scientific Committee on Oceanic Research (document 7.2) and tabled also a Special Report, on International Ocean Affairs, as prepared by a joint working group appointed by ACOM/FAO, by SCOR and by the Advisory Committee of the WMO. Moreover, he observed that the construction of SCOR had been revised to facilitate the coordination of activities of SCOR and, among others, of IAPSO. He also observed the feasibility of joint SCOR/IAPSO working groups.
38. Mr. Hermann presented the Report of the Joint ICRS/TAIFO/SCOS/Unesco Panel of Experts on Oceanographic Tables and Standards (document 8.14). (Cf. also the report from the Third Meeting of the Panel, held 4-5 October 1967 in Banff; (document 8.13). The Association decided to congratulate and to thank the National Institute of Oceanography, of the United Kingdom, for the excellent work accomplished.

39. Prof. Jerlov presented the Interim Report of the SCOR Working Group 15 (with TAIFO and Unesco) on Photosynthetic Radiant Energy in the Sea, as prepared by Mr. Tyler (document 7.5.1).

40. Dr. Swallow presented the Interim Report of the SCOR Working Group (with TAIFO and Continuous Current Velocity Measurements (document 7.2.2). He urged all oceanographers, performing current measurements, to make simultaneous comparative measurements using different types of current meters close to each other.

41. M. Kyriès présenta le Rapport du groupe de travail "Marée en Mers profondes" (Commun groupe de travail de ICRS/SCOR/Unesco, SCOR GT 22, sur la Marée en Mers profondes" (document 8.2).

42. The Report from meetings of the IOUS Scientific Committee on Water Research (COWAR), as prepared by Prof. Eriksson (document 7.3), was presented by the Secretary.

43. Mr. Hettler presented the Report of the IUGG Tsunami Committee (document 6.3). The Association observed that the Committee recommended that IAPSO (and IASPSS) designate representatives on the Tsunami Committee in order that their respective programmes be coordinated as effectively as possible.

44. The Secretary of the Association made a statement concerning the IUGG Committee on Space Research (document 6.4).

45. The Statement, made by Dr. von Horsten on behalf of the International Heat Flow Committee, was tabled (document 6.5).

46. The Association was informed about the Resolutions and Recommendations of the United Nations Conference on the Standardization of Geographical Names, held in Geneva, 4-22 September 1967.

47. The Association was informed about the World Map, in Scale of 1: 2,500,000 now under preparation in Hungary and in some other countries.

48. Dr. Maxwell presented, on behalf of the Ad hoc group (see para. 20), the following report.

I. The Ad hoc working group recommends that the Statutes of the Association be amended to read as follows:

2. The objects of the Association are:

(a) To promote the study of the scientific problems relating to the ocean and interactions taking place at its boundaries, chiefly in so far as such study may be carried out by the aid of mathematics, physics and chemistry;

(b) To initiate, facilitate and coordinate research into, and investigations of, those problems of the ocean which require international cooperation.

(c) To provide for discussion, comparison and publications.

II. Further, the Ad hoc working group recommends that the name of the Association be changed to the International Association for the Physical Sciences of the Ocean (IAPSO) in order to reflect the changes proposed in the Statutes.

III. While not specifically asked to consider the long-range objectives of the Association, the Ad hoc working group determined that this was a necessary part of its task.

In this connection the group recommends that the next General Assembly of the Association (IAPSO) be convened jointly with SCOR, IARO, the marine geological group of IOUS, and those meteorologists interested in air-sea interaction problems.

In addition to convening joint scientific sessions among these groups, it is recommended that this meeting consider the possibility of establishing an International Union of Marine Sciences (IUMS) which could contain associations dealing with the physical sciences, the biological sciences, the geological sciences and the meteorological sciences concerned with the oceans.

The President of the Association presented the Draft Resolutions Nos. 1 and 10, as prepared by the Executive Committee. After some amendments the Resolutions were adopted unanimously.

49. The President of the Association presented a proposal for the new structure of the Association, as prepared by the Executive Committee. After some amendments the Resolution No. 2 was adopted unanimously.

50. Following the proposal by Prof. Wooster, it was decided to submit the Resolutions Nos. 1, 2 and 10 immediately to the Secretary-General of the United Nations.

51. Dr. Swallow presented the Report of the Nominating Committee (see para. 11).

52. M. Menachi était élu représentant de l'IAPSO dans le IUGG Committee on Critical Data.

53. The Director of the Permanent Service for Mean Sea Level, Dr. Rossiter was nominated the IAPSO candidate for IUGG representative in PMS.

54. The Association resolved to collaborate with the WDC Steering Committee (Resolution No. 6) and decided to agree with SCOR on the appointment of Dr. Menashev as the Joint IAPSO-SCOR representative in the said Committee.

55. The Association resolved to collaborate with the IUGG Committee on Tsunami (Resolution No. 4) and nominated Prof. K.O. Reif the IAPSO representative in the said Committee.

56. The Executive Committee informed the Association that it had not yet been able to prepare a final proposal, concerning the U.S.R. proposal (1111) for creation of a new IAPSO Scientific Committee on (Physics and) Computers in Oceanography. It was decided that the new Executive Committee shall study the proposal further.

57. Two additional amendments were proposed to the Statutes of the Association, one of them giving the new definition of the "assemblies" and also resulting in...
additional relevant changes, the other referring to the "representatives of
more than one country". These amendments and also that one referred to in
para. 48 of these minutes were adopted. (The new Statutes are reproduced as
document 3.5.)

58. Three amendments were made to the By-laws of the Association on the
definition of the "period" between assemblies, on the expiration of the "period"
and on the tasks of the Executive Committee. (The new By-laws are reproduced
as document 3.5.)

(document 3.5) was adopted.

60. Three members for each of the commissions were elected unanimously, as
proposed by the Nominating Committee (document 3.2.3):

(1) Commission on Marine Geophysics: Dr. Udintsev (Chairman),
Dr. Heezen, Dr. Laughton.
(2) Commission on Marine Chemistry: Dr. Goldberg (Chairman),
Dr. Skopintsev, M. Menaché.
(3) Commission on Physical Oceanography: Dr. Stewart (Chairman),
Dr. Yoshida, Prof. Jerlov.

61. Three members for each of the Scientific Advisory Committees were elected
unanimously, as proposed by the Nominating Committee (document 3.2.3):

(1) Committee on Tides and Mean Sea Level: N. Syvitski, Dr. Voigt,
Mr. Cartwright. These elections were made on the understanding that
Dr. Rossiter would ex officio be a member of this Committee and the
Chairman of the Committee for the time being.
(2) Committee on General Bathymetric Chart of the Oceans:
Dr. Laughton, Dr. Heezen, Dr. Udintsev.

62. Three members for each of the Working Groups of the Association were
elected unanimously, as proposed by the Nominating Committee (document 3.2.3):

(1) Working Group on Bibliography and Classification: Dr. Modal
(Chairman), Mr. Privett, Dr. Jacobs.
(2) Working Group on Symbols, Units and Nomenclature in Physical
Oceanography: Mr. Creasey (Chairman), Dr. J.L. Reid, Dr. Ivanov-
Franzkevich.

63. The Association adopted the proposal (para. 13; document 9.1) for co-
opting other members for the commission, scientific advisory committees and
working groups.

64. Prof. Revolle was nominated the IUGG representative in SCOR.

65. Dr. Nunke, Mr. Cartwright and Dr. Voigt were nominated the IAPSO represen-
tatives in the Joint IAPSO/SCOR/Wesco Working Group on Deep-Sea Tides.

66. The Association endorsed all the nominations of IAPSO representatives in
the inter-association and other working groups and scientific committees, as
listed in document 14.2.

67. The Association adopted the Report of the ad hoc committee on marine
geodesy (14.4.4a) and the Resolution No. 1 on the marine geodesy.

68. The Association adopted the Resolution No. 4 on the membership in the
Scientific Advisory Committee on General Bathymetric Chart of the Oceans.
69. The Association adopted the Resolution No. 8 on the use of certain radio frequencies for transmission of oceanographic and meteorological scientific data from sea.

70. The Association adopted the Resolution No. 9 on the cooperation with appropriate international organizations to promote scientific discussions of the oceanographic aspects of the problem of marine pollution (of para. 16).

71. The Association adopted the Resolution No. 11 on the International Oceanographic Tables and on the definition of salinity and the relation between salinity and chlorinity in the introduction to Table Ia therein.

72. The Association adopted the Resolution No. 12 on a joint IANAP-IAPSO session on the subject of air-sea interactions.

73. The Association decided to submit the Resolutions 1 to 12 to the Inter-governmental Oceanographic Commission and to the ICES Scientific Committee on Oceanic Research.

74. The Association elected Prof. G. Dietrich President for the next period.

75. The Association elected Prof. Monin and Prof. Uda Vice-Chairman for the next period.

76. Dr. Maxwell was elected the Secretary of the Association for the next two periods.

77. M. Kyriakos was elected Secretary adjoint for the period suivante.

78. The Association elected the following four additional members for the Executive Committee: for the second term Capt. Capurro (Argentina) and Dr. R. Nochordt (Australia); for the first term Dr. Lai (India) and Dr. Rossiter (United Kingdom).

79. Prof. Revelle, as the retiring President, proposed the following resolution which was adopted by acclamation:

"The International Association for the Physical Sciences of the Ocean,

being aware of the great effort in planning and organization undertaken over a period of two years by the local committee of Bern in preparation for the XIV General Assembly of the Association,

being profoundly grateful for the generous hospitality and the many services provided for all of us by the local committee and their fellow citizens of the City and Canton of Bern,

expresses thereby its appreciation and thanks to Dr. M. Oesterhaus, Dr. P. Kohler, Dr. R. Neberlein, and the Rector of the University of Bern, to all their colleagues in the local committee, and to their efficient, cheerful and hard-working staff."

80. Prof. Revelle, as the retiring President, proposed the following proposal which was adopted by acclamation:

"The International Association for the Physical Sciences of the Ocean,

being profoundly grateful for the untiring work of Dr. Illo Hola in his capacity as Secretary of the Association during the four years from 1963 to 1967,
1. Adoption of the Agenda

2. Presidential Address

3. Administration
   3.1 Tabling of National Reports
   3.2 Report of the Secretary for the period 1963-1967
   3.3 Report on the activities of the Standard Sea Water Service, for the years 1963-1966 (Hermann)
   3.4 Financial Report for the years 1963-1966 (Secretary)
   3.5 Financial estimates for the next period (Secretary)
   3.6 Resolutions passed by the XIII General Assembly, 1963; actions taken
   3.7 Amendments to the IAPSO Statutes, adopted by the General Assembly at Oslo, August 1948
   3.8 Amendments to the IAPSO By-laws, adopted by the General Assembly at Oslo, August 1948
   3.9 Election of Rapporteurs for IAPSO Symposia and other scientific meetings of the General Assembly
   3.10 Appointment of the Nominating Committee

4. Reports of Scientific Committees of the Association, for the period 1963-1967
   4.1 Committee on Tides (Eyring)
   4.2 Committee for Mean Sea-Level and its Variations (Rossiter)
   4.3 Committee on Oceanographical Observations from Weather Ships
   4.4 Committee on Bibliographical Classification (Model)
   4.5 Committee on General Bathymetric Chart of the Oceans (Goosenhelm)
   4.6 Committee on Chemical Oceanography
   4.7 Committee on Bibliography on Physical Oceanography (Model)
   4.8 Committee on Radiant Energy in the Sea (Jerlov)
   4.9 Committee on Near-Shore Oceanography (LaPoue)

5. Reports of the IAPSO representatives in Inter-Association Committees, for the period 1963-1967
   5.1 IAPSO-IAHS Scientific Committee on the Interaction between Atmosphere and Oceans (Charnock)
   5.2 IASH-IAPSO Working Group on a Global Survey of the Fluctuations of Glaciers (Lemon)

6. Statements by the IAPSO nominees or other oceanographic members in the IUGG Committees with oceanographic interests
   6.1 Committee on Geophysics Bibliography
   6.2 Upper Mantle Committee
   6.3 Tsunami Committee (Petier)
   6.4 Committee on Space Research (of IUGG) (Secretary)
   6.5 Committee on the Problems of Geochemistry
   6.6 International Heat Flow Committee (von Herzen)

7. Reports of the IAPSO nominees in the ICSU Committees with oceanographic interests
   7.1 Scientific Committee on Antarctic Research (Deacon)
   7.2 Scientific Committee on Oceanic Research ( Revelle)
   7.2.1 SCOR WG 15 (with IAPSO and Unesco) on Photosynthetic Radiant Energy (Tylor)

7.2.2 SCOR WG 21 (with IAPSO) on Continuous Current Velocity Measurements (Swallow)

7.3 Scientific Committee on Water Research (Eriksson)

8. Reports of the IAPSO nominees in the Inter-Agency Committees
   8.1 Joint ICSU/IAPSO/SCOR/Unesco Panel of Experts on Oceanographic Tables and Standards (Hermann)
   8.2 Joint IAPSO/SCOR/Unesco Working Group on Deep-Sea Tides (Byrnes)

9. Establishment of Scientific Committees
   9.1 Proposal for a new procedure for nomination of members of the committees (Secretary)
   9.2 Re-establishment of the former committees: disbandments, changes in the terms of reference, changes in the membership
   9.3 Creation of new committees
   9.3.1 U.S.S.R. proposal to create a new IAPSO Scientific Committee on Computers in Oceanography
   9.3.2 Other proposals

9.4 Proposal for creation of a Joint Unesco/IMCO/IAPSO/WMO Group of Experts on the Statistical Data on Winds and Waves

10. U.S.S.R. proposal to consider the role of IAPSO in relation to the IUGG International Committee on Geophysics, to be transformed eventually into the IUGG Commission on Data Exchange

11. Lists of the speakers and their papers to be presented in the various symposia and other meetings of IAPSO

12. Proposal to change the name of the Association

13. Further items originating from IUGG

14. Further administration
   14.1 Adoption of resolutions
   14.2 Nomination of IAPSO representatives in Inter-Association and other Committees and Working Groups
   14.3 Election of the Executive Committee

15. Place and date of the next IAPSO General Assembly

16. Other business
The support of the said bodies will be needed for the Working Group in the future as well. For this reason the proposal is now being made to transform this group into a Joint IAPSO/SCOR/Unesco Working Group on Deep-Sea Tides.

The U.S.S.R. Geodetic-Geophysical National Commission is proposing the creation of a new IAPSO "Scientific Committee on Theory and Computers in Oceanography".

Resulting from the urgent need of statistical data on waves along the main shipping routes, as indicated by the exchange of views between INCO, ISSC, and JOC, a proposal is now being made for creation of a Joint Unesco/INCO/ISSC/IAPSO/CMOD Group of Experts on the Statistical Data on Winds and Waves.

Finally, measures should be taken to make the Scientific Committee of the Association more effective in their work. Perhaps the most important step to this end would be to raise funds enough to allow the Committee to arrange meetings and other undertakings during the period between general assemblies. Moreover, I have taken the initiative to produce a proposal for the new procedure for nomination of members for the Scientific Committee.

5. Relations with other Associations of the Union

The IANAP-IAPSO Scientific Committee on the Interaction between Atmosphere and Ocean will present its own report.

The recommendation adopted by the Association in 1963 for creation of an IASH-IAPSO Working Group on a Global Survey of the Fluctuations of Glaciers has not yet been realized.

6. Relations with IUGG

The relations of the Association with the International Union of Geodesy and Geophysics have been most satisfactory. It gives me a great pleasure to inform the Association that the General Secretary of the Union, Prof. George Garland, has been especially cooperative with the Association.

Since the results of the good relations with the Union will be evident in our deliberations in numerous ways, I shall not refer to them in this report.

7. Discussion concerning the future structure of the Union, possibly affecting the Association

Two actual reasons have made the reorganization of the Union, and especially the rearrangement of its general assemblies, desirable and even necessary:

(a) The general assemblies of the Union have become too large to be handled effectively.

(b) Steps should and could be taken to increase the efficiency of the Associations.

Detailed reports on the development and proposals for the measures to be taken will be presented to the General Assembly of the Union. Nevertheless, even the Association may wish to be informed on some points.

First of all, the Report and Recommendations on Future Structure of the Union by the Four-Member Committee, in 1964, contained among others the following observations:

The Committee agreed that a solution shall be found for the following five most urgent problems:

(a) Improvement in the internal structure, as related to the distribution of scientific disciplines among Associations, with increased precision in the definition of the purpose of each Association.
(b) Relations with other Unions, including overlap with IUGS and IUGS: relations with Special and Scientific Committees of ICSU; relations with governmental bodies.

(c) Increase in effectiveness in planning and co-ordinating specific research projects.

(d) Increase in effectiveness of general assemblies.

(e) Changes in administrative structure and other modifications to the Statutes.

The Committee recommended that the Associations, as groups of scientists working in closely related branches of geophysics, and the Union of Associations, be maintained as at present.

As far as IAPSO is concerned, the Committee did not make any specific recommendations concerning the fields covered by the Association "as there does not appear to be a need for an association of physical oceanography". There are problems concerning relations with SCOR and governmental bodies, as described below. The attention of the officers of IAPSO should be brought to the need for this Association to increase its influence in all possible ways.

Concerning IUGS, the Committee observed that there is some overlap in the case of marine geology, and IAPSO should keep in touch with IUGS.

Moreover, the Committee recommended that the Associations should act as scientific advisors to intergovernmental bodies, in their own fields. A particular problem with IOC is that SCOR is the adviser. IOC should be asked to re-examine this relation, to give IAPSO a similar role.

The Committee pointed out the vital importance that the bureaus of Associations take an active role in planning and co-ordinating projects. It realizes that the availability of the time of officials and the facilities for administrative meetings, as well as the secretaries, must be actively in touch with the activities of their Associations.

The Committee did not favor a rigid grouping of Associations, but recommended that small general assemblies continue, with longer intervals between, and that Associations be free to meet, jointly if desired, in these intervals. It is of great interest to observe some of the comments made on the above report of the Four-Member Committee by the President of this Association:

"The recommendation that a section on the Chemistry of the solid earth be created in the IAPSO (and hence that the name be changed to International Association of Geology and the Earth's Interior) is certainly better than nothing in recognizing the great importance of geochemistry. But such a section would not help to enlist the chemists who deal with the atmospheric, oceanic, and extraterrestrial phases of geochemical cycles. It makes little sense to disperse these scientists among the oceanographers, hydrologists, meteorologists, agronomists, and planetary scientists when they would much rather talk to each other. The newly founded Association of Geochemistry has been pushed into the arms of IUGS by our inactivity. It may be too late to do anything about this, but I think we should make a real try. The theoretical and experimental thinking of the geochemists is much more closely related to that of the geophysicists than to the geologists."

"One difficulty with the suggestion about IAPSO being a direct advisor of IOC and UNESCO is that if these intergovernmental bodies have more than one advisor they would try to place the advisors off against each other. This enables the officers of the intergovernmental agencies to ignore all the advice they receive and do in instead what some functionary wanted to do all along. -- I think a much better solution is the one we have just proposed here at the ICSU meeting in Bombay - to involve IAPSO (and the corresponding sections of marine geology in IUGS and biological oceanography in IUBS) much more closely in SCOR by giving them representation on SCOR's Executive Committee and enlarged to eight by adding the President of IAPSO and of the ocean section of IUGS and IUBS. Beside giving IAPSO a real voice and continuing activity relationship with SCOR, the change would have several advantages for SCOR."

When following the discussion concerning the possible changes in the structure of the Union and especially in the arrangement of the general assemblies and other activities of the Associations, at least I have become convinced that this discussion has been most fruitful. The drastic changes in the structure of the Union, as originally proposed, will not be made. However, the discussion forces the Union and the Associations into new vigor and new activity. This fact will reflect itself, I believe, even in the present General Assembly of the Association.

8. Relations with the International Union of Geological Sciences

The Secretary of the Association has been in contact with IUGS and also took part in the 22nd International Geological Congress, held in New Delhi, 14th through 22nd December, 1964.

In the above Congress IUGS appointed a Commission for Marine Geology the tasks of which include among others:

(a) An appraisal of the present status of marine geological research.

(b) A proposal of recommended activity that would strengthen national efforts in marine geology.

(c) The organization of a symposium on submarine geomorphology and geology in 1967 in collaboration with the International Association of Physical Oceanography.

(Planned symposium will be referred to elsewhere in this report.)

Moreover, in connection with the above Congress, a committee meeting was held at which the problems brought about by the undetermined position of geochemistry in relation to the various international unions, especially to IUGS and to IUBS. After discussion and exchange of views the unanimity for the establishment of an International Geochimical Association was confirmed. However, considering the seriousness of problems related to the affiliation of the new Association to one of the Unions, the meeting resolved that a final conclusion can be reached only after further comprehensive examination of the question.

The first meeting of the International Geochimical Association was held in Paris in spring 1967. The Association decided to become a constituent of the International Union of Geological Sciences; however, the need for close cooperation with IUBS and its Associations was emphasized.

9. Relations with the International Union of Biological Sciences

The Secretary has been in contact with the Secretary-General of IUBS. The result of this contact is indicated by the following words in a letter of IUBS, as of May 22, 1966:

"IUBS does not yet have a section on oceanography but we hope to establish one at the forthcoming XV General Assembly in Prague on July 18-22. When this section is established and functioning, its officers will have as one of their principal duties collaboration with societies such as yours, on symposia. I shall call the attention of the newly elected officers to possible joint symposia with your Association. I, myself, believe that this collaboration will be of great value to both groups."

Actually, the established section of IUBS had its first meeting 4 June 1966 in Moscow and took the name "The International Association for Biological Oceanography."
10. Relations with the Scientific Committee on Oceanic Research

While the Scientific Committee on Oceanic Research is an international group, organized by the International Council of Scientific Unions, and charged with furthering international scientific activity in all branches of oceanic research, the objects of IAPSO are:

(a) to promote the study of scientific problems relating to the oceans, chiefly in so far as such study may be carried out by the aid of mathematics, physics and chemistry;

(b) to initiate, facilitate and co-ordinate research into, and investigations of, those problems of physical oceanography which require international cooperation;

(c) to provide for discussion, comparison and publications.

Thus the field of activity of IAPSO is covered also by the field of SCOR operations, the joint area being that of the physical oceanography. In order to avoid unnecessary duplication of efforts and to warrant for the most effective use of research and other resources, the Secretary of the Association has carried numerous discussions with the representatives of SCOR. Originally efforts were made to settle between SCOR and IAPSO a precise division of tasks; however, since such efforts did not prove successful, it was felt that an analogous goal can be achieved through close collaboration.

The joint IAPSO/SCOR working groups indicate this welcome spirit of collaboration. Moreover, on the initiative of IOGC, ICSU invited SCOR to modify its constitution, so that the President of IAPSO, as well as the Presidents of the International Association for Biological Oceanography of IUBS and of the Commission for Marine Geology of IUGG, would be ex officio members of the SCOR Executive Committee. This proposal was accepted by SCOR, providing that the parent Unions accept responsibility for the expenses of these ex officio members. In addition, IUGG continues to have the right to appoint a member to the general committee of SCOR.

11. Relations with other Committees of ICSU

The Association was represented in the Oceanography Working Group of the Scientific Committee on Antarctic Research by Dr. Deacon who will report on the collaboration.

The Association was represented in the Scientific Committee on Water Research by Prof. Eriksson who will report on the collaboration.

The ICSU Abstracting Board has been provided with the requested material concerning the activities of the Association.

12. Relations with Unesco and IOC

The relations of the Association both with Unesco and with the Intergovernmental Oceanographic Committee have been most satisfactory.

With the International Council of Scientific Unions as the main scientific advisory body for Unesco, even the Association, through IUGG, has an opportunity to express its views of Unesco on the oceanography programme of Unesco and on IOC. These views have covered the following points:

The Association wishes to note the continuously increasing need for concerted international action for exploration of the ocean and its resources and recognizes with great satisfaction the considerable progress achieved in this direction due to the successful activities of IOC and to the implementation of the

* see 3.7 for revision of objectives of the Association

Unesco programmes in the field of marine science, of exchange of information in oceanography, of promotion of modern methodology in marine research, and of technical assistance to Member States in developing their national oceanographic programmes.

Furthermore, the Association wishes also to note that, as a result of this concerted action of the States, members of the IOC, the necessary scientific foundation for exploitation of the ocean's resources is being laid and continuously consolidated.

Taking into account the growing significance of hydrodynamical and other theoretical approaches, and of the numerical methods, made possible by the recent development of computers, Unesco should pay particular attention to the furthering of such work, both otherwise and in collaboration with IAPSO.

Being aware of the existence of the great (non-biological) marine resources, which hypothetically can be made available as a result from basic and applied research, Unesco should concentrate more than hitherto efforts on the study of the chemistry of sea-water and of the utilization of its components, and on the marine geophysical investigation, including the inventories and the technical utilization of the marine resources.

Knowing the approaching seriousness of the increasing marine pollution and being aware of the lack of basic knowledge of phenomena governing the said pollution, Unesco should further investigations into the relevant basic problems of physics, chemistry and sedimentation, and biology.

Unesco should use more widely and effectively extra-budgetary sources of finance for execution of the oceanographic programme, and should take into account, when planning the programme in oceanography for a longer period, not only the above specific proposals, but also the continuously growing need for concerted international actions for the exploration of the ocean and the consequently growing expenditures of IOC.

Finally, being aware that the implementation of the Unesco oceanographic programmes can best be achieved in numerous cases in the frame of co-operation with other bodies with analogous interests and tasks and, frequently, on regional basis, the Association wishes to stress the need of further intensification of Unesco's collaboration with intergovernmental bodies (PAG, WMO, etc.), those of the ICSU family (IAPSO, IUGG, SCOR) and regional bodies such as ICES.

13. Symposium held during the period between Assemblies of 1963 and 1967

(1) A Symposium on the Recent Developments in the Tide Gauge Instrumentation was organized, jointly with Unesco, May 3rd to 6th, 1965, in Paris, with Dr. Rosselet as convener.

(2) A Symposium on the Use of Computers in the Analysis and Prediction of Tides and Tidal Currents was organized, jointly with Unesco, May 7th to 9th, 1966, in Paris, with Hydrographer of the French Navy as convener.

(3) A Symposium on Mathematical-Hydrodynamical Investigations of Physical Processes in the Sea, was held May 25th to 28th, 1966, in Moscow, with Professor W. Hansen as convener.

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(4) A Symposium on Antarctic Oceangraphy, organized jointly by SCOR/SCOR/ TAPSO/UNESCO, was held in Santiago, Chile, September 13th to 16th, 1966, with Prof. Mosby and Dr. Currie as scientific secretaries.

(5) A Symposium on Mean Sea Level was organized April 13th to 15th, 1967, in Washington, D.C., jointly by TAPSO, U.S. Coast and Geodetic Survey, The American Geophysical Union, with UNESCO's support, as Dr. June G. Battullo as convener.

NOTE: Following the decision of the 22nd International Geological Congress, to arrange a marine geological symposium in 1967, jointly by the International Union of Geological Sciences and the International Association for Physical Sciences of the Ocean, numerous efforts were made to carry this scheme into effect. Finally, because of the postponement of the UGG General Assembly until 1967, it was decided to postpone the date of the Symposium.

14. Publications of the Association

(a) Publications Scientifiques

No. 21. "Manual of instruments and methods for measuring currents". The publication of such a volume was being prepared by the Editorial Committee on Current Measurements, disbanded at the General Assembly, in 1963. Because of practical reasons, the typographical error being amongst them, the project was cancelled.

No. 22. Bibliographical classification. The original volume, published in 1963, covered the following four languages: English, French, German and Italian. The supplementary volume is being prepared by the Committee in Bibliographical Classification. For this volume the Russian, Spanish and Japanese manuscripts are already available, while the Arabic text is still missing.

No. 23. Bibliography on mean sea levels 1919-1958. This volume, prepared by the Committee for Mean Sea Level and its Variations, was published in 1964. The volume appeared also as UGGI Monograph No. 21.

No. 24. Monthly and annual mean heights of sea level 1962-1964 and unpublished data for earlier years. This volume will be printed shortly.

No. 25. The report on the two tidal symposia held in Paris in May 1965 will appear in print shortly.

No. 26. The theory of oceanic circulation as developed in the U.S.S.R. over the past fifty years, V.G. Stockmann. This volume will appear in print shortly.

(b) Procès-Verbaux:

No. 8. General Assembly at Helsinki, August 1960. The manuscript is under preparation.

No. 9. General Assembly at Berkeley, August 1963. The manuscript is under preparation.

(c) Additional publications:

Standard terminology in optics of the sea. This volume was prepared by the Committee on Radiant Energy in the Sea and published in 1964 in the Chronique de l'UGGI, No. 57.

Abstracts of papers to be presented in the Symposia and other meetings of the International Association for the Physical Sciences of the Ocean, September 25th - October 7th, 1967, Berne, Switzerland.

Remarks:

An agreement was reached in 1965 with Swets and Zeitlinger, of Amsterdam, to reprint the out-of-print volumes of the Bulletin de la Section d'Oceangraphie de l'UGGI, and of the Publications Scientifiques and Procès-Verbaux of TAPSO.

15. Conclusions

With the unexpected growth of the marine sciences, including physical oceanography, the Association has to find more effective and more rapid working methods than hitherto. Below are listed some of the obvious possibilities to this end.

(1) The Association should pay great attention in the execution of its tasks to their global character.

(2) The Association should send its representatives or observers to all significant marine conferences and symposia. Such representatives should prepare reports to be used by the Association and Union.

(3) The Association should continue to undertake contracts with UNESCO and IOC to arrange symposia and prepare manuscripts.

(4) The ex officio representative of TAPSO in the Executive Committee of SCOR must be responsible for an effective collaboration and for an appropriate division of tasks between the two bodies. The Association should not only be interested in the actions taken by SCOR but should feel its responsibility for them as far as the physical oceanography is concerned.

(5) In consequence of its limited funds and its other relevant limitations, the Association must work jointly, beside SCOR, with other governmental and non-governmental organizations, such as UNESCO and IOC, UGU, IUSSI, other Associations of UGGI, etc., whenever appropriate.

(6) The Executive Committee of the Association must have at least one meeting during the period between the General Assemblies.

(7) The election of members for the Executive Committee should always be made with great care. An even geographical distribution of the members over the whole globe is always an advantage; however, it is more important to have an effective than an all-global Executive Committee, if the two qualifications cannot be combined into one body. The elections should be well prepared by a Nominating Committee. Only persons who are active in their science and who are energetic and interested enough to be able to contribute to the work of the General Assembly must be elected into the Executive Committee. All the members of the Executive Committee must guide, in a collective sense, the actions taken by the Secretary.

(8) One of the tasks of the President must be to guide the Secretary. He should also supervise the actions of the Scientific Committees and Working Groups.

(9) For the ensuing years the Association will need an energetic and effective Secretary. The election of the Secretary must be prepared with great care. Such preparations should be carried out mainly before the beginning of the General Assembly in order to find the best possible candidate.

(10) The Secretary should in the future be paid a salary, even if it is only one, since only this way some useful work can be obtained from the Secretary.

(11) The terms of reference for the Scientific Committees and Working Groups should be, in general, more precise and more limited in order to make their rapid fulfillment possible.
(12) The election of members into the Scientific Committees and Working Groups of the Association should be prepared with greater care than in the past. The memberships should be kept at a minimum in order to make the meetings and other undertakings less expensive and even otherwise easier to arrange. A direct election of all members of such a group does not always lead to the best result. It would be better to elect in the business meeting of the Association for each group only a nucleus, which could then propose to the ensuing meeting how to supplement its membership with additional members, who must be actual specialists in the field.

(13) The Scientific Committees and Working Groups should convene at least once during the lengthy period between the general assemblies. In connection with the general assemblies, enough time should be reserved for the meetings of the said groups. It would also be advantageous to link, whenever possible, the symposia of the Association with the scientific committee already existing or to be created.

It is the conviction of the present Secretary that the above measures would prove not only feasible but also beneficial. The Association would become more powerful and more effective to perform its tasks better than otherwise possible at present. Moreover, the Association would thus become a welcome party for collaboration with any relevant organization. The whole oceanographic community, and IUGG as well, would profit from such development.

Ilmo Hela
Secretary

REPORT ON THE IAPSO STANDARD SEA WATER SERVICE
FOR THE YEARS 1963-66
Document 1.3

The production of Standard Sea Water has continued during the four years period in question. The total sale of Standard Sea Water in the years 1963-66 amounted to 72,901 ampoules or in average 18,225 ampoules per year. This is a fairly high number compared with the conditions before the IGY, where the yearly sale was about 2,000 ampoules. The Standard Sea Water was distributed to 47 countries all over the world.

Eight batches of Standard Sea Water were produced during the period. The dates of filling and the chlorinity of the batches are listed in the table below. The analyses of the batches was in all cases made by me.

<table>
<thead>
<tr>
<th>Batch</th>
<th>P-48</th>
<th>P-47</th>
<th>P-46</th>
<th>P-45</th>
<th>P-44</th>
<th>P-43</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Batch</th>
<th>P-42</th>
<th>P-41</th>
<th>P-40</th>
<th>P-39</th>
<th>P-38</th>
<th>P-37</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dates</td>
<td>30/5-63.</td>
<td>11-64.</td>
<td>10-62.</td>
<td>4-63.</td>
<td>17/12-62.</td>
<td>16/12-62.</td>
</tr>
</tbody>
</table>

The production capacity of the Service has been increased by introduction of a heat insulated P.V.C. container of 4.4 m³ capacity for mixing of the sea water. From batch P-43 the sea water was heated to 27°C and brought into equilibrium with the air before filling. The sea water in the ampoules is thus undersaturated with air and formation of air bubbles in conductivity meters avoided, even under tropical conditions.

The sea water for the production was from the surface of the North Atlantic Ocean, normally between 12°-20° N. L. In the laboratory it was filtered through paper filters and in the container mixed with about 1% distilled water in order to obtain a chlorinity of about 19.37%. The glass ampoules were made of AR glass from the "Reiniglasseverke", Germany.

The Standard Sea Water Service has yielded a financial support of Da. Kr. 53,000 to the construction of the apparatus for measuring absolute conductivities under construction of S.I.O., England.

Freda Hermann
Director
## Receipts

<table>
<thead>
<tr>
<th>Receipts</th>
<th>IUGG</th>
<th>GRANTS &amp; CONTRACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 IUGG ALLOCATION</td>
<td>16.236</td>
<td></td>
</tr>
<tr>
<td>2 UNESCO GRANTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 OTHER GRANTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 CONTRACTS WITH UNESCO, etc.</td>
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<td></td>
</tr>
<tr>
<td>5 SALES OF PUBLICATIONS</td>
<td>1.409</td>
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<tr>
<td>6 MISCELLANEOUS</td>
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<td>7 TOTAL RECEIPTS</td>
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<tr>
<td>8 CASH ON HAND AND IN BANKS</td>
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<tr>
<td>January 1, 1963</td>
<td>1.790</td>
<td></td>
</tr>
<tr>
<td>10 TOTAL</td>
<td>19.681</td>
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## Expenditures

<table>
<thead>
<tr>
<th>Expenditures</th>
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<tbody>
<tr>
<td>11 ADMINISTRATION</td>
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<tr>
<td>11.1 Personnel</td>
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</tr>
<tr>
<td>11.2 Quarters (rents and services)</td>
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</tr>
<tr>
<td>11.3 Supplies and Equipment</td>
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<td>11.4 Communications</td>
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<tr>
<td>11.5 Travel (administrative only)</td>
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<tr>
<td>11.6 Miscellaneous 1963: 1.050</td>
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<tr>
<td></td>
<td>402</td>
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<tr>
<td>12 PUBLICATIONS</td>
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<tr>
<td>12.1 C.R. Assemblies</td>
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<tr>
<td>12.2 C.R. Symposa</td>
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<tr>
<td>12.3 Periodicals</td>
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<tr>
<td>12.4 Others (1963)</td>
<td>1.340</td>
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<tr>
<td>13 ASSEMBLIES</td>
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<tr>
<td>13.1 Organization (1963)</td>
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</tr>
<tr>
<td>13.2 Travel</td>
<td></td>
</tr>
<tr>
<td>14 SYMPOSIAS</td>
<td></td>
</tr>
<tr>
<td>14.1 Organization</td>
<td>2.000</td>
</tr>
<tr>
<td>14.2 Travel</td>
<td>5.286</td>
</tr>
<tr>
<td>15 SCIENTIFIC MEETINGS</td>
<td></td>
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<tr>
<td>16 GRANTS (Permanent Services, etc.)</td>
<td>2.703</td>
</tr>
<tr>
<td>18 CONTRACTS WITH UNESCO, etc.</td>
<td></td>
</tr>
<tr>
<td>19 MISCELLANEOUS</td>
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<td>20 TOTAL EXPENDITURES</td>
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</tr>
<tr>
<td>21 CASH ON HAND AND IN BANKS</td>
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<tr>
<td>December 31, 1966</td>
<td>3.999</td>
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<tr>
<td>23 TOTAL</td>
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</table>

### Estimated Receipts:

<table>
<thead>
<tr>
<th>Estimated Receipts</th>
<th>Regular Budget</th>
<th>Extraordinary Budget</th>
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</thead>
<tbody>
<tr>
<td>1. IUGG regular allocations</td>
<td>24,000</td>
<td>-</td>
</tr>
<tr>
<td>2. IUGG extra allocations</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>3. UNESCO contribution to joint activities</td>
<td>20,000</td>
<td>-</td>
</tr>
<tr>
<td>4. Sales of publications</td>
<td>3,000</td>
<td>-</td>
</tr>
<tr>
<td>5. Estimated Total Receipts</td>
<td>27,000</td>
<td>20,000</td>
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<tr>
<td>6. Balance on Hand, 1 January 1968 (approx.)</td>
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<td>-</td>
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<tr>
<td>7. Total</td>
<td>27,000</td>
<td>20,000</td>
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### Budget of Expenditures:

<table>
<thead>
<tr>
<th>Budget of Expenditures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Administration (Excl. travel)</td>
<td>5,500</td>
</tr>
<tr>
<td>9b. Travel (administration only)</td>
<td>1,200</td>
</tr>
<tr>
<td>9. Publications:</td>
<td></td>
</tr>
<tr>
<td>Assemblies</td>
<td>2,000</td>
</tr>
<tr>
<td>Symposium</td>
<td>3,000</td>
</tr>
<tr>
<td>Others</td>
<td>1,000</td>
</tr>
<tr>
<td>10. Assemblies:</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>1,000</td>
</tr>
<tr>
<td>Travel</td>
<td>2,000</td>
</tr>
<tr>
<td>11. Symposium:</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>1,500</td>
</tr>
<tr>
<td>Travel</td>
<td>1,500</td>
</tr>
<tr>
<td>12. Meetings of Commissions, Scientific Advisory Committees, and Working Groups</td>
<td>6,000</td>
</tr>
<tr>
<td>13. Grants (Permanent Services)</td>
<td>1,000</td>
</tr>
<tr>
<td>14. Total Budgeted Expenditures</td>
<td>27,000</td>
</tr>
<tr>
<td>15. Estimated Cash on Hand and in Banks 31 December 1971</td>
<td>-</td>
</tr>
<tr>
<td>16. Total</td>
<td>27,000</td>
</tr>
</tbody>
</table>

Ilmo Hola
Secretary
The above estimate is based upon the following assumptions:

1. The Association will have its own General Assembly in 1969.
2. The Association will take part, but in a limited scale only, in the General Assembly of the Union to be arranged in 1971.
3. The Commissions, Scientific Advisory Committees and Working Groups of the Association will arrange some meetings and other undertakings during the period between the assemblies.
4. The regular allocation from the Union will be $6,000 annually.
5. Unesco will contribute financially to the arrangement of joint symposia and other similar undertakings, as indicated.
6. The income for the publications will amount annually to $750 on an average.

RESOLUTIONS PASSED BY THE XIII GENERAL ASSEMBLY, 1963

Document 3.6

Resolution No. 3
The International Union of Geodesy and Geophysics
Considering that the interests of geophysicists in the IUGG is well demonstrated by the program presented at the Berkeley Assembly and that this interest was the result of the IUGG action to form the ad hoc Committee on the Problems of Geochronology and support its activities, resolves that the ad hoc Committee should be supported and enlarged to include representatives of IAV, IASH, IAMAP, IASPEI, IARSG and IAGA to facilitate programming of future joint symposia.

Resolution No. 31
The International Union of Geodesy and Geophysics
Considering the research project initiated by Dr. W. Munk and his collaborators of the Institute of Geophysics and Planetary Physics of the University of California, to study the interaction between the principal tidal components and long-period meteorological phenomena, convinced of the value of this work to our understanding of changes in sea level and the potential value of the detailed analysis of very long series of tidal observations at selected stations to geophysics as a whole, and noting that these data in a form compatible with electronic computing techniques will be made available to the observing authority, commends this project to all those organizations possessing suitable data.

Resolution No. 32
The International Union of Geodesy and Geophysics
Adopts the report and recommendations of the first meeting of the joint panel of experts on the equation of state of sea water (IG/114B of 4 December 1962, issued by Unesco) together with the additional report of the panel prepared at its second meeting (IG/114B of 18 August 1963) clarifying the proposed redifinition of salinity and specifying additional measurements still to be undertaken.

Considers that the panel has successfully accomplished its task within its terms of reference, as outlined in the Resolution of the Hydrographical Committee of ICES, and that therefore these terms of reference should be redefined.

Recommends
1. that the "joint IGU/IAPSO/SCOR/Unesco Panel of Experts on Oceanographic Tables and Standards", be requested:
   a) to carry out all the necessary preparatory work for publishing new oceanographic tables;
   b) to advise on the certification of standard sea water;
   c) to advise on such further investigations as may be desirable.
2. that for these new tasks the composition of the Panel be reconsidered by the sponsoring organizations; additional members might be required to advise on the nature of the tables and on the appropriate computer techniques.
3. that the International Bureau of Weights and Measures be informed of the work of the Panel, and be invited to send an observer to the next meeting.

4. that the date of the next meeting of the Panel be determined by the Director, Office of Oceanography, Unesco, after due consultation with the members of the Panel.

5. that the Unesco Office of Oceanography be asked to continue financial support of this important work, covering further meetings of the Panel and necessary items of measuring equipment.

6. that the Intergovernmental Oceanographic Commission should be requested to inquire among its members whether any of their institutions are in a position to contribute towards this work.

Resolution No. 84

The International Association of Meteorology and Atmospheric Physics

Resolves to form, with IAPSO, a Joint Scientific Committee on Atmosphere-Ocean Interaction, composed of not more than eight members with the following terms of reference:

a) to review the requirements of and foster research within the field of atmosphere-ocean interaction;
b) to provide advice on subjects in this field, on request, to individuals as well as to national and international organizations.

Resolution No. 103

The International Association for Physical Sciences of the Ocean

Considering:

1. the need for a denser network of tide gauges throughout the world oceans, and
2. the joint proposal of its Committees on Mean Sea Level and on Tides that an international symposium be held, preferably in 1964, on the subject of tide gauge instrumentation for use particularly in high latitudes and on remote oceanic islands.

Approves of and recommends the symposium to the IUGG.

ASSOCIATION INTERNATIONALE DES SCIENCES PHYSIQUES DE L'OCEAN
Union Geodesique et Geophysique Internationale
Document 3.7

STATUTS

Adopted by the General Assembly at Berne, October 1967

I. Objects, Composition and Membership of the Association

1. The International Association for the Physical Sciences of the Ocean (IAPSO) is a constituent of the International Union of Geodesy and Geophysics. The Association is subject to those articles of the Statutes and By-laws of the Union which apply to Associations, and also to these Statutes.

2. The objects of the Association are:

(a) To promote the study of scientific problems relating to the ocean and interactions taking place at its boundaries, chiefly in so far as such study may be carried out by the aid of mathematics, physics and chemistry;
(b) To initiate, facilitate and co-ordinate research into and investigations of, those problems of the ocean which require international co-operation;
(c) To provide for discussion, comparison and publications.

3. Those countries which adhere to the Union are Members of the Association.

By resolution of a General Assembly of the Association, other interational organizations which are concerned with the study of physical sciences of the ocean may be admitted to Membership, with the status of guests.

II. Administration

4. The Authority of the Association shall be vested in the countries adhering to the Union, and exercised collectively by their delegates meeting in General Assembly of the Association.

5. The Association shall hold business meetings at the General Assemblies of the Union, to be held normally once every four years.

The Association may recommend to the Executive Committee of the Union, at a General Assembly of the Union, arrangement of joint sessions of two or more Associations or of joint meetings of two or more Committees or Commissions, for the discussion of topics of an interdisciplinary character.

With the concurrence of the Executive Committee of the Union, the Association may arrange General Assemblies and other meetings of its own in the interval between the General Assemblies of the Union, either singly to deal with topics of specific interest, or jointly with another Association or other Associations.

6. The General Assembly of the Association shall elect the President, the two Vice-Presidents, the Secretary and the Deputy-Secretary of the Association.
7. The Bureau of the Association shall consist of the President and Secretary. Its duties shall be to conduct the affairs of the Association in accordance with the decisions of the General Assemblies of the Association. It shall prepare the Agenda for General Assemblies.

8. The General Assembly of the Association shall elect, from countries which adhere to the Union, four persons who, together with the President, Vice-Presidents, Secretary and Deputy-Secretary, shall constitute the Executive Committee of the Association.

III. Voting

9. On scientific matters, each delegate present shall have one vote.

10. In questions of administration or of mixed, administrative and scientific character not involving questions of finance, voting shall be by countries, each country having one vote with the proviso that its subscription shall have been paid up to the end of the year preceding the voting.

11. In questions involving finance, voting shall be by countries, with the same provision as for administrative questions. The number of votes for each country shall be one greater than the number of its category of membership of the Union.

12. In case of doubt as to which class a question belongs, and in all cases of equality of votes, the chairman shall decide.

13. A delegate shall represent only one Member Country. An adhering country not represented by a delegate may forward by post its vote on any specific question of an agenda.

14. Guests will not vote.

IV. General

15. These Statutes shall be changed only by a majority of two thirds of the votes cast at a General Assembly by delegates or by post.

16. The Association may make By-Laws which may be changed by a simple majority of the votes cast at a General Assembly by the delegates or by post.

17. This English text shall be the authoritative text of the Statutes of the Association.

BY-LAWS

Adopted by the General Assembly at Berna, October 1967
Document 3.8

I. Membership of the Association

1. It is recommended that each adhering country shall form a National Sub-Committee for the Physical Sciences of the Ocean, to which correspondence may be addressed.

2. Each adhering country and each international member may contribute to the Agenda of General Assemblies of the Association.

II. Administration

3. (a) The President and Vice-Presidents of the Association shall be elected for one period, the term “period” being taken to mean the interval between the ends of two successive General Assemblies of the Association other than Union Assemblies, except that if no such General Assembly of the Association is held in the interval between two General Assemblies of the Union, the election of officers will take place at second General Assembly of the Union.

(b) The Secretary and Deputy-Secretary shall be elected for two periods, and may be re-elected for subsequent single periods.

4. The Secretary shall manage the routine business, conduct the correspondence, preserve the records, and arrange the preliminaries of General Assemblies.

5. Of the four persons referred to in Article 8 of the Statutes, two shall retire after each General Assembly where elections have taken place and they shall not be eligible for re-election until after the expiration of one period. Each retiring member shall have served at least as long as each non-retiring member.

6. The Executive Committee shall:

   (a) Prepare for the Executive Committee of the Union recommendations concerning the arrangements, at a General Assembly of the Union, of scientific meetings to be confined to joint sessions of two or more Associations or of Joint meetings of two or more Committees or Commissions, for the discussion of topics of an inter-disciplinary character.

   (b) Seek for the concurrence of the Executive Committee of the Union, for the arrangement of General Assemblies and other meetings of the Association in the intervals between the General Assemblies of the Union, either singly to deal with topics of specific interest, or jointly with another Association or other Associations.

   (c) Fill any vacancy which may occur among the officers of the Association between General Assemblies. Such appointments shall be subject to the subsequent approval of the next General Assembly. Tenure of office for part of a period shall not be counted as a period for the purpose of these By-laws.
(d) Consider matters of general administration and finance, and report thereon to the General Assembly.

(e) Make recommendations on matters of policy.

(f) Frame the budget for the ensuing period and report to the General Assembly of the Association and to the General Secretary of the Union. The budget period of the Association coincides with the budget period of the Union.

(g) Advise upon the distribution of funds.

(h) Consider proposals for changes in the Statutes and By-laws, and report thereon to the General Assembly.

7. Officers designated by these By-laws for special duties or for special committees may appoint substitutes in their stead. Notice of the intention to do so must be sent in writing to the President or Secretary. No substitute shall represent more than one officer.

8. Decisions and actions of the Officers and Committees of the Association, taken during and between General Assemblies, shall be subject to the sanction of the General Assembly.

9. Proposals for the Agenda of a General Assembly shall reach the Secretary six months before the General Assembly. The Secretary shall send the Agenda to adhering countries, through the National Sub-Committees where such exist, at least four months before the General Assembly. No question which has not been placed on the Agenda shall be discussed unless a proposal to that effect be approved by two-thirds of the votes of the countries represented at the Assembly.

III. Finance

10. The President and Secretary shall individually have power to sign documents on behalf of the Association.

11. The Secretary shall receive the allocations of funds from the Union, and administer the funds of the Association. At the end of the calendar year preceding a General Assembly of the Union he shall prepare and send to the General Secretary of the Union the Accounts of the Association.

12. Each Account shall be audited by a qualified accountant.

13. Travelling expenses may be paid by the Secretary, but only (a) in connection with meetings on specific Association business, and (b) when those concerned represent the Association and not adhering countries or other organizations, and (c) in cases where those concerned cannot draw proper allocations from their own national sources. Such payments may cover travelling costs and a reasonable contribution to other expenses while attending such meetings.

RAPPORT

sur l'activité du COMITE des MARÉES

(COMITÉ ON TIDES)

Document 4.1

Les attributions du Comité des Marées se résument en trois points:

a) développement de l'observation à la côte et au large (notamment: amélioration du matériel et des méthodes d'observation)

b) développement de l'étude et de la prédiction du phénomène (notamment: application des méthodes mathématiques modernes et des moyens de calcul de conception

c) diffusion des observations et des études (notamment: normalisation des supports de diffusion)

Ces attributions animent le comité des Marées à une liaison étroite avec le Comité sur le niveau moyen de la mer et ses variations et avec le Comité sur la bibliographie en Océanographie Physique.

Depuis la dernière Assemblée de l'AIGRE, le Comité des Marées a organisé, conjointement avec le Comité sur le Niveau Moyen de la Mer et ses Variations, un double symposium, au cours duquel ont été passés en revue:

- le matériel d'observation à la côte et au large ainsi que l'organisation des réseaux nationaux d'observateurs.

- l'application du calcul mécanographique aux problèmes d'analyse des observations et de la prédiction.

Les actes de ce symposium ont fait l'objet de la publication No. 27 de l'AIGRE.

Le Comité, réuni à Paris en 1965, a adressé au Comité Exécutif de l'AIGRE, deux recommandations:

La première concerne l'échange des prédictions de marée et de courants de marée.

"Le Comité des Marées estime que l'usage de documents normalisés est très souhaitable pour l'échange des prédictions de marée et de courants de marée et que ces documents doivent permettre l'introduction directe, sans recopié, des prédictions dans les ordinateurs et les tabellieurs. Il est cependant que la définition de ces documents normalisés est de la stricte compétence de Bureau Hydrographique International et elle recommande que l'intérêt de cet organismes soit suivi sur cette importante question".

La deuxième recommandation concerne la création d'un groupe de travail pour "la Marée par grande profondeur". Le Comité des Marées estime nécessaire la création d'un groupe de travail dont l'activité serait consacrée:

- au développement des moyens d'observation de la marée par grande profondeur.

- à la préparation d'un programme d'observation, couvrant l'ensemble des mers du globe et destiné à être accompli dans le cadre d'une collaboration internationale.

Ces deux recommandations ont eu les destinations suivantes:

La première a été portée devant la dernière Conférence du Bureau Hydrographique International (Monaco Avril-Mai 1967). Cette Conférence a décidé d'inscrire l'étude des documents normalisés parmi les travaux confiés à son Bureau de Direction.

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La seconde a abouti à la création du groupe de travail "au deep-sea tides", dirigé par le Dr. Munk et patroné par le Comité des Marées. Ce groupe s'est réuni à Moscou puis à La Jolla, des instruments ont été approuvés et des directives pour un programme d'observation ont été élaborées; ils en sera rendu compte au cours du symposium prévu pour le 29 Septembre. En outre, la Commission Intergouvernementale d'océanographie, saisie de ces travaux, a recommandé aux États membres de se préparer à participer à une entreprise internationale, visant à couvrir les mers profondes d'un réseau d'observations de marée, suivant les directives de l'IAPSO et de son groupe de travail.

M.M. EVRIÈS
Président du Comité des Marées

REPORT OF THE COMMITTEE FOR MEAN SEA LEVEL AND ITS VARIATIONS

Document 4.2

This Committee has continued to act as an advisory panel to the Permanent Service for Mean Sea Level of the "Fédération des Services Permanents d' Astronomie, de Géophysique et de Geodesie". Since the Berkeley Assembly this group has been engaged on the following tasks:

1. Publications
IAPSO Publication Scientifique No. 25 (IUGG Monographic No. 26), 1964. "Bibliography on Mean Sea Level, 1779-1958".

In addition, the manuscript of IAPSO Pub. Sci. No. 26 (Monthly and annual heights of mean sea level, 1962-1964) is now completed. This is the first data publication to be produced for the Service by computer.

2. Continuation of M.S.L. Bibliography

In response to a clearly indicated need to update the bibliography, the Committee has under consideration procedures for so doing.

3. Publication of all existing M.S.L. data

It is proposed that the Service produce a publication containing consolidated M.S.L. data to replace all previous Pub. Sci. Every attempt will be made to present the time series for each station to a single datum.

4. A Global tide gauge network

The Intergovernmental Oceanographic Commission, at its third session in 1964, endorsed the proposals of the Permanent Service and the Special Committee on Antarctic Research for a global network of permanent tide gauge stations. IOC Resolution III-7 is attached as an appendix to this report; this resolution has had a noticeable effect in increasing the number of permanent stations reporting M.S.L. data to the Permanent Service.

5. Symposia

The Committee has been responsible for convening two symposia since the Berkeley Assembly.

The first was a joint Unesco-IAPSO symposium on tide gauge instrumentation held in Paris during 1963, in conjunction with a symposium on the analysis and prediction of tides and currents convened by the IAPSO Committee on Tides. The proceedings of both these symposia are now in print.

The second symposium on Mean Sea Level, was also a joint Unesco-IAPSO venture: it was held in Washington, D.C., the U.S. Environmental Science Services Administration acting as host. A summary of the proceedings is to be produced.

6. Permanent Service Research

On behalf of Special Study Group No. 22 of IAG, an investigation has been completed into the use of mean sea level data, for European stations, for purposes of oceanographic levelling and the determination of secular variations. The results have appeared in the Geophysical Journal of the Royal Astronomical Society, Vol. 12, 1967.
The determination of the average seasonal variation of sea level, from all available data, referred to as Berkeley, has not been completed. It is proposed that the results be published, preferably with a scientific assessment of their relevance to seasonal variations in associated oceanographical and meteorological parameters.

7. Increase in Permanent Service Commitments

In addition to the annual grant provided by ICES for the operation of the Service, UNESCO and IAPSO have financially supported specific, non-recurrent items.

A general increase in the volume of data handled, requests for data-processing services, and requests for the Permanent Service to provide more background information concerning recording stations to users of the data publications, is well under way.

Unless recurrent funds can be found for doubling the Permanent Service staff, the Service will shortly be unable to meet all the demands. The staff presently numbers one.

8. Committee meetings

The Committee has been very active in correspondence, and has held formal meetings in 1965 and 1967.

J. R. Rossiter
Secretary

IOC RESOLUTION III-7

Tide Gauges

The Intergovernmental Oceanographic Commission

Having studied the report UNESCO/IOC/III-9, prepared for the Commission by the Permanent Service for Mean Sea Level, and believing that a greater knowledge of sea level is vital to both oceanographic and meteorological research:

Requests Member States (i) to study the existing network of permanent tide gauges shown in the above report, (ii) to inform the Permanent Service for Mean Sea Level, through the Secretariat of the Commission, of any errors in the "Index of Gauges" and also to report details of any additional gauges as and when established, and (iii) to consider the possibility of filling gaps in the network and to report findings to the Secretariat of the Commission;

Recommends further that Member States arrange for close liaison to be maintained between agencies operating tide gauges and scientists working in the field of sea level studies to ensure that research requirements are considered when new gauges are installed and in the processing of sea level records;

Recommends that a Symposium on Tide Gauge Instrumentation be held in Paris in May 1965, jointly by UNESCO and IAPSO, and that standardization of presentation of data for automatic processing and the need for offshore oceanographic buoys and platforms to be fitted with tide gauges where practical, be discussed;

Considers that the installation of gauges and the presentation of data should take into account all uses to which sea level data are put, both scientifically such as in the theoretical relationship between coastal levels and those in the open sea and for such practical purposes as tidal prediction, port operation, coastal engineering, tsunami warning, etc.

Asks Member States who may have surplus gauges that they are willing to lend or present to other countries to inform the Secretariat of the Commission so that this information may be promulgated in "International Marine Science".

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The Chairman and Secretary have repeatedly attended meetings of the International Federation for Documentation (FID) which is responsible for the Universal Decimal Classification. They looked after the interests of IAPSO and advised FID in other fields, as e.g., geophysics, with regard to overlappings with physical oceanography.

UDC 551.46, Physical Oceanography, is more and more used in all parts of the world for classifying oceanographic publications.

In IAPSO Publication Scientifique No. 22 UDC 551.46 was published in the English, French, Italian, and German languages. At the General Assembly at Berkeley, 1963, it was resolved to publish the Russian, Japanese, Spanish, and Arabic versions in a supplement to Publication Scientifique No. 22. Despite all efforts of the Committee, it has not been possible to obtain the Arabic version of UDC 551.46, as, according to Mr. S.A. El Wardani, "there exist no formal Arabic equivalents for most of the terms".

The Committee now proposes to the General Assembly to publish the Russian, Spanish, and Japanese versions in the supplement.

P. Møgel
Chairman
RAPPORT SUR L'ACTIVITÉ DU COMITÉ GECOS
Document 4.5

1. Durant la période considérée, le Comité GECOS a eu une activité assez régulière marquée par l'arrivée d'environ 240 pièces de correspondance et l'envoi d'une centaine de lettres, de circulaires ou de rapports.

2. On peut y ajouter les travaux accomplis par le Comité d'édition (Editorial Board) et les membres du Comité chargés, l'un de la nomenclature des formes du relief sous-marin, l'autre des appellations géographiques. Ce dernier Sous-Comité a procédé notamment à un certain nombre d'enquêtes par correspondance.

3. D'autre part le Comité a tenu, du 4 au 9 Mai 1964, à MONACO, une réunion plénière dans les locaux du Bureau Hydrographique International (BHI). Parmi les diverses actions traitées on peut mentionner principalement :
   - la mise au point d'une nomenclature des formes du relief océanique.
   - Trente-sept termes ont été retenus et définis, vingt-deux synonymes ont été rattachés.
   - En outre un Sous-Comité spécial a été créé afin de donner à la nomenclature une forme définitive en vue de sa publication, notamment en l'associant à des références bibliographiques, d' exemples géographiques et de croquis schématiques.
   - Le choix des appellations géographiques devant figurer sur les nouvelles éditions des feuilles de la GERGO. Un Sous-Comité a été constitué avec mission de choisir et d'uniformiser les appellations à adopter;
   - Le choix des sondages et le tracé des isobathes en vue d'établir, à partir des minutes (plotting sheets) au 1/10.000.000, la maquette des feuilles de la carte au 1/10.000.000. A ce point de vue, quelques modifications des isobathes ont été apportées à la mission du Comité d'édition, lequel est chargé d'assurer une interprétation cartographique correcte des concepts géologiques et géophysiques;

4. En 1964 le Président du Comité GECOS est intervenu comme conseiller technique du BHI dans les négociations qui eurent lieu entre ce Bureau et le Service Hydrographique soviétique puis entre ce Bureau et l'Institut Géographique National (IGN) français. Les deux establishments avaient offert un lien et l'autre de se charger de l'élaboration des maquettes à l'échelle de 1/10.000.000, ainsi que du dessin, de l'impression et de la publication des feuilles de la carte. On sait que finalement le BHI a passé une convention à cet effet avec l'Institut Géographique National auquel le Service Hydrographique français a accepté d'apporter son concours pour la vérification des travaux concernant la bathymétrie.

5. Durant la période quadriennale considérée, le Comité GECOS a été conduit à plusieurs reprises à modifier légèrement sa propre composition ainsi que celle des deux Sous-Comités et du Comité d'édition. La composition actuelle de tous ces groupes remonte au 1er Mars 1966 et est donnée en annexe. La première réunion de l'année 1964 a été rendue nécessaire par le décès, survenu le 1er Juin 1964, du docteur Dr. Theodor STOCKS, de Hambourg, qui était membre du Comité et avait accepté les fonctions de rapporteur pour les questions de nomenclature du relief sous-marin.


Il reste à faire un travail analogue pour les 8 feuilles polarisées C et E, ainsi que pour l'ensemble des 24 feuilles, des accidents du relief qui, guère d'importance moindre, pourraient cependant comporter une appellation géographique.

REMARQUE. Le Sous-Comité des apppellations géographiques n'a eu besoin jusqu'à présent que de 11 termes de la nomenclature des formes du relief immergé pour désigner toutes les formes que s'il a jugé utile de qualifier sur la carte. On peut penser que, lorsqu'auront été achevés et publiés l'important travail du Sous-Comité de nomenclature des formes du relief océanique, une plus grande variété de termes pourra être utilisée pour la GERGO, notamment sur l'aris du Comité d'édition.

7. En raison du rythme assez rapide adopté par le BHI pour la mise en édition des diverses feuilles de la GERGO (édition complète tous les cinq ans) il est devenu pratiquement impossible de laisser au Comité d'édition le délai relativement long qui lui est nécessaire pour effectuer les travaux de son ressort.

8. Le président du Comité GERGO tient à exprimer ses chaleureux remerciements aux membres du Comité qui se sont tous efforcés de lui apporter leur concours le plus actif dans la mesure où leur permettaient leurs activités principales.

PROPOSITIONS CONCERNANT LE FONCTIONNEMENT DU COMITÉ GECOS DANS LES ANNÉES A VENIR

I. Conformément aux suggestions du Secrétaire de l'AIDSO, il sera procédé au renouvellement des membres du Comité, compte tenu des possibilités de coopération de chacun à l'œuvre commune.

II. L'activité du Comité sera partagée comme précédemment entre trois Sous-Comités dont les présidents seront choisis au cours de l'assemblée Générale de BERN:
   - le Sous-Comité de nomenclature des formes du relief océanique
   - le Sous-Comité des apppellations géographiques
   - le Sous-Comité des sondages et isobathes, qui remplacera le Comité d'édition dans les conditions exposées au paragraphe suivant.

III. L'organisation matérielle mise au point ces dernières années pour la production d'une édition tous les cinq ans des 24 feuilles de la GERGO conserve malgré des modifications nécessaires à se révéler très efficace. La centralisation des sondages océaniques par le BHI, les concours apportés à cet organisme par les Services Hydrographiques volontaires pour l'établissement des minutes (plotting sheets), à l'échelle de 1/10.000.000, ainsi que par l'Institut Géographique National et le Service Hydrographique français pour l'établissement des maquettes des feuilles à l'échelle de 1/10.000.000 et pour la publication de ces feuilles permet d'atteindre le rythme souhaité entre les deux feux de documentation bathymétrique tenue régulièrement à jour des travaux récents.

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Miais ce rythme, comme nous l’avons dit, ne laisse pas toujours au conseil scientifique qu’est le Comité GEBCO un temps suffisant pour accomplir pleinement sa tâche particulière dans l’activité d’ensemble. Le genre est spécialement rendu par le Comité d’édition qui a pour mission essentielle de tenir compte de concepts géologiques et géophysiologiques dans l’établissement des marquetteries à 1/10.000.000 a partir des minutes à 1/1.000.000. Ce travail correspondant est très long, d’une part en raison du grand nombre de minutes correspondant à chaque marquetterie et d’autre part en raison de la nécessité de faire examiner les documents par les divers membres du Comité d’édition afin d’éviter que l’ouvrage International devienne l’illustration d’une école particulière.

A vrai dire, pour les régions où les sondages sont nombreux, la carte bathymétrique, qui doit avant tout, dans le tracé des isobathes, respecter les profondeurs mesurées, pose pas de problèmes morphologiques, les contours étant en réalité imposés par les sondages des minutes et par les isobathes qu’ils permettent de tracer avec précision. Au contraire, pour les régions peu explorées, qui seraient à peu près entièrement laissées en blanc sur les cartes marines, la figuration de la GEBCO, avec ses nombreuses lignes, semble à délimiter celles-ci par des isobathes tracées imaginairement et laissées en tant interrompues pour bien montrer l’incertitude qui les affecte. Les spécialistes de la morphologie sous-marine seraient sans doute en mesure de proposer des tracés appuyés sur des hypothèses plus rationnelles, mais les isobathes conserveraient néanmoins un caractère hypothétique peu compatible avec la précision et l’exactitude que l’on est endroit d’attendre d’une carte bathymétrique.

Compte-tenu de toutes ces considérations et du fait que les éditions précédentes de la GEBCO étaient, dans l’ensemble, très soignées, je pense que l’on pourrait laisser l’Institut Géographique National établir la marquetterie au 1/10.000.000 des feuilles de la carte, avec le concours du Service Hydrographique de la Marine, puis procéder à la publication des feuilles correspondant aux marquetteries.

Ce n’est que dans l’intervalle de cinq ans entre une telle édition et l’édition suivante que le Comité GEBCO, et, en particulier, son Comité d’édition devenu le Sous-Comité des sondes et isobathes, pourraient faire une critique détaillée des feuilles publiées, tant en ce qui concerne l’interprétation du relief sous-marin fourni par les minutes qu’au point de vue du choix des appellations géographiques et de la terminologie morphologique. Bien entendu, toutes les observations alors faites seraient prises en considération dans l’édition suivante des feuilles examinées.

Il ne semble que, seul, ce mode de coopération pourrait conduire à une telle à jour régulière de la GEBCO, tout en laissant aux autorités scientifiques le temps nécessaire pour améliorer les éditions successives dans les domaines intéressés par leurs disciplines.

A. Gougenheim
President du Comité GEBCO

COMPOSITION DU COMITÉ GEBCO
après le ler Mars 1966

President: A. GOUHENHEIM (France)
Secrétaire: F.W.G. NAIKER (IUGG)
Membres: P.I. BRIERLEY (USSR) T. MATSUMAKI (Japan)
F.M. EDVALSON (USA) R.W. MENARD (USA)
R. EMMER (Allemagne) L.N. PARCO (Royama Uni)
A.J. GUILCHER (France) A.G. SKEE (Italie)
B.C. HEEZEN (USA) R.B. STEWART Jr (USA)
J.F.P. HENDERSON (A Uni) G. UDINZSHEV (URSS)
G. LACLAVERIE (France) A. VIGILIERI (Rhône)
A.S. LAUGHTON (R Uni) Sous-Comité de Nomenclature des formes du relief Oceanoïque

President: F.M. EDVALSON Membres: B.C. HEEZEN
President: A.S. LAUGHTON N.W. MENARD
Adjoint: A.G. SKEE G. UDINZSHEV

Sous-Comité des Appellations Géographiques

President: T. MATSUMAKI Membres: A.J. GUILCHER
President: L.N. PARCO G. UDINZSHEV
President: B.C. HEEZEN A. VIGILIERI
Adjoint: N.W. MENARD

Comité d’Edition

Membres des-qualités: Le Directeur de l’Institut Géographique National (France)
Le Directeur de Service Hydrographique de la Marine (France)
Terms of Reference: To promote standardization as complete as possible of bibliographic references in the specialized reviews regularly publishing oceanographic bibliographies.

When standardizing the bibliographic way of citation, the citation of titles of periodicals is most complicated.

International rules have therefore to be elaborated to standardize the abbreviations of titles of periodicals. The elaboration of international rules was initiated by the “World List of Scientific Periodicals”, 1925-1927. The next step was the “International Committee of Intellectual Co-operation” of the League of Nations. The first international rules of abbreviation were published in Paris in 1930 as “Code International de l’Abreviation des Titres de Periodiques”. In 1935 the “World List”, too, applied the international rules in its 2nd edition. Then, in 1938, the “International Federation of the National Standardizing Associations” undertook the task of presenting the rules to all standardizing bodies of the countries for acceptance. After World War II, the “International Organization for Standardization (ISO)” again approached the problem. An “International Code for the abbreviation of titles of periodicals” was accepted in 1953 and published in 1954. The IAPSO Committee on Bibliography on Physical Oceanography agrees that the international rules shall also form the basis for oceanographic periodicals.

But, naturally, the rules do not contain standardized abbreviations, only sentences in about six paragraphs. Each paragraph is provided with the respective exceptions. The report is not the right place to enumerate the paragraphs but it should set up this rule: each individual person or author, resp., using abbreviations ought to know the paragraphs. This also applies to editors of lists of periodicals, e.g. to the latest edition of the “World List”, 4th ed. 1963/65, which sticks to the older abbreviations. Therefore, the Committee on Bibliography on Physical Oceanography was not able to use such indices and thus elaborated the abbreviations of nearly 400 oceanographic periodicals given as Appendix to this Report.

The Committee on Bibliography on Physical Oceanography proposes to IAPSO to print this Index.

F. Model
Secretary

(Enclosures:
Appendix I: "Titles of Journals with Abbreviations"
Appendix II: Proposals by the Secretary of the Committee)
REPORT OF THE COMMITTEE ON NEAR SHORE OCEANOGRAPHY

Document 4.9

Professor V. Zenkovitch, Chairman of the Committee on Near Shore Oceanography has written to me, a committee member, and I quote, "Unfortunately I cannot at this time attend the assembly in Switzerland...", and he goes on to say, "the best solution" (for our report) "of the problem would be if committee members from all countries deliver their reports to the meeting". He goes on to hope that much scientific achievement has occurred and that the meeting will be of much interest to the participants.

In accordance with Professor Zenkovitch's instructions, I have compiled a report on Near Shore Oceanography which summarizes a large number of studies. These are grouped Under Water Motion, Acoustic, Chemical, Biological and Geological studies. Needless to say they do not cover all the work in shallow water in this rapidly expanding field, but are representative samples of current work. For further details I invite you to read the report. Copies are available.

With the permission of the Indian Delegation, I would like to call your attention to a Symposium on "Coastal and Near Shore Oceanography" organized by the Indian National Committee on Oceanic Research and the National Institute of Oceanography, held in Cochin in November 1966. Papers at the Symposium covered all phases of near shore oceanography. A copy of the abstracts which were published in the International Indian Ocean Newsletter (September 1966) is attached.

E.C. LaFond

(Enclosures:

1. Letter from Professor V. Zenkovitch dated 20 May 1967 to E.C. LaFond.
2. Report - "Near Shore Oceanography" by E.C. LaFond. Material prepared as part of the report to the International Association of Physical Oceanographers by the Committee on NEAR SHORE OCEANOGRAPHY, Berne, Switzerland, September 1967.
On the occasion of the 11th General Assembly in Berkeley, 1963, IASH proposed the setting up of the above Working Group and requested IAPSO to appoint two representatives to serve on the group. The two representatives were Prof. Juno Patullo and myself.

Thereafter the situation became confused since I was unable to make contact at Berkeley or for some time later, with any official of IASH who had any knowledge of the group. After considerable correspondence I was eventually referred to the secretary for the Commission on ENOW and IGC. I learned that the formation of the Working Group concerned with fluctuations of glaciers was still under discussion. IAPSO's interest in this matter appears to have been overlooked and on many occasions I have been asked to define the terms under which IAPSO should be involved.

The present position is as follows:

1. An initial study of the fluctuations of glaciers has been completed by Engineer Peter Kasser of Zürich and this is about to be published jointly by IASH and Unesco, subject to finances being available.

2. It now appears that a Permanent Service rather than a Working Group will be set up. Within the last few days this has been approved by IGUS and funds have been allocated although the formal approval of IGUS is still required. The latter will be sought in Rome on October 9th.

3. There has been prior agreement that a Permanent Service will be operated by Kasser from Zürich.

4. The Permanent Service will have a small directing board of three or four persons. It has not yet been decided whether or not IAPSO will be asked to appoint one member of this board but this will be discussed in Rome on October 9th.

G.W. Lennon

The Tsunami Committee met on 27 September 1967 following the Tsunami Symposium at Berna and prepared the following report:

1. A bibliography on tsunamis has been prepared by the U.S. Coast and Geodetic Survey and published under the auspices of the ITIC.

2. The Committee notes the offer of the U.S.S.R. to compile an atlas of marigrams showing tsunamis, endorses the proposal, and urges all member states to cooperate in the program.

3. The Committee notes the creation of the International Tsunami Information Center at Honolulu, Hawaii, and urges all member states to support the organization both by supplying pertinent data and by assigning scientists to the center for tsunami research.

4. The Committee proposes that a tsunami symposium be held in Honolulu in 1969 in order to inform all interested scientists of recent research and to acquaint these scientists with the facilities and research environment at the ITIC (reported in paragraph 3). The Tsunami Committee proposes to meet again at the 1969 symposium and respectfully requests that IUPO provide funds for necessary travel to this meeting.

5. The Committee recommends that IAPSO and IASPEI designate representatives on the Tsunami Committee in order that their respective programs be coordinated as effectively as possible. These representatives may be present members of the Committee or new members.

S.D. Zotler
Chairman
3. As an indirect application of the above data collecting system, it seems quite feasible that, on the basis of their ability to determine buoy positions, the satellites can be used rather effectively for an all-weather navigation system.

4. Furthermore, the satellites can be used to transmit high density data from research vessels to shore-based computer centers for processing and comparison with existing observations.

5. Oceanography is related to space research also in the study of the crust and mantle of the earth beneath the sea - the large-scale aspects of the history and structure of our planet - and how they can be compared to the other bodies in the solar system.

6. An additional possibility is that, by measuring the outgoing radiation from the earth in different parts of the spectrum, both the infrared and the visible spectrum, it may be possible to get a vertically integrated picture of the carbon dioxide and water vapor contained in the air and how this varies over the ocean. This would provide a tool for studying the interchange of carbon dioxide and water vapor between the ocean and the atmosphere.

Mr. James M. Brodugama, who has been elected in 1963 as the IAPSO representative for a Committee on the Role of Planetary Sciences in 1966, should the Union decide to create such a Committee, provided ICUS through the Union, with a wealth of information.
In oceanic regions, accurate heat-flow measurements depend on the temperature stability, both short and long term, of the near-bottom water. This implies a minimum depth of water for valid heat-flow measurements by the usual techniques, but this minimum is not presently known. A similar limitation may apply to measurements in lakes on continents. Conversely, the heat-flux through the ocean floor may influence the detailed temperature structure in near-bottom waters, which may clarify the processes of exchange of energy and matter at this boundary.

Several papers on these subjects are being presented at the International Symposium on Geothermal Problems (Zürich, October, 1967).

R. von Herzen
Working Groups

The following working groups have been active in the last four years (those marked * have been discharged):

WG 10 Oceanographic Tables and Standards (with ICES, IAPSO and UNESCO)
WG 11* Indian Ocean Atlases
WG 12* Abstracts and Bibliographies
WG 13* Zooplankton Sampling Methods (with ICES and UNESCO)
WG 14* General Scientific Framework for the Comprehensive Study of the World Ocean
WG 15 Photosynthetic Radiant Energy (with IAPSO and UNESCO)
WG 16* General Problems of Intercalibration and Standardization
WG 17* Determination of Photosynthetic Pigments (with UNESCO)
WG 18* Biological Data (with ACMPR)
WG 19 Micropaleontology of Bottom Sediments
WG 20* Radiocarbon Estimation of Primary Production (with ICES and UNESCO)
WG 21 Continuous Current Velocity Measurements (with IAPSO and UNESCO)
WG 22* Marine Pollution (with ACMPR)
WG 23 Zooplankton Laboratory Methods (with UNESCO)
WG 24 Estimation of Primary Production under Special Conditions (with IEB/PIM)
WG 25 Nutrient Chemistry
WG 26 Implementation of UN Resolution on Resources of the Sea (with ACMPR and WMO/AC)

Symposia

The following symposia have been held or are scheduled:

"Scientific Exploration of the South Pacific", La Jolla, 18-20 June 1968.

Other Activities

An important function of SCOR is to furnish scientific advice to the UNESCO program in oceanography and to the Intergovernmental Oceanographic Commission. In some cases this advice is prepared by establishing an appropriate working group; in other cases, questions are referred to SCOR members and national committees, or are discussed in detail by the Executive Committee.

SCOR also assisted in the organization of the Second International Oceanographic Congress (Moscow, 30 May - 9 June 1966) and is now studying the most effective way of organizing any future oceanographic congress. Close liaison has been maintained with other Special and Scientific Committees of ICSU, particularly with SCOR and SCIDP, and with the IOOS Committee on Atmospheric Sciences.

INTERNATIONAL REPORT OF THE SCOR WORKING GROUP 15 (WITH IAPSO AND UNESCO)
on
PHOTOSYNTHETIC RADIANT ENERGY IN THE SEA
DOCUMENT 7.2.1

Working group 15 - "Photosynthetic radiant energy in the sea" - was formed by SCOR in 1963 with cooperation from UNESCO and IAPSO.

The group held its first meeting in October, 1964. At that meeting important decisions were made which have since guided the work of the group. It was decided that the working group would deal only with the problem of measuring the amount of radiant energy available in the sea, rather than the energy actually utilized by the plants for photosynthesis.

It was further decided that the measurement should be confined to the wavelength region 350 to 700 nm and that the measurement should be expressed in quanta rather than in energy units.

It was recognized that research would be required to develop a suitable detector and technique and individual members of the working group agreed to undertake the following research:

1. The measurement of the spectroradiometric characteristics of the energy available underwater was undertaken by Tyler.
2. The estimation of the available energy by means of photocells and narrow band filters was undertaken by Ivanoff.
3. The estimation of the available energy by means of photocells and broad band filter was undertaken by Jerlov.
4. The estimation of errors in radiant energy measurements and the redesign of an incubator were undertaken by Jitits and Tyler.
5. The investigation of a suitable light meter was undertaken by Tyler and Ochakovsky.

A second meeting of Working Group 15 was held in August 1966. At this meeting reports were given by the various members of the group on the research they had agreed to undertake.

On the basis of these reports recommendations were made for further research in preparation for sea trials of the instrumentation. The recommendations were:

1. That Jerlov continue with the construction of a quanta meter in accordance with a set of general specifications agreed upon by the group.
2. That Ivanoff continue his investigations into the use of phototubes and filters for estimating total quanta or energy.
3. That Ochakovsky continue work on a thermopile in conjunction with an ancilliary prism for measuring total energy.
4. That Tyler, Ivanoff and Jerlov cooperate in the development of instruments and methods for spectral irradiance measurements.
5. That Tyler investigate the advantages and disadvantages of using hemispherical collectors vs flat collectors.
6. That Ochakovsky and Ivanoff investigate the effect of sun altitude and sea state on the value of the attenuation coefficient.

7. That Tyler and Jirsa investigate the effect of angular distribution of the light field within the incubator.

8. That Tyler and Saito investigate further the problem of suitable filters for use with the incubator.

At the second meeting it was also proposed that sea trials of the instrument be conducted in the Spring of 1969 and that full scale sea trials be conducted in the Summer of 1969.

At the present writing sea trials of the instrumentation for measuring radiant energy are scheduled for May, 1969, in the Gulf of California.

Full reports of both meetings of Working Group 15 have been published by Unesco as Unesco Technical Papers No. 2 (1965) and No. 5 (1966).

J.E. Tyler
Chairman

REPORT OF SCOR WORKING GROUP 21 ON CONTINUOUS VELOCITY MEASUREMENTS

Document 7.2.2

Terms of Reference:

To design, and propose means of carrying out, an intercomparison at sea of the principal current measuring systems now employed for the continuous recording of current velocity on moored stations.

Sponsorship:

Jointly by SCOR, Unesco and IAPSO.

Summary of Activities:

The Group has met twice this year, but before the first meeting it had been agreed by correspondence that the most effective way of meeting the terms of reference was, first, to attempt a modest intercomparison experiment with the framework of the Woods Hole Buoy programme. Consequently, the main purpose of the first meeting of the Group, held at the National Institute of Oceanography, Wormley Godalming, on 16th April 1967, was to plan such a comparison in detail.

The minutes of that meeting (attached as appendix I) may be summarized briefly as follows. All members were present, and agreed that for this first attempt at an intercomparison only the following types of current meters should be used: Aleskeyev (to be provided by Chokotillo and Shekhtvato), Bergen (Kvinge), Geodine (Poffonoff), Fliesey (Swallow) and Tielmannsmesser (Biedler). It was proposed that two Geodine meters and one of each of the other types should be put closely spaced near 500m depth in each of three moorings, to be laid a few miles apart near WHOI site "D" (35° 20'N, 70°W), and left in place with the meters running at their maximum sampling rate for 5 days. The moorings could then be hauled for a second 5-day period, with the option of some rearrangement of meter positions.

In the second meeting, at the Woods Hole Oceanographic Institution and at sea in the R.V. "Gosnold", during July 1967, this intercomparison experiment was carried out. It is too early for a full report to be written, but an account in the form of a cruise report is attached as appendix II, and the main features are outlined here. It was unfortunate that B. Chokotillo and B. Shekhtvato were unable to attend, and no Aleskeyev meters could be included in the intercomparison. The rest of the Group met as arranged at Woods Hole on 6th July, and, after re-calibrations in the towing tank sailed in the "Gosnold" for Station "D". Three moorings were laid on 16th-17th July and recovered on 24th July.

On returning to Woods Hole, the records were rapidly processed and it was possible to compare some of the results before the Group dispersed on 2nd August.

Conclusions:

The terms of reference have been met in the sense that an intercomparison experiment was designed, and the means proposed (and employed) for carrying it out were adequate to produce some data suitable for further analysis. The aim of the experiment was, of course, to obtain records from a variety of current meters, placed in the sea in a situation where they might be expected to behave similarly, and to see to what extent any differences in the results could be
accounted for by the known characteristics of the instruments. Any further variations might then be interpreted either as unexpected differences in response of the meters or as real differences of current. First, though, the moorings have to be laid, the current meters have to work properly, and then they have to be recovered. With some good luck the first and last of these three basic requirements were met, but more than half of the current meters developed faults of varying degrees of seriousness during only a week's run. The first conclusion from our intercomparison experiment is, that more attention should be paid to designing for reliability in routine production of current meters. Fortunately at least one of each kind of instrument gave some usable output, and a rough preliminary comparison showed an encouraging similarity in the results.

Proposals:

More detailed comparison must await further processing of the data, and it seems desirable that the Working Group should meet again when this has been done, in a few months' time.

The Working Group recognizes that this intercomparison was a very limited one, both in duration and in numbers and variety of current meters used. Further comparisons are needed. We should like to hear from anyone who has made similar experiments or is planning to do so in the future.

Acknowledgements:

The Group wishes to express its gratitude to its sponsoring bodies, for providing funds for travelling and subsistence and, to some extent, for transport of equipment. At the same time, we are ever more indebted to the Woods Hole Oceanographic Institution and the U.S. Office of Naval Research for their support of the actual intercomparison experiment itself. We wish to acknowledge the indispensable help of Captain H. Seibert and the crew of the R.V. "Gosschild", and of James Gifford and Clayton Collins of the Woods Hole Buoy Group, who did most of the work of laying and recovering the moorings. We are grateful also to Ferris Webster and John Maitais for their capable handling of data for the current meters and for their continuing contributions to its analysis.

"APPENDIX II"

Report on Meeting of SCOR Working Group 21, on Continuous Velocity Measurements
6th July - 1st August 1967

Introduction:

The second meeting of SCOR Working Group 21 took place, partly at the Woods Hole Oceanographic Institution and partly at sea in the R.V. "Gosschild", during the period 6th July to 1st August 1967. The following members were present: N.P. Fofonoff, T. Kvinge, G. Siedler, J.C. Swallow. Unfortunately K.A. Chekhtilov and B. Shevkhtov were not able to attend.

Our aim in this second meeting was to make an intercomparison of current meters, by calibrating them in a tow tank and by putting them out in closely spaced moorings, as proposed in the minutes of the first meeting of the Group, and to see to what extent the differences between the various current meter records could be explained in terms of the response characteristics of the instruments themselves.

Three of each of the following types of current meter were available:

- Geodyne (tape recording) (Fofonoff)
- Geodyne (film recording)
- Bergen (Kvinge)
- Tiefenstrommesser (TSM) (Siedler)
- Plessey (Swallow)

Calibration:

The most striking differences between the types of meters available are in the following features:

(a) sampling rate (every 5 sec. for Geodyne, 5 min. for others) and related differences in rate of response of speed and direction sensors.

(b) method of suspension, related to type of speed sensor (Bracket mounting for Plessey and TSM, using propellers; in line with mooring for Geodyne and Bergen, using Savonius rotors).

(c) threshold speeds (ranging from 2 cm/sec for Geodyne to 3-5 cm/sec for Plessey) and nonlinearity of the relationship between speed and rate of rotation of speed sensor.

Previous observations with Geodyne meters at the proposed site showed that the energy of horizontal motions with periods shorter than 5 min. would probably be too small to contribute a serious amount of noise in the records from the meters sampling at 5 min. intervals, even if the extra filtering action of their direction sensors compared to the Geodyne vane was ignored. It seemed likely therefore that item (c) above would be a more important source of differences in the results than (a) and (b), and most of the towing tank trials were aimed at determining the shape of the speed calibration curve and threshold speeds for each type of meter. The Bergen, Plessey and TSM instruments were calibrated, at about a dozen speeds in the range 2 - 35 cm/sec, though the size of the TSM compared to the cross section of the tank made the absolute value of its calibration doubtful. Some crude visual measurements were made, with each meter,
of the acceleration of the speed sensor when released from rest while being
towed at various steady speeds. Calibration runs were made on this occasion
on only one Goodyne rotor, since this sensor had already been studied in great
detail (Rosenoff and Brown 1967). Check calibrations were made on one Bergen
and one Plessey meter, after the moorings had been recovered and the instruments
had been in the sea for approximately 1 week.

In converting the recorded rotation of a speed sensor into current, a
simple linear relationship (not necessarily through the origin) is usually
adopted, characteristic of a particular type of current meter. Departures
from linearity occur mainly at speeds below 10 cm/sec, and fortunately speeds
in this range were encountered during most of the intercomparison period.
Variations of individual meters, from the mean for that type, were of the
order of 1 cm/sec. Fuller details of the calibrations will be given in a
later report.

Narrative of Cruise:

The "Gosnold" left Woods Hole p.m. 13th July and reached site "P" the next
day. With two kinds of current meters being bracket-mounted, and with the hope
of getting the moorings more closely spaced, it was proposed to lay the moorings
anchor-first. This had not been done before with the equipment available, and
it was soon evident that the drum of pre-cut mooring wire would have to be re-
spooled more tightly before they could be used. This took about 12 hrs., and
then an attempt was made to lay the first mooring, on 15th July.

The 680 kg. Stimson anchor, having considerable drag when rigged normally,
causd excessive fluctuation of tension in the wire while lowering. In only a
moderate swell, and before long the wire broke, causing the loss of an acoustic
release but fortunately nothing more. Subsequent anchors were rigged with
their narrowest side downwards, to minimize drag, and on 16th July the first
two moorings were laid successfully. There was no difficulty in handling the
various current meters closely spaced in the moorings, in fact the 8m. nylon
spacers, put in below the bracket-mounted meters, could have been shortened to
only 1m. without inconvenience. The only untoward incident was the breaking of
a nylon tag line which could have caused the loss of 5 current meters, but
luckily a stopper had been hooked on in time, and it held. The third mooring
was laid without incident on 17th July. The positions and general arrangement
of moorings and current meters are shown in Figures 1-3. More gasoline had
been used than had been expected, in driving the winch for re-spooling the wire,
and the "Gosnold" returned to Woods Hole for more supplies. On returning to
site "P" a.m. 20th July, the moorings were found in their expected positions,
approximately in a right-angled triangle with short sides 1.5 and 2.2 km.

During the next four days, several observations were made with a lowered sensing
digitizer (LD) through the depth range occupied by the current meters. The
LD records temperature, conductivity, pressure and relative current at 2-sec.
intervals in digital form. Water samples were taken during some lowerings.

Positions are shown in Figure 1. Fixes were made on the acoustic beacons, and
on beacons belonging to other moorings in the area, and the depths of the three
subsurface floats were determined by echo-sounding. From the latter, the actual
depths of the current meters in each mooring have been inferred. They are
listed in Table 1 below.

<table>
<thead>
<tr>
<th>Mooring No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodyne (tape)</td>
<td>477m</td>
<td>492</td>
<td>500</td>
</tr>
<tr>
<td>Bergen</td>
<td>478</td>
<td>493</td>
<td>501</td>
</tr>
<tr>
<td>Plessey</td>
<td>481</td>
<td>496</td>
<td>504</td>
</tr>
<tr>
<td>TSM</td>
<td>485</td>
<td>500</td>
<td>508</td>
</tr>
<tr>
<td>Goodyne (film)</td>
<td>488</td>
<td>503</td>
<td>511</td>
</tr>
<tr>
<td>Bottom</td>
<td>2589</td>
<td>2594</td>
<td>2591</td>
</tr>
</tbody>
</table>

All three moorings were recovered on 24th July, the first two without inci-
dent. The acoustic release of the third one did not fire when triggered, but
the timed release worked as planned. There were no difficulties in handling the
current meters from the "Gosnold". It was an advantage being so close to the
water (about 1m) with the closely spaced current meters.

None of the instruments showed any obvious external signs of corrosion or
fouling. Some corrosion had however occurred on galvanized fittings in the
neighborhood of the stainless steel parts of the Bergen and Plessey meters, de-
spite precautions taken to insulate them. Two of the Plessey current meters had
leaked slightly, about 5 cm³ of water in each.

The "Gosnold" arrived back in Woods Hole p.m. 25th July.

Data Processing:

A special effort was made to get the records processed quickly. The tapes
and films from the Goodyne meters were read by the Goodyne Co. and returned
to Woods Hole. The films from the TSM's were developed at Woods Hole and read by
eye, cards being punched for each 5-min. reading. The tapes from the Bergen and
Plessey meters were sent to Bergen and London respectively for reading, and output
lists were returned to Woods Hole by list July. Cards were then punched from
these lists.

Not all the current meters had worked satisfactorily. A first impression of
the quality of the records is tabulated below:

<table>
<thead>
<tr>
<th>Mooring No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodyne (tape)</td>
<td>Good</td>
<td>Good</td>
<td>Stuck Compass?</td>
</tr>
<tr>
<td>Bergen</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Plessey</td>
<td>No Data</td>
<td>Mainly Good</td>
<td>Fragmentary Data</td>
</tr>
<tr>
<td>TSM</td>
<td>Good</td>
<td>No Speeds</td>
<td>No Speeds</td>
</tr>
<tr>
<td>Goodyne (film)</td>
<td>Weak Film</td>
<td>Weak Film</td>
<td>Weak Film</td>
</tr>
</tbody>
</table>

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TABLE II

Quality of Records (as of 1st August 1967)

<table>
<thead>
<tr>
<th>Mooring No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goodyne (tape)</td>
<td>Good</td>
<td>Good</td>
<td>Stuck Compass?</td>
</tr>
<tr>
<td>Bergen</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Plessey</td>
<td>No Data</td>
<td>Mainly Good</td>
<td>Fragmentary Data</td>
</tr>
<tr>
<td>TSM</td>
<td>Good</td>
<td>No Speeds</td>
<td>No Speeds</td>
</tr>
<tr>
<td>Goodyne (film)</td>
<td>Weak Film</td>
<td>Weak Film</td>
<td>Weak Film</td>
</tr>
</tbody>
</table>

-71-
It is expected that useful data may be extracted from some of the imperfect records. The Geodyne film records, which gave excessively scattered results when machine-read, can be read at 5-min. intervals by eye. The TBN's with no speed output have produced usable direction records. The records from the two Plessey meters that had leaked slightly (on moorings 1 and 3) were very weak, and it seems possible that they may have been partially demagnetized by leakage currents through the recording head while the tapes were being rewound, but parts of the record from No. 3 may be usable.

By 1st August it was possible to make rough visual comparisons of some preliminary analyses of the data from at least one of each kind of current meter. Progressive vector diagrams had been plotted showing the cumulative movement of water past the current meters, which were encouragingly similar both in overall displacement and in smaller detail. Histograms were plotted, of the speeds and directions recorded in each 2-hour period by one of each type of current meter, to provide another compact presentation of the data for comparison. Convenient means of making these and other analyses of current meter data have been developed at Woods Hole (e.g. Webster and Pofonooff 1965, 1966).

What needs to be done now is, first, checking and editing of the data. Subsequent analysis to allow intercomparison may include, besides the methods mentioned above, computation of shear between data from different meters (to locate systematic deviations), comparison of vector average and arithmetical average speeds (to reveal systematic differences due to varying fluctuations of recorded direction), comparison of spectra (may reveal instrumental differences in frequency response).

There is also the possibility of comparing these data with the records from two long-term moorings, at site “D” throughout the intercomparison period. It seems likely that, after this further analysis of the data has been made and circulated to members of the Working Group, a third meeting may be necessary for discussion before a full report can be written.

REFERENCES


1. The committee has met three times, the first time in Paris, June 8-11, 1965; the second time in Paris, February 22-25, 1966, and the third time in Rome January 24-27, 1967. An informal meeting of some members of the COMAR committee was held in Geneva, Italy, on October 16-17, 1966, in connection with a IAH Symposium on the Hydrology of Lakes. I was able to attend the first and the third meeting.

2. The Committee consists of representatives from the various Associations of IUGG and of some other Unions with a great weight to the International Association of Scientific Hydrology. The terms of reference of the relevant ICSU resolution read: "...A Scientific Committee on Water Research to study the problems of international water resources in all its aspects, to formulate and execute a program of research on that subject, and to act as advisor, on behalf of ICSU, to Unesco and other international bodies (WHO, FAO, UNESCO) on problems pertaining to the International Hydrological Decade."

3. During the ICSU Meeting in Bombay in early 1966 COMAR was discussed and some dissatisfaction was expressed concerning the activity up till then the committee. It was stressed that the committee should take a greater initiative in IHD problems and should widen its interest to all aspects of water within physical, life and social sciences. Furthermore, the lack of statutes was considered a source of dissatisfaction.

4. At the second meeting the criticism was considered and in view of a considerable biological interest in water problems, it was decided to invite a representative for the International Biological Programme to join the committee. At this meeting a draft constitution for COMAR was discussed.

5. At the Rome meeting in early 1967 a final form for the statutes was agreed upon which will be submitted to ICSU for final approval. In these statutes the role of COMAR is stated to be (in free translation from French)

   a) to study, in all aspects, problems of world water resources and to formulate and promote research programmes accordingly.
   b) to establish necessary contacts with those governmental and non-governmental organizations which are concerned with water problems in order to ensure a proper co-ordination of research.
   c) to act as advisor on behalf of ICSU to Unesco and other organizations like WHO, FAO, IABO and WHO on problems pertaining to the International Hydrological Decade. The statutes also contain details on representation and on a bureau for execution of decisions, financial committee, etc.

6. Some scientific matters discussed by the committee so far are of interest to IAHSO. A survey of available data on sediment transports to the oceans is being made with a view of estimating the yearly global amount. Data are not too good but the IHD programme will finally give better data.

In the world water balance programme better run-off data to the oceans will be provided. The atmospheric flux pattern of water vapor is likely to be studied in detail during the IHD which will make it possible to map the water balance of the ocean surfaces more in detail.

7. COMAR seems at present to have an extremely important task not only during the IHD but for all future. As its experience grows its co-ordinating and initiating activity will become more and more useful.

Erik Eriksson
REPORT OF THE JOINT ICES/IAPSO/SCO/UNESCO PANEL OF EXPERTS ON OCEANOGRAPHIC TABLES AND STANDARDS

The main progress made since the last meeting of IAPSO in the work of establishing new oceanographic tables and standards can shortly be reviewed as follows:

1. Conductivity ratio-salinity tables.

New chlorinity determination were made by Fred Cukkin, National Institute of Oceanography, Great Britain, on the sea water samples collected from all parts of the oceans. As the method used by Cukkin showed to be more accurate than the method previously used by Riley, only the measurements of Cukkin and Cox were used in the calculation of the tables. From the chlorinity and salinity can be estimated formula \( S = 1.80655 \cdot CLN \). Roland Cox and collaborators calculated the tables in the following way.

From the measurements on the samples collected within 200 m of the surface a fifth order polynomial was fitted giving salinity as a function of conductivity ratio at 15°C (\( R_{15} \)). The polynomial was the following:

\[
S = -0.08996 + 28.29720 \cdot R_{15} + 12.80832 \cdot R_{15}^2 - 10.67869 \cdot R_{15}^3 + 5.98624 \cdot R_{15}^4 - 1.32131 \cdot R_{15}^5.
\]

This equation should be the future definition of salinity. From the equation tables were computed at KNO, Great Britain, for calculation of salinity from conductivity ratios. The tables were published by Unesco and KNO in October 1966.

2. Refraction index measurements.

Dr. J.S.M. Rusby, KNO, has made measurements of refractive index on 40 sea water samples. Tables of refractive index will be published by Unesco in the near future.

3. Measurements of specific gravity of sea water are going on at KNO. Measurements of the thermal expansion coefficient will be made by Dr. Bykkin, Academy of Sciences, Leningrad and Schleicher and Bradshaw at Woods Hole Oceanographic Institution are making measurements of thermal expansion under pressure.

4. For the measurements of the absolute conductivity of sea water an apparatus was constructed at KNO mainly designed by Roland Cox. Some modifications will still have to be made before the measurements can be made with sufficient accuracy. Measurements of conductivity of sea water under pressure are being made at Professor K. Krombel's laboratory, Kiel University.

5. Measurements of sound velocity as a function of pressure, temperature and salinity are being made at Professor Krombel's laboratory, Kiel University.

Fred Hermann

ICES/IAPSO/SCO/UNESCO PANEL OF EXPERTS ON OCEANOGRAPHIC TABLES AND STANDARDS

(THE THIRD MEETING, BERN, 4-5 OCTOBER 1967)

Document 8.1.a

Future additions to the International Oceanographic Tables

1. Refractive index/salinity (J.S.M. Rusby, KNO) in print.

2. Oxygen saturation values for sea water (R. Grasshoff, Kiel, and E. Green, MIT, USA). Ready in 1967 if ICES accept the recommendation that the values published by Green and Carrett should be used.


4. Specific gravity from salinity or conductivity (McCartney, KNO). Probably ready in late 1968.

d) L'ordre de priorité pour les lieux de mesure est la suivante:
aa) le long du rebord du plateau continental avec des couples de stations, l'une sur le plateau, l'autre dans les grands fonds,
bb) le long de lignes perpendiculaires à la côte, allant depuis la côte jusqu'aux grands fonds,
c) dans les zones où la théorie, ou le calcul sur modèle, ou l'extrapolation des observations côtières laissent présumer l'existence de points amphidromiques pour les ondes principales de la marée d'origine astronômique,
dd) en tout autre lieu où un phénomène oceánographique, autre que la marée, mais pouvant lui être lié, se manifeste de façon particulièrement intense.

M.M. SYRIES
The scientific committees of IAPSO should get better conditions than in the past to fulfill their important tasks. This significant goal can be reached, at least to a certain extent, if funds can be made available to the committees for meetings and other undertakings between the general assemblies. Moreover, in a few cases a close collaboration with relevant committees or other groups of IOC, SCOR, ICSB, etc. will both make the work more effective and the financial problems involved easier to solve.

Moreover, in a few cases some members of the scientific committees of IAPSO have not been actual experts on the problems to be dealt with by the relevant committee. This fact is seen also in the relative passiveness of such members. Some of the committees have had even too many members which fact has made their between-assembly meetings expensive and otherwise difficult to arrange.

I wish to propose for the consideration of the IAPSO General Assembly a new procedure for the nomination of members of the Committees:

(i) The IAPSO General Assembly in session will elect directly only three members for a Committee and will decide on the terms of reference for the Committee and for its period of work.

(ii) The IAPSO General Assembly will ask the three members to co-opt additional members, not more than three to five, to their Committee. The names of the additional members will be reported to the Executive Committee. When co-opting such additional members, attention must be given only to their personal expertise on the relevant scientific field.
5. Committee on General Bathymetric Chart of the Ocean

Chairman: Ingénieur Hydrographe Général A. Gouzenheim (France)
Secretary: Mr. A.E. Ducef (Italy)
Members:
- Mr. L.N. Pascoe (United Kingdom)
- Prof. P.L. Bezurow (U.S.S.R.)
- Prof. Bruce C. Huxen (U.S.A.)
- Dr. H.F.P. Hermon (United Kingdom)
- Dr. H.W. Hodgson (U.S.A.)
- Vice-Admiral A. Viglietti (Monaco)
- Mr. Takuchi Matsuoka (Japan)
- Prof. A.A. Guichet (France)
- Dr. Harris D. Stewart (U.S.A.)
- Prof. Theodore Stocks (F.A.G.)
- Mr. Frederick M. Edwallson (U.S.A.)

6. Committee on Bibliography on Physical Oceanography

Chairman: Ingénieur Hydrographe Général A. Gouzenheim (France)
Secretary: Dr. F. Models (F.A.G.)
Members:
- Prof. G. Allert (Italy)
- Dr. J.N. Carruthers (United Kingdom)
- Prof. A.P. Laktionov (U.S.S.R.)
- Mr. A.E. Miller (U.S.A.)
- Mr. Jens Swed (Denmark)
- Dr. G.S.R. Deacon (United Kingdom)

7. Committee on Radiant Energy in the Sea

Chairman: Prof. N.G. Jerlov (Denmark)
Secretary: Dr. J.E. Tyler (U.S.A.)
Members:
- Prof. A. Ivanov (France)
- Dr. J. Joseph (Monaco)
- Prof. J. Joseph (Monaco)
- Prof. A.G. Kosznikov (U.S.S.R.)
- Dr. T. Sasaki (Japan)

8. Committee on Chemical Oceanography

Chairman: Dr. D.E. Carritt (U.S.A.)
Secretary: Dr. Francis A. Richards (U.S.A.)
Members:
- Prof. S.V. Vuervich (U.S.S.R.)
- Dr. L.H.H. Cooper (United Kingdom)
- Dr. B.N. Ketchum (U.S.A.)
- Dr. Y. Miyake (Japan)
- Prof. M. Picotti (Italy)
- Prof. D. Lal (India)

9. Committee on Near-Shore Oceanography

Chairman: Prof. V.P. Zenkovich (U.S.S.R.)
Secretary: Mr. H.J. Schoemaker (Netherlands)
Members:
- Mr. R. Ronnefeld (France)
- Mr. J.H. Caldwell (U.S.A.)
- Dr. J. Joseph (Monaco)
- Dr. C.A.M. King (United Kingdom)
- Dr. O. Kolp (U.S.A.)
- Dr. E. LaFond (U.S.A.)
- Prof. O.K. Lomdeyev (U.S.S.R.)
- Dr. Michitaka Usuki (Japan)
I. Commissions:

(1) Commission on Marine Geophysics:
   Chairman: Dr. G. Udintsev (U.S.S.R.)
   Members: Dr. B.C. Hoozen (U.S.A.)
             Dr. A.S. Laughton (U.K.)
   Co-opted members

(2) Commission on Marine Chemistry:
   Chairman: Dr. H.D. Goldberg (U.S.A.)
             Dr. B.A. Skopintsev (U.S.S.R.)
             M.H. Menaché (France)
   Co-opted members

(3) Commission on Physical Oceanography:
   Chairman: Dr. R.W. Stewart (Canada)
             Dr. K. Yoshida (Japan)
             Prof. Nils Jerlov (Denmark)
   Co-opted members

II. Scientific Advisory Committees:

(1) Committee on Tides and Mean Sea Level:
   Chairman: Dr. J.R. Rossiter (U.K.)
             M.M. Efrois (France)
   Members: Dr. S.S. Voyt (U.S.S.R.)
             Mr. D.S. Cartwright (U.K.)
   Co-opted members

(2) Committee on General Bathymetric Chart of the Oceans:
   Chairman: Dr. A.S. Laughton (U.K.)
             Dr. B.C. Hoozen (U.S.A.)
             Dr. G. Udintsev (U.S.S.R.)
   Co-opted members

III. Working Groups:

(1) Working Group on Bibliography and Classification:
   Chairman: Dr. F. Mode (P.R.G.)
             Mr. D.M. Privett (U.K.)
             Dr. W.C. Jacobs (U.S.A.)
   Co-opted members

(2) Working Group on Symbols, Units and Nomenclature in Physical Oceanography
   Chairman: Mr. J. Crease
             Mr. J.L. Reid (U.S.A.)
             Dr. G.N. Ivanov-Frantskevich (U.S.S.R.)
   Co-opted members
U.S.S.R. PROPOSAL FOR CREATION OF A NEW IAPSO SCIENTIFIC
COMMITTEE ON COMPUTERS IN OCEANOGRAPHY

Document 9.3.1

The necessity of creating such a new Committee is brought about by the
problems of rapid processing of incoming data, their full-scale use, the
development of technical means of automatic collection and transmittance of
observational data. These problems, at present being studied by oceanogra-
phers in many countries, evolve into a number of questions which require
international cooperation, exchange of views on the national approaches,
and exchange of experience on the new methods of transmittance and process-
ing of information.

The main objectives of the Committee should be:
- discussion of the most effective methods and means of processing
  oceanographic data,
- distribution, to the oceanographic community, of the latest
  achievements in this particular field.

Practical ways to achieve these objectives are:
(1) Arrangement of scientific symposia in the above field.
(2) Elaboration of proposals for standardization of the processing
    of oceanographic information.
(3) Compilation of algorithmic file and of programs for automatic
    processing of oceanographic data and publication of such material.

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PROPOSAL FOR CREATION OF A JOINT UNESCO/IMCO/ISO/IAS/IAPO/WMO
GROUP OF EXPERTS ON THE STATISTICAL DATA ON WINDS AND WAVES

Document 9.4

"For a certain period of time, the Intergovernmental Maritime Consultative
Organization (IMCO) has been in contact with the Intergovernmental
Oceanographic Commission (IOC) trying to stimulate some international
action in order to provide ship designers with the necessary statistical
data on waves. The well-known existing sources of wave data have proved
to be not sufficient. Apparently the existing data are still limited in
quantity and do not necessarily refer to the main shipping routes of the
oceans. Thus, a strong need exists for the numerous visual observations
of waves along the main shipping routes, accumulated during the past, to
be interpreted in terms of some statistical characteristics of wave
spectra. This cannot be done without additional studies on the corre-
lation between visual observations and the statistical results of
instrumental wave recording. There is also a strong need for bringing
together experts on waves, ship's stability and design, maritime meteor-
ology (since wind statistics are also involved)."

The Secretary of the IOC has pointed out that his above words (1 March 1967)
may be a good reason for creating another joint group of experts, this time
between IMCO/UNESCO/ISO/IAS/IAPO/WMO, in order to embark on the studies. Also
SCOR may be interested in the project.

In addition, the following words (1 May 1967) of Dr. Beacon, on the subject,
must be quoted as well:

"...But the greatest difficulty is to get wave recordings along the
trade routes. There are not enough research ships, and IMCO and the
shipowners will not cooperate with scientifically to the extent of fitting
wave-recorders and stopping their ships for routine observations. In
this situation we must do the best we can with the ships that we can
use, such as weatherships and lightships and extrapolate from the
results.

Published work, for example, "The presentation of wave data from
voluntary observing ships", NPL Ship Division, Ship Report 49, July
1964, shows that it will be worthwhile making a careful study of the
visual observations made by merchant ships in the WMO observations on
which IMCO wishes to rely (and a report will soon be issued), but the
comparisons between visual observations and recordings made in Ship
Report 49, seem to give a clear indication that further international
pressure for visual observations, extended collections of data, and
attempts to use sophisticated methods of analysis on what are question-
able observations, are not likely to add significantly to what already
has been done and will soon be published.

In the long run the solution is most likely to be obtained from
numerical ocean-wide hindcasting based on meteorological data. New
York University already has a year's set of directional wave spectra
at a grid of points covering the North Atlantic, and other labora-
tories are working on programs for producing similar information.
This sort of data, provided it is reasonably correct, and it is
being proved to be so by comparison of wind and wave data, is prob-
ably the only sort that can fully answer the ship designers' problems.
Their detailed, advanced requirement is not likely to be answered by
visual observations of a complex, moving surface."
What IAPSO should do is to have a committee to thrash out the problem.... The International Ship Structures Committee has considered much the same problem as IMCO, and Professor Dornstein of HRN was one of the principal workers concerned. A committee at Berne might help, if it has a detailed assessment to consider ....

With a view to the above statements, IAPSO may wish to adopt the following Draft Resolution (see Resolution No. 7).

U.S.S.R. PROPOSAL TO CONSIDER THE ROLE OF IAPSO IN RELATION TO THE IUGG INTERNATIONAL COMMITTEE OF GEOPHYSICS, TO BE TRANSFORMED EVENTUALLY INTO IUGG COMMISSION ON DATA EXCHANGE

Document 10

During the XIVth General Assembly of IUGG the International Committee on Geophysics will eventually be transformed to IUGG Commission on Data Exchange, with representatives of the Associations as its members.

The U.S.S.R. Geophysical Committee is proposing to IAPSO that, during the XIV General Assembly, a group of representative oceanographers should get together to discuss the interests of IAPSO especially on the following points:

1) Representation of IAPSO in the IUGG Commission on Data Exchange.
2) Prospects of data exchange through the World Data Centers, extension of types of data to be delivered, etc.
3) Coordination of data exchange with other associations of IUGG, this item referring to the data in the fields of maritime meteorology, of upper mantle studies, of heat flow, etc.

Discussion of such questions would make it possible for the IAPSO representative in the said Commission to have the backing of IAPSO on basic problems of oceanographic data exchange and of exchange problems relating to the work of other associations and committees. Moreover, such a discussion on the non-governmental level of IAPSO scientists would prove useful for the execution of the work of Data Centers.
DRAFT RESOLUTION ARISING FROM THE RESOLUTION PASSED
BY THE FIRST MARINE GEODESY SYMPOSIUM
Document 14.1.4

The International Association of Physical Oceanography, cognizant of the
following Resolution passed by the First Marine Geodesy Symposium, held at
Columbus, Ohio, September 28-30, 1966, under the cosponsorship of Battelle
Memorial Institute and the U.S. Coast and Geodetic Survey:

"Recognizing that the Symposium has focused the attention of scientists
and engineers on the interrelation of inertial systems and gravity sensing
instruments with the earth's gravity field and a geodetic reference net-
work encompassing the environment of the oceans,

and also recognizing the various other interdisciplinary and international
aspects of the subject of the Symposium, recommend that the International
Association of Geodesy and the International Association of Physical Ocean-
ography consider the planning of joint meetings on these broad subjects
during the 14th General Assembly,

and also consider the establishment of commissions or special groups within
the IUGG to provide a forum for future symposia and other means of promoting
international cooperation in Marine Geodesy."

being aware that it was too late to arrange joint meetings on the above
broad subjects during the XTV General Assembly,

resolves to collaborate with the International Association of Geodesy in
the arrangement of such meetings in connection with future general assem-
bles of the two Associations,

and also resolves to take part in the work of an IAG-IAPSO working group
on marine geodesy, if established.

REPORT OF THE AD HOC COMMITTEE ON MARINE GEODESY TO CONSIDER
JOINT MEETINGS WITH THE IAG
Document 14.1.4.a

The ad hoc committee on marine geodesy moves to accept the recommendation by
the First Marine Geodesy Symposium to consider the planning of joint meetings of
the IAPSO and IAG on the subject of geodetic measurements at sea.

The ad hoc committee suggests that, for the present, the scope of the Mean
Sea-Level Committee of IAPSO be extended to represent the IAPSO in joint activi-
ties with the IAG. This scope may include (1) the establishment of a world-wide
equipotential datum at sea and (2) studies of the time- and space-dependent
departures of sea-level from that datum due to astronomical, meteorological,
hydrographical and geological events.
IAPSO REPRESENTATIVES IN INTER-ASSOCIATION AND OTHER COMMITTEES AND WORKING GROUPS
Document 14.2

IAPSO-IAHS Scientific Committee on the Interaction between Atmosphere and Oceans
Dr. A.S. Monin (U.S.S.R.)
Prof. R.W. Stewart (Canada)
Prof. P. Welander (Sweden)

IASH-IAPSO Working Group on a Global Survey of the Fluctuations of Glaciers
Mr. G.W. Lennon (U.K.)
Dr. June G. Pattullo (U.S.A.)

IUSS Committee on Tsunami
Prof. H.D. Reid (U.S.A.)

IUGG Committee on Space Research
Ex officio: Secretary

IUGG Committee on the Problems of Geochemistry
Dr. E.D. Goldberg (U.S.A.)

IUGG Committee on Critical Data
K.M. Menchhé (France)

International Heat Flow Committee
Ex officio: Secretary

IUGG ad hoc Committee on Science Teaching
Prof. F. Groen (Netherlands)

SCAR WG in Oceanography
Dr. G.E.R. Dacon (U.K.)

SCOR
a) Representative of IUGG: Prof. R. Revelle (U.S.A.)
b) Representative of IAPSO: Ex officio: President

SCOR WG 15 (with IAPSO and Unesco) on Photosynthetic Radiant Energy
Prof. N. Jerlov (Denmark)
Dr. J.E. Tyler (U.S.A.)

SCOR WG 21 (with IAPSO) on Continuous Current Velocity Measurements
Mr. T. Kvinge (Norway)
Dr. G. Siegler (F.R.G.)

ICSU WDC Steering Committee
Dr. I.M. Belousova (U.S.S.R.)

ICSU Scientific Committee on Water Research (COMAR)
Prof. E. Eriksson (Sweden)

Joint ICSU/IAPSO/SCOR/Unesco Panel of Experts on Oceanographical Tables and Standards
Prof. W. Kroebel (F.R.G.)

Joint IAPSO/SCOR/Unesco Working Group on Deep-Sea Tides
Dr. W. Munk (U.S.A.)
Mr. D.E. Cartwright (U.K.)
Dr. S.S. Voyt (U.S.S.R.)

Joint Unesco/IMCO/IBSC/IASPO/WMO Group of Experts on the Statistical Data on Winds and Waves
Dr. R. Durrestein (Netherlands)
OFFICERS OF THE ASSOCIATION 1963-1967

- 94 -

Prof. R. Bevila (President)
Prof. B. Kallenberg (Vice-President)
Prof. K. Hidaka (Vice-President)
Prof. J. Mele (Secretary)
Hydrographer on Chief M. Eyriès (Deputy Secretary)
Prof. L. M. Brekhovskikh, U.S.S.R.
Capt. L.R.A. Capurro, Argentina
Prof. G. Dietrich, F.R.G.
Dr. D. J. Rochford, Australia

OFFICERS APPOINTED AT BUSHE:

- 95 -

Prof. G. Dietrich (President)
Prof. A.S. Munin (Vice-President)
Prof. M. Uda (Vice-President)
Dr. A.R. Maxwell (Secretary)
Hydrographer on Chief M. Eyriès (Deputy Secretary)
Capt. L.R.A. Capurro, Argentina
Dr. D. Lal, India
Mr. D.J. Rochford, Australia
Dr. J.R. Rossiter, United Kingdom
RESOLUTIONS NO. 1-12
Document 14.1

Resolution No. 1

The International Association of Physical Oceanography;
considering that the traditional term 'physical oceanography' does no
longer reflect the whole range of scientific problems, relating to the ocean
and interactions taking place at its boundaries, which can be studied chiefly
by the aid of mathematics, physics and chemistry;
being aware of the fact that the physical sciences of the ocean today have
as their elements;
(a) marine geophysics and appropriate aspects of marine geology; the shape,
structure, composition and history of the sea floor and coasts, and the
processes which change them;
(b) marine chemistry; the organic and inorganic constituents of the ocean
and their budgets;
(c) physical and meteorological oceanography; the motions and the propa-
gation of energy in the ocean, and the interaction between atmosphere and
ocean in large- and small-scale;
resolves to change the name of the Association to the International Asso-
ciation for the Physical Sciences of the Ocean (IAPSO).

Resolution No. 2

The International Association for the Physical Sciences of the Ocean;
considering that the effective work of the Association requires a variety
of subordinate bodies, each appropriate to a certain task;
resolves that the following bodies will be created:
(a) commissions, corresponding to the subject areas defined in Resolution
No. 1, and serving to:
(1) provide for exchange of views and comparison of results and
methods by organizing global and regional meetings and symposia,
(2) take measures to promote the gradual coalescence of international
organizations responsible for different branches of marine sci-
ences,
(3) supplement the expertise of the Executive Committee of the Asso-
ciation;
(b) Scientific Advisory Committees; serving to advise international sci-
entific operating services;
(c) Working Groups, serving to study specific scientific problems, usually
on an ad hoc basis and often in association with other scientific organi-
zations;
resolves to create the following three Commissions:
(1) Commission on Marine Geophysics
(2) Commission on Marine Chemistry
(3) Commission on Physical Oceanography.

resolves to maintain the following two Scientific Advisory Committees:

(1) Committee on Tides and Mean Sea Level, with the following terms of
reference:
(a) to act as a scientific advisory panel to the Permanent Service
for Mean Sea Level and to other agencies,
(b) to propose working groups, as necessary, to examine new develop-
ments in relevant disciplines and co-opt such other members as are
necessary to deal with specialized problems that will arise,
(c) to facilitate cooperation between oceanographers and geodesists
in problems of mutual concern;
(2) Committee on General Bathymetric Chart of the Oceans, with the
following terms of reference:
(a) to act as a scientific advisory body to the Bureau Hydrographique
International, in Monaco,
(b) to encourage and to promote surveys and topographic charting of
the deep ocean, including speed preparation and publication of the
General Bathymetric Chart of the Oceans,
resolves to have, for the time being, two Working Groups of its own:
(1) Working Group on Bibliography and Classification, with the following
terms of reference:
(a) to publish a supplement of the Publication Scientifique No. 22,
containing the Japanese, Russian and Spanish versions of the Uni-
versal Decimal Classification for Physical Oceanography (UDC 551.46),
(b) to complete and publish a list of oceanographic periodicals with
abbreviations,
(c) to make arrangements by which it will be possible (i) to take
care of oceanographic interests in future developments of the Uni-
versal Decimal Classification in this field and related subjects
and (ii) to follow the new technical developments in the field of
documentation;
(2) Working Group on Symbols, Units and Nomenclature of Physical Ocean-
ography, with the following terms of reference:
(a) to examine the literature of physical oceanography in order
to ascertain which physical quantities occur with sufficient
frequency that standardization of usage is desirable;
(b) to choose for the quantities selected:
(1) a name, with a clearly stated definition,
(2) a unit,
(3) an abbreviation for the unit (e.g., m for metre, g for gram),
to be used after numbers,
(4) a symbol for the quantity (e.g., f for the vertical component
of the earth's vorticity), to be used in analytical expressions,
(c) to ensure, in performing the task under (b), reasonable consistency
with usages in other branches of science and in particular in physics,
and as much as possible to preserve usage which has already become
standard in oceanography,
(d) to publish the results of decisions made under (b) in at least one
journal of physical oceanography, and to notify the editors of all
journals, which accept articles on subjects in physical oceanography,
of these decisions.
authorizes the Executive Committee of the Association to enter into joint arrangements with other appropriate organizations in order to form and support joint working groups on specific scientific problems as required, and to nominate members of such groups on behalf of the Association, subject to subsequent reporting to the General Assembly of the Association;

reaffirms its intention to collaborate in its tasks with the Intergovernmental Oceanographic Commission, UNESCO, WHO, Scientific Committee on Oceanic Research (of ICES), the International Union of Geodetic Sciences and with other associations of IUUG, such as IANAP, IAG, ISH, etc., as well as with other international organizations concerned.

Resolution No. 3
The International Association for the Physical Sciences of the Ocean;
cognizant of the following resolution passed by the First Marine Geodesy Symposium, held at Columbus, Ohio, September 28-30, 1966, under the co-sponsorship of Battelle Memorial Institute and the U.S. Coast and Geodetic Survey:

"Recognizing that the Symposium has focused the attention of scientists and engineers on the interrelation of inertial systems and gravity sensing instruments with the earth’s gravity field and a geodetic reference network encompassing the environment of the oceans, and also recognizing the various other interdisciplinary and international aspects of the subject of the Symposium, recommend that the International Association of Geodesy and the International Association of Physical Oceanography consider the planning of joint meetings on these broad subjects during the 14th General Assembly, and also consider the establishment of commissions or special groups within the IUUG to provide a forum for future symposia and other means of promoting international cooperation in marine geodesy."

being aware that it was too late to arrange joint meetings on the above broad subjects during the XIV General Assembly;

resolves to adopt the recommendation by the First Marine Geodesy Symposium to consider the planning of joint meetings of the IAPSO and IAG on the subject of geodetic measurements at sea;

considering moreover that the joint activities of the above two associations may include (1) the establishment of a world-wide equipotential datum at sea and (2) studies of the time- and space-dependent departures of sea-level from that datum due to astronomical, meteorological, hydrographical and geological events;

resolves further to invite IAG to nominate no less than two geodesists to the newly formed IAPSO Scientific Advisory Committee on Tides and Mean Sea Level to facilitate cooperation between oceanographers and geodesists in problems of mutual concern.

Resolution No. 4
The International Association for the Physical Sciences of the Ocean;
having decided to maintain the Scientific Advisory Committee on General Bathymetric Chart of the Oceans;

being aware of the wide interests of various oceanographical and hydrographical organizations in the topographical charting of the deep ocean, including speedy preparation and publication of the General Bathymetric Chart of the Ocean;

resolves to invite the United Nations Organization, the Intergovernmental Oceanographic Commission, the Scientific Committee on Oceanic Research (of ICES), the International Union of Geodetic Sciences and the International Association of Geodesy to appoint representatives to the said Committee.

Resolution No. 5
The International Association for the Physical Sciences of the Ocean;
cognizant of the great significance of the Tsunami studies carried out, among others, under the auspices of the IUUG;

considering the contribution that physical oceanography can make in the above work;

resolves to collaborate with the IUUG Committee on Tsunami and to nominate an Association representative in the said Committee.

Resolution No. 6
The International Association for the Physical Sciences of the Ocean;
cognizant of the proposal to change the Comité International de Geophysique (of IUUG) into a WDC Steering Committee;

being aware of the necessity of close collaboration between the said WDC Steering Committee and the groups representing the oceanographic data centers and their use;

resolves to collaborate with the WDC Steering Committee;

decides to agree with the Scientific Committee on Oceanic Research on the appointment of a joint representative on the WDC Steering Committee.

Resolution No. 7
The International Association for the Physical Sciences of the Ocean;

considering that further development of international cooperation, with regard to obtaining necessary data on external forces and other factors affecting ships’ stability and the effect of winds and waves on other structures, can be meaningfully planned only on the basis of advice obtained from a group of experts representing both engineering and wave research interests;

recommends the creation of a Joint UNESCO/WHO/IUGG/IAPSO/WHO Group of Experts on the Statistical Data on Winds and Waves;

resolves to contribute to the work of such a group of Experts by appointing a representative to it and enabling him to participate in the assigned work.

Resolution No. 8
The International Association for the Physical Sciences of the Ocean;

endorsing strongly the request of the Intergovernmental Oceanographic Commission and of the World Meteorological Organization for assignment of certain radio frequencies within the 3-30 megacycles region for exclusive use by the oceanographic and meteorological scientific communities for transmission of data from sea;

being aware that use of such frequencies will become an absolute necessity within the next five years for the safe conduct of environmental science at sea;

being informed that the opportunity of obtaining such frequencies may not be available again for at least a decade;
Resolves that the President of the Association should communicate with the President of the World Administrative Radio Conference on Maritime Mobile expressing the urgent request of the XIV General Assembly of the Association that every possible consideration be given by the WARC to this proposal for use of certain radio frequencies for transmission of oceanographic and meteorological scientific data from sea.

Resolution No. 9

The International Association for the Physical Sciences of the Ocean;
recognizing that pollution of the seas by industrial, agricultural and domestic waste products is increasing;
being aware that the problems to be solved are interdisciplinary and require collaboration between physical, chemical and biological oceanography and other disciplines;
resolves to cooperate with appropriate international organizations to promote scientific discussions of the oceanographic aspects of the problem of marine pollution.

Resolution No. 10

The International Association for the Physical Sciences of the Ocean;
cognizant of the growing need for closer, interdisciplinary working contacts in the field of marine sciences;
requests the Executive Committee to study, in collaboration with other international organizations, interested in oceanography, and to report to the XV General Assembly of the Association on the desirability and feasibility of establishing an International Union of Marine Sciences (IUBS) which would contain associations dealing with sciences concerned with the ocean, that is, with marine geophysics and geology, marine chemistry, physical and meteorological oceanography, and marine biology;
resolves to convene, if practicable, its XV General Assembly jointly with the Scientific Committee on Oceanic Research (of ICSU), with the International Association of Biological Oceanography (of the IUBS), with the Commission on Marine Geology (of IUGS) and with ITAMAP, in particular, with those sections interested in air-sea interaction problems.

Resolution No. 11

The International Association for the Physical Sciences of the Ocean;
considering that the techniques for precise estimation of dissolved salts in sea water have been significantly improved during recent years, particularly by the introduction of conductivity methods;
noting the careful experimental work establishing the relationship between conductivity ratio, chlorinity and temperature carried out under the leadership of the late Dr. R.A. Cox;
further noting the review and endorsement of this work by the Joint ICES/IAPSO/IOC/UNESCO Panel of Experts on Oceanographic Tables and Standards, and the publication by UNESCO of the International Oceanographic Tables, based on this work;
resolves to endorse the International Oceanographic Tables and the definition of salinity and the relation between salinity and chlorinity contained in the introduction to Table 1 in therein, and to recommend their use by oceanographers.

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The International Association for the Physical Sciences of the Ocean;
being aware of the IANAP resolution inviting IAPSO to hold a joint IANAP-IAPSO session on the subject of air-sea interactions;
resolves to accept the invitation;
requests the Executive Committee to take the necessary actions in cooperation with IANAP.
DELEGATES AND GUESTS ATTENDING IAPSO GENERAL ASSEMBLY

AT BERN

ARGENTINA

Aragno, F. J.

Capurro, L.

AUSTRALIA

Cooper, A. N.

AUSTRIA

Lauscher, F.

CANADA

Banks, R.

Bennett, A. S.

Brockle, J.

Dohler, G. C.

Dudall, I. W.

Forrester, W. D.

Gibert, R. L.

Johannesen, O. M.

DENMARK

Hermann, R. F.

Jarlov, N. G.

Kullenberg, G. E. B.

Lundgren, B. G.

Møgards, K.

FEDERAL REPUBLIC OF GERMANY

Brettschnieder, G.

Dietrich, O.

Grasshoff, K.

Hansen, W.

Resselmann, K. F.

Hollan, E.

Kemenecke, M. K.

Kielmann, J.

Krauss, W. M.

Magaard, L.

Plies, J.

Ramming, H. G.

Roether, W.

Sündermann, J.

Tomczak, H., Jr.

Von Trepka, D.

Weidemann, H.

Zabel, W.

FINLAND

Kofoed, P. A.

Lisztien, K.

FRANCE

Berton, G. R.

Bonneville, R.

Bourgain, J. R.

Chabert D'Hieres, G. C.

Chezelet, R. P.

Buffo, J. H.

Kyriak, M. M.

Gelis, R. G.

Geot, R. L.

Gerlier, P.

Grela, J. A.

Gougenheim, A.

Guerit, R. G.

Hyacinthe, J. L.

Ivanov, A. I.

Jacon, H.

Laurent, L. C.

Laurent, P. L.

Leblanc, P.

Manache, M.

Mercier, J. M.

Miche, J. M.

Moreel, A.

Mourlon, M.

Otto, O. F.

Ottenheimer de Gail, P. O.

Pack, S. P.

Bouger, J. S.

Buellin, R. P.

Saint-Bulby, B.

Sehernia, F.

GERMAN DEMOCRATIC REPUBLIC

Rupfer, P.

Striggow, K.

GREAT BRITAIN

Browne, K.

Britten, C.

Cartwright, D. E.

Cloet, R. L.

Cooper, L. H. N.

Crease, T.

Darbyshire, J.

Davies, G. H.

Deacon, G. E.

Gill, A. E.

Gould, W. J.

Griffiths, D. K.

Harvey, J. G.

Heape, M. S.

Hughes, P.

Johnston, R.

Lennon, G. W.

Peregrine, D. H.

Pugh, D. T.

Rees, A. I.

Rasmussen, J.

Simpson, J.

Swallow, J. C.

Tait, R.

Talbot, J. W.

Thorpe, S. A.

Tucker, W. H.

Turner, E. S.

Watson, A. G.

Wiseman, J. D. H.

Woods, J. D.

INDIA

Lal, D.

Venkatavaradan, V. S.

ISRAEL

Dishon, M.

Pekeris, C. L.
ITALY
Aliverti, G.
Rossolaco, M.
De Malo, A.
Frassetto, R.

JAPAN
Hidaka, K.
Miyako, Y.
Sasaki, T.

MEXICO
Cocho Gil, F.

MONACO
Joseph, J.

NETHERLANDS
Bijker, E. W.
Dorrestein, E.
Koele, L. A.

NORWAY
Boeyum, G.
Sgrin, J.
Gade, H. G.

SOUTH AFRICA
Anderson, F. P.

SPAIN
Borruenguer, D. A.
De Castillejos, F.

SWEDEN
Fonselius, S. H.
Lybeck, L.
Saqi Gupta, R.
Svensson, A.

Biland, Jur. K.
Chavas, F.
Geiss, J.
Gilleron, F.
Heberlein, H.
Hegner, E.

Aksharaungra, S.

Adams, K.
Arason, G.
Arzhaninou, G.
Arm, W. S. von
Austen, T. S.
Barakos, P. A.
Beattie, T. P.
Beckerley, G. F.
Beckerley, J. C.
Behman, D. S.
Bradford, B. E.
Burt, W. V.
Calins, J. L.
Cochrane, J. D.
Cohlan, B. F.
Copper, B. K.
Crombie, D.
Devereux, R. F.
Eckart, C.
El Wardani, S.
Graham, R. M.
Edwallon, P. M.
Rofonoff, N. P.
Puglistor, P. C.
Rutens, W. L.
Mendes, M. C.
Nickley, T.
Hockstra, P.
Hunkins, K. L.
Iseas, J. D.
Jelsissiani, C. P.
Jennings, P. D.
Keeling, C. D.
Ketcham, B. H.
Knauss, J. A.
LaFond, R. C.
La Violette, P. E.
LaVastu, T.
Lambert, R. B.

Nederland, A.
Ryddeger, P.
Peters, C. J.
Thams, J. C.
Wyse, F.

Sharafeldin, S.

Adams, W.
Armason, G.
Arzhaninou, G.
Arm, W. S. von
Austen, T. S.
Barakos, P. A.
Beattie, T. P.
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Keeling, C. D.
Ketcham, B. H.
Knauss, J. A.
LaFond, R. C.
La Violette, P. E.
LaVastu, T.
Lambert, R. B.

Loosie, K. G.
Lyman, J.
Magnitsky, A. W.
Maxwell, A. E.
McGarry, J. W.
Miller, A. R.
Okubo, A.
Olios, B. E.
Pandolf, J. P.
Pope, J. W.
Pot, T.
Fitchard, D. W.
Rattray, M. J.
Reid, J. L.
Reid, R. G.
Revelle, R.
Robinson, A. R.
Schell, I. T.
Schooler, A. H.
Schule, J. J.
Schulman, B. E.
Seckel, J. K.
Smith, R. L.
Smith, R. E.
Stanton, B. W.
Stromel, H.
Taft, B. A.
Taylor, J. R.
Vastano, A. C.
Voorhis, A. D.
Warren, B. A.
Washburn, A. L.
Webster, T. F.
Wells, B. R.
Wright, W. R.
Wittmann, W. I.
Wooster, W. S.
Wyczki, K.
Zettel, R. D.
ABSTRACTS OF THE SCIENTIFIC PAPERS

I. Symposium on General Circulation of the Oceans

II. Symposium on the Currents of the Indian Ocean, in Relation to the Monsoons

III. Symposium on Deep-sea Tides

IV. Symposium on Surface Waves

V. Symposium on Tsunami

VI. Symposium on Internal Waves

VII. Symposium on Diffusion: Theories, Experiments at Sea

VIII. Symposium on the Hydrodynamical-Numerical Methods in Physical Oceanography

IX. Symposium on Computers in Oceanography

X. Symposium on Physical Properties of Sea Water

XI. Miscellaneous Papers:

XIA. Mainly on Tides and Mean Sea Level

XIB. Mainly on Descriptive Oceanography

XIC. Mainly on Chemical Oceanography

XID. Mainly on Oceanographic Instruments
The following papers were given:

(Chairman – Roger Revelle)

1. H. Stommel (U.S.A.)
   (No abstract)
   The Growth of Awareness of the Complexity of Ocean Circulation

2. J.D. Cochrane (U.S.A.)
   Eastward Tropical Currents in the Atlantic Ocean off Northern South America in 1963 and 1964

3. K. Yoshida and T. Kidokoro
   (Japan)
   Subtropical Countercurrents

4. J. Noel and J. Merle (Nouvelle Caledonie)
   (Paper given by H. Piton)
   Analyses et sub-superficiels des courants superficiels durant une periode de 8 jours at 170°E

5. K. Volgi, H.-J. Brosin and D. Wehring (G.D.R.)
   (No abstract)
   Further Results about the Equatorial Undercurrents in the Atlantic

(Chairman – H. Mosby)

6. D.J. Baker and A.B. Robinson
   (U.S.A.)
   Experimental and Theoretical Investigations in a Laboratory E-plane Ocean Model

7. S.I. Tjurjakov (U.S.S.R.)
   (Paper given by B.A. Tareyev)
   Experience of Calculation of the Three-Dimensional Circulation in the North Atlantic

8. H. Stommel and C. Rooth (U.S.A.)
   The Wind and Density Differences as Cause of Circulation

9. P. Welander (Sweden)
   A Theory of Combined Wind-driven and Thermal Circulation

10. G.T. Headler (Canada)
    A Model of Thermohaline Circulation

11. W.L. Gates (U.S.A.)
    A Numerical Study of Transient Rossby Waves in a Wind-driven Homogeneous Ocean

12. B.A. Tareyev (U.S.S.R.)
    Two-layer Nongeostrophic Model of Baroclinic Instability in Atmosphere and Ocean

13. A.Z. Gill (U.K.)
    A Model of the Antarctic Circumpolar Current

(Chairman – G. Dietrich)

14. K. Hunkins (U.S.A.)
    Inertial Oscillations of Plitcho's Ice Island (T-3)

15. J.L. Reid and R.J. Lynn (U.S.A.)
    Properties and Circulation of Deep and Abyssal Waters

16. L.W. Worthington and W.R. Wright
    (U.S.A.)
    On the Deep Water Masses and Circulation of the North Atlantic

17. S. Tabata (Canada)
    Circulation of the Northeast Pacific Ocean as Deduced from Isentropic Analysis

18. F.C. Fuglister (U.S.A.)
    Cyclonic Eddies Formed from the Meanders of the Gulf Stream

19. J.G. Harvey (U.K.)
    The Movements of Sea-bed and Sea-Surface Drifters Released in the Irish Sea 1965-66

20. L.V. Shannon (South Africa)
    The Oceanic Circulation Pattern off South Africa

21. M. Kore-Armanda (Yugoslavia)
    Water Exchange between the Adriatic Basin and Eastern Mediterranean
In: THE GROWTH OF AWARENESS OF THE COMPLEXITY OF OCEAN CIRCULATION

N. Stommel, Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A.

(No Abstract)

Discussion of Paper I:1

D.W. Pritchard: My comment should not be interpreted as critical of the presentation of Professor Stommel, since I consider the animated depiction of the three-dimensional circulation pattern which he has presented, as well as the numerical model he referred to, are of great value to oceanography. It should be remembered, however, that these depictions essentially deal with the North Atlantic only, with no cross-equator flow allowed. If some 40 x 10^8 m^3 s^-1 sinks to supply the North Atlantic deep water, and this water is retained in the North Atlantic Basin only, before ascending again to the surface layers, a residence time of approximately 100 years for the deep water is obtained, rather than the 800 years or so which one deduces from the distribution of natural tracers for the world oceans.

I:2. EASTWARD TROPICAL CURRENTS IN THE ATLANTIC OCEAN OFF NORTHERN SOUTH AMERICA IN 1963 AND 1964

John D. Cochranen, Texas A & M College, U.S.A.

The flow pattern off northern South America between 33° and 50°W is inferred from serial and direct current data taken in summer 1964 and secondarily from data of winter and summer cruises in 1963. Outstanding features in the upper thermocline layers are three long segments of eastward flow, interconnected within the region by three anticyclonic eddies.

The first segment from the west entered the region near 8°N with a highly saline core. It continued to an area off the north limb of an anticyclone centered on the Amazon at 1°N, 44.5°W. Near 65°W the segment branched. The north branch turned back northwestward and then eastward to form part of the second eastward segment. The south branch (the east limb of the Amazon anticyclone) extended to about 1°S, apparently constituting a connection from the first eastward segment to flow near the Equator.

From Cape Sao Roque the Guiana Current extended along the continental slope of South America. As far as the Amazon anticyclone, the south limb of which formed, its upper thermocline was highly saline. It may have contributed to the first eastward segment at the Amazon anticyclone. Flow to the northwest of the anticyclone was notably less saline.

The second eastward segment began near 10°N, 45°W. There a rather small flow from the north was joined by the north branch of the first eastward segment. The second segment extended at least to 34°N. This flow, also highly saline, is identified as the Equatorial Current. It was present in March and August 1964.

The third eastward flow may be identified in the east as the Equatorial Undercurrent. In 1963 at about 36°W, the flow was clearly indicated by the mass field and measured directly at about 100 m depth. Strong eastward flow at 100 m depth was also measured in March 1963 at 35°W and in August 1963 at 33°W. The flow apparently received water from both north and south at about 36°W in March 1963 and August 1964 and at 35°W in August 1963. A branch of the Guiana current supplied the water from the south.

Marked eastward flow at 100 m on the Equator was never measured west of 40°W. But the case did eastward flow at 40°W provided evidence of eastward flow in both summer cruises. Contributions to this flow came apparently from the north by way of the anticyclones between the eastward flows in the north and the Equator.

Discussion of Paper I:2

M. Uda: What relationship between ridges or troughs in accelerations potential does or does not exist between bottom topography or wind conditions?

J.D. Cochranen: There was no very evident relationships of details of the acceleration potential fields during the 1964 cruise to the wind or bottom topography.

I:3. SUBTROPICAL COUNTERCURRENTS

Kozo Yoshida and Yosikoko Kitokoro, Geophysical Institute, Faculty of Science, University of Tokyo, Tokyo, Japan

The seasonal charts of transports, surface and thermocline topography for world oceans, computed theoretically from statistical wind stress distributions, reveal eastward transports along the zones of lower subtropical latitudes during spring; late fall to late spring.

The narrow eastward currents as predicted from wind-stress data seem to be related to those actually indicated at 1° lat. between 20°S and 25°S of the western North Pacific in recent cruises (YAMANAKA et al., 1965: UDA and HASEMURA, 1967). They resemble also the eastward jet observed in the southern Sargasso Sea as described by VERHIES and HERSEY (1964).

General resemblance between the predicted and observed features lead us to suspect that the seasonal wind-stress structures might essentially be responsible for these widespread occurrence of the eastward flows at lower subtropical latitudes. The existence of troughs in the anticyclonic wind stress vorticity during some months of years is quite clearly found and is likely to provide a favorable condition for the east-going flow. This interpretation may be in a sense similar to that for the Equatorial Countercurrent and perhaps also for the South Equatorial Countercurrent.

Discussion of Paper I:3

T. Lawarski: Further independent support to the results of Yoshida-Kitokoro can be offered from the Fleet Numerical Weather Central (Monterey) synoptic OCS Theta analyses (i.e., directional second derivative computations of synoptic sea surface temperature distribution). These analyses clearly show the subtropical countercurrents in winter halved of the oceans. However, these currents are quite variable and weak in some seasons.
Yoshida: I am pleased to see those substantial evidences shown to us, supporting our results. The agreement seems remarkable.

Lacombe: A zone of easterly current was found, with OKE measurements, in the Indian Ocean, between latitudes 12° and 18° South, in March.

Yoshida: The similarity between your direct measurements and our prediction in the Indian Ocean appears very encouraging.

J. Reid: I have tried sometimes to explain the existence of South Equatorial Countercurrents in the Pacific and Atlantic Oceans in terms of zonal wind stress. At that time the wind stress data were tabulated at five degree intervals of latitude. This seemed too coarse to show the existence of such narrow currents with any confidence.

Yoshida: It is true that the wind stress data are not detailed enough to demonstrate such narrow currents. However, somewhat averaged features could well be found even from these wind stress distributions. Of course, the detailed structure of the flow can hardly be calculated. The subtropical countercurrents should occur on the equatorial side of the calm belt near the boundary between the Westerlies and the Trade Wind Zone, which can relatively well be defined from these smoothed wind stress distributions.

M. Uda: I would like to add some comments based on our recent studies (in the NW Pacific Ocean): 1) In the upper layer (0-50 m depth) there is mainly a wind driven circulation superimposed on geostrophic currents as Dr. Yoshida emphasized. 2) In the 50-300 m depth, deeper subtropical countercurrents seem geostrophic and exists the entire year. 3) The velocity of NW Pacific subtropical countercurrent 0.1 - 1.2 knot and has an average eastern component of 0.6 - 0.7 knots. The transport is about 1/10th of Kuroshio Current between 20° - 25°N. The current is centered at 22 - 23°N along the 22 - 23°C isotherm line at 100 m depth.

Yoshida: Our present interpretation as a wind-induced transport may not contradict with Uda's view of a geostrophic balance, but probably Dr. Uda and we are talking about the same thing.

I-4. ANALYSE DES COURANTS SUPERFICIALS ET SUB-SUPERFICIALS DURANT UNE PERIODE DE 8 JOURS A 170°E


Une série de stations hydrologiques, effectuées dans l'océan Pacifique du 21 au 30 novembre 1965 par le navire océanographique "CORIOLOIS" en un point fixe à l'équateur et à 170°E, a montré l'existence d'une structure complexe des courants ainsi qu'une évolution importante dans le temps à la fois des intensités et des directions de ces courants.

L'analyse du courant moyen note que le long d'une verticale, la circulation n'est pas zonale et que le courant varie avec la profondeur tant en direction de la surface et 50 m de profondeur a tourne ensuite vers l'est pour être franche d'est à 100 m ; entre 100 m et 150 m il est orienté vers le sud pour être de sud-est à 150 m ; la profondeur augmentant il portait de nouveau vers l'est avec un noyau d'est franc à 220 m. A 100 m de profondeur le courant d'est était maximal ; la vitesse du courant dans les deux noyaux d'est était plus grande le soir que le matin, 0,9 noyade contre 0,6 noyade, alors qu'à 150 m elle semblait être constante. La variation de la direction avec la profondeur était plus importante le matin que le soir ; les directions s'inscrivaient dans un angle de 120° le matin autour de la direction moyenne, le soir l'angle était de 20°.

Il est particulièrement intéressant de remarquer que le ralentissement matériel du courant d'est dans les deux noyaux était associé à une intensification de la composante sud du courant à 150 m, c'est-à-dire à une rotation vers le sud, sa vitesse restant constante.

Bien que les variations ainsi décrites présentent un caractère cyclique indéniable, la fréquence de nos mesures n'a pas permis de préciser la période principale de ces évolutions. Cependant des renseignements ultérieurs laissent supposer une période voisine de 12 heures. Cette fréquence est égale à la fréquence fondamentale des ondes internes étudiées lors de la même croisière.

Discussion of Paper I-4

Bruce A. Taft: The double maximum in current velocity described at 170°E resembles some profiles made in the Indian Ocean on the western side of the ocean in 1963. These profiles showed a maximum current in the upper layer but the eastward transport in the two layers was approximately equal.

I-5. FURTHER RESULTS ABOUT EQUATORIAL UNDERCURRENTS IN THE ATLANTIC


I-6. EXPERIMENTAL AND THEORETICAL INVESTIGATIONS IN A LABORATORY F-PLANES OCEAN MODEL

D.J. Baker, Jr. and A.R. Robinson, Pierce Hall, Harvard University, Cambridge, Massachusetts, U.S.A.

A laboratory model ocean has been constructed following the strict geometrical constraints necessary to approximate the description of fluid flow in spherical geometry by the F-plane. The homogeneous fluid is confined in a basin of radius 20 cm in a thin spherical shell of radius 95 cm and thickness
I18. THE WIND AND DENSITY DIFFERENCES AS CAUSE OF CIRCULATION


A very simple fluid system is presented in which both wind stress and density difference produced by heating and evaporation are permitted to produce circulation. It is found that under certain conditions the equilibrium solution for steady circulation is not unique and that finite perturbations of the system can change the stable state to another under constant external driving. Stochastic initial conditions produce a non-uniformly dense class of solutions. There is a mechanism for producing T-S relationships, and extremely non-linear response to fluctuating driving terms.

Discussion of Paper I18

Scholl: The Eastern Boundary Current is a product of wind stress and density differences. What special case of your model is it?

Stommel: I think a satisfactory theory of Eastern Boundary Currents has not yet been developed.

Welander: In a similar problem (a tube-circulation driven only by heating and cooling) it has been found that all steady state solutions may become unstable and the system carries out relaxation oscillations or a more complicated random motion forever. Does something similar happen in your model?

Stommel: We looked for ways of getting oscillations in our model and did not find them.

Isaac: The North Pacific appears to behave in some ways that qualitatively resemble the simple model described. By several criteria, large regions of the North Pacific that are of higher or lower temperature than "normal" are broader than regions of "normal" temperature. Normal temperature appears to be transient between more persistent or stabler regimes.

Stommel: No comment

I19. A THEORY OF COMBINED WIND-DRIVEN AND THERMAL OCEANIC CIRCULATION

Pierre Welander, Oceanografiska Institutionen, Göteborg, Sweden

An Ekman-type, two-layer model of the wind-driven circulation, including the f-effect and the topographic effect, predicts motion in the upper layer similar to the uniform depth model by Stommel (1948). In the lower layer the motion is confined to the western boundary region, in the normal case where \( \frac{f}{B} \ll 1 \). {f is the Coriolis parameter, \( B \) the depth, \( y \) a northward coordinate.} A weak gyre that connects to the boundary region by a free jet is found in any interior region where the \( f/B \)-contours are closed. In the North Atlantic Ocean such a region exists near the Azores.

Introducing a thermal circulation in the form of a concentrated, polar sink region and a general upwelling elsewhere, as suggested by Stommel, one has to add a poleward boundary current in the upper layer and an equatorward boundary

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current in the lower layer. Moreover, a strong gyre and an associated free jet must be added in the lower layer, in the region of closed f/ω-contours. The details of the total circulation are worked out in a few cases for the North Atlantic, varying the coefficient of friction and the magnitude of the upwelling velocity. It is suggested that the deep gyre at the Azores and the jet that connects this to the western boundary should be an observable feature of the North Atlantic circulation.

I:10. A MODEL OF THERMOLINE CIRCULATION

G.T. Needler, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada

A steady-state model is presented for the interior region of an unbounded ocean driven from the surface by differential heating and the convergence or divergence of the Ekman layer. For the case that the density is taken to vary exponentially with depth, a solution is presented which satisfies boundary conditions on the surface below the Ekman layer and on the ocean floor. For the case that the characteristic depth of the thermocline is much less than the depth of the ocean, a relationship is given between the characteristic depth, the east-west temperature gradient, the Ekman velocity and the asymptotic vertical velocity is directed upwards.

The solutions are examined for an ocean of finite depth for which the normal component of velocity at the bottom is zero. For this case it is found that the vertical scale and surface temperature were specified, there is some freedom in fitting the Ekman velocity. This is done by adding to the system a barotropic velocity field which follows bottom temperature contours. This field may be chosen in such a way that the vertical velocity at all depths is directed to the bottom - a result which is in contrast to the conclusions of previous boundary-layer models for the thermocline.

I:11. A NUMERICAL STUDY OF TRANSIENT ROSSBY WAVES IN A WIND-DRIVEN HOMOGENEOUS OCEAN

W. Lawrence Gates, The RAND Corporation, Santa Monica, California and University of California, Los Angeles, California, U.S.A.

The primitive hydrostatic equations for a rectangular homogeneous ocean with a free surface on the f-plane are integrated numerically for 60 days from an initial state of rest and undisturbed depth of 400 m. A zonal wind stress simulating the steady mid-latitude wind regime and a lateral eddy viscosity (10^8 cm^2 sec^-1) are assumed. A series of transient Rossby waves of approximately 2000 km length form in the central and eastern portions of the basin and undergo amplitude, speed and shape modulation as they propagate westward at about 1 m sec^-1. The northwest boundary current in the west (about 1 m sec^-1) and the offshore countercurrents (about 10 cm sec^-1) in the northeast may be identified as the first stationary members of a continuing series of waves, with subsequent transients showing characteristics of reflected Rossby waves and remote equatorial westward propagating waves with smaller maximum amplitudes. The standing wave pattern (wavelength about 600 km) in the northwest is a characteristic non-linear effect associated with a characteristic meridional asymmetry or tilt of the axes of the waves such that the waves move in a (non-linear) northward eddy transport of zonal momentum, much in the manner of their atmospheric counterparts. After a spin-up period of about 12 days, the total potential and kinetic energy display damped oscillations with the basin's free period (16 days), which may also be identified with the period of the dominant transients. Rossby waves reach progressively smaller amplitudes at positions progressively farther from the western shore, after which they decay and are eventually absorbed into the southern portions of the western boundary current or countercurrent. Transient meridional currents as large as 6 cm sec^-1 are present in mid-ocean as late as 60 days, however, and a completely steady state evidently requires somewhat longer to be achieved. Near geostrophic equilibrium is maintained throughout, with a meridional Ekman flow of the order of 1 cm sec^-1.

Discussion of Paper I:10

Gates: In no experiment performed to date has the wind stress suddenly been turned off. It seems likely, however, that there would be a slow decay of the western boundary current system, along with the presence of the damped Rossby wave regime.

Brockeler: Measurements over the past several years in the North Atlantic of sound velocity and temperature seem to reveal incident and reflected Rossby waves but their wavelength is about 500 km and not 1000 km. Can your model explain these?

Gates: The shortest (reflected) Rossby waves in the present model are close to 1000 km than to 500 km in length. This wavelength depends upon the orientation of the reflecting boundaries and upon the mean ocean depth (divergence effect), and could conceivably be lowered to nearer 500 km by these effects. Standing waves in the presence of an eastward zonal current will also decay of the order of 600 km in the present model, as are baroclinic or internal planetary waves. The observations would, therefore, appear to be within the domain of generalized oceanic Rossby waves, of which the present theory is the simplest case.

I:12. TWO-LAYER NONGEOSTROPHIC MODEL OF BAROCLINIC INSTABILITY IN ATMOSPHERE AND OCEAN


Small nongeostrophic wave disturbances superimposed on the simple two-layer Margules flow are considered. Internal gravity waves are eliminated by means of special filter approximation. The finite width of the flow, arbitrary depths of the layers, f-effect are taken into account. It is shown, that instability region is confined to a certain range of vertical velocity shear, and in this direction our results are near to those of Arakon for continued model. In other aspects the considered problem is certain generalization of the Phillips model. The instability diagrams are calculated.

I:13. A LINEAR MODEL OF THE ANTARCTIC CIRCUMPOLAR CURRENT

A.E. Gill, C.S.I.R.O. Marine Laboratory, Sydney, Australia (U.K.)

A bottom-friction wind-driven model of the Antarctic circumpolar current is examined. The geometry includes what are thought to be the main features affecting the current, namely a gap corresponding to Drake Passage and a partial barrier
Potential density, in which density is calculated from the in situ temperature and salinity values moved adiabatically to sea-surface pressure, has been useful in defining mixing surfaces for shallow water. However, deeper water can use a deeper reference pressure, for example 4000 dbaths, and call the density parameter \( \sigma_r \). This quantity increases monotonously downward to near the bottom of the water masses. It rises so far from its reference pressure that it probably loses its usefulness as a representation of a mixing surface. Instead, the isopycnals rise to near the bottom of the water masses. This rise is often due to the influence of the bottom of the ocean, which is often referred to as the isopycnal line or the isopycnic line. In this way one might be able to trace the water masses from one to another through the Antarctic Circumpolar Current, where the density variations of the water masses are so great that any single reference pressure can be seriously misleading.

Discussion of Paper 1:15

M. Doo: Can you correlate the movement or formation of deep water on potential density surfaces to the distribution of dissolved oxygen?

Reid: I believe that oxygen will be very useful in verifying and augmenting the results of this sort of examination. It seems important to estimate the amounts first from temperature, salinity, and density without consideration of other variables and then to test the estimates with such other properties as have been measured.

1:16. ON THE DEEP WATER MASS AND CIRCULATION OF THE NORTH ATLANTIC

L.V. Worthington and W.R. Wright, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

The potential temperature/salinity relationship of the cold water (\(< 1^\circ\)) throughout the North Atlantic is described on the basis of oceanographic data obtained during an eight year period centered around the International Geophysical Year of 1957-1958. The five main existing sources of deep and bottom water are delineated and estimates are made of the amount of water contributed by each source, substantiated, where possible, by direct current measurements. A cold water circulation budget for the North Atlantic based on the O/S distribution, dynamic computations and recent deep current measurements is offered.

1:17. CIRCULATION OF THE NORTHWEST PACIFIC OCEAN AS DEDUCED FROM ISOSTATIC ANALYSIS

S. Tabata, Pacific Oceanographic Group, Nanaimo, British Columbia, Canada

An examination of the circulation of the northeast Pacific Ocean is made, based on oceanographic data collected during 12 cruises between 1955 through 1962. In general the circulation pattern obtained from the use of isotopic analysis is similar to that based on geostrophic flow; however, in detail it
differs, particularly with respect to the shape of eddies and meanders that are present in the region. In addition to the large cyclonic eddy of the Alaska Gyre area; anticyclonic eddies lying between Chenega Trough and Station P, and west of Vancouver Island. Cyclonic eddies between Station P and Vancouver Island and also between Kodiak Island and Chichagof Island and an anticyclonic eddy just west of Chichagof Island occur frequently.

Due to the influence of these eddies or meanders, there appears to be a semi-permanent area where more defined transport can occur. Offshore transport of warm, low-oxygen water, characteristic of water lying adjacent to the Pacific coast of Canada and U.S.A., occurs off Chichagof Island, off Queen Charlotte Island, and to some extent, off Kodiak Island and Alaska Peninsula. The latter can be considered as part of cyclonic eddies on the Alaska Current. Cold, high-oxygen waters lying between the warm waters are transported inshore.

A rise of temperature on the surface occurred at Station P during 1957-1958 and again in 1959-1960. In the former the dissolved oxygen content increased and in the latter it decreased. It is concluded that the warming during 1957-1958 is associated primarily with the northeastward transport of oceanic water, but the 1959-1960 warming appears to be due to westerly transport or water from the coastal region.

Amongst the interesting points evident in the data are:

a) During all winters flow adjacent to the Pacific coast of Canada is northward.

b) A large U-shape meander frequently occurs north of Station P.

c) A reversed flow (eastward) occurred off Kodiak Island in 1958 due to the influence of a large anticyclonic eddy off the Island.

d) A cell of warm, low-oxygen water present to northeast of Station P during the summers of 1958 and 1969 is believed to be water of coastal origin that has subsequently been pinched off by intrusion of cold water from the west.

e) Recognizable changes in circulation can occur in a period of three months as compared to data from Spring and Summer of 1959 indicates.

A sampling program designed to examine the development and decay of eddies or meanders by concentrated surveys in relatively small areas appears desirable.

1:18. CYCLONIC EDDIES FORMED FROM MEANDERS OF THE GULF STREAM

F.C. Puglister, Woods Hole Oceanographic Institution
Woods Hole, Massachusetts, U.S.A.

Cyclonic eddies formed by meanders breaking away from the Gulf Stream were observed on the Sargasso Sea during longshore cruises from early September, 1965, through late February, 1966. Two distinct eddies of this type were found on nine separate occasions in Lats. 35-39°N, Longs. 60-69°W. Although the eastern eddy was always distinctly larger than the western, the radial of both diminished at about the same average rate (1/3 km/day); extrapolation suggests life spans for these eddies of about one year. Shortly after breaking away from the Straits, both eddies lost rapidly 12-13 cm/sec westward, but after the first month of observations their paths become highly erratic, with no movement toward the southeast. Despite these common features, it is not fully certain that the same pair of eddies was located on all cruises. The maximum surface speed in the eddy was close to 150 cm/sec, with no decrease in speed apparent during the entire period of observation.

The path taken by an eddy formed in March 1967 is described. This eddy is tagged with drogues attached to parachutes at 100 m depth and the trajectories of the currents in the eddy are shown. The eddy is still being followed at the time of this symposium.

Discussion of Paper 1:18

M. Uda: a) Have you studied the relationships between the formation or development of eddies and the passage of atmospheric disturbances?

b) We noticed such eddies in the polar frontal zone (along Kuroshio and Oyashio Fronts) are associated with high biological concentrations (fishes, etc.). What was the biological activity in your eddies?

F. Puglister: a) I have not made this study.

b) We have not yet measured the biological concentrations.

B.A. Taft: Do these eddies extend to the bottom?

F. Puglister: I believe that the eddies do extend to the bottom when they are first formed because I believe the Gulf Stream in this general area reaches to the bottom. We have the evidence of deep floats showing that, after three months, the eddies not extend to the bottom but to perhaps 3000 m.

1:19. THE MOVEMENTS OF SEA-BED AND SEA-SURFACE DRIFIERS RELEASED IN THE IRISH SEA 1965-66

J.G. Harvey, Department of Physical Oceanography, Marine Science Laboratories, Menai Bridge, United Kingdom

Approximately 500 sea-bed and 500 sea-surface drifters were released in the Irish Sea on each of four occasions at about three-monthly intervals. The sea-bed drifters were the standard Woodhead sea-bed drifters; the sea-surface drifters comprised drogues, identical to those used in the sea-bed drifters, suspended 65 cm below a small float. The overall return rate of each type of drifter has been about 34%, with significant seasonal variations in return rates being found. Charts are presented showing the general pattern of movement of each type of drifter from each series of releases. Some similarities between the movements of sea-bed drifters released in the different seasons are noted, contrasting with the marked differences between the movements of sea-surface drifters released in the different seasons.

The movements of the sea-bed drifters are found to bear little relationship to the bottom topography, but in some instances are similar to the flood and ebb tides. The movements of the sea-surface drifters are shown to be closely related to surface motions. When the wind blows from between south and west the sea-surface drifters tended to move to the left of the wind, whereas when it blew from between west and north or from between east and south they tended to move to the right of the wind. It is suggested that these deviations are due to their being deflected along the coasts. The wind factor, k, was apparently greater when the wind blew from the south than when it blew from the north, and this is attributed to a northerly flowing residual current in the surface layers of the Irish Sea. When this effect is eliminated the value of k for the design of sea-surface drifters used appears to lie between 1.5 and 2.0.

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The effects of wind, wave motion and friction on drifters are considered, and the extent to which either sea-bed or sea-surface drifters may be used to determine residual water movements is discussed. Comparisons are made between the movements of the standard sea-bed drifters and the movements of small numbers of drifters with drogues 2-1/2 m above the sea floor which were released simultaneously, and also between the standard sea-surface drifters and small numbers of drifters with drogues 2-1/2 m below the sea-surface, and reasonably close agreement is found in each case. Attention is drawn to the marked vertical shears in residual currents which must exist at intermediate depths in the Irish Sea if the drifters do represent actual water movements at the depths at which their drogues are located.

Discussion of Paper 11:19

Tomczak: When comparing wind direction and drifting of drogues it might not be sufficient to use the starting and the end point of the drogue, especially when the drogue goes along a coast because a small wind perturbation of some hours will result in a large scatter of the points of retrieval. The true value may certainly be calculated from the drogues which moved farthest.

Harvey: I agree that it is not entirely satisfactory to use the starting and the end point of every sea-surface drifter's trajectory in comparing their movements with the wind. The main sources of error are, I think, that drifters might become entangled with obstacles, or lie on a beach unfound, for some time before recovery. It is to allow for this that I have used the upper quartile values of $K$ as the best estimates available of the true values of $K$. I do not think that a true value would have been obtained by considering only the sea-surface drifters which moved farthest.

Britton: What evidence is available to indicate that the effect of the surface float is negligible? How much of the float is out of the water?

Harvey: In calm conditions less than 2 cm of the surface float protrudes above the water surface. Taking account of the relative size and shapes of the surface floats and the subsurface drogues it would seem that the drag exerted on the float even by very strong winds would be insufficient to move the subsurface drogue through the water at a significant velocity.

Tabata: What technique was used to recover the drifters?

Harvey: We relied on the general public to find them on beaches and fishermen to recover them at sea, and paid a small reward for their return.

1:20. THE OCEANIC CIRCULATION PATTERN OFF SOUTH AFRICA

L.V. Shannon, South African Division of Sea Fisheries, Pretoria, South Africa

During the past seventeen years the Division of Sea Fisheries has conducted extensive hydrological observations in the waters within two hundred miles of the South African coast. The results of these investigations have been augmented by expeditions into the Indian and Atlantic Oceans, covering the area between latitudes 20°S and 47°S and longitudes 2°E and 56°E. These cruises have added materially to our knowledge of oceanic circulation around South Africa.

The near-shore region comprises the Agulhas and Benguela Current systems. The Agulhas Current, characterized by surface temperatures and salinities of 22°C - 25°C and 35.2 o/oo - 35.5 o/oo respectively, flows in a south-westerly direction along the East Coast. The main body of this current varies in width from 20 to 100 miles. Although surface velocities are generally between one and two metres per second the Agulhas Current is not merely a surface phenomenon but extends to considerable depths. The Benguela Current, which is generally associated with cool, upwelled water on the West Coast, flows in a northerly to north-westerly direction at about 25 to 30 cm/sec. The current is, variable both in direction and speed. Upwelling along the West Coast is dependent upon latitude and season.

The off-shore area can for the sake of convenience be divided into the South-west Indian Ocean, the Subtropical Convergence, the Sub-Antarctic region, the Agulhas-Atlantic Mixing Area and the South-east Atlantic.

In the off-shore region of the South-west Indian Ocean, the presently available data show little evidence of well defined surface currents. Subtropical Surface Water, Subsurface Water, Indian Central Water, Antarctic Intermediate Water, Deep Water and Bottom Water were present in this region. Subsurface currents were detected at a depth of circa 200 m north of 30°S. Central Water was found as a layer of linear S/S relation, separating the Subsurface from the Intermediate layers, and moving sluggishly northwards. The Antarctic Intermediate Water, characterized by a salinity minimum of circa 34.4 o/oo moved slowly northwards at 900 m - 1300 m; part of it was apparently deflected and flowed south-westerly in the vicinity of the Agulhas Current. Deep Water, characterized by a salinity maximum of circa 34.8 o/oo, penetrated eastwards into the Indian Ocean from the Atlantic. North Indian Deep Water (34.70 o/oo), moving southwards, overlaid the Atlantic Deep Water.

The Subtropical Convergence was present at about 42°S. Surface temperatures across the Convergence dropped southwards by as much as 10°C in 50 miles, accompanied by a salinity decrease of 1.7 o/oo. In the Subantarctic region surface temperature and salinity ranged from 4.2°C to 7.5°C and 33.60 o/oo to 33.92 o/oo respectively. The cold water of formation of Central Water was present near the Subtropical Convergence was clearly evident. Circulation patterns around the Convergence were, however, complex and difficult to resolve.

Separating the Indian and Atlantic Oceans is a zone of mixing. Numerous eddies extending to depths in excess of 1000 m were observed in this region. These eddies, apparently associated with the numerous seamounts in the area, had the effect of altering the shape and position of the Subtropical Convergence.

The water masses present in the South-east Atlantic were similar to those in the Indian Ocean. Evidence was obtained that eddies formed in the mixing zone move bodily into this region before finally petering out. Hedges and seamounts here had a pronounced effect on circulation and the distribution of water masses. Observations made in the South-east Atlantic were in good agreement with those made by the Discovery and Meteor about 25 years ago.
I:21. WATER EXCHANGE BETWEEN THE ADRIATIC AND EASTERN MEDITERRANEAN

Mira Zage-Armanda, Institute of Oceanography and Fisheries
Split, Yugoslavia

The relation between two basins, the smaller (continental) and the larger (more maritime), is considered. Several factors affect simultaneously the continental character of the Adriatic which result in a specific seasonal rhythm of the water exchange with the eastern Mediterranean. In summer the Adriatic gives lighter water to the surface layer, it receives the heavier in the intermediary and perhaps gives still heavier water (formed earlier) to the bottom layer. In winter the Adriatic receives lighter water in the surface and intermediary layers, and gives the heavier to the bottom layer. Such seasonal fluctuation of the character of water exchange is intensified still more by the system of winds and the distribution of air pressure in winter and summer over the central and eastern Mediterranean. Two predominant winds, NW in summer and SE in winter, have a rather analogous course with regard to the surface water movement, and besides intensifying the seasonal characteristics of water exchange it can be considered that they regulate the range of this exchange with their intensity.

The distribution of air pressure over the central Mediterranean passes also through the characteristic changes in the warm and cold periods. In summer it is characterized mostly by the meridional (lower pressure in the east) and in winter by the zonal (lower pressure in the west) course of isobars. It seems that in summer this low pressure "sucks in" the surface water in the Levant, and in winter in the Adriatic. Thus in the surface layer of the central Mediterranean the well known S stream prevails in summer and N stream in winter. This means that in the water exchange between the Adriatic and the Ionian sea in the surface layer SE stream prevails in summer and NW in winter. In the central Mediterranean the circulation in summer is such that the surface S stream is compensated by the W stream in the intermediary layer (in the water exchange between the Adriatic and the Ionian sea the corresponding directions are SE and NW). In winter N and NW streams in the surface and intermediary layers are compensated by the S and SE streams in the bottom layer. The maps of isohalines from surface and 300 m, for the winter and summer periods, prove such dynamic conditions.

II. SYMPOSIUM ON THE CURRANTS OF THE INDIAN OCEAN, IN RELATION TO THE MONSOONS

Convener: G. Dietrich 20 September 1967

The following papers were given:

(Chairman - Hakon Mosby)

(Chairman - J.C. Swallow)
3. B.A. Warren (U.S.A.) A Hydrographic Section off Somalia Occupied at Three Stages of the Monsoon Cycle
4. W.S. Wooster (U.S.A.) Seasonal Changes in the Upper Kilometre of the Western Arabian Sea
5. R.L. Smith (U.S.A.) The Horizontal and Vertical Field of Motion along the Southeast Arabian Coast During the Southeast Monsoon
7. J. Swallow (U.K.) Some Observations on the South Equatorial Current in the Western Indian Ocean in 1964
8. F.P. Anderson (South Africa) Time Variations in the Agulhas Current off Natal
9. K.G. LaFond and E.C. LaFond (U.S.A.) Spring Circulation in the Bay of Bengal
11. K. Wyrński (U.S.A.) On the Analysis and Classification of Water Masses in the Indian Ocean
Ten years ago a resolution was passed to carry out the International Indian Ocean Expedition (IOE). In 1957 the Comité de l’année géophysique internationale (CAGI) could state at a meeting in Gothenburg (Sweden) that the investigations within the frame of the International Geophysical Year (IGY) were going to be a great success. The nations were prepared for international scientific cooperation, only some stimulation was necessary. In Gothenburg the new idea of the IOE was discussed, and an organization was proposed. The Scientific Committee on Oceanic Research (SCOR) was responsible for the coordination until 1962, after which this was taken over by UNESCO.

The IOE took place from 1959 to 1965 with the cooperation of 20 nations with 40 research vessels. Up until now this was the most intensive engagement in marine science. When all observations have been worked up (this will take several years) our conceptions from the Indian Ocean will have changed in many ways. Even though this large expedition did not fulfill everyone’s expectations, the question remains whether this was due to wrong planning or to erroneous expectations. I believe we should not distinguish between right and wrong because we can only judge after knowing all the facts and circumstances. One cannot approach an immense undertaking in the field of science on a basis of military logistics. By nature scientists are more interested in specific problems, and less in large-scale synoptic surveys carried out in a routine style, which was not to be done just once, but to be repeated in each of the seasons. Hence the planning was meant to provide information and recommendations to potential participants, rather than regulations and specific directions.

The sea-going phase of the IOE ended December 1965. Dozens of papers have been published in the meantime, among them those which include the older data and knowledge from the beginning of the IOE (A.H. Murtae, 1959; J.M. Ovchinnikov, 1961; R. Veyem, 1957; D. Wyzek, 1961) and other papers which interpret the observations of the different expeditions. This number is increasing. Many publications are contained in the four volumes of the Collected Reprints of the UNESCO, others were communicated at the Second International Oceanographic Congress in Moscow in 1966. Today, 11 more speakers have asked to present their reports, for which I would like to give my whole hearted thanks. It cannot be my task to consider all reports which were published with regard to the Indian Ocean. J.C. Swallow has given in his morning lecture on the Second International Oceanographic Congress in Moscow, 1966, remarkable insight into three topics: first, the variable equatorial undercurrent in the Indian Ocean; secondly, the Somali Current; and thirdly, some hints on the deep circulation. I do hope that these reports will be published in the near future. Today I should like to restrict myself to two other topics to which I have some personal acquaintance. Concerning the observations obtained with R.V. “Meteor” at sea in 1964-65, and the working up at our institute in Kiel by G. Dietrich, W. Düing, K. Grasshoff, P.H. Koske, G. Krause, G. Siedler and J. Ulrich, by H.P. Schmidt at the German Weather Service, and by W.D. Schwill at our National Computer Center. Some of these contributions have been published in 1967, others will follow shortly. The two topics I would like to discuss are the water masses and the time dependence of the circulation of the surface layer, in respect to the Arabian Sea.

The results mentioned are based on the following reports:


12. Siedler, G. Schichtung- und Bewegungsverhältnisse am Südausgang des Roten Meeres. (Conditions of layering and water movements in the entrance of the Red Sea) "Meteor"-Forschungsergebnisse, Reihe A, 4. (In print)


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III:2. ON THE TEMPERATURE AND SALINITY STRUCTURE IN THE UPPER 2000 METERS OF THE ARABIAN SEA

G. Krause, Institut für Meereskunde der Kiel University, Kiel, F.R. Germany

During the Indian Ocean Expedition of R.V. "Meteor" in 1964-65 the spreading of water of the Red Sea was investigated off the Somali coast. Temperature and salinity were measured continuously as a function of the depth by a bathyprobe at every station. The original continuous data were smoothed using a running mean of 70 meters which eliminated fine-structure showing no spatial coherence between stations. This method allows hydrographic sections to be drawn which show the main structure horizontally and vertically of temperature and salinity. There are large differences between the averaged sections and those obtained by hydrographic casts.

Besides the smoothing of data it was also necessary to make a new definition of a water mass which is based on a threshold value with respect to the surrounding water masses. Based on this definition the spreading of water of Red Sea origin into the Arabian Sea was discussed. The results are:

1) The main outflow of the Red Sea water is concentrated within a distance of 350 km off the Somali coast.
2) The direct influence of Red Sea water downstream ends near the equator.
3) It is suggested that spatial variations, found from section to section, are due to meandering of the flow.

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4) The water which is influenced by the Red Sea outflow is separated from underlying water masses by a sharp discontinuity layer, the vertical gradient of which increases with distance from the source. The explanation is based on the loss of energy of the flow.
5) The continuous records very often show two well defined temperature and salinity maxima at depth. There are two possible explanations:
   a) There is a distinct stratification of the overflow at the strait of Bab el Mandeb with Arabian Sea water above flowing into the Red Sea and an underlying layer of Red Sea water flowing into the Gulf of Aden. The periodic mixing of the two water types due to the tides is proposed as a mechanism for the formation of the two maxima in temperature and salinity observed along the Somali coast.
   b) The effect of bottom topography in the inner Gulf of Aden causes the outflow to be divided into two arms of nearly equal water transport. The southern part of the outflow takes place in a large area, the northern one in a very small channel with no lateral mixing. The two arms have a different history which will cause two layers of different densities further downstream.

As measurements of the Mediterranean outflow have shown also two or three maxima at depth; it is supposed that the first explanation is more probable.

III:3. A HYDROGRAPHIC SECTION OFF SOMALIA OCCUPIED AT THREE STAGES OF THE MONSOON CYCLE

Bruce A. Warren, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

Hydrographic stations were occupied by the Argus, Meteor, and Atlantis II along a nearly common line running out from the coast of Somalia, during the southwest monsoon and the early and late stages of the northeast monsoon, in 1964-65. The profiles of temperature salinity and dissolved-oxygen concentration are examined for evidence pertaining to possible reversal of flow at intermediate depths, matching that at the surface. The water in the central Somalia Basin appeared much the same during both monsoons; on the section from the southwest monsoon, however, the mid-depth water close against the continental slope was distinctly fresher and higher in oxygen than that further offshore, while on both sections from the northeast monsoon the inshore water was both more saline and lower in oxygen than that offshore. Reference to the general distribution of properties in the Indian Ocean indicates that this change is compatible with penetration down at least to intermediate depths of the seasonally reversing current-system of the northeastern Indian Ocean.
An analysis has been made of approximately 1500 oceanographic stations from the Arabian Sea in a study of seasonal changes of possible importance to fisheries of the region. Data were combined in the form of quarterly charts (1) at the surface, (2) on surfaces of equal specific volume anomaly at intermediate depths, and (3) on the 1000 m level surface; at the surface and 1000 m all data were used as individual values while for the isentropic charts, characteristic curves were averaged by 2-1/2 degree squares.

During the northeast monsoon, a southward surface current is present (December through February) along the Somali coast south of 8°N, with mean speeds of approximately 100 cm/sec. During this season, lowest surface temperatures are found in the north and extend farthest south along the western boundary, as do the high salinities of the northern Arabian Sea; surface nutrients are everywhere low. During the southwest monsoon, surface flow reverses along the Somali coast, the northward flow reaching its maximum in July with an average speed exceeding 250 cm/sec. Lowest surface temperatures are now off the Somali and Arabian coasts, relatively low salinity water extends northward along the western boundary from the equatorial region, and surface nutrients reach extreme values in isolated regions off Somalia and Arabia.

Below the surface on the isentropic surface of \( \sigma-t = 300 \) (equivalent to \( \sigma-t = 24.96 \)), the change from winter to summer is evidenced by a pronounced decrease in depth, the presence of low salinity water, and surface increase of oxygen concentration along the western boundary. On the deeper surface of \( \sigma-t = 100 \) (equivalent to \( \sigma-t = 27.07 \)), the same changes are much less evident but can still be detected.

The 1000 m surface is generally considered to lie far below the influence of seasonal surface effects. Even here, the winter period is associated with some evidence for southward penetration of warm, saline and low oxygen water from the northern Arabian Sea. At this depth, onset of the powerful southwest monsoons does not seem to be so influential as the relaxation and southwest flow that accompanies its cessation.

**III:5. THE HORIZONTAL AND VERTICAL FIELD OF MOTION ALONG THE SOUTHEAST ARABIAN COAST DURING THE SOUTHEAST MONSOON**

Robert L. Smith, Department of Oceanography, Oregon State University, Corvallis, Oregon, U.S.A.

Under the assumption that the horizontal motion is composed of (1) a geostrophic flow prescribed by the slope of the sea surface and the density distribution and (2) a Ekman flow in the surface layer, the horizontal and vertical field of motion along the SE Arabian coast during the SW monsoon is computed. Using data from R.R.S. Discovery Cruise I, which surveyed the SE Arabian coast upwelling region in June to August 1963, the relative geostrophic and Ekman transports are computed. The topography of the sea surface, which is necessary to compute the absolute transports, is found by the method Wyrski used in his study of the Peru Current upwelling region (Scripps Inst. Oceanography Proc. 33-346, 1963). This method equivalently defines levels of no motion and the levels found are compared with those determined by Burstein's method. The level of no motion in the southern part of the region is between 900 and 1000 db, the two methods being in agreement. In the north the agreement is less good. The wind stress computed from the shipboard wind velocity observations using the usual square law are in good agreement with those computed by Zilakas for this region in Japan (Ats 77-123, 1958). Coastal upwelling occurs along 1000 km of the coast and may amount to as much as \( 10^5 \text{ m}^3/\text{sec} \).

**III:6. EQUATORIAL UNEPERCURRENT OF THE INDIAN OCEAN AND ITS RELATION TO MONSOON PHASE**

Bruce A. Teff, Scripps Institution of Oceanography, La Jolla, California, U.S.A.

Subsurface current measurements along the equator by Argo and Discovery show the Undercurrent was present during two periods: March-April 1963 and March-June 1964. The observations suggest that the Undercurrent occurs at the end of the northeast monsoon and under certain circumstances persists into the early period of the southwest monsoon. Establishment of the Undercurrent during the northeast monsoon may lag the time of set up of the surface Northeast Monsoon Current by about 3 months. Time required for set up of the Undercurrent is less than 45 days.

The Undercurrent on the western side of the ocean was much stronger in 1964 than in 1963 and it also persisted longer into the year. Wind measurements reported to the Indian Meteorological Centre in Bombay during 1963 and 1964 show that in phase between northeast and southwest monsoons on the western side of the ocean occurred in April of both years. The winds during the first six months of 1964 were somewhat stronger than in 1963, but there was not a significant difference between the years in the relative size of the meridional and zonal components of stress. At the present time, the observed difference in the Undercurrent of 1963 and 1964 cannot be explained by existing theories of the Undercurrent.

**III:7. SOME OBSERVATIONS OF THE SOUTH EQUATORIAL CURRENT IN THE WESTERN INDIAN OCEAN IN 1964**

J.C. Stalhouse, National Institute of Oceanography, Worlley, Surrey, United Kingdom

North-south sections were made in longitudes 56°E and 67.5°E by the R.R.S. Discovery in March-April 1964. Parts of these sections were repeated in June-July of the same year. Although there is clearly a seasonal increase in westward transport in the upper-surface layers, it is not easy to estimate its magnitude. In the 0-200 decimetric layer, between latitudes 7°S and 15°S, the increase in westward transport appeared to be over 50% when calculated relative to 1000 decimetric, but was less than 20% when calculated relative to the bottom. Using available deep current observations as reference velocities, the increase in transport appeared to be nearly 30%.
Vigorous movement was apparent to depths of at least 1000 meters, and there were significant differences between the repeated sections, but it is not clear to what extent these deeper changes may be seasonal.

In the sections at 67.5°S there was a shearzone at 10°S at intermediate depths (200-1000 meters) which was more clearly marked in June than in April, with eastward-moving water to the north of 10°S and westward movement in the southern part of the section. The column of low salinity water at these depths, designated "equatorial frontal water" by Rochford, was seen to be moving westwards, but its continued westward flow was limited to depths less than approximately 400 meters ($S_{e}$ less than 26.7) by the sill between Saya de Malts and Nazareth Banks.

Marked changes in transport at intermediate depths (200-1000 meters) occurred in the gap between Seyetelles Bank and Saya de Malts Bank. In March the flow there was strongly westwards; in July it was weak, and an Argos section on 59°S in September 1954 suggested strong eastward flow through this gap.

II:8. TIME VARIATIONS IN THE AGULHAS CURRENT OFF NATAL

F.P. Anderson, South African Council for Scientific and Industrial Research, South Africa

For some years now the Oceanography Division of the S.A. National Physical Research Laboratory has been exploiting the "free drift" method of measuring currents off the Natal coast. A locally made hyperbolic radio-navigational aid is run by the division to measure the drift of the vessel while relative currents are measured by a meter suspended at depths to 1000 meters. In addition to current speed and direction, depths and temperatures are measured and water samples are taken. Outputs on deck are in three forms viz., analogue, digital printout and punched paper tape. Extensive use is made of computer processing of data.

Early exploratory cruises across the Agulhas current showed large variations in speed and width of the current, while the western edge changed its position relative to the coast by up to 20 km. Between the current and the coast large eddies appear resulting in periodic reversals in current direction close to the coast.

Recent cruises have been planned to shed more light on the time variations in the current system and there is some evidence of a correlation between the current system and the atmospheric pressure gradient along the coast.

Confirmation of the complexity of the circulation off the Natal coast is confirmed by numerous airborne radiation thermometer flights.

II:9. SPRING CIRCULATION IN THE BAY OF BENGAL

K.G. LaFond and E.C. LaFond, U.S. Navy Electronics Laboratory, San Diego, California, U.S.A.

The circulation in the Bay of Bengal has been investigated on several cruises conducted by Andhra University; also on the first cruise of the K/An ton Bruin, made in Spring of 1963 in connection with the International Indian Ocean Expedition.

During the first part of the Anton Bruin cruise, the NE monsoon winds prevailed, resulting in peripheral upwelling along the Burmese coast. During the latter part of the 2-month cruise, upwelling developed along the east Indian Coast.

Other circulations in the Bay of Bengal are caused by tidal currents and result in tidal ranges in the northern part of the Bay of Bengal which are among the greatest in the world. Tidal current action across the continental shelf affects sediment sorting, with the coarser sediment found on the central outer shelf. Unusually high internal waves, manifested as tidal rips at the sea surface, were recorded in the Bay of Bengal and the Andaman Sea.

Horizontal and vertical circulations influence the chemical and physical properties of the water as well as the distribution of organisms. Upwelling, though short lived, also affects organic production in the Bay of Bengal.

II:10. EFFECTS OF MONSOONS ON THE VARIABILITY OF CURRENTS, WATER MASSES AND FISHERIES CONDITIONS IN THE EASTERN INDIAN OCEAN

Michitaka Udaka, Tokyo University of Fisheries, Japan

Seasonal and year by year changes of hydrographical conditions in the Eastern Indian Ocean were studied based on the data and maps in IOE (1959-65), Australia, Japan, U.S.A., U.S.S.R., in comparison to the monthly climatic maps and data obtained in the same period. Throughout the whole surveys we found a remarkable zone of discontinuity in the meridional section maps and horizontal distribution maps of water temperature, salinity, dissolved oxygen and nutrient salinity near the latitudes around 15°S in the Eastern Indian Ocean as a basic structure.

A considerable variation of distribution patterns of those oceanographic elements, particularly of the winter in 1963-64 compared to that of 1962-63, indicating the northward shift of current-systems and upwelling area of colder and lower saline water (affected by the Subantarctic Intermediate Water) in the zone between the southwardflowing of Sunda Islands and the Northwest coast of Australia, intercepted by the highly saline South Indian Ocean Water and the highly saline Northwestern Indian Ocean Water, and the southward expansion of lower saline water in the surface layer west to Sumatra. Such oceanographic changes correspond to the variation of wind-system and pressure-system over the Indian Ocean and Asiatic Continent. Variability of oceanic climate was illustrated by isotherms and salinohaline maps at meridional sections and horizontal levels above 600 m. depth.
Best fishing grounds of tunas are located along the marginal zone of the Equatorial Upwelling areas (5° - 10°S) limited by that Northwestern Indian Ocean Saline Water and the South Indian Ocean Central Water.

In response to the oceanic changes above mentioned the tuna fisheries since after 1963 turned to be improved from once declined situation of hooked rate.

II:11. ON THE ANALYSIS AND CLASSIFICATION OF WATER MASSES IN THE INDIAN OCEAN

Klaus Wyrtki, Department of Oceanography, University of Hawaii, U.S.A.

Existing methods to describe water masses are critically investigated. Wüst's core-layer method is found most suitable for subsurface water masses. Sverdrup's definition of central waters is criticized because it chiefly describes water within the main thermocline, represents mixing products, and disregards surface water masses. Surface water masses are at present not classified in any consistent way. A classification of surface water masses according to the climatic areas of their origin is given. The main classes are: tropical surface water, subtropical surface water, transition water, subpolar water, polar water. These main water masses are separated by the major frontal systems in the oceans, and their relation to the warm water sphere and the cold water sphere is discussed. This classification is illustrated on the example of the Indian Ocean.

III. SYMPOSIUM ON DEEP-SEA TIDES

Convener: N. Eyriès 29 September 1967

The following papers were given:

1. W. Munk (U.S.A.)
   Abyssal Arrays for the Study of Tides and Planetary Waves
   Chairman - M. Gougenheim

2. N. Eyriès (France)
   Dégrammages de grande profondeur
   Chairman - J.R. Roseoller

3. A. Easton and J. Radok (Australia)
   The Tides Along the South Coast of Australia

4. S.S. Voit (U.S.S.R.)
   (Paper given by R. Radok)
   Deformation of Long Waves with the Gradual Changes of the Basin Depth

5. N.S. Neaps (U.K.)
   Some Remarks on Tidal Theory and its Possible Relevance to a Program of Deep Sea Tidal Measurement
   A Practical Approach to Deep-Sea Tide Measurements Near the British Isles

   No abstract
   Body Tides, Fluid Tides and Ocean Currents in the Deep Ocean of the Coast of Northern California

7. A.A. Novozemski, M. Ewing and M. Flingel (U.S.A.)
   Tidal Wave in Deep Sea Channel with Variable Cross-section

8. A.V. Nekrasov (U.S.S.R.)
   (Paper given by N.C. Holmeshott)
III:1. ARYSSAL ARRAYS FOR THE STUDY OF TIDALS AND PLANETARY WAVES

W.H. Munk, Institute of Planetary Physics, University of California, U.S.A.

Serial measurements of pressure and velocity for times of the order of a month at deep sea stations are becoming possible. We shall discuss the use of arrays of such instruments for the purpose of studying tides and other long-period waves.

III:2. MAROGRAPHES DE GRANDE PROFONDEUR

M. Sylies, Service Hydrographique, France

Le phénomène de la maree, défini par les hypothèses qui lui sont spécifiques, obéit aux lois de l'hydrodynamique qui permettent d'écrit une nombre suffisant de relations entre les paramètres principaux qui sont: le champ des vitesses et la pression. La solution générale du système des équations est précisée par les conditions que ces paramètres principaux doivent satisfaire sur les surfaces limites du domaine, fond et parois continentales et surface libre de la mer. Le contrôle expérimental de la solution particulière, ainsi précisée, nécessite la mesure de ces paramètres principaux.

La mesure de la vitesse, du moins du "court" qui est sa composante horizontale, aux profondeurs les plus grandes est, sinon facile, du moins possible depuis déjà longtemps; par contre, celle de la pression au fond des océans est récente et fait appel à des méthodes technologiques modernes. Ce sont ces instruments qui sont décrits comparativement au point de vue:

- de l'organe détecteur
- de l'enregistrement
- de la mise en œuvre

Il s'agit, en particulier, des marographes mis au point aux États-Unis par le "Coast and Geodetic Survey" et l'"Institute of Planetary Physics" de l'Université de Californie, en France par l'Association pour l'étude des Grande Profondeurs Océaniques.

Si tous ces instruments utilisent le "centimètre d'eau" comme unité de mesure, il est clair qu'ils mesurent tous le paramètre principal Pression et non le paramètre secondaire Hauteur d'eau comme le font la plupart des marographes côtiers.

III:3. THE TIDES ALONG THE SOUTH COAST OF AUSTRALIA

A. Easton & R. Padoy, Horace Lamb Center Fluids University, Bedford, Australia

The South coast of Australia is predominantly zonal. It extends from 117°E at Albany to 147°E at Hobart between 31°S and 42°S. A wide continental shelf in the Great Australian Bight with a large section undisturbed by submarine canyons offers a unique opportunity for the study of the tides in the deep sea and on the continental shelf. Records from nine coastal stations were analyzed with a view to the design of such an experiment under close to two dimensional flow as is possible on the Earth.


III:4. DEFORMATION OF LONG WAVES WITH THE GRADUAL CHANGE OF THE BASIN DEPTH


This paper deals with the deformation of long waves on the shelf when the sea depth is decreasing gradually. The analytical solution has been obtained for the case when the basin depth is falling down according to the linear law. It is assumed that on the oceanic edge of the shelf $x = k$ the law of wave amplitude alternation is taken depending on the time, i.e. $x = f(t)$. Let's take the rectangular coordinate system where the origin $O$ is a point in the undisturbed surface, axis $Ox$ is directed along the coastline, axis $Oy$ is normal to the coastline, and axis $Oz$ is directed vertically downwards. The shelf boundary is parallel to coastline, and the basin depth in the points, determined by the coordinate $x$, is given as $h = h_0 + ax$ where $h_0$ is the basin depth at the oceanic edge of the shelf.

Assuming that water oscillations at the oceanic edge of the shelf begin at a certain time moment $t = 0$, i.e. $f(0) = 0$ with $t > 0$, and do not depend on $y$, we may get an elevation $z(x, t)$ in the form

$$z = \frac{1}{2\pi^2} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \exp(-i\lambda) \bar{\Phi}(m, x) f(s) d\lambda d\omega$$

where $w_0 = (g^2 + 4\omega^2)^{1/2}$, $1/\omega$ is the angular speed of the basin rotation, $f(s)$ is the Laplace transform of the function $f(t)$. The form of the function $\Phi(w, x)$ is determined by boundary conditions, for instance, if the depth of the basin is gradually decreasing to zero, the function $\Phi(w, x)$ may assume the form

$$\Phi(w, x) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \phi(z, m, \psi(x)) \frac{\sin \omega t}{\omega}$$

The analysis of this solution allows us to make a conclusion that the wave amplitude is increasing in the approaches to the coastline, and to determine the speed of wave propagation. Some particular cases are being investigated; one of them characterizes the establishment of the periodical regime. Furthermore, the problem is to be made more complicated after the introduction of some additional normal pressure forces, moving over the basin surface and simulating wind fields.

The second part of the paper deals with the propagation of waves over the shelf on the assumption that the oscillation amplitude at the oceanic edge of the shelf is being changed depending on the coordinate $y$. A number of special cases is being examined.
Co-tidal charts for the world oceans already exist and, in the main, have been derived from coastal observations by interpolation and using dynamical principles. In this work, the influence on the tidal regime of continental shelves, areas of high frictional dissipation of tidal energy, has not generally been taken into account. Also, tidal heights assumed along boundaries in the open ocean must inevitably be suspect. It is suggested, therefore, that in the forthcoming program of deep sea tidal measurement observations should be taken mainly, in the first instance, along the oceanic edges of shelf seas and along lines separating oceanic regions. Boundary values of tidal elevation, and possibly tidal current, would then be available for further applications of dynamical theory. Theoretical studies might be made using (1) the method of finite differences, which involves the solution of a system of linear algebraic equations, to find the tides at a network of points over the oceanic area in question, or (2) the theory in tidal dynamics proposed many years ago by Professor Proudman, which so far has only been applied to the Indian Ocean.

At the Tidal Institute work is being carried out to determine the distribution of the M4 tide over the northeastern European shelf, using the initial value method involving a numerical step-by-step procedure. It is hoped that this will throw more light on the tidal dissipation in the area, and the conditions on tidal elevation and current which apply along the oceanic boundary. Both of these matters are of relevance to the formulae of the deep sea tidal problem in the North Atlantic.

A PRACTICAL APPROACH TO DEEP-SEA TIDE MEASUREMENTS NEAR THE BRITISH ISLES

D.B. Cartwright, National Institute of Oceanography, United Kingdom

(No Abstract)

III.6.2

BODY TIDES, FLUID TIDES, AND OCEAN CURRENTS IN THE DEEP OCEAN OF THE COAST OF NORTHERN CALIFORNIA

Ali A. Nowroozi, M. Ring and M. Flegel, Lamont Geological Observatory, Columbia University, Palisades, New York, U.S.A.

Instruments are included in the Lamont Geological Observatory ocean bottom geophysical station for measurement of oceanic tides, current magnitudes, current direction, body tides (surface tilts), and changes in gravity. The station was implanted 100 miles WNW of San Francisco at a depth of 3901 meters in May 1966. From spectral analysis of 46 days of continuous data from these instruments, the amplitudes of various harmonics of tides and currents and their corresponding phase differences were estimated. Good correlation between water current amplitudes and tidal amplitudes is observed. Significant spectral peaks are found for both currents and tides corresponding to the O1, K1, N2 and M2 component. It is concluded that the measured ocean-bottom currents at this

location are produced primarily by tides. The maximum spectral amplitude, 2.4 cm/sec, was obtained for the M2 component of current. The N2 component of tide is leading the M2 component of current by 45.4 degrees. The total dissipation energy for all the components is 30 x 10^7 sec^-1. Gravity tides of roughly 0.3 mgal maximum peak-to-peak amplitude are observed. Harmonic analysis of the gravity data is in progress.

III.6.3

TIDAL WAVE IN A DEEP CHANNEL WITH VARIABLE CROSS-SECTION

A.V. Nekrasov, Hydrometeorological Institute, Leningrad, U.S.S.R.

The transformation of a long harmonic tidal wave in its propagating in a channel with variable cross-section is considered without taking into account Coriolis force, friction and nonlinear effects. The continuous partial reflection of the initial wave takes part of its energy to distribute it among the "back" and "following" radiation. The characteristics of the oscillation resulting from the passing of the initial wave along any part of channel can be determined by means of numerical integration of wave equation in the limits of this part of channel, providing the completely progressive wave must exist at the downstream relative to the direction of the initial wave end of the mentioned channel part. Putting such a boundary condition at different points of the channel one can trace in detail the process of propagation and transformation of the initial wave to reveal the causes of the characteristics of the final oscillations in the channel. In order to analyze the structure of oscillations some relations between the sea-level vertical elevations and its longitudinal gradients are used. This makes it possible to obtain the distribution of standing and progressive components (or incident and reflected waves) along the channel for the different stages of the initial wave propagation. A number of numerical examples is also considered. In particular, the intensity and character of a long wave reflection from the bottom slope of different steepness are evaluated. The accuracy of the numerical integration is estimated by comparing some results to an analytical solution. The method can be used for determination of the contributions of the bottom and coastline peculiarities to the real picture of tides in some natural prolonged basins. The computation of this kind may also be useful when the influence of the continental slope on the oceanic tidal waves of tsunami is investigated.

Observations de l'animateur

Au cours de ce symposium présidé par M. GOUGHEAD, Président du Comité Français de l'U.S.G, puis par le Dr. ROBERTS du Tidal Institute of Liverpool, les deux principaux sujets d'intérêt ont été:

- le développement des théories mathématiques des oscillations de masse dans l'océan;
- la possibilité de contrôle de ces théories par une instrumentation adaptée qui comportera essentiellement la mesure du champ de pression sur le fond de la mer, la mesure du champ de courant et celui du champ de température.

Les discussions ont montré que le Programme de travail complet devait comprendre:
- d'une part une observation générale du champ de pression en commençant par le rebord des plateaux continentaux et les pertuis de communication entre grandes aires océaniques: le but principal de cette opération est de fournir des conditions aux limites pour deux domaines dans lesquels l'étude doit se poursuivre indépendamment savoir: les profondeurs moyennes entre le rebord du plateau et la côte et les grandes profondeurs à partir du rebord du plateau vers le large.

- d'autre part la recherche de domaines dont la structure morphologique est simple et se rapproche du modèle des théories les plus simples (baie australienne par exemple).

Il a été également indiqué que l'observation par grandes profondeurs des champs de pression et de courant devait non seulement permettre une évaluation des hypothèses actuelles sur les oscillations de masse mais à en suggérer, presque sûrement, de nouvelles relatives notamment aux mouvements du globe lui-même.

IV. SYMPOSIUM ON SURFACE WAVES

Convener: Malcolm J. Tucker 27 September 1967

The following papers were given:

(Chairman - A.H. Schooley)

1. K. Hasselmann (F.R. Germany)  Wind Waves
3. H.R. Nicholson, T. Zasvastu and  Atlantic
   W.E. Hugert (U.S.A.)  Sea and Swell Forecasts
   Southern Baltic Sea from the  Gaussian Distribution

On the Use of Resonant Backscatter  of Hectometric Radio Waves for
Studying the Spectra of Ocean Waves
Summary of the Discussion on Paper IV.1

The discussion centered mainly on two points. Firstly, in connection with the exponential growth mechanism of waves, it was pointed out that the measured drag coefficients vary widely and some are large enough to satisfy Miles' theory. Perhaps this scatter in measurements is due to the drag coefficient being high during initial stages of growth and then dropping as the high-frequencies in the wave spectrum become saturated. However, Miles' theory is also suspect because it predicts a peak in the wind spectrum corresponding to the peak in the wave spectrum, but this has not been observed in practice.

Secondly, the question was raised as to what measurements would be required to resolve some of the discrepancies in our understanding of the wave-generation process. Professor Hasselmann replied that a series of wave measurements down to the generating path would allow the calculation of the rate of wave growth, and that at a few points 3-component wind measurements should be made so that the spectrum of energy transfer could be calculated.

IV.2. NUMERICAL PREDICTION OF SURFACE WAVE SPECTRA OVER THE NORTH ATLANTIC
J. Darbyshire and J.H. Simpson, Departments of Physical Oceanography, Marine Science Laboratories, Manai Bridge, United Kingdom

A computer program, written in Elliott Algol, has been set up to predict wave frequency and directional spectra over a grid of 100 square miles of the North Atlantic. The frequency spectrum formulae used are those of Darbyshire (1959) and Pearson and Modakovitz (1963). The energy direction assumed is a normal type one but other kinds like the one obtained by the S.W.O.P. project can also be used. There is also incorporated a feature which allows for the effect of contrary winds on waves. The program has run successfully with both the Elliott 405 and Atlas computers and predictions were made for high waves recorded during the last part of December 1959. The results using both frequency spectrum forms agree very well with the observed spectra at weather stations 2 and there is also good agreement between predicted significant heights, periods and directions with observations at other places.

The program can easily be modified to take a finer grid mesh and closer time intervals.

IV.3. SEA AND SWELL FORECASTS

The quality of wave, wind and pressure observations at sea is described and the effects of different sea surface and surface air properties on geostrophic wind/surface wind ratio are demonstrated.

The methods of numerical analyses and forecasts for wave heights, periods, and direction are outlined and the numerical methods for computing swell propagation are explained. Results of verification of wave forecasts are given.
The corresponding distribution density is

\[ f(x) = \frac{1}{\sqrt{2\pi}} \exp \left\{ -\frac{1}{2} \left[ \frac{x^2}{\alpha^2} - \alpha \left( \frac{x}{\alpha} \right)^3 + \beta \left( \frac{x}{\alpha} \right)^3 \right] \right\} \]

The last of the inequalities (6) is a direct consequence of the fact that a df. is a non-decreasing function. The parameters \( \alpha, \beta, \phi \) may be calculated by means of the graph of \( \psi[f(x)] \). From equation (5b) the following approximate formulae may be derived:

\[ \alpha \approx 5 \frac{\alpha}{1-\beta} \]

\( \beta \approx 5 \frac{1-\beta}{1-\beta} \)

Discussion of Paper IV:4

In reply to a question, Dr. Strigov said that his statistical distributions were not strongly comparable with those of other workers, since they depended greatly on local conditions. They were taken 100 to 200 m. from shore in a depth of 2 to 3 m.

IV:5.

On the use of resonant backscatter of heteromeric radio waves for studying the spectra of ocean waves


It is known (1, 2) that radio waves propagating along the surface of the sea are selectively scattered backwards by components of the sea waves which have lengths of half the radio wavelength, and which are travelling radially to the transmitter. The scattered signals have a Doppler shift which is characteristic of the radio frequency used. It is thus possible that a radar system of variable frequency could be used to study the energy spectrum of the sea surface at considerable distances.

An account will be given of preliminary experiments designed to explore this possibility. The observations were made in the Gulf of Mexico using frequencies between 2 and 10 MHz. Thus the wavelengths of the sea waves observed were between 75 m and 15 m. The experiments verified that the Doppler shifts of the scattered signals were as expected from theory. Observational ranges of 200 km were obtained but there is evidence that the range is smaller at night. This is thought to be due to tropospheric influences on the radio wave propagation. Two antennas having moderate directivity and oriented at right angles were used to demonstrate that it was possible to distinguish waves travelling in different directions.

It is concluded from these experiments that it should be possible, using equipment developed for the purpose, to make observations of the directional sea wave spectrum out to distances of perhaps 400 km in the sea wavelength range of 300-15 meters or greater.

Discussion of Paper IV:5

Professor Hasselman pointed out that the wave-wave interaction formalism is applicable to the radio backscattering problem and allows the doppler shift to be calculated simply.

In reply to a question, Dr. Crombie said that the range obtained was maximum during the day and minimum at night. The backscattered radio waves had a spectral width which appears to vary with wind speed, and useful information could perhaps be gained from this.

V. SYMPOSIUM ON TSUNAMI

Convenor: Robert O. Reid - 27 September 1967

The following papers were given:

1. Wm. K. Adams (U.S.A.)
   Progress in Tsunami Research at the University of Hawaii

2. K. Iida (Japan)
   Spectra and Generation Mechanism of the Niigata Tsunami of June 16, 1964, in Japan

3. B.W. Wilson (U.S.A.)
   Characteristic Signatures of the Alaskan Tsunami of March 1964

4. P.E. Green (U.S.A.)
   Applications of Large Aperture Array Techniques to Tsunami Warning

5. S.L. Solovyev and G.C. Ram
   (U.S.S.R.)
   Tsunami Recurrence in the Pacific

6. A.C. Vaetano and W.G. Van Dorn
   (U.S.A.)
   Tsunami Response at Wake Island; Comparison of the Hydraulic and Numerical Approaches

7. H.G. Loomis (U.S.A.)
   Relationship of Coastal Resonances to Long-Wave Amplification
V1. PROGRESS IN TSUNAMI RESEARCH AT THE UNIVERSITY OF HAWAI'I

Wm. Mansfield Adams, University of Hawaii, Honolulu, Hawaii, U.S.A.

Since 1963 the tsunami research group has made advances in the study of the focal movement of tsunamigenic earthquakes, the development of self-contained instrumentation for deep-ocean observation of tsunamis, and has proposed several changes or additions to the Seismic Sea-Wave Warning System.

Progress is evidenced by three new associations. Most important is the Joint Tsunami Research Effort (JTER), an agreement between the Environmental Science Services Administration (ESSA) and the University of Hawaii for mutual cooperation in research on tsunamis and related phenomena. Also, the Tsunami Research Advisory System of Hawaii (THASM) has been formed to provide testing facilities in real time of experimental instrumentation, analysis procedures, and decision making. To provide adequate access to the scattered literature on tsunamis, the Hawaiian Archives for Tsunamis (HAT) has been formed. Microfilm copies of collections, bibliographies, indexes, etc., are being issued to those active in tsunami research.

Discussion of Paper V1

In response to questions from S.L. Solovey (U.S.S.R.) additional discussion was given regarding information which can be extracted from records of T-phases. Also the progress in respect to the mid-ocean tsunami gauge was discussed by the author.

V2. SPECTRA AND GENERATION MECHANISM OF THE NIKOYA TSUNAMI OF JUNE 16, 1964, IN JAPAN

Kumita Tida, Nagoya University, Nagoya, Japan

The coastal distributions of tsunami run-up height and initial motion are discussed in connection with the generation of tsunamis. The tsunami height seems to decrease with an increase in the distance from the epicenter according to the simple relation H = 1/r at least near the source. The distribution of initial motion of tsunami waves elucidates the crustal deformation at the tsunami source.

The spectra of tsunami waves recorded at various stations along the coast of the Japan Sea are obtained by a Fourier analysis, from which the period of the maximum spectral intensity is determined as the predominant period of a tsunami. The wave length associated with the predominant period of the tsunami is comparable to that estimated from the linear dimension of the area of tsunami origin, which is obtained by refraction diagram and by the area of aftershock activity. The area of aftershock activity is approximately equal to the area of tsunami origin obtained by refraction diagram technique.

The maximum vertical displacement in a tsunami source, as estimated from the formula

\[ \log a = 0.5 \log E - 0.45 M - 4.85, \]

in which E is the tsunami energy, M the earthquake magnitude, is almost the same as that observed at the sea bottom near the source. The relationships among the earthquake focal mechanism, the crustal deformation, and the mechanism of tsunami generation are synthetically explained.

Discussion of Paper V2

In response to a question raised by T.P. Barnett (U.S.A.), the method of spectral analysis of the tsunami records was discussed by the author.

The author also pointed out in response to a question by S.L. Solovey (U.S.S.R.), that it was his opinion that the initial elevation of the sea inside the tsunami generating area was approximately two meters above normal level.

W.M. Adams (U.S.A.) raised a question concerning an apparent conflict between the conclusions drawn from the seismic data and the change of bottom topography.

V3. CHARACTERISTIC SIGNATURES OF THE ALASKAN TSUNAMI OF MARCH, 1964

Basil W. Wilson, Science Engineering Associates, San Marino, California, U.S.A.

Subjective analysis has been made of selected tide gauge records from stations throughout the Pacific Ocean area which showed representative disturbances caused by the Alaskan tsunami of March 27/28, 1964. These analyses disclose the characteristic beat patterns of the principal long wave trains that emanated from the source region. A non-beating evanescent wave system of longer period but lower amplitude is also discovered, as well as shorter period oscillations which apparently arise through a selective energy transfer process which favors resonances in particular coastal regions. The period of the principal wave train varies from about 1.5 to 1.9 hours, depending on distance from the source, and the initial wave is positive. The period of the longer waves seem to vary from about 3 to 5 hours and the leading waves at different places are positive and negative. Without exception the shorter period waves have leading waves that are negative, and they tend to occur in waves. These latter waves frequently attain amplitudes considerably in excess of the underlying parent waves; at Hilo, Hawaii, for example the amplitude ratio was as great as 9. The propagation of the tsunami waves across the Pacific is illustrated by their wave front positions at hourly intervals, derived from the wave arrival times at islands and Pacific boundaries. These fronts establish the gross features of the source region, which is then further examined in the light of the known movements of the sea bed during the earthquake. Some properties of the tsunami waves relating to wave height and period are derived from the analyses and are related to earthquake magnitude and propagational change. There appears to be reasonable agreement between observation and theory (insofar as the latter has been applied) to account for some of the characteristics noted.

Discussion of Paper V3

B.D. Zetler (U.S.A.) drew attention to the fact that the various superimposed waves for the different tide records shown by Wilson seemed to imply a comparable spectra whereas other studies have shown that the spectra for the same tsunami at different places are quite different.
The experimental Large Aperture Seismic Array, built in Montana as part of the Vela Uniform program, includes a number of features of interest for tsunami warning. Real-time computations on the sensor outputs take place continuously at the LASA Data Center. Rapid epicenters, accurate to about a degree or less on large events, are computed from short-period P-arrival times over the aperture. Magnitude, first motion, and complexity can also be computed on line currently. Off-line experiments on P at magnitudes below 5.0 show that it is considerably more reliable on data from the large array than for other types of observatories and attempts are being made to automate this. For the large, and more complex events, surface/body energy ratios and surface wave dominant period, which are easily measured automatically, may provide collateral data for estimate of depth. Results of these procedures will be presented.

Discussion of Paper V:4

The author discussed the accuracy of epicentral positions along the west coast of South America in response to a question raised by L.M. Murphy (U.S.A.).

V:5. TSUNAMI RECURRENCE IN THE PACIFIC

S.L. Solovev and Go Chan Nam, Sakhalin Complex Scientific Institute, Siberian Branch of Academy of Sciences, U.S.S.R.

The tsunami scale for tsunami classification is discussed. In addition to maximum tsunami height on the coast (Hmax), the average tsunami height on the coast (h) adjacent to tsunami source, and the length (L) of coast inundated to the altitude h are taken into account. Correlations among Hmax, h, and L are obtained.

It is proposed to classify tsunamis according to the mechanism of their generation, and six different types of tsunamis are discussed. Analogous to the seismological terminology, the concept of tsunami maximum L, intensity I and magnitude m is introduced.

Seventeen tsunami-generative zones are outlined within the Pacific and the adjacent seas. On the basis of published data, a list of Pacific tsunamis is compiled which comprises about 400 entries. The type of generation, values of L, I, and m and approximate coordinates of the source are attributed to all tsunamis.

The frequencies of tsunamis according to their magnitude are found for the majority of zones. These values are compared with the frequency of earthquakes in the same area. Maps of the known tsunami sources in the Pacific and the so-called tsunami activity of the ocean are constructed. In conclusion, the effect of strong directivity of some tsunamis is briefly discussed.

Discussion of Paper V:5

The author discussed the use of the terms tsunami intensity and tsunami magnitude and how he estimates magnitude in response to a question raised by K. Iida (Japan). N.M. Adams (U.S.A.) concurred with the author that a better definition of tsunami magnitude is important.

V:6. TSUNAMI RESPONSE AT WAKE ISLAND: COMPARISON OF THE HYDRAULIC AND NUMERICAL APPROACHES

Andrew C. Vatnang and William G. Van Dorn, University of Florida and Scripps Institution of Oceanography, U.S.A.

The study of the interaction between long plane waves and an isolated island has value in the interpretation of tsunami records made at such sites as well as forming a step in the development of techniques for the examination of interactions with island chains. Wake Island has been selected on the basis of its singular nature and the relevance of this study to a unique set of tsunami recordings. These wave records were taken at Wake Island and constitute the closest representations of deep water tsunami yet obtained.

The hydraulic model reproduced a portion of the Pacific Ocean surrounding Wake Island in a tank 500' x 400' x 12'. The construction of the island topography and several adjacent sea mounts was carried out on an undistorted scale of 1:57,500. Monochromatic plane waves scaled on the basis of the Froude number for periods in the tsunami range were introduced at the end of the tank by a 12' generator bar. Wave measurements at two positions in the far field and nine positions around the island were used to calculate the amplitudes and phases of the response at the island shoreline. A theoretical correction for dissipation of the wave system by viscous effects was included in the data analysis.

The numerical model was designed to duplicate the hydraulic model as closely as possible. The calculations were carried out with a grid system based on an orthogonal, perturbed polar coordinate system which has a constant coordinate value for the island shoreline and a normal polar coordinate configuration in the far field. A numerical integration procedure based on classical linearized long wave equations was used to evaluate the response produced by monochromatic plane waves incident on a numerical analogue of the island and surrounding topography. The boundary condition at the island was one of no radial flow while a radiation condition was employed in the far field for the scattered waves.

A favorable comparison exists between the results of the two models and they form a consistent representation of long wave interaction within the limitations of their construction and approximations. The numerical system has a high degree of resolution that verified details of the response patterns indicated by the hydraulic model. Both models predict similar sheltering features as well as maxima and minima in the patterns.
VI. SYMPOSIUM ON INTERNAL WAVES

Convener: W. Krause 4-5 October 1967

The following papers were given:

(Chairman - N.P. Pofonoff)

1. M. Rattray, Jr. (U.S.A.)
   General Review of our Knowledge on Internal Waves

2. M. Mork (Norway)
   The Response of a Stratified Sea to a Space- and Time-dependent Windstress

3. M. Tomczak, Jr. (F.R. Germany)
   On Resonances of Wind-Generated Internal Waves in a Continuously Stratified Shallow Sea

(Chairman - H. Lacombe)

4. J. Darbyshire (U.K.)
   Internal Waves on Snowdonian Lakes

5. P.H. Leblond (Canada)
   On the Interaction of Internal Waves and Horizontal Shear Currents

6. L. Nagaard (F.R. Germany)
   Internal Waves as Perturbation of Geostrophic Motions

7. R. Kenyon (U.S.A.)
   Wave-Wave Scattering for Surface Internal Waves

(Chairman - W. Krause)

8. F. Webster (U.S.A.)
   Observations of Inertial-Period Waves in the Deep Sea

9. C.H. Mortimer (U.S.A.) and M.A. Johnson (U.K.)
   Observational and Theoretical Investigation of Long Internal Waves in Lake Michigan

10. J. Kielmann (F.R. Germany)
    Spectra of Internal Waves in the Baltic Sea

11. K.P. Bowden and R.A. White (U.K.)
    Vertical Structure of Temperature Fluctuations in an Oceanic Thermocline

12. N.P. Pofonoff (U.S.A.)
    Internal Tide Generation and Propagation from Continental Shelves. I. Ray Theory

13. M. Rattray, Jr. (U.S.A.)
    Internal Tide Generation and Propagation from Continental Shelves. II. Normal Modes
Characteristics of Internal Tide in Shoaling Coastal Waters

Ondes internes liées à la marée dans le Détroit de Gibraltar et dans ses abords

Calculation of Internal Wave Fields using Ray Theory

Standing Internal Waves in Rectangular Tanks

Mixing Across Sharp Density Interfaces

Experiments on Breaking Internal Waves and Shear Flows

Impulsively Started Oscillations in a Rotating, Stratified Fluid

Internal Waves Vertical Motion Measured with a Neutrally Buoyant Rotating Float

Thermal and Current Shear Structures of the Upper 240 Metres in the Pacific Ocean

The Geostrophic Approximation and Internal Waves

VII.1. GENERAL REVIEW OF OUR KNOWLEDGE ON INTERNAL WAVES

M. Bailey, Jr., University of Washington, Seattle, Washington, U.S.A.

(No Abstract)

VII.2. THE RESPONSE OF A STRATIFIED SEA TO A SPACED-A TIME-DEPENDENT WINDSTRESS

M. Nork, Geophysical Institute, University of Bergen, Bergen, Norway

First part of the theory is concerned with general analytic expressions for the response of the ocean of constant depth to atmospheric pressure and wind stress. In this second part the theory is applied to specific models where wind stress is the only atmospheric force.

The equilibrium density field (statically stable) is unspecified in the analytic expressions, but the eddy viscosity is taken to be inversely proportional to the static stability. The validity of the last assumption together with a slip condition at the bottom is discussed. For periodic motion and the first stage of a forced motion starting from rest the results seem realistic. The horizontal velocities show a rapid transition in layers of great stability as is often observed.

The present theory is a linear one and the equations for three-dimensional motion are solved for the vertical displacement with the aid of an expansion in eigen-functions which give the vertical dependency so of as in the frictionless case of free internal waves. For the chosen forms of the external forces the series converge rapidly and the resulting solution well described by 4-5 terms, the surface mode included. Different applications of the theory are considered. Firstly the response of separate internal waves to a periodic windstress is investigated, and an amplitude factor is calculated; secondly the most significant terms are added in order to give a more complete picture of the total response. The response of the sea to a suddenly created windstress is investigated in detail. The displacement of selected density surfaces at different stages of development is illustrated.

VI.3. ON RESONANCES OF WIND-GENERATED INTERNAL WAVES IN A CONTINUOUSLY STRATIFIED SHALLOW SEA

M. Tomczak, Jr., Oceanographic Research Department of the Navy, Kiel, F.R. Germany

The resonance behavior of an exponentially stratified sea with uniform depth and without horizontal boundaries, when a fluctuating wind stress acts tangentially upon its surface, is studied and compared with the known free oscillation states defined by eigen values. It is shown that the resonances are identical with the eigen oscillations in a deep ocean, whereas in shallow water only the eigen oscillation of lowest order coincides with a resonance, but the next two resonances are found between the lowest mode and the next two modes.
VI:4. INTERNAL WAVES ON SNOWDONIAN LAKES

J. Darbyshire, Department of Physical Oceanography, Marine Sciences Laboratories, Menai Bridge, United Kingdom

Several of the lakes in North Wales are over 30 metres deep and have a very marked thermocline during the summer months. They are, thus, ideal models for the study of internal waves. These were recorded by using a thermistor chain, with thermistors spaced at 1 metre intervals, suspended from a buoy. A continuous record of the output of each thermistor was obtained as well as the wind speed and direction and the air temperature. It was found that the density stratification was closely approximated by taking three layers with different density gradients. This distribution gives in theory an infinite number of resonant periods but only the first few roots are of practical significance and these agree very well with the dominant periods obtained by spectral analysis of the thermistor records.

The lake system was considered analogous to a set of electrical resonant circuits, one circuit for each resonant period and the wind stress across and along the lake as a variable electrical input and so by using electrical transient theory the variation of isotherm height with time could be synthesized from the wind stress. These syntheses agree very well with the variations actually observed. It was possible by this means to estimate how the response of the lake to the wind stress varies with various frequencies and also with the depth of the thermocline.

VI:5. ON THE INTERACTION BETWEEN INTERNAL WAVES AND HORIZONTAL SHEAR CURRENTS

P.H. Leblond, Institute of Oceanography, University of British Columbia, Vancouver, Canada

Attention is drawn to the multiplicity of mechanisms susceptible of influencing the energy density of a train of internal waves and to the difficulty of attributing to any one of these mechanisms the observed difference in internal wave energy between two distant stations without detailed knowledge of oceanographic conditions in the space interval between those stations.

The energy exchange through radiation stress interaction in horizontally variable currents is discussed in more detail with the help of ray theory. A numerical example for semi-diurnal internal tides, based on conditions prevailing in the Gulf of Alaska, shows that irreversible dissipative effects, geometrical focusing and interaction with weak vertical shears are of similar importance in the energy balance. The interactions with horizontal shears, which in their area of weak currents seems relatively important, should not be entirely dismissed from the oceanic context as these are areas where the currents are strong enough for this type of interaction to predominate.

VI:6. INTERNAL WAVES AS PERTURBATION OF GEOSTROPHIC MOTIONS

L. Hogaard, Institute for Marine Research, Kiel University, Kiel, P.R. Germany

In a -plane, linear internal waves have been studied as perturbations of a zonal geostrophic current. It has been shown that the critical latitudes may be influenced considerably by currents of such a type. It turns out, additionally, that there exists a considerable influence of such currents on the cut-off frequencies of the spectrum and on the wave length of internal waves.

VI:7. WAVE-WAVE SCATTERING FOR SURFACE AND INTERNAL WAVES

K. Kenyon, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

Based on a theory of weak wave-wave interactions in a random gravity wave field and using ocean temperature measurements as initial information we give some computations of energy transfer rates which indicate: (1) that wave-wave scattering among internal waves may be most important in shallow water and may partly explain the monotonic decrease from tidal to higher frequencies of spectra of temperature fluctuations in the deep ocean, and (2) that scattering of swell energy into internal wave energy may not be an important generating mechanism for internal waves in the ocean.

VI:8. OBSERVATIONS OF INERTIAL-PERIOD WAVES IN THE DEEP SEA

Perris Weisberg, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

Inertial-period oscillations have been observed by numerous investigators at deep-sea locations ranging from sub-tropical to polar latitudes. Although observational techniques have favored surface-layer measurement, there is evidence from all depths, including near-bottom measurements. There is no strong evidence that the amplitude of inertial-period motions is strongest near the surface.

Deep-sea observations of currents collected over an array of moored current meters for a seven-week period are discussed in detail. Cross-spectral analyses of the measurements show that the inertial motions are coherent horizontally over much greater scales than they are coherent vertically. It is concluded that the inertial-period motions are internal, possibly with a high vertical mode.
VII.9. OBSERVATIONAL AND THEORETICAL INVESTIGATION OF LONGER INTERNAL WAVES IN LAKE MICHIGAN

C.R. Martiniere, Center for Great Lakes Studies, University of Wisconsin, Milwaukee, Wisconsin, U.S.A., and M.A. Johnson, National Institute of Oceanography, Worsley, United Kingdom

Long internal waves in basins of 'Great Lakes' size have been little studied, although their observation is less difficult than in the open ocean in some respects, e.g. accessibility from different shore bases, relatively shallow water and negligible tidal range and currents. On the theoretical side, Coriolis force is very important for internal oscillations, in contrast to small lakes, but not the latitude variation of Coriolis parameter, except in one respect noted below. In the vertical, the single, relatively sharp thermocline, with very nearly isothermal conditions (4°C) below, is closely approximated by a quartic model density profile for which the normal mode equations are analytically soluble. The first vertical mode is observed to be predominant, probably due to observe in the observation area (central southern part of the lake) of depth irregularities near thermocline depth, and of such less rapid damping (this is estimated, using several theoretical models, also including bed friction, and recent numerical values of the transfer coefficients in lakes and shelf seas, to be over-critical for wave) for second and higher modes). In the horizontal, the long waves may be divided into (1) progressive disturbances with maximum amplitude near the shore and period, if completed, much exceeding inertial, and (2) modes with horizontal variation oscillatory and either standing or progressive in the direction (north-south) of elongations of the lake, and with periods only slightly below the local inertial value for the lower modes. Comparison of the theoretical predictions for these modes (standing or progressive Poincare waves for a rectangular channel of uniform depth) with the observations (current and temperature-depth profiles at fixed stations and bathythermograph profiles from cross-lake ferries) enabled, for several separate calculations of a few days, individual low modes to be identified. The north-south coverage was insufficient to test the theoretical prediction of northward change from oscillatory to exponential latitude variation in the lowest transverse mode, due to latitude variation of Coriolis parameter.

Largely due to the lake's orientation, generation of the internal oscillations is principally from cross-lake thermocline slopes produced by wind stress in individual travelling meteorological disturbances. Non-wave currents are more variable and much weaker than in the ocean, and only have appreciable effects on boundary waves and higher vertical modes.

VII.10. SPECTRA OF INTERNAL WAVES IN THE BALTIC SEA

J. Kielman, Institute for Marine Research, Kiel University, Kiel, F.R. Germany

Since 1961 we studied the spectral behavior of current velocities, temperature fluctuations at different depths and positions in the Baltic.

The general shape of all spectra of the horizontal components u, v of the orbital currents can be approximated by the power law

$$v = C \times f^{-0.8}$$

in the range of 50 to 100 hours.

However, in the range from 2 to 50 hours, all spectra show a distinct increase of the energy level which is assumed to be due to internal waves. For each frequency v the vertical distribution of the Fourier-components y (v, z) of u,v are approximated by a finite sum of eigenfunctions y

$$y(v, z) = \sum_{n=1}^{N} c_n(v) \psi_n(z)$$

where $\psi_n(z)$ is gained by numerical integration of the differential equation describing the vertical dependence of internal waves.

It turns out that the modes have isotropic; their directions are nearly equally distributed.

VIII.1. VERTICAL STRUCTURE OF TEMPERATURE FLUCTUATIONS IN AN OCEANIC THERMOCLINE

K.F. Crow and R.A. White, Department of Oceanography, University of Liverpool, United Kingdom

Three series of temperature profiles, obtained at half-hourly intervals at fixed positions using a Bissett-Berman salinity-temperature-depth system, have been analyzed with a view to investigating the vertical structure of the fluctuations. The series were (1) in the vicinity of the ocean weather ship Jullett (52°1'/N, 20°W) extending over 2 1/2 days in July 1965, (2) near the Canary Islands (20°N, 18°W) for 6 days in January 1966, and (3) about half-way between Madeira and the Azores (35°E, 21°W) for 8 days in July 1966. In each case, the spectra of the fluctuations at about 12 levels between the surface and 300 m were determined in the frequency range 0.2 to 1 cycle per hour for series (1) and 0.05 to 1 cycle per hour for series (2) and (3). The coherency and phase angles between the fluctuations at different levels were also computed. Data will be presented showing how these quantities varied with depth and frequency, and the bearing of the results on the character of the fluctuations will be discussed.

VIII.12. INTERNAL TIDAL GENERATION AND PROPAGATION FROM CONTINENTAL SHELVES. I. Huck Theory

R.P. Esfandier, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

The spatial distribution of amplitudes of internal waves excited at a fixed frequency, such as the tidal frequency, is governed by a hyperbolic differential equation. Consequently, the solutions are propagated along characteristic surfaces.

Assuming that a continental shelf represents a strong source for internal waves of tidal period, the method of characteristics is applied to deduce the spatial distribution of the baroclinic field excitation in the interior of the ocean away from the shelf.

The continental slope south of Cape Cod is comparable to the slope of the characteristic surface so that little bottom reflection is present until deep
water is reached. The tidal internal waves appear to be confined to a relatively narrow layer by limiting characteristic surfaces. These theoretical deductions are being used to guide the design of an experiment to measure the spatial fluid of tidal currents near the continental slope south of Cape Cod.

VI:13. INTERNAL TIDE GENERATION AND PROPAGATION FROM CONTINENTAL SHELVES. II. MODAL MODES

M. Slatery, Jr., University of Washington, Seattle, Washington, U.S.A.

The breaks of continental shelves are regions of strong coupling between surface and internal tides. The modal structures of the internal waves over the shelf and in the adjacent ocean are obtained for a simple theoretical model in which the shelf break is approximated by a depth discontinuity. The internal waves propagate away from the break in both directions. Those travelling into the ocean are presumably attenuated and appear as progressive waves only. Those travelling landward must either lose their energy by dissipation or else be reflected. Depending on the relative proportion of energy dissipated and reflected they may change their character from that of progressive waves to that of standing waves.

For large depth changes at the shelf break, the energy density of the seaward travelling progressive waves is largest between the rays emanating from the continental shelf. Fine structure in the energy distribution between these rays depends upon the character of the internal waves on the continental shelf.

VI:14. CHARACTERISTICS OF THE INTERNAL TIDE IN SHALLOW COASTAL WATERS

J.L. Collins, U.S. Navy Electronics Laboratory, San Diego, California, U.S.A.

Experiments conducted along the Southern California Coast during 1965-1966 indicate that thermocline strength variations are induced in shoaling water by internal tidal waves. Power spectrum analysis shows gradient strength oscillations to occur at periods of 24 and 12 hours, which correspond to the dominant internal tidal frequencies in the area investigated. Major peaks in the gradient strength spectrum also occur at periods of 9 and 6 hours, revealing nonlinear and double frequency interactions of the tidal oscillations.

These findings are applicable to forecasting the internal tide and constant gradient strength changes.

VI:15. ONDES INTERNES LIÉES À LA MARÉE DANS LE DÉTROIT DE GIBRALTAR ET EN SES ABORDS

H. Jacome et C. Riches, Laboratoire d'Océanographie Physique, Muséum National d'Histoire Naturelle, Paris, France

L'étude des résultats de mesures prolongées d'hydrologie et de courant effectuées simultanément par plusieurs navires en Mai et Juin 1961 en divers points du détroit de Gibraltar et de ses abords met en évidence le caractère des profils des ondes internes liées à la marée dans les parties Ouest et Est du détroit.

L'amplitude de ces ondes s'atténue de part et d'autre du Souil.

A) Dans l'Ouest du détroit, 5°55', 2 W (A), l'onde interne, dont l'amplitude totale est d'une soixantaine de mètres, n'a qu'une avance de phase d'environ une demi-heure sur la marée superficielle; elle semble verrouillée sur le courant superficiel. Plus à l'Ouest, l'amplitude totale n'est plus que de 30 mètres vers 6°20'W et seulement de 20 mètres environ par 6°40'W, point où l'onde interne intérresse seulement la partie supérieure de la couche de mélange.

B) Vers l'Est, l'amplitude diminue, mais le profil garde un caractère huité qui semble lié à l'influx de courant entrant conséquent sur le Souil un peu avant l'heure de la Pleine Mer et qui se propage vers l'Est pour passer vers 9 h le centre du détroit sur le méridien de Tarifa; il parait ensuite se perdre dans la partie Sud-Ouest du détroit. Il semble qu'il y ait à l'Est du Souil un décalage plus ou moins progressif de la Pleine Mer de l'onde interne.

Le tracé de profils de l'onde dans l'espace met en évidence la singularité qu'introduit le Souil du détroit.

La position moyenne de l'interface comble de l'Ouest vers l'Est. A l'Ouest, l'isohaline 37% située à environ 170 mètres en moyenne, par 5°55', 2 W, se trouve vers 330 mètres vers 6°20' W, bien que le fond du chenal n'ait qu'une change d'immersion. Par 6°40'W, l'interface se trouve vers 670 mètres par fonds de 720 mètres environ. L'eau médiiterranéenne garde notamment son individualité malgré les forts courants qui l'entament en raison de la forte diffusion de densité dans la zone de l'interface.

On présentera de façon préliminaire quelques résultats d'étude d'ondes internes en différents points du détroit, telles que les révèle l'emploi, en 1967, de la bathysphonde Hovlandstwærke, à un système d'un profil thermique et de conductivité tous les 1/4 d'heure.

VI:16. CALCULATION OF INTERNAL WAVE FIELDS USING WAVETHEORY

M. Sandstrom, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada

For wave frequency less than the local Vaisala frequency, the perturbation equations are spatially hyperbolic and can therefore be integrated along the characteristics. This fact is used in two-dimensional applications to calculate wave properties for several illustrative cases. Experimental evidence confirms the predictions of small amplitude theory.

VI:17. STANDING INTERNAL WAVES IN RECTANGULAR TANKS

Karl-Henning Knappe, Oceanographic Research Department of the Navy, Kiel, F.R. Germany

A system is described for generating standing internal waves in a rectangular tank. The present state of studying these waves is reported.
break as a result of local shear, although in this case breaking is found at the wave node, for it is there that the shear is greatest.

An experimental technique will be described which allows careful and controlled study of the stability of laminar stratified shear flows for velocity profiles, \( u(z) \), and gravitationally stable density profiles, \( p(z) \), which are related so that:

\[
 u(z) \propto \left( \frac{p(z)}{p(z_{0})} \right)^{1/2} \left( \frac{\rho_{2}}{\rho_{1}} \right) ^{1/2} \frac{g}{H} \frac{\Delta p}{\rho_{1}}
\]

where \( H \) is the fluid depth.

The apparatus consists of a closed rectangular tube, which may be filled with a stratified (brine) solution. When the tube is slightly tilted, a completely predictable flow occurs under gravitational forces if initiated, which accelerates uniformly in the body of tube, although waves propagate into the center of the tube from the two ends. A flow having been set up in this way, it is then possible to return the tube to the horizontal position and to observe the fluid motions, made visible by dye in the central shear flow region. The Richardson number which may be achieved is proportional to the inverse square of the time for which the tube is tilted away from the horizontal position.

Provided that the events to be observed occur in a short time, both the effect of the waves propagating from the tube ends and viscous effects at the walls of the tube may be small.

Observations made so far have been of the instabilities which occur in the accelerating flow, before the tube is returned to the horizontal position. It is found that the experiments are repeatable, in that the instability manifests itself at the same time and with the same wavelength from one experiment run to the next if conditions are the same. Instability is found to take the form of a beautiful and fairly regular array of rolls with horizontal axes at right angles to the direction of flow, which resemble those found in the instability of a homogeneous shear flow behind a step. A film showing the onset of instability will be shown.

Results at present indicate that a system in which the velocity and density profiles are both approximately linear is stable as predicted by Eliassen, McLand and Kis (1951), whereas instability is found when the density (and concentration) of the brine is increased. A comparison may be made with theoretical predictions (e.g., with Miles and Howard, 1964).

The apparatus may conveniently be used to demonstrate the onset of instability in shear flow by using immiscible fluids, and further experiments will be made to investigate this (Kelvin-Helmholtz) situation. Lee waves and hydraulic jumps in the stratified shear flow behind an obstacle may easily be generated and studied, and this is of particular interest in view of the recent theory and predictions about wave attenuation in the critical layer by Booker and Bretherton (1967).
VI:20. IMPULSIVELY STARTED OSCILLATIONS IN A ROTATING, STRATIFIED FLUID
Myr C. Henderson, Scripps Institution of Oceanography,
La Jolla, California, U.S.A.

The motion near a spherical source harmonically oscillating at frequency ω after starting impulsively in a rotating, stratified fluid is discussed. There is a far reaching analogy between the motion in a rotating, homogeneous fluid and that in a non-rotating but stratified fluid. In the special case of constant Väisälä frequency, free oscillations at this frequency obey a modified Taylor-Proudman theorem and consequently appear only outside of a vertical cylinder circumscribing the spherical source except when it is oscillating at exactly the Väisälä frequency. The ultimate flow is harmonic with frequency ω except on those cones tangent to the sphere along which energy at frequency ω may be propagated by free waves.

VI:21. INTERNAL WAVES: VERTICAL MOTION MEASURED WITH A NEUTRAL BURNT ROTATING FLOAT
A.D. Voorhis, Woods Hole Oceanographic Institution, Woods Hole,
Massachusetts, U.S.A.

Internal waves are usually detected by measuring the temperature fluctuations of a moored or towed thermometer. It is never clear, however, whether the changes observed are due to waves or parcels of water with differing temperatures which are drifting by the sensor. Described here are the results from a new instrument, developed by D. Webb at Woods Hole, which measures directly the vertical motions due to these waves. This instrument is a spherical glass float fitted with tilted vanes around its equator and ballasted to be neutrally buoyant at a predetermined depth. Because the compressibility of the float is less than that of water slow vertical motions due to internal waves produce a relative vertical flow past the float vanes causing the float to rotate. This rotation is detected relative to a magnetic compass within the float and transmitted acoustically to ship-towed hydrophone at the surface. In November 1966 one of these floats was launched at a depth of 1100 meters in the slope water south of the New England coast near 39°20' N, 70°00' W. It was tracked by ship for six days and a continuous record of vertical motion was obtained over this period. In the record vertical oscillations with periods of 2-3 hours and amplitudes of 10-15 meters were particularly evident. A spectrum of the vertical motion showed a very sharp cut-off at a period of about 90 minutes which corresponds to the Väisälä period at the float depth. Other measurements with this instrument are shown and their significance discussed.

VI:22. THERMAL AND CURRENT SHEAR STRUCTURES OF THE UPPER 240 METERS IN THE PACIFIC OCEAN
R.G. LaFond and K.G. LaFond, Marine Environment Division,
U.S. Navy Electronics Laboratory, San Diego, California, U.S.A.

The thermal structure of the upper 240 meters of the ocean throughout the North Pacific was studied by means of towed sensors. The thermal detail derived from these data is equivalent to that which could be gained by lowering a bathythermograph every 37 meters across the ocean.

Current meters attached at four levels along the chain provide relative current speed. This simultaneous recording of temperature and current shear is related to the size and shape of the internal thermal structures.

All isotherms in the thermocline exhibit vertical oscillations which vary widely in amplitude and frequency. The amplitude is inversely proportional to the vertical density gradient of the water. The frequency, expressed as the power spectrum, contains peaks in the bandwidth between 5 and 8 minutes. Other frequencies, corresponding to tidal and meteorological phenomena, are also present in the power spectrum.

The direction of propagation of the internal waves, as determined from a Doppler shift in frequency, was established by towing in multi-directional patterns. The dominant directions appear to be influenced by the topography.

The most irregular thermal structures and the current shear are found at oceanographic fronts and in major current systems. The variance in the depth of isotherms is about ten times greater in such areas than on either side. Internal oscillations in the isotherms are influenced by weather, currents and topographic boundaries. One dominant wavelength encountered is 500-1000 meters long. It is possible to predict some oscillations from data of weather and tide.

VI:23. THE GEOSTROPHIC APPROXIMATION AND INTERNAL WAVES
W.D. Forrester, Bedford Institute of Oceanography,
Dartmouth, Nova Scotia, Canada

A survey carried out in the fall of 1965 to compare calculated geostrophic currents in a cross-section of the St. Lawrence estuary (46°7'N, 60°4'W) with directly-measured currents is briefly described. Simultaneous measurements of temperature and salinity were obtained in the cross-section by towing the strings of water bottles and tripping them by clockwork at a pre-set time. Observations were taken in this manner on successive days at a different phase of the semi-diurnal lunar tide each day.

Harmonic analysis of the directly-measured currents reveals evidence of an internal standing wave along the axis of the channel with a semi-diurnal lunar tidal period. The geostrophic calculations and the cross-channel tidal stream indicate that there is also a cross-channel internal wave of tidal period associated with the node of the axial wave.
The effect of the cross-channel internal wave is to introduce a tidal oscillation into the geostrophic shear that is almost 180° out of phase with the tidal oscillation in the real current shear. A simple theory is advanced that is in qualitative agreement with the observations. It is concluded that the natural period of cross-channel oscillation of an appropriate internal wave is an important time scale to consider when planning or interpreting measurements of geostrophic current.

SUMMARY OF THE CONVENTER

The Symposium dealt with periodic phenomena in stratified water, called internal waves. After the general review, given excellently by Professor Nattray, the first two papers by Dr. Mork and by Dr. Tomczak were devoted to wind produced internal waves. There followed a third paper on the same subject by Professor Darbyshire. We then switched over to interaction processes. The first two papers were on interaction between internal waves and currents (papers by Dr. Leaon and by Dr. Magaard). The last paper of the morning session was given by Dr. Kenyon on wave-wave interaction.

Time for discussion was very limited. Because of the high standard of these theoretical contributions, most problems were discussed privately within small groups, working on the same subject.

The afternoon sessions started with four contributions based on observations. These were papers by Dr. Webster, by Dr. Mortimer and Johnson, by Mr. Kielermann and by Professor Bowden. These articles and the discussion showed the great complexity of the fluctuations we observe in the ocean. The last papers of the afternoon session dealt with internal tidal waves (by Dr. Poforoff, by Professor Nattray, by Mr. Cairns, and by Professor LaCombe).

On October 5th most contributions were on tank experiments, which may help considerably to close the gap between theory and observation. Papers by Dr. Sandstrom, by Mr. Konecke, by Dr. Turner, and by Dr. Thorpe showed excellent experiments. The symposium continued with a contribution by Dr. Rendershott on similarities between the effects of stratification and rotation. The final three papers were on observations (by Mr. Voozhis, by Dr. LaPons, and by Mr. Fornstead).

It was obvious from the contributions and the discussions that theory and observation still do not form a completely coherent pattern. Many unsolved problems remain; but some comparisons of the existing theories with experiments or observations have yielded encouraging results.
The following papers were given:

(Chairmen - Prof. Bonten and B. Saint-Guily)
(Rapporteur - J.W. Talbot)

1. D.W. Pritchard (U.S.A.)
A Review of Present Theoretical and Experimental Knowledge of Diffusion in the Oceans

2. K. Wyrtki (U.S.A.)
The Spectrum of Ocean Turbulence between 40 and 1000 Kilometers

3. H. Weidemann (F.R. Germany) and M.P. Visser (Netherlands)
Results of the ICES Diffusion Experiment "NEEMO 1965"

4. H. Sendner (F.R. Germany), J.W. Talbot (U.K.) and G.C. van Dam (Netherlands)
Considerations regarding the Interpretation of the Results of the ICES Diffusion Experiment "NEEMO 1965"

5. R.V. Osmedov (U.S.S.R.)
(Paper given by B.A. Tarutyev)
The Study of Turbulent Diffusion of Pollution in the Sea by Fluorescent Tracer Method

6. A. Okubo (U.S.A.)
Some Remarks on the Importance of the "Shear Effect" on Horizontal Diffusion

7. I. Dugstad (Norway)
Longitudinal Diffusion in Periodic Shear Flow

8. B. Saint-Guily (France)
Effet de la thermocline sur la diffusion à partir d'une source

9. P. Welander (Sweden)
Which Oceanographic Parameters Determine the Vertical Exchange Coefficient?

10. G. Kullenberg (Denmark)
In situ Measurements of Horizontal and Vertical Diffusion in the Thermocline in Swedish Coastal Waters

11. J.D. Woods (U.K.)
The Effect of Fine Structure on Diffusion through the Thermocline

12. A. Ivanoff (France)
Méthode de mesure du coefficient de diffusion turbulente des eaux à la verticale

13. J.L. Hysacinte (France)

14. J. Joseph (Monaco)

15. P. Croen (Netherlands)

16. G.C. van Dam and J.C. Schönfeld (Netherlands)

17. V.P. van der Burgh (Netherlands)
VIII.1. A REVIEW OF PRESENT THEORETICAL AND EXPERIMENTAL KNOWLEDGE OF DIFFUSION IN THE OCEANS

D.W. Pritchard, Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Maryland, U.S.A.

The movement and spread of a tracer material introduced into the ocean in an instantaneous point source is described in terms of the spectrum of eddy diffusion. Comparison of the several theoretical solutions for a radially symmetric diffusion pattern with observations shows that as a whole the observed data do not clearly support any of the theoretical expressions, even though each of the theories appears to be supported by one or another of the individual studies. In most cases the dispersing cloud of tracer material has an elongated, or elliptical pattern. This elongation is shown to be related to a shear in the mean current field. A theoretical solution which includes horizontal and vertical diffusion, and horizontal and vertical shear in the current field, satisfactorily describes both the variation of peak concentration with time and the elongation of the isolines of tracer concentration.

VII.2. THE SPECTRUM OF OCEAN TURBULENCE BETWEEN 40 AND 1000 KILOMETERS

K. Wurtschi, University of Hawaii, Honolulu, U.S.A.

Networks of closely-spaced hydrographic stations are used to calculate the structure function for the depths of the 20° isotherm over distance between 20 and 1400 kilometers. In the central Pacific Ocean the 20° isotherm is situated near the center of the thermocline where the spectral power is a typical peak near 400 kilometers, which is related to large geostrophic eddies of corresponding dimensions. The remainder of the spectrum increases monotonically in the range 400 to 1400 kilometers. There are appreciable differences of the spectrum from cruise to cruise. In contrast to the spectra of the thermocline, the spectra of the mixed-layer depth often remain relatively insensitive to time variations, and are valuable for assessing the accuracy of predictions of thermal structure. The computed spectra cover the gap between ordinary turbulence and the large-scale ocean circulation.

VII.3. RESULTS OF THE ICES DIFFUSION EXPERIMENT "RHEINO 1965"

H. Weidemann, Deutsches Hydrographisches Institut, Hamburg, F.R. Germany, and J.H. Visscher, Royal Netherlands Meteorological Institute, De Bilt, Netherlands

On the recommendation of ICES a large diffusion experiment was carried out in the North Sea during August-September 1965. Scientists and ships from Germany, the United Kingdom and the Netherlands took part in this operation which involved the release of 2000 kg of rhodamine-B dye and produced a dye patch with a measurable area of more than 3000 km² after a period of 24 days.

This experiment was to fill the gap between those with smaller scales and those with much larger scales as Fojones and Vine's experiment or as Joseph and Sender's calculations with Mediterranean water in the Atlantic. After some aerial photographs in the first days there were 10 horizontal surveys run by the ships.

1 to 4 vessels with a total of more than 3000 nautical miles. Moreover 30 stations were made for surveying the vertical dye distribution. Nine recording current meters were anchored in various depths in the vicinity of the release point at 3 stations with an average separation of 70 km.

The horizontal surveys showed very complicated and changing shapes, certainly partly due to the imperfect release technique. The measured areas, however, produced reasonable results, the total area apparently increasing nearly linearly. Whereas the maximum concentrations were decreasing with a factor of 6 to 6, the maximum areas were increasing with a factor of 6 to 6. Independent evaluations of the same data by different scientists gave us some indication on the reliability of the measured areas, the scattering only under unfavorable conditions exceeding 10 percent. The evaluation showed some irregularities, particularly with surveys No. 7 and No. 9 where the horizontal areas as well as the recalculated total dye quantity resulting from the vertical measurements were obviously too small. Probably some parts of the dye were missed during these surveys.

The current measurements which were analyzed by computers showed considerable shear motions particularly in the near-surface layer. So the vectorial difference between two of the stations during 4 days between surveys No. 8 and No. 9 was as high as about 50 km. Comparisons of the increase of the measurable patch length and the residual current components in the direction of the dye patch axis seem to indicate a fairly good parallelism.

VII.4. CONSIDERATIONS REGARDING THE INTERPRETATION OF THE RESULTS OF THE ICES DIFFUSION EXPERIMENT "RHEINO 1965"

H. Sender, Deutsches Hydrographisches Institut, Hamburg, F.R. Germany, and J.H. Visscher, Fisheries Laboratory, Lowestoft, Suffolk, United Kingdom, and G.C. van Dorn, Rijkswaterstaat, Den Haag, Netherlands

The results of the RHEINO experiment indicate horizontal distributions which are relatively complex, but overall they appear to be suitable material against which to compare the theoretical predictions made for homogeneous isotropic diffusion processes. Measurements of the distribution of dye at a fixed depth are also individually quite complex, but, taken together, suggest a rate of vertical penetration which is remarkably regular and corresponds approximately to the relation vertical penetrations to (time)²/3.

The later horizontal distributions correspond approximately to the exponential distributions predicted by Joseph and Sender in 1969 and suggest vertical distributions for the mean diffusion velocity f increasing from about 0.4 to 1.0 cm/sec by the last survey. The general form of the variation of area within a particular isoline as a function of time is also, in agreement with Joseph and Sender.

There is some suggestion in the results that the diffusion coefficient-scale relationship varied during the course of the experiment and that this was independent of the appropriate turbulent energy distributions and of their dependence on the recent wind velocities and other sources of energy for the areas concerned.

It was shown that the concentration distributions exhibit persistent deviations from theoretical predictions. A satisfactory agreement with the results as a whole of the obtained if we apply a random diffusion distribution of the form

\[ \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(x^2+y^2)} \]

where a and b are parameters which are evaluated empirically, and it is suggested that their time dependence is influenced by alteration of the turbulent energy spectrum associated with storm force winds.
Turbulent exchange processes are responsible for the formation of fields of different hydrological characteristics (temperature, salinity, oxygen, etc.) in the ocean. The knowledge of turbulent diffusion parameters is indispensable for computing the behavior of industrial wastes discharged into the sea.

To study the turbulence diffusion in the sea it is rather convenient to use the method of fluorescent dyes (tracers). Low concentrations of the dye may be detected in the sea by an optical instrument furnished with a sensitive receiver and light source for generating fluorescence of the tracer. Such an instrument, the fluorometer, has been designed at the Institute of Oceanology, the U.S.S.R. Academy of Sciences. The instrument is responsive to $10^{-16}$ g of dye per 1 cm$^3$ of water. A set of devices has also been developed for realizing instantaneous and continuous sources of pollution.

The experiments were made in the Black Sea from two small trawling ships. From one of the ships (anchored) a tracer was released and the second ship made measurements with the instrument's sensor placed overboard. The distribution of the tracer concentration was recorded on board the ship.

Single recordings of the tracer concentration distribution in both the dye "tail" (at a continuous pollution source) and the dye patch (at an instantaneous source) are rather irregular which is due to a turbulent character of water motion in the sea. Yet, averaging of separate recordings for a number of identical realizations results in more regular distribution curves, sometimes close to the normal ones and sometimes different from them. Approximation of the averaged concentration distributions by solutions of the diffusion equations with differently specified coefficients made it possible to determine these coefficients and relate them to the phenomenon scale, density stratification and other factors.

VII.6. SOME REMARKS ON THE IMPORTANCE OF THE "SHEAR EFFECT" ON HORIZONTAL DIFFUSION

A. Ochs, Chesaapeke Bay Institute, The Johns Hopkins University, Baltimore, Maryland, U.S.A.

The shear effect means that the combined action of the variable mean current and transverse turbulent mixing produces an effective longitudinal diffusion. It has recently become apparent that current shear can play an important role in the horizontal spread of contaminants in the sea. By the use of a simple model for the shear effect, we can interpret most of the features of dye-release experiments, such as the shape of a dye-patch and the behavior of the peak concentration with time. The model has some intimate relation to various theoretical models developed on the basis of purely random movements of water. Some other aspects of the shear effect are also discussed. They are (i) the horizontal spread of minute particles which is not equal to that of the ambient water, (ii) the longitudinal diffusion in an oscillatory current with shear, and (iii) a possible role of the shear effect in large-scale mixing, e.g., the mixing of a water mass entrained in the Kuroshio.

VII.7. LONGITUDINAL DIFFUSION IN PERIODIC SHEAR FLOW

I. Dupont, Universitet i Bergen, Geofysisk Institutt, Norway

The analysis used by G.I. Taylor (1954) to describe turbulent diffusion in a circular pipe has been extended to the case of a periodically varying mean flow. In order to display the differences in diffusive properties between steady flow and periodic flow, a simple model is treated in detail. The model is a wide channel of depth $h$ with mean flow independent of the longitudinal and lateral coordinates $x$ and $y$. The coefficient of vertical diffusion $K_v$ is taken to be independent of the vertical coordinate $z$.

In the case of steady flow it is well known that the apparent coefficient of diffusion in the direction of the mean flow $K_x$ is inversely proportional to $K_v$. For a periodic mean flow it is found that the apparent coefficient of diffusion $K_{exp}$ varies with time. However, if the transport is integrated over a period, assuming the longitudinal gradient of diffusing material $K_0$ to be constant, it may be shown that $K_{exp} = 0$ when $K_0 = 0$. Then as $K_0$ increases $K_{exp}$ increases to reach a maximum for $K_0 = 1.6 \times 10^6$ cm$^2$/sec whereafter decreases again so that $K_{exp} = 0$ for $K_0 > 1.6 \times 10^6$ cm$^2$/sec. Here $\omega$ is the frequency of the periodic current. Thus $K_{exp}$ is inversely proportional to $K_v$ only for large values of $K_0$.

A comparison between the discussed model and observations in the Nersoy Estuary by K.P. Bowden (1964) shows a high degree of conformity. Bowden's calculations give a time-depth mean value of $K_x$ of about 20 cm$^2$/sec. In the present model where $K_0$ is taken to be $K_0 = 0$, then $K_0 = 0.1 K_0$, which in this case corresponds to $K_x = 2.3 \times 10^5$ cm$^2$/sec which leads to $K_{exp} = 1.1 \times 10^6$ cm$^2$/sec. This value may be compared with the value $1.7 \times 10^5$ cm$^2$/sec obtained by Bowden by means of direct measurements of the transport and $\omega$.

VII.8. EFFET DE LA THERMOCLINE SUR LA DIFFUSION A PARTIR D'UNE SOURCE

B. Saint-Guily, Muséum d'Histoire Naturelle, Paris, France

La thermocline est un caractère fondamental des océans et des mers. Elle joue un rôle de frontière entre l'eau froide et l'eau chaude. Cependant, elle est souvent séparée d'une barrière immatérielle. La durée de la diffusion turbulente à travers la thermocline est étudiée à partir des valeurs du coefficient de diffusion déterminées par divers modèles mathématiques. Le temps de passage ainsi obtenu est au minimum de l'ordre d'une semaine.

VII.9. WHICH OCEANOGRAPHIC PARAMETERS DETERMINE THE VERTICAL EXCHANGE COEFFICIENT?

P. Weislander, Oceanografiska Institutionen, Göteborg, Sweden

It has been attempted to correlate the vertical exchange coefficients ($K_v$, $K_w$, etc.) with the Richardson number, (d) the Brunt-Väisälä frequency, (N) etc... in the sea. Usually one finds a large scatter in the result and only general trends can be seen. This raises the question which parameters should be chosen.
It is argued that the momentum transport and the Brunt-Väisälä frequency are the appropriate parameters in approximately steady situations. A formula is presented that gives the $A_w$ and $K_w$ in the case where the turbulence is partly generated by local shear, partly comes from large-scale horizontal eddies in the sea, through a 'cascade' process. In the limiting case where only shear-turbulence exists one finds that $A_w$ and $K_w$ proportional to $K^{-3/2}$, and in the limiting case where only externally generated turbulence exists one finds these coefficients proportional to $K^{-1/2}$.

In the time-developing situation another set of parameters must be used. These are dependent on two ways, one with strong diffusion of momentum and density, and an approach to a steady state, and one with strong diffusion of momentum or a small or even reversed diffusion of density. In the second case one can end up with sharp thermoclines or haloclines that do not represent steady situations but that only change very slowly.

VII:10. IN SITU MEASUREMENTS OF HORIZONTAL AND VERTICAL DIFFUSION IN THE THERMOCLINE IN SWEDISH COASTAL WATERS

G. Kullenberg, Institute of Physical Oceanography, University of Copenhagen, Denmark

A recording in situ instrument for measuring the concentration of fluorescent dye (rhodamine B) in the sea has been developed. It consists of two photo-multipliers, one actuated by daylight and fluorescent light and the other by daylight only, connected in such a way that the effect of daylight is eliminated. The depth is recorded by a pressure-sensing unit. The sensitivity range is $5 \times 10^{-7}$ to $5 \times 10^{-11}$ in concentration units, the whole range being easily covered by the control units on board.

The instrument has been used in Swedish coastal waters with a view to investigate the diffusion in the thermocline and/or halocline; observations have also been obtained below the thermocline at a depth of 25-30 m. The dye was injected in the thermocline (halocline) as a momentaneous point-source coloring a spot 5-10 m in diameter and 1 m thick. To ensure contact the injection is made at a convenient distance from a parachute floating in the thermocline, and concentration is being recorded continuously, the position of the dye spot being plotted relatively to the parachute. During the experiments, which continued 5-15 hours, the dye spot is covered in different directions, its thickness being recorded at intervals.

The vertical diffusion coefficient, being supposed to be constant during each experiment, is computed using Fick's law. The resulting values are low, ranging from $10^{-5}$ to $50 \times 10^{-5} \text{ cm}^2/\text{s}$. An inverse relationship is established between the diffusion coefficient and the Richardson number, which ranges between .5 and 20.

The horizontal diffusion being studied at hand of the theory of Joseph and Sendner (1958): a linear relationship is established between the diffusion velocity and the absolute value of the difference of the current velocities at the upper and lower limits of the dye spot. Calculated values of the diffusion velocity are between .01 and .3 cm/s.

VII:11. THE EFFECT OF FINE STRUCTURE ON DIFFUSION THROUGH THE THERMOCLINE

J.D. Woods, Meteorological Office, Bracknell, United Kingdom

Eye tracer experiments carried out in Malta by divers have shown that the summer thermocline is divided into a series of 3-4 m. thick layers, in each of which the temperature gradient and current shear are rather weak and the turbidity and salinity are relatively uniform. Those layers are separated by thin sheets, whose temperature gradient and shear are far stronger than those found in the adjacent layers. At the center of each sheet (typical thickness 10 cm) is a laminar flow region, only a few millimeters thick. Simultaneous soundings made 100 km apart have shown that, in calm weather, the thermocline laminations extend unbroken for long distances; however, they are broken by strong mixing at coast or in rough weather, and it seems likely these provide the ultimate limit to the horizontal extent and the persistence of the fine structure.

Vertical transport through the thermocline is impeded by the thin zone of laminar flow (molecular conduction) in each of the sheets. However, steep internal waves found on the sheets have been observed to cause localized shear instability, leading to the generation of internal breakers and subsequently a patch of turbulence. For a brief period this patch of turbulence acts as a highly conducting aperture through the otherwise nearly impermeable molecular zone. It is argued that these apertures may provide the principal mechanism for vertical transport through the thermocline.

The sheets also prevent the feeding downwards of surface generated turbulence and, consequently, the layers in the thermocline are only very weakly turbulent. The mechanism of generating this weak turbulence is unclear. Because the turbulence is so weak, horizontal transport in the thermocline is essentially advective, although enhanced transport is observed at the sheets due to the action of internal waves.

VII:12. MÉTHODE DE MESURE OPTIQUE DU COEFFICIENT DE DIFFUSION TURBULENTE DES EAUX À LA VERTICALE

Alexandre Tristan, Laboratoire d'Océanographie Physique de la Faculté des Sciences de Paris, France

En définissant $z$ un coefficient de diffusion turbulente à la verticale et une vitesse de sédimentation en eau calme $N$ par les relations

$$dm \over dt = - \frac{1}{4} dz$$

et

$$dm \over dt = Wc$$

(où $c$ est la concentration des eaux de mer en particules en suspension à la profondeur $z$ et $W$ la vitesse horizontale de la particule de taille $c$ en mouvement dans un intervalle de temps $dt$), et en évaluant que pour un régime stationnaire la sédimentation et la diffusion turbulente se compensent, on obtient la relation suivante:

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\[ c = \frac{W}{\frac{dC}{dz}} = \frac{W}{d} \log C \] (1)

Supposons par ailleurs qu'un échantillon d'eau de mer prélevé à la profondeur \( z \) soit disposé dans un récipient cylindrique vertical de section \( dA \), et considérons à l'extrémité supérieure de la colonne liquide un élément de hauteur \( \Delta h \). La concentration des particules en suspension dans cet élément est

\[ c = \frac{dm}{dA, \Delta h} \]

\( n \) étant la masse des particules présentes dans l'élément considéré. En l'absence de tout phénomène de turbulence ou de convection, la sédimentation se fait librement, et à une variation \( dc \) de la masse des particules présentes correspond une variation de concentration

\[ dc = \frac{dm}{dA, \Delta h} \] (2)

L'élément considéré se trouve à l'extrémité supérieure de la colonne liquide, \( da \) (change de signe) représente la masse de particules traversant l'aire horizontale \( da \), constituant la limite inférieure de l'élément. On a donc par définition de la vitesse de sédimentation,

\[ -\frac{dm}{dA, \Delta h} = W.c.e.t.dA \]

c qui, joint à l'équation (2), donne

\[ W = -\frac{dc}{c} \Delta h \]

et joint à l'équation (1)

\[ \delta = -\frac{dc}{dz} \Delta h \] (3)

Autrement dit le coefficient de diffusion turbulente à la verticale pourrait être déduit à toute profondeur de la connaissance des variations avec la profondeur de la concentration des eaux de mer en particules en suspension, et de celle de la vitesse de variation (initiale) de la concentration en particules au voisinage de sa surface libre d'un échantillon prélevé à la profondeur considérée, et que l'on laisserait sédimenté.

Les mesures directes de concentration \( c \) en particules en suspension n'étant guère commodes, on peut essayer de les remplacer par des mesures du coefficient de diffusion optique \( \delta \), celui-ci dépendant essentiellement des matières en suspension. Si dans l'équation (3) on remplace \( c \) par \( f(\delta) \) on obtient

\[ \delta = -\frac{dc}{dz} \Delta h \]

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la condition toutefois que la relation entre \( c \) et sort indépendante de \( z \) et de \( c \), ce qui est certainement faux en toute rigueur, mais peut constituer une première approximation. Le problème reviendrait dans ces conditions à déterminer les variations avec la profondeur du coefficient de diffusion optique, ce qui ne présente pas de difficultés, et à mesure au voisinage de sa surface libre la vitesse de variation initiale du coefficient de diffusion optique d'un échantillon prélevé à la profondeur considérée et abandonné à la sédimentation, ce qui a exigé la réalisation d'un sédimentomètre optique, et par ailleurs, n'est pratiquement possible que si les matières en suspension sont en majorité minérales et présente une vitesse de sédimentation suffisante.

La méthode a été appliquée durant l'été 1965 aux îles Bermudes, par fond de sable extrêmement fin (en sorte que la quantité de particules mises en suspension suit les variations de l'état de turbulences de l'eau), par 14 à 15 mètres de profondeur. On a trouvé qu'en moyenne le coefficient de diffusion turbulente à la verticale aurait les valeurs suivantes aux profondeurs indiquées:

<table>
<thead>
<tr>
<th>Profondeur (m)</th>
<th>7</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitesse (cm²/sec)</td>
<td>22,4</td>
<td>8,0</td>
<td>4,6</td>
<td>2,0</td>
<td>37,4</td>
</tr>
</tbody>
</table>

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Elle a de nouveau été appliquée en mai 1967 dans la région de Kosi-bé (Madagascar), toujours sur fond de sable fin, par 9 mètres de profondeur environ. On a trouvé qu'en moyenne il avait les valeurs suivantes:

<table>
<thead>
<tr>
<th>Profondeur (m)</th>
<th>1 à 6</th>
<th>7,50</th>
<th>8,50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitesse (cm²/sec)</td>
<td>24</td>
<td>10,5</td>
<td>0,9</td>
</tr>
</tbody>
</table>

VIII.13. ÉTUDE DE LA DIFFUSION TURBULENTE HORIZONTALE À PETITE ECHELLE AU MOYEN DE LA DISPERSION DE FLUOCS INDIVIDUALISÉS

J.-L. Hucqinie, Laboratoire de Mécanique des Fluides, Université de Grenoble, France

Pour la connaissance de la diffusion horizontale à petite échelle, il est important de déterminer si, dans des conditions de turbulences données, celle-ci se produisit ou non sous l'effet de l'équilibre universel des petits turbulences ou si cette hypothèse se vérifie. Il est utile de préciser les domaines de temps et d'espace dans lesquels s'appliquent les modèles théoriques correspondants ainsi que la valeur numérique des constantes qui interviennent.

Dans ce but, nous avons défini une méthode générale d'essais utilisant une mesure, par photographie aérienne, de la dispersion d'un groupe de flotteurs individualisés, considérant les distances barométriques comme valeurs d'une fonction aléatoire, on procède en premier lieu à une analyse "intégrale" du phénomène en prenant comme variable le temps de diffusion. Cette analyse s'appuie sur la connaissance d'un coefficient de dispersion et d'un coefficient de diffusion turbulente. On procède ensuite à une analyse "différentielle" a deux ou trois points de phénomène en prenant comme variable l'échelle du phénomène. Cette seconde analyse utilise la définition d'un coefficient du type
II:14. THE MONACO-METHOD TO INVESTIGATE SMALL RANGE DIFFUSION PROCESSES IN DIFFERENT DEPTHS

J. Joseph, International Laboratory of Marine Radioactivity, Monaco

A new method, to measure the turbulent diffusion in different depths of the sea in the linear dimension of few decimeters, was developed in the International Laboratory of Marine Radioactivity at Monaco. The principle is, to measure the horizontal distribution of some hundreds of calibrated small beads, which fall with a velocity of about 10 cm/sec through a vertical distance of about 1 m. During the falling time of about 10 sec the beads are distributed by the turbulent diffusion in different compartments of a recepter.

The treatment of observations can be made using the old system drawing lines of equal concentration of beads or by statistical methods with the help of computers.

Some results are discussed. The order of magnitude of the observed diffusion-velocities is 0.2 - 0.3 cm/sec. Different possibilities to develop and apply the method will be discussed.

II:15. VERTICAL TURBULENT EXCHANGE AND HORIZONTAL TRANSPORT OF SUSPENDED MATTER BY CURRENTS

P. Groen, Instituut voor Aardwetenschappen, Amsterdam, Netherlands

Two problems are dealt with in this paper: 1. the problem of the equilibrium load and transport of suspended matter in a steady current and 2. the net (residual) transport of suspended matter by an alternating current (tidal current).

The vertical distribution of suspended matter and its horizontal transport depend on the functional form of \( K(z) \), i.e., of the eddy diffusivity as a function of the vertical coordinate \( z \). When using a bilinear form, and using the same form for computing the vertical distribution of the velocity, we find that it is possible to express the total transport of suspended matter in simple analytical form (in contrast to what is found by using different forms of \( K(z) \), e.g., the one which leads to the well-known logarithmic velocity profile). A difficult point in the problem is the "saturation concentration" of the suspension at the very bottom, which is used as a boundary value.

On the basis of certain simple assumptions it is found that the total transport varies with \( u_o \), the "friction velocity", as \( u_o^m \) with \( m \) ranging from 2 to 5, depending on the ratio \( v/u_o \), where \( v \) is the falling velocity of the particles, higher values of this ratio giving higher values of \( m \).

A tidal (alternating) current with zero net volume transport and equal maximum current strengths of flood and ebb currents may cause a non-zero net (time-integrated) transport of suspended matter, if only the current variations from flood to ebb and from ebb to flood are symmetrical. This is because in the non-steady state the actual suspended load is lagging behind the (theoretical) equilibrium load and the effect of this lag for the flood current is different from the effect for the ebb current, if there is such an asymmetry. A simple computation shows, for instance, that, if the time interval from maximum flood to maximum ebb currents is appreciably longer than the interval from maximum ebb to maximum flood current, there is an appreciable excess transport of suspended matter in the direction of the flood current.

II:16. EXPERIMENTAL AND THEORETICAL WORK IN THE FIELD OF TURBULENT DIFFUSION PERFORMED WITH REGARD TO THE NETHERLANDS' ESTUARIES AND COASTAL REGIONS OF THE NORTH SEA

G.C. van Dam and J.C. Schenfeld, Rijkswaterstaat, Den Haag, Netherlands

Salt distributions in the estuaries have been analysed from the point of view of one-dimensional Pickland-type diffusion. Since stationary conditions hardly ever occur, the analysis was performed entirely non-stationary, with the aid of a digital computer. For two estuaries, good agreement for the salt movement has justified the theoretical prediction of waste and oxygen distributions. For a third estuary, computations are being prepared. Attempts are being made to relate exchange processes to tidal movements, geometry and salt wedge phenomena.

Results of tracer experiments in the sea at short distances from the Dutch coast have been related with non-Pickland diffusion theories and are being applied in mathematical models which are used for theoretical analysis as well as predicting purposes. The ratio between peak concentrations with instantaneous release experiments and those obtained with the experiments in the central North Sea (Joseph, Sendner, Wallermann (1958, 1962); DUNGEY 1965) shows a good correspondence with current-velocity ratios from the viewpoint of diffusion in a Kolmogorov-range.

II:17. CALCULATION OF AVERAGE SALINITY DISTRIBUTIONS IN CANALS, ESTUARIES AND SEA

P. van der Burg, Rijkswaterstaat, Den Haag, Netherlands

The main objective for this study was an investigation of the possibilities for the prediction of the longitudinal salinity distributions in our open seas and arms of the Netherlands' estuaries in the southwestern part of the Netherlands. The Rotterdam Waterway remains as the single natural outlet for the flow of the river Maas and Meuse. With respect to several problems of water management a reliable prediction method for determining the salinity distribution as a function of the changing factors of the river-flow and depth is of utmost importance.

Analyzing the available data of salinities and amounts of flushing water in different navigation canals in the Netherlands, where salt-intrusion takes place, a relation was found between the longitudinal salinity-gradients, the
average velocities of the flushing process and the depth of the channels. Applying this result to the situations in the open sea arms and estuaries the same relation fits between the longitudinal salinity-gradients at low water slack, the average velocities of the tidal sub-currents and the maximum depths of the channels in the estuaries.

The empirical formula can be written as:

\[ \frac{\Delta S}{\Delta X} = 2 \cdot d \cdot \frac{V}{s} \cdot e^{-0.0014 \cdot X} \]

where \( S \) at L.W.S. in p.p.m. chloride, averaged over depth.

d = depth of halocline profile in m.

\( V \) = average velocity of sub-currents (m/sec) in T = 44800 sec.

\( s \) = section length in m.

The application of this empirical formula is not limited to channels and estuaries but can also be applied to seas with varying salinity distributions.

The empirical relation will be deduced and examples of the calculations will be demonstrated.

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SUMMARY OF THE CONVENOR AND THE RAPPORTEUR

This Symposium was divided roughly between papers dealing with horizontal diffusion, vertical diffusion and inshore effects. The 17 papers to be presented during the single day available resulted in a particularly tight programme which left less time for discussion than was felt to be desirable. It is probable that the afternoon papers suffered particularly in this respect.

Comments on the papers naturally revealed various attitudes to the problems under consideration but there was a significant interest shown in seeking physical causes for aspects of the diffusion problem which have previously been interpreted only in statistical language. This interest has most practical value where the processes are of comparatively short duration. We may thus expect to find increasing interest in the part played by such external effects as current shear of moderate scale and of surface wind velocity on rates of diffusion. Where longer term diffusion is concerned the main interest may still center on statistically averaged effects.

We find the inshore scientist giving particular attention to the local conditions of current shear and wind, offshore there may be less need to work in terms of the particular conditions but the air-sea energy exchange may still play an important part in the diffusion process on the surface. Thus the scientist dealing with inshore diffusion problems may find it more important to modify general laws in the light of the particular conditions in his area.
The following announced papers were given:

(Chairman - O. Arnason)

1. W. Hansen (F.R. Germany)  Applications of Hydrodynamical-
Numerical Methods to Problems of Physical Oceanography

2. R. Bonnefille (France)  Calcul de les ondes-maries dans un
ensemble de bassins rectangulaires
par la méthode des
fonctions propres

3. C.P. Jeleinski (U.S.A.)  Numerical Computations of Storm
Surges with Bottom Stress

4. M. Laska (Poland)  Nanking of the February 1962
Baltic Surge by Means of Hydro-
dynamical-Numerical Method

5. S. Grijaua O. (Mexico)  On the Tides in the Gulf of
California

Propagation in the North Sea by
Means of Hydrodynamical-Numerical Methods

(Chairman - Robinson)

Flow and Sea-Surface Temperature

8. L. von Treptka (F.R. Germany)  Numerical Computations of Tides in
Oceanic Basins of Variable Depths

9. A. Svansson (Sweden)  Determination of the Wind Stress
Coefficient by Water Level Computations

10. J.P. Pandofo (U.S.A.)  Some Experiments with a Physical-
Numerical Model of the Atmosphere-
Ocean Planetary Boundary Layer

11. G. Brettschneider (F.R. Germany)  Application of Hydrodynamical-
Numerical Methods to the Investiga-
tion of Non-Linear Processes in Shallow Waters

Recently, in marine hydrodynamics numerical techniques like N.M.-methods have
been developed in order to forecast and predict physical data, especially the
motion in the sea. These methods are based on the hydrodynamical equations and
in so far quite different from those which are normally used for predictions
published in tide tables. Experiments have been made with tides and tidal
currents, storm tides and drift currents and other motions occurring in tidal estu-
aeries, in adjacent and marginal seas and in the ocean. The results show that
the differences between predicted and measured data are considerably small and
that non-linear interactions among the constituents of the motion make it neces-
sary to include all effective terms into the computation. The nonlinearities
become important in shallow water and in coastal areas. Depth distribution and
coastal configuration play an important role, and the motion is strongly affected
by the geometry of the sea. Finally, it may be said that the N.M.-methods are a
helpful mean to understand the motion and its physics in the sea and may become
a standard tool to solve forecast and prediction problems.

VIII:2. CALCUL DES ONDES-MARIES DANS UN ENSEMBLE DE BASSINS
RECTANGULAIRES TOURNANTS PAR LA METHODE DES FONCTIONS
PROPRES

R. Bonnefille, Service S.A.N.U.H. d'Electricite de France,
Laboratoire National d'Hidrologie, Chato, France

Ce travail consacré la partie originale d'une these à soutenir prochain-
ment par l'auteur à l'Université de Grenoble. La méthode utilise les fonctions
propres $\lambda_n$ et $\beta_n$ d'un bassin rectangulaire de côté $a$ et $b$ tournant,
proportionnelles aux produits:

$$\cos n\pi (x/a), \quad \sin n\pi (y/b),$$

$\sin n\pi (y/b)$ $\sin n\pi (x/a)$, $\cos n\pi (y/b)$

m et n étant des entiers positifs ou nuls, introduites par Taylor en 1921 et
Goldbrough et Crac en 1931, pour déterminer les oscillations à longue période
daux bassins contiguës, ASSP et UGCD, a profondeur constante et sans frotte-
ment, les oscillations étant entretenues par une condition aux limites de courant
quelconque le long du coté AF.

La solution est cherchée sous la forme de deux séries doubles:

$$f = \sum \sum C_{mn} \phi_n \psi_m$$

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valables chacune dans les rectangles. L’application de la formule d’Ostrogradsky aux fonctions f et φm, procédé valable aussi à la singularité du point D d’après les travaux de J. Kvatvchenko et A. B. Apté, et le récurrence des solutions de longue durée conduisent à déterminer les coefficients φm et φm en résolvant un ensemble de cinq systèmes infinis d’équations linéaires. L’algèbre matricielle remplace cet ensemble à une seule relation matricielle linéaire aisément résolvable à l’aide d’un ordinateur. Quelques applications numériques à des bassins de différentes longueurs par rapport à celle de l’onde-marée permettant de juger de l’effet de la force de Coriolis.

VIII.3. NUMERICAL COMPUTATIONS OF STORM SURGES WITH BOTTOM STRESS

Chester F. Jenneanazzi, ESRA Institute for Oceanography, Sea Air Interaction Laboratory, Silver Springs, Maryland, U.S.A.

In a previous report that neglected bottom stress in computations, methods were developed to construct coastal tide surges with the aid of nomograms; these nomograms were restricted to storms landfalling from the sea at speeds greater than 10 mph and at not too acute a crossing angle to the coast. This report removes the restrictions to include storms traveling in any direction, at any speed, relative to a straight line coast; it also includes storms not making landfall. The removal of these restrictions required the introduction of a dissipating mechanism to control the growth of large amplitude surges, initialization effects and the build-up of large coastal transports.

VIII.4. HINDCASTING OF THE FEBRUARY 1962 BALTIC SURGE BY MEANS OF HYDRODYNAMICAL-NUMERICAL METHOD

Mieczysław Laska, Marine Station of the Polish Academy of Sciences, Sopot, Poland

In the period between the 13-21 of February 1962, due to the action of strong winds especially in the Southern Baltic a severe storm surge occurred. To achieve a useful forecasting method of these phenomena the known hydrodynamical-numerical method was used to reproduce the above mentioned surge. Theoretical basis for storm surge reproduction, by means of hydrodynamical-numerical computation, has been developed in 1956 by W. Hansen. The hydrodynamical equations of motion and continuity, in this method, are vertically integrated from the surface to the bottom. To solve the equations numerically the values of u, v and t should be calculated with certain boundary and initial conditions. The author has chosen a three-dimensional model (right hand system). In his calculations the Central and Southern Baltic was taken into account, assuming that this area is a closed basin with homogeneous water. The grid system consists of 167 squares; mesh width = 40 744 m and time step = 10 min. Calculations were executed on the Elliott - 803 B digital computer. Theoretically received values were compared with observed water level data at 18 tide gauge stations. The agreement between observed and computed data is quite satisfactory and showed a great applicability of this method for prediction of storm surge phenomena which occur along the Polish coast rather often.

VIII.5. ON THE TIDES IN THE GULF OF CALIFORNIA

Nicolas Ovialus G., Instituto de Geofísica, Torre de Ciencias, Ciudad Universitaria, Mexico

This paper describes the procedure followed to compute the propagation of some tide waves in the Gulf of California, showing the results obtained and compares the results with observed data.

The tides in this part of the world are big compared with those of other regions and it has become of interest the question of using the energy of tides for industrial purposes.

The method used is the one developed by W. Hansen known actually as R.N. Method. This method treats the problem as an Initial-boundary-value problem, transforms the simplified hydrodynamic differential equations into finite differential equations and solve the latter numerically.

In the case of the gulf of California the tides are important only in the northern part of the Gulf, and for this reason that region was considered. Along the southern boundary, which lies on the sea, a proper wave was prescribed as boundary value. Along the coast, it was prescribed that the water could only flow along the coast.

Having at hand the characteristics of the waves which constitute the main tide components it is possible to compute the amount of energy which can be used for industrial purposes.

VIII.6. INVESTIGATION OF WATER MASS PROPAGATION IN THE NORTH SEA BY MEANS OF HYDRODYNAMICAL-NUMERICAL METHODS

Jürgen Sündemann, Institut für Meereskunde der Universität Hamburg, F.R. Germany

In connection with the problems of coastal water pollution and sand transport in the German Bight investigations of propagation processes in the North Sea have been carried out. A continuous displacement of water masses is mainly caused by tides, wind and horizontal density gradients. The influence of these three factors on the water mass propagation in the North Sea is investigated in the Institut für Meereskunde Hamburg by means of hydrodynamical-numerical methods. The following results are obtained. Nonlinear effects cause a nonharmonic behavior of tides in coastal areas and lead (averaging over a tidal period) to a continuous water transport, the so-called residual currents. Along the English coast the water is displaced to the south; then, with increasing velocities, the residual currents displace the water masses along the Dutch coast into the German Bight, which is passed in a north-west direction. In the Skagerrak the water masses join the Baltic stream and flow out of the North Sea along the Norwegian coast. The wind over the North Sea causes permanent displacements of the water masses. Numerical computations with a temporally limited wind effect show, that the water masses do not return to their initial position after the wind has stopped blowing. The westerly winds, predominating over the North Sea, generate a current system which is similar to that of the residual currents of tides. Only preliminary results have as yet been obtained with reference to the influence of horizontal density gradients on the water mass propagation.
computed from the linear hydrodynamical equations, including terms of acceleration, wind stress, atmospheric pressure and bottom friction. For a period of one week in October 1958 the mean square deviations between theoretical and observed levels are computed for various "pairs" of the constants $K$ and $S$ in $g w + K w$ and $q w = S U$ ($q w = wind\ stress, \; tr = bottom\ stress, \; w = wind\ velocity$ and $U = water\ transport$).

VIII.10. SOME EXPERIMENTS WITH A PHYSICAL-NUMERICAL MODEL OF THE ATMOSPHERE-OCEAN PLANETARY BOUNDARY LAYER


The thermo-hydrodynamic laws governing the behavior of the atmosphere-ocean fluid system within the planetary boundary layer have been formulated into a simplified physical-numerical model which is susceptible to numerical integration under various initial and boundary conditions. The model incorporates infrared radiative transfer within the atmosphere. The vertical eddy exchange of horizontal momentum, heat, salinity and specific humidity is modeled using eddy transfer coefficients which depend upon the local Richardson number. The formulas for these coefficients are adapted from the previous work of Kitaigorodsky (1961), Mark and Anderson (1960), Morin and Oikshov (1954) and Priestley (1959). The interface boundary conditions presently used prescribe constant values of temperature and specific humidity, continuity of velocity and stress and balance between evaporation and salinity flux. The evolution of the velocity and salinity at the interface are computed from the preceding conditions. Constant values of order 1 km and at the lower boundary (at a height of a few hundred meters) of the system. Provision is made for the specification of a temporally constant but baroclinic horizontal pressure gradient. The horizontal transport of momentum, heat, salinity and specific humidity may also be computed from specified constant horizontal gradients of these variables. The results of a series of preliminary numerical investigations will be discussed. Commencing with linear periods of the order of five days have been computed to determine the influence of the following vertical profiles of changes in atmospheric pressure gradient, oceanic salinity, evaporation and long-wave radiation.

VIII.11. APPLICATION OF HYDRODINAMICAL-SIMULATION METHODS TO THE INVESTIGATION OF NON-LINEAR PROCESSES IN SHALLOW WATERS

Gotfried Bretschneider, Institut für Meereskunde der Universität Hamburg, F.R. Germany

The investigations are based on numerical solutions of the non-linear hydrodynamical equations of motion and the continuity equation. Using an electronic computer, they are numerically solved by means of the 85-method developed by W. Hansen. Several models with different depth distribution and different boundary values have been set up. First, the influence of the depth distribution in an ocean basin on the corresponding solution has been investigated. The numerical results indicate that there is a relation between the depth distribution and the non-linearities of the solution. Furthermore, the relation between different motion processes has been investigated. The solutions of the numerical models indicate that the effect of the interaction cannot be neglected in the solution of a hydrodynamical problem. This can be seen by comparing the complete solution with the one obtained by linear superposition of the separate solutions.
Numerical techniques, based on the hydrodynamical equations, were used for investigations of motions in the sea, caused by tides, wind effect or mass distribution. According to the practical possibilities or the aim of studies, experiments had been made in oceanic basins or in estuaries, in adjacent and marginal seas, in the ocean and moreover in a river-sea combination. Calculations of actual storm surges and of the propagation of tidal waves, for instance in the Baltic Sea and in the Gulf of California respectively, showed the utility of these methods for the understanding of notional action in the sea just as the application of a numerical model, which succeeded in reproducing main features of the Gulf Stream. Finally such numerical experiments turned out to be of interest following up practical purposes as in the computation of available tidal energy or in the investigation of coastal water pollution and sand transport.

The capacity of the available computers did not suffice to compute motions in the ocean without using open boundaries. The values, which had to be prescribed at these open boundaries, had been gained by interpolation, starting from coastal values, on account of lacking questionable measurements and have therefore to be regarded as a source of inaccuracy leading to differences between computed and observed data. In this connection it was suggested that the expeditions should be planned intensifying the consideration of the necessities of theoretical investigations. Moreover a larger capacity of disposable computers was in some numerical experiments looked upon as a condition for improving models for hindcasting, for example by rendering possible the incorporation of barometric pressure and stratification. Further calculations had been performed in oceanic basins in order to study the influence of shallow-water regions on nonlinear processes and on the dissipation of tides' energy. The corresponding results revealed the great importance of such areas within the ocean, thus including requirements to the size of the grid net to be used. Nonlinearity had been introduced into these models, besides in terms of the quadratic law of bottom friction, in respect to the spatial variability of depth in the equation of continuity. A method, determining oscillations of long period by means of eigenfunctions in a system of rectangular basins, permitted to decide the effect of Coriolis force under various conditions, however, turned out to be hardly applicable to generalizations of the system, owing to the necessity of inverting several infinite systems of linear equations.

IX. SYMPOSIUM ON COMPUTERS IN OCEANOGRAPHY

Convener: C.L. Pekeris 2 October 1967

The following papers were given:

(Chairman - C.L. Pekeris)

1. C.L. Pekeris and Y. Accad (Israel)

Experiments with the Solution of Laplace's Equations for the Tides in World Oceans

2. E.S. Heaps (U.K.)

A Two-Dimensional Numerical Sea Model

3. W.H. Munk (U.S.A.)

Tide Prediction

4. J.R. Rossiter and G.W. Lennon (U.K.)

An Intensive Analysis of Shallow-Water Tides

5. D.R. Cartwright (U.K.)

The Response of Sea Level to Tidal and Meteorological Forces, Including Tide-Surge Interactions

(Chairman - W.H. Munk)

6. B.D. Zetler (U.S.A.)

Recent Computer Applications to Tidal Procedures

7. V.P. Shapikha (U.S.S.R.)

Analysis of the Oceanographic Fields Based on Non-synchronous Data

(Paper given by I.M. Beloussov)

8. I.M. Beloussov, A.I. Toffe and V.P. Emilga (U.S.S.R.)

On the Possibility of the Use of Mathematical Methods for the Description of the Bottom Relief

9. P.M. Wolff (U.S.A.)

Processing and Synoptic Analyses of Oceanographic Data on High Speed Computers

10. B.D. Lortzarevic, H. Reiniger and D.R. Wells (Canada)

Shipboard Operation of Digital Computers

11. H. Dushman (U.S.A.)

Determination of Average Ocean Depths
IX:1. EXPERIMENTS WITH THE SOLUTION OF LAPLACE’S EQUATIONS FOR THE TIDES IN THE WORLD OCEANS

C.L. Feikert and V. Acream, Department of Applied Mathematics, The Weizmann Institute of Science, Rehovot, Israel

The aim of this investigation is to solve numerically Laplace’s tidal equations for the real world oceans with their variable depths. Some results will be presented of solutions obtained for the M2 tide for various models of the world oceans. The discussion will be based mainly on a world ocean of variable depth in which the coastline is defined by arcs of 2° in longitude and latitude. The depths used are based on actual soundings of the ocean bottom. Some evidence will be presented showing the sensitivity of the theoretical tides obtained to changes in the configuration of the coastline and of the topography of the ocean bottom. A discussion will also be given of the convergence of the numerical solution as the computational grid is reduced.

IX:2. A TWO-DIMENSIONAL NUMERICAL SEA MODEL

N.S. Rose, Tidal Institute and Observatory, University of Liverpool, United Kingdom

The model has, in the first place, been developed for the detailed investigation of various types of North Sea storms surge, particularly the external surge. As in some earlier investigations the linearized hydrodynamical equations are solved numerically using a finite-difference grid and a step-by-step procedure in time. However, the special feature of the present approach is that, within the basic grid system, it is possible to choose a general form of sea boundary; the computations are then carried out accordingly, on a digital computer, using an ALGOL program. In this sense the aim has been to develop a numerical tool of fairly wide application for the study of surge and tidal phenomena in adjacent seas.

For the North Sea, surges experienced at several ports around the shores of the Sea have been compared with those derived numerically. Also, contour lines of sea-level disturbance have been drawn showing patterns of surge development. Perhaps for the first time, the continental shelf sea surrounding the British Isles has been treated as a single dynamical unit, and the influence of flow through the Strait of Dover on surge levels in the North Sea has been studied.

The progress of the work has depended on the availability of a large modern digital computer with a large quick-access store. A significant part of the work has been concerned with logical structure of the computer program which solves the organizational problems presented by the generality of the approach.

IX:3. TIDE PREDICTION

W.R. Munk, Institute of Geophysics, University of California, San Diego, California, U.S.A.

The response method of tidal prediction, developed by D.E. Cartwright and the speaker, will be reviewed, together with some recent related work by Gallagher and the speaker on “time domain” prediction for extremely non-linear systems. Apparently some of the harmonic energy leaking out of non-linear basins is in global equilibrium, and can thereby be detected at deep basin stations.

IX:4. AN INTENSIVE ANALYSIS OF SHALLOW-WATER TIDES

J.A. Rossiter and G.W. Leamen, Tidal Institute and Observatory, University of Liverpool, United Kingdom

The non-linear terms in the laws of hydrodynamics, in so far as these apply to tidal generation in shallow water areas, create considerable complication in attempts to define tidal phenomena numerically. The classical harmonic technique has been assumed adequate in circumstances where shallow water effects are well developed. This assumption is based upon the fact that the laws of generation of shallow water tides in terms of harmonic constituents are not fully understood so that the significant constituents have not been identified, nor has their distribution among the species been determined.

Attempts to overcome these difficulties in the past have not been completely successful. Dooodson’s harmonic shallow water procedure provides an excellent basis for the determination of times and heights of high and low water but does not attempt to define tidal elevations at intermediate points on the tidal curve and would be excessively cumbersome in such an application. Horn’s method is data extending over nineteen years in order to provide an adequate basis for analysis.

This paper describes the use of computer techniques in an intensive application of the conventional harmonic method to tides in the estuary of the River Thames. Some 54 new tidal constituents of significant amplitude have been determined in this area and their effect in the improvement of tidal predictions has been evaluated and compared with the Dooodson harmonic shallow water process.

The analysis has also allowed an investigation of the background noise present in tidal data sets, incoherent features and transient periodicities, inter-tidal interaction and the interaction between tidal and meteorological phenomena.

IX:5. THE RESPONSE OF SEA LEVEL TO TIDAL AND METEOROLOGICAL FORCES, INCLUDING TIDE-SURGE INTERACTIONS

D.E. Cartwright, National Institute of Oceanography, United Kingdom

The Munk-Cartwright response method of tidal analysis is applied to six ports around Britain with more severe non-linear content than those analyzed previously. The linear admittances for a coherent pattern, and, except for
the "cusp region" within (2 cmol ± 4 cmol), the 2nd order interactions with the semi-diurnal tide have coefficients which are reasonably in line with those describing interaction between the tide and the surge (or "noise").

It is noted that the 2nd order interaction of the semi-diurnal tide with itself is strongly frequency-dependent. Also, the third order interaction varies with the cube of the primary amplitude, in apparent contradiction to the usual assumption of a quadratic friction law.

In analogy to the tidal response, the linearized response to the meteorological forces is expressed in terms of the first six coefficients of a Taylor expansion of the atmospheric pressure over the relevant shallow sea area. The response is found to have considerable time-dependence, as one should expect from other work on storm surges.

To complete the prediction formalism, the sea level at another port is included, to allow for "external surges," and a self-prediction of the residual error partially corrects long-term errors in low and tidal frequencies.

IX.6. RECENT COMPUTER APPLICATIONS TO TIDAL PROCEDURES
B. D. Keller, Physical Oceanography Laboratory, Institute for Oceanography, U.S. Environmental Sciences Services
Administration, U.S.A.

Within the past few years, the traditional procedures with respect to tide observations, reductions, analysis and prediction have been greatly modified through the use of electronic computers. Tide observations are obtained on punch paper tape records that are then translated to punched cards. After the data are edited, the reduction program computes and outputs times and heights of high and low waters, mean tidal intervals, various ranges and datum planes, and monthly extremes. The harmonic constants for a year of data are obtained by a least squares solution. Although the traditional Fourier analysis for individual frequencies is still used for 15 and 29 day analyses, this is done on an electronic computer. Rotary tidal current observations for 29 day series are converted to two series of vectors, parallel to and normal to the major axis of the current ellipse. The program then computes the tidal constants for the principal constituents for each set of vectors and the non-tidal current. The mechanical tide predicting machine, in use since 1912, has been replaced by computer programs, thus providing greater flexibility in the choice of tidal constituents. In a recent study to improve shallow water predictions, power spectrum analysis was used as a part of the technique for identifying significant hidden frequencies; it is anticipated that the "fast Fourier transform" will replace this method in the future.

IX.7. ANALYSIS OF THE OCEANOGRAPHIC FIELDS BASED ON NONSYNCHRONOUS DATA
V. P. Shestova, Marine Hydrophysical Institute, Ukrainian Academy of Sciences, Sevastopol, U.S.S.R.

Vertical and horizontal distribution of the oceanographic elements (temperature, salinity, density) can be studied at present on the basis of expeditionary observations only. Conditionally these observations are believed to one moment of time, but in fact all oceanographic stations are made at various moments of time even if several research vessels participate in the expedition. In the construction of charts and interpolation of the values of an element (temperature, density, etc.) for points grid, one commits errors of two kinds:

1) the errors conditioned by non-synchronous observations, and
2) the errors of the spatial interpolation.

The errors of the first kind appear owing to the substitution of a value of any element at a certain moment of time by a value at another moment. The mean square error of this substitution is a function of time and represents a square root of time structural function. An error of the interpolation can be estimated also, if the spatial correlation (or structural) function is known.

Calculation of these errors permits to know accuracy of the fields of any elements and to plan oceanographic expeditions in such a way that the errors do not exceed the fixed value.

IX.8. ON THE POSSIBILITIES OF THE USE OF MATHEMATICAL METHODS FOR THE DESCRIPTION OF THE BOTTOM RELIEF

In two previous papers it was shown that the use of the relief levelling along the profiles and the analysis of the distribution of depths, the mean square characteristics of the inclinations made it possible to obtain quantitative description along the profile of the bottom relief was proposed as well (5). In place (along the profile but also in space) is proposed. On the basis of bound-

This problem can be considered as a particular case of Gauss's classical problem: a definition of the most authentic meaning of the function on the squares procedure. It is necessary to show the maximum authentic meaning of arrangement of measured points. We consider that the depth at a given point is approximated by the polyhedral of the third degree, the coefficients of which were determined from the condition of the minimized terms:

\[ \sum_{i,j} P_n \left( \sum_{i,j} a_{ij} x_i^j + m_{ij} \right)^2 \]

where \( N \) is a number of points, provided by measuring; \( x_i, y_i \), and \( m_i \) are certain coordinates of the points and the depth at these points; \( P_n \) is some weight factor; \( a_{ij} \) are coefficients of the polyhedral at a given point \( (x,y) \).

The computations were carried out by the computer which solved the system of regular equations for coefficients:

\[ \sum_{i,j} a_{ij} x_i^j = \sum_{i,j} \left( \alpha_{ij} x_i^j - m_i \right) \]

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Here, coefficients $a_i$ determine the approximate surface and the coefficient $a$ is the depth sought.

In one of the areas in the Arabian-Indian ridge provided by the measurement corresponding calculations were made. They give adequate data between estimated profiles and experimental ones, which were not included in the computer processing. It is probably expedient to use the proposed procedure of computation for different elements studied in oceanology and geophysics.

After choosing the best class of approximate functions it will be possible to use the characteristics applicable in differential geometry for the analysis of computed surface.

IX.9. PROCESSING AND SYNOPSIS ANALYSES OF OCEANOGRAPHIC DATA ON HIGH-SPEED COMPUTERS

P.H. Wolff, U.S. Fleet Numerical Weather Facility, Monterey, California, U.S.A.

The atmosphere and the ocean constitute a coupled system. Most of the driving forces of the ocean are atmospheric. Therefore, the numerical analyses of the properties and motion of ocean surface layers are computed numerically at Fleet Numerical Weather Facility in connection with corresponding numerical weather analyses on high-speed digital computers. The principles of these analyses are outlined and examples given.

The density of surface and subsurface synoptic observations is shown and their computerized retrieval, checking and analysis are described, with the consideration of accuracy, density and space-time variability.

Further imminent developments in progress for computerized numerical oceanographic analysis/forecasting are indicated.

IX.10. SHIPBOARD OPERATION OF DIGITAL COMPUTERS

R.G. Langaracig, R. Seidinger and D.E. Wells, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada

Without model experiments or controllable environment, research in oceanography consists primarily of collection, collation, and compilation of observations. A large number of very expensive data points must be synthesized and analyzed before the creative step of interpretation can be reached. In order to generate results of scientific importance, it is essential that the scientist's application effort be diverted from collection to interpretation of data.

A digital computer on board the research ship can control the quality and rate of data acquisition, carry out first level data reduction for immediate interpretation and control the experiment while it is happening. In addition, the man-machine interaction within the special shipboard environment will influence the decision making process and will make possible a new type of experiment. For full implementation of a shipboard computer system, background support must be developed. Special attention must be paid to training the operators, programmers and maintenance technicians in addition to the development of a new research philosophy.

During the past two years, two EDP-8 computers have been used on two ships on 6 different cruises. The computer running time exceeds 2,000 hours without any serious maintenance problems. Two groups of programs have been developed to process geophysical data collected while the ship is underway and oceanographic station observations. The use of the computer at sea makes it possible to make decisions on the basis of the cruise data while the ship is in the area under investigation. Although the data processing will become more sophisticated, it is evident that the most important advances will be made by using computers for experiments which would not be performed without on-line computer control.

IX.11. DETERMINATION OF AVERAGE OCEAN DEPTHS

Menahem Diabol, NASA Goddard Institute for Space Studies, New York, N.Y. (Permanent address: The Weizman Institute of Science, Rehovoth, Israel)

The problem of determining average ocean depths for some region of the world-ocean, or over all the oceans together, is encountered in some oceanographic work (such as determining the ocean tides theoretically), where numerical computations have to be carried out. In these cases it is usually required to represent the actual variable depths by average values taken over some regular grid units.

To obtain representative local average depths, the approach developed by the author draws from an analogy in numerical meteorology where, for analysis purposes, data received from scattered observation points over a hemisphere have to be transformed to data at the points of a regularly arranged grid. Contributions of available depths at the vicinity of grid-points are averaged if required, are weighed with respect to their distances from the grid-points, taking into account, eventually, known general structural features of the region under consideration. The process consists of repetitive scanning of the grid, applying successive corrections to arbitrary starting values of depths. Mathematical smoothing is interposed between the scans.

The need for “raw data” to be used in the computation of the depth averages motivated the recent establishment of a fully computerized library of deep sea soundings. This data library provides automatic access to a worldwide coverage of deep sea soundings for qualitative studies of submarine topography. The soundings contained on the master plotting sheets for deep sea soundings maintained by the U.S. Naval Oceanographic Office, the Lamont Geological Observatory, the Hydrographic Departments of the United Kingdom, South Africa, Australia, New Zealand, the Netherlands, and Germany have been used as the basic source information for the new digital library. The soundings are recorded by employing recently-developed semi-automatic instruments, known as digitizers, and are stored on magnetic tape. The library now includes over one million data points from about 10,000 track segments originally plotted on over 2,000 source sheets.

Details concerning this data library and its use in connection with the computation of average depths will be presented and discussed.
The Symposium showed an emphasis on tides, reflecting the interest and taste of the convenor who also gave the first paper. Pekeris could report substantial progress since the first announcement six years ago at Helsinki of his pioneering attempt to solve the Laplace tidal equation for the real world oceans. The problem of allowing for coastal dissipation of tides remains to be attacked. Kemp reported on certain two-dimensional numerical modes of tide calculations with particular emphasis on including the meteorologically generated surges which may sometimes be the cause of extensive damage. Noeiter described the work by himself and Savino of shallow water predictions in the time domain, as compared to the Boussinesq method for shallow water predictions in the frequency domain. In a similar vein, Zoller discussed the use of computers in evaluating tidal constituents involving a much larger number of such constituents as had been traditionally the case. He also referred to computer methods for obtaining times and heights of extreme. Munk reported on the "response method" of tide prediction, using computer generated hour-by-hour amplitudes of spherical harmonics as inputs into optimum filters. An argument was made for time domain rather than frequency domain prediction for shallow ports. Cartwright has included bi- and even trilinear filters for response predictions at North Sea ports, using meteorological as well as gravitational inputs. He thus includes tide-tide, tide-tide-tide and tide-surge interactions in his predictions. The results look promising indeed.

Belousov reported, on behalf of Shaikov, the analysis of oceanographic fields based on non-synchronous data, with emphasis on optimal methods of interpolation. He also reported, on behalf of himself, Wolff and Welge, the use of mathematical methods for the description of bottom relief. The emphasis was on interpolation by polynomials, but some early attempts on Fourier analysis was also referred to. The work by Wolff on the description and predictions of vary oceanographic variables by machine methods was reported on. Hancock reported, on behalf of himself, Reckinger and Welge, the shipboard use of digital computers at the Bedford Institute of Oceanography. He emphasized the need for a gradual approach to the use of shipboard computers, but went on to illustrate the very great advantages to be obtained by some real-time analysis at sea. Finally, Bishop reported on his very extensive compilation of ocean depths, using a computer for quality control and compilations.

The foregoing papers indicate the use of computers in all phases of oceanography; data taking, analysis, theory and mathematical modeling. At the present stage of development a symposium devoted to the role of computers in oceanography runs in danger of becoming a hodge-podge of miscellaneous. Three years from now the use of computers in all these activities will have become so commonplace that we doubt whether any future symposium will be devoted to this subject.

X. SYMPOSIUM ON PHYSICAL PROPERTIES OF SEA WATER
Convenor: Fred N. Kornblum 6 October 1967

Before opening the meeting the convenor reminded of the late Dr. Roland A. Cook, who according to the original plans should have convened the Symposium. His death was a serious blow to physical oceanography and especially to the branch of this science which deals with the physical properties of sea water.

The following papers were given:

(Chairman - John Lyman)

1. R.L. Ribe and J.C. Holmes (U.S.A.)
   An Empirical Equation Relating Sea Water Salinity, Temperature, Pressure and Electrical Conductivity

2. I.W. Dusdall (Canada)
   D.N. Connors and
   P.R. Woyt (U.S.A.)
   The Partial Equivalent Volumes and Conductances of the Major Salts in Sea Water

3. A. Mau and A. Johannin (France)
   Variation de l'indice de refraction de l'eau de mer avec la chlorinité, la longueur d'onde et la température

4. G. Beardsley (U.S.A.)
   Relations between the Inherent and Apparent Properties of Sea Water, as Determined by an Approximate Solution of the Equation of Radiative Transfer

5. G. Girard et M. Menaché (France)
   Essais d'étude experimentale de la loi de variation de la masse volumique de l'eau en fonction de sa composition isotopique

(Chairman - Nils Jerlov)

6. T. Sasaki (Japan)
   Optical Properties of the Water on the Kuroshio

7. T. Sasaki (Japan)
   Angular Distribution of Scattered Light in Deep Sea Water of the Kuroshio

8. M.G. Neuvim (U.S.S.R.)
   Some Results of Optical Measurements in the Deep Water Zones of the Ocean

9. G. Lundgren (Denmark)
   Irradiance Measurements in the Sargasso Sea

10. A. Morel (France)
    Etude pour diverses longueurs d'onde de l'indicatrice de diffusion de la lumière des eaux de mer
An empirical equation relating sea water salinity, temperature, pressure, and electrical conductivity

R.L. Ribe and J.C. Howe, Testing Division, Instrumentation Department, U.S, Naval Oceanographic Office, U.S.A.

An empirical relationship between electrical conductivity, salinity, temperature, and pressure, which is derived from the experimental data for sea water of Bradshaw and Schlickeirch, and of Brown and Allenforth and in conformity with the International Tables is expressed by:

\[(1+x)H(35-S)^2 \times (35-8) - (8-R+1+x) \times \left(\frac{1}{1+R}\right) = 0\]

Equation (1)

where,

- S = salinity in parts per thousand (P.P.T.),
- T = in situ temperature in degrees Celsius (°C),
- P = in situ pressure in decibars,
- x = the ratio of the change in electrical conductivity due to pressure effects to the conductivity at one atmosphere, at the in situ temperature.

\[x = \left[1 + (8.893 \times 10^{-8}) - (5.7 \times 10^{10}) p^2 \right] \left[4.496 \times 10^5 \exp \left(273 \times 16592\right) \right]^{-1}

G = the rate of change of electrical conductivity with salinity change. Some small, second-order, salinity effects have been moved to a different part of the main equation.

\[G = 0.017482 - (5.009 \times 10^{-4}) T - (2.453 \times 10^{-6}) S^2 + (1.05 \times 10^{-7}) T^3\]

The ratio of the in situ electrical conductivity to that of 35 P.P.T. sea water at atmospheric pressure and 15°C is an empirical relation for the ratio of the electrical conductivity of 35 P.P.T. sea water at the in situ temperature to that of 35 P.P.T. sea water at 15°C, both at atmospheric pressure.

\[\frac{G}{R} = 0.675245 + (0.02033166) T - (1.9 \times 10^{-5}) T^2 - (1.942692 \times 10^{-7}) T^3 - (6.724914 \times 10^{-9}) T^4\]

(R), (A), and (G) are functions which were derived in the development of Eq. (1).

\[H = (3.67 \times 10^{-10}) - (9.683 \times 10^{-10}) T + (2.973 \times 10^{-12}) T^2 - (3.59 \times 10^{-14}) T^3\]

\[A = 3.899 \times (2.99 \times 10^{-9}) T - (1.62 \times 10^{-10}) T^2 + (2.5 \times 10^{-12}) T^3\]

\[D = 0.731 \times 0.00029\]

Values of (R), (P), and (T) can be inserted into Eq. (1) and the corresponding values of (35-S) can be calculated. Equation (1) can be solved by usual methods for a second-order polynomial in (35-S), or by treating the second-order term in (35-S) as a small correction to the linear term in (35-S). This second method introduces negligible error.

This relationship agrees better than ±0.01 P.P.T. when compared to the results of references for the region of salinity from 30 to 40 P.P.T., temperature from 0°C to 25°C, and pressure from zero to 1000 decibars. For the usual in situ conditions as experienced in the "real ocean" agreement is about ±0.006 P.P.T.
Sea water has been treated as a two component system comprised of sea salt and water, where sea salt is defined as an anhydrous mixture of salts whose ion concentrations bear the same ratio to the chloride concentration as is found in sea water. The specific conductance of sea salt is used in the specific volume and specific conductance of sea water, respectively. The calculations give the increase in conductance due to the addition of one equivalent of sea salt.

\[ V_1 = \frac{3V}{10^6} \text{ m}^3\text{ mol}^{-1} \text{ mol}^{-1} \text{ L}^{-1} \]
\[ \Delta \lambda = \frac{3L}{10^6} \text{ m} \text{ mol}^{-1} \text{ mol}^{-1} \text{ L}^{-1} \]

\[ \Delta \lambda \text{ is the increase in total conductance (C) of an infinitely large volume of sea water, contained between two parallel plates 1 cm apart, due to the addition of one equivalent (n) of salt.} \]

Discussion on Paper X:2

Grashof stressed the importance of making such measurements at a standard state of the carbon dioxide system and mentioned that the influence on conductivity of the in situ change of the pH is one order of magnitude greater than the varying change in the ionic composition.

Hereau drew Dr. Duval's attention to the fact that the scatter of the points in the chlorinity-conductivity curve in Rollox Cox's paper in "Satur" were mainly due to errors in the chlorinity analysis and only to a smaller extent to differences in ionic composition.

X:3. VARIATION DE L'INDICE DE REFRACTION DE L'EAU DE MER AVEC LA CHLORINITE, LA LONGUEUR D'ONDE ET LA TEMPERATURE

Annick Neuh et Andréa Johanim, Gilles, Faculté des Sciences de Bret, Finistère, France

Les indices de réfraction d'une eau de mer stalon de chlorinité 19,37% forni par le Standard Sea-Water Service de Copenhague et de dilutions de cette eau de mer stalon ont été mesurés pour des températures inférieures à 30° et des longueurs d'onde comprises entre 4 047 Å et 6 438 Å.

A titre de comparaison, quelques mesures ont été effectuées également avec une eau prélevée dans l'océan Atlantique.

Les mesures ont été faites à l'aide d'un prisme creux, placé sur le plateau d'un géomètre au minimum de déviation. C'est un prisme à deux cavités superposées qui peuvent recevoir soit l'eau, une eau bidistillée et l'artézienne eau de mer stalon, soit deux eaux de chlorinités différentes, permettent ainsi une détermination simultáne des indices de réfraction des deux eaux considérées et, par conséquent, de leur différence.

Le prisme est thermostaté à des températures comprises entre 0° et 30°. La différence de température entre les deux cavités est stabilisée à 0,025°C. Une variation de degré de cet ordre entraîne une variation de l'indice de réfraction de l'ordre de 5x10⁻⁶, ce qui est au delà de la précision des mesures optiques qui est de 3x10⁻⁶.

La littérature ne fournit actuellement, à notre connaissance, de données sur la variation de l'indice de réfraction de l'eau de mer avec la chlorinité, la température et la longueur d'onde.

X:4. RELATIONS BETWEEN THE INHERENT AND APPARENT OPTICAL PROPERTIES OF SEA WATER, AS DETERMINED BY AN APPROXIMATE SOLUTION OF THE EQUATION OF RADIATIVE TRANSFER

George Beardley, Department of Oceanography, Oregon State University, Corvallis, Oregon, U.S.A.

The scalar apparent optical properties of sea water are a set of seven measurable that describe the behavior of the submarine light field. These properties are related to the inherent optical properties—the extinction coefficient and the scattering functions—through the equation of radiative transfer.

A numerical approximation to the equation of transfer was programmed for solution on a high speed digital computer. The technique is based on dividing the hydroxol into a system of thin slabs, and then solving the transfer equation for each slab. No multiple scattering events are allowed in an individual slab. The method converges rapidly due to the relatively high absorption always present in natural hydroxols. The results of the equation of radiative transfer, as well as the apparent optical properties, is presented in tabular form, allowing one to predict the submarine light field at any location if the two inherent optical properties and the incident daylight radiance field are known.

Calculations were made for a variety of typical sea water conditions by using a single three parameter model for the scattering function. The scattering model is based on an empirical fit of scattering data from several locations, and it retains the highly directional characteristic of the phase function of natural hydroxols. The results, presented in both graphic and tabular form, allow one to predict the submarine light field at any location if the two inherent optical properties and the incident daylight radiance field are known.

X:5. ÉTUDE EXPERIMENTALE DE LA LOI DE VARIATION DE LA MASSE VOLUMIQUE DE L'EAU EN FONCTION DE SA COMPOSITION ISOTOPIQUE

G. Girard, Bureau International des Poids et Mesures, Sevres, et M. Menaché, Office de la Recherche Scientifique et Technique Orsay-Paris, France

L'eau pure étant, jusqu'ici, le seul liquide pouvant servir de référence dans les déterminations de la masse volumique de l'eau de mer, une meilleure connaissance de sa masse volumique est nécessaire.

Nous avons entrepris des essais en vue d'apprécier expérimentalement la validité de la relation établie par l'un de nous (Menaché, M., Metrologia, 3 (3), 1967, 58-63) entre la masse volumique de l'eau et sa composition isotopique.

Les mesures consistent à peser un cylindre en acier inoxydable "Fomal D", dont la masse et le coefficient de dilatation thermique sont connus avec une
précision suffisante, dans divers échantillons d'eau dont la composition isotopique est déterminée par ailleurs.

Ce cylindre, qui appartient au BUREAU INTERNATIONAL DES Poids ET MESURES (B.I.P.M.) et dont la masse est voisine de 1 kg, a été l'objet d'une série de déterminations de masse volumique, effectuées de 1952 à 1964, par les principaux laboratoires métrologiques du monde, dont le B.I.P.M. (Bonnoure, A., Proces-verbaux C.I.P.M., 32, 1964, 103-118).

Les pesées sont faites par GÉRARD au B.I.P.M., sur la nouvelle balance hydrométrique STARTON du Bureau International.

Les différences de masse volumique à mettre en évidence en fonction des différences de composition isotopique des divers échantillons d'eau étudiés sont extrêmement faibles, et seraient facilement masquées par les erreurs de mesure ou celles pouvant être entraînées par les autres facteurs dont dépend la masse volumique de l'eau, à savoir: la température, la pression et la concentration en gaz atmosphériques dissous.

Les erreurs relevant de la température sont, de loin, les plus importantes. Nous avons dû effectuer toutes nos expériences à une même température: 22±0,1°C. À cette température la variation de la masse volumique de l'eau, pour un dégré C, est égale à 227.10⁻³ kg/m³. Pour atteindre, dans ces conditions, la précision de 1.10⁻⁷ kg/m³, nous avons dû veiller à ce qu'aucun des pasages hydrométriques, la température, en tous les points du bain, soit homogène, constante et définie à une précision de 0,003°C près.

L'influence de la précision et de la concentration en gaz atmosphérique dissous, dans les conditions actuelles de mesure, est suffisamment bien connue vis-à-vis de la précision recherchée.

Au début et à la fin de chaque pesée hydrométrique, nous déterminons entre autres: la pression atmosphérique, la température de l'eau, la concentration en gaz atmosphérique dissous, en oxygène-18 et en deutérium. Les analyses isotopiques sont faites par les soins de M. NIEF, au CENTRE D'ETUDES NUCLEAIRES DE SACLAY.

Les résultats des déterminations de masse volumique ont ramenés à 22°C, une atmosphère normale et une concentration nulle en gaz dissous. La masse volumique d'une eau répondant à ces conditions et ayant une composition isotopique constante, par exemple celle du S.M.G.W., est une constante qui s'élimine dans les différences de masse volumique entre deux échantillons d'eau de composition isotopique différente. Ces différences s'expriment ainsi uniquement fonction des différences correspondantes de composition isotopique.

Les premiers résultats obtenus confirment la validité de la relation établie, avec une précision de l'ordre de 1.10⁻⁷ kg/m³.

X:7. ANGULAR DISTRIBUTION OF SCATTERED LIGHT IN DEEP SEA WATER

Tadayoshi Sasaki, Tokyo University of Fisheries, Japan

The angular distribution of scattered light in deep sea water, whereas the Kuroshio region, was measured and interesting results about average diameter of particles suspended in this deep sea water, total number of particles in a unit volume, etc. were obtained by methods described below.

Samples of deep sea water to be tested were taken at various depths down to 6,000 m below the sea surface and the angular distribution of scattered light in the samples was measured and the angular distribution curve obtained by the measurement was compared with that theoretically obtained by applying Mie theory to the light scattering due to suspended particles in deep sea water and discussed. In applying Mie theory the following items were assumed:

1) Suspended particles in deep sea water are non absorbing and isotropic spherical particles.

2) These particles are homogeneous polydispercing particles, whose size distribution function is expressed by the following equation:

\[ f(r) = r(r - r_0) e^{- \frac{r}{C}} \]

where \( f(r) \) is the number of particles per unit volume with radii between \( r \) and \( r+dr \), \( C \) is a normalization constant, and \( r_0 \) and \( b \) are parameters characterizing the distribution.

The theoretical angular distribution curves are made for with respect to three different relative refractive indices, \( n = 1.45, 1.20 \) and 1.25 respectively by treating the particle radius, the modal radius and the total particle number in the unit volume as variables.

It is found that the angular distribution curves obtained by measurements are larger than theoretical curves at the backward scattering but two curves are much smaller at the forward scattering.

X:8. SOME RESULTS OF OPTICAL MEASUREMENTS IN THE DEEP WATER REGIONS OF THE OCEAN

H.S. Bourquin, Marine Hydrophysical Institute, Ukrainian Academy of Sciences, Sevastopol, U.S.S.R.

Formerly investigations of optical properties of deep sea waters were carried mainly on samples bottles from depths out. Instruments for telemetering optical measurements, recently developed in the Marine hydrophysical Institute of the Ukrainian Academy of Sciences allow us to make hydrophysical investigations 'in situ' at depths up to 3,000-3,000 m. These researches give us the possibility to establish and study some qualitatively new phenomena in the deep sea.

It is found that the vertical distribution of beam transmittance attenuation is not stationary, but fluctuates casually. The average amplitude and character
of fluctuations depend strongly on hydrological and hydrodynamical structure of water. The frequency spectrum of fluctuations within 0.005-0.3 cps was investigated. The measurements of fluctuations may serve as a sensitive indicator of optical, hydrological and hydrodynamical inhomogeneity of waters. They may also be used for studying eddy diffusion processes in the ocean.

New instruments are an effective means for investigation of suspended matter distribution in the deep ocean. In the Black Sea at 120-170 m depth a sharp thin layer of a rather high concentration of suspended matter has been discovered with the aid of the marine pulse transmittance-meter. Formation of this layer is due to the peculiarities of dynamical processes at the Black Sea depths. The position of the layer corresponds to maximum velocity of vertical currents.

New devices are useful to investigate bottom currents, mud flows and other processes connected with interaction of water flows and sediments. Four main types of suspended matter distribution near bottom were established.

Cited examples show the usefulness and effectiveness of application of the designed optical methods and devices for solution of some problems in physical oceanography, marine geology, hydrobiology and other branches of marine science.

Discussion on Paper X:8

Beardsley: Please explain the different structures in the three time dependent traces of beam transmission shown in the slide.

Neuynin: In the first case the variation can be explained by the fact that the observations were taken near a layer with great variation in beam transmission, in the second case the variation is due to single particles and in the third case the structure is an effect of turbulence.

X:9. IRRADIANCE MEASUREMENTS IN THE SARGASSO SEA

G. Lundberg, Institut of Physical Oceanography, Copenhagen, Denmark

Measurements of irradiance as a function of depth and wavelength have been made from "H/S Dana" in the Sargasso Sea during the 24th and 25th of March 1966. Observations were made from 0 - 150 m at clear-sky conditions with an instrument of photomultiplier type. The results exhibit the properties of very clear water.

X:10. ETUDE POUR DIVERSES LONGUEURS D'ONDE DE L'INDICATRICE DE DIFFUSION DE LA LUMIERE DES EAUX DE MER

André Marcel, Laboratoire d'Océanographie Physique de la Faculté des Sciences de Paris

For divereses longueurs d'onde (576, 546, 436, 405, 366 nm), on a tracé les indicatrices de diffusion de la lumière de diverses eaux de mer, allant d'échantillons très limpides à d'autres, au contraire, très turbides.

Il apparaît que pour un échantillon donné, les coefficients angulaires de diffusion (exprimés par rapport au benzène pris comme éthanol), diminuent régulièrement lorsque la longueur d'onde décroît. Les indicatrices conservent la même forme aux diverses longueurs d'onde, s'il s'agit d'eaux très diffusantes; au contraire, pour les eaux limpides, les indicatrices sont différentes et deviennent d'autant moins dissymétriques que la longueur d'onde est plus courte. Dans ce dernier cas, la diffusion moléculaire cesse d'être négligeable et la tendance à la symétrie s'explique par la part relative de la diffusion moléculaire qui est telle que décroît celle de la diffusion par les particules. Ceci implique donc pour les particules une sélectivité de la diffusion inférieure à celle de la diffusion moléculaire.

Ce point a été précisé en portant en fonction du coefficient de diffusion à 90° mesuré à λ = 546 nm, les coefficients à 90° mesurés aux quatre autres longueurs d'onde. La répartition des points expérimentaux suit assez bien les lois linéaires, et de la pente des droites on peut déduire la sélectivité de la diffusion par les particules. Il en ressort, qu'à 90° tout au moins la dépendance spectrale serait exprimée par une loi sensiblement en λ⁻³; cette loi reste approximativement vérifiée pour d'autres angles considérés (30°, 45°, 135° et 150°) ce qui serait une conséquence du fait que l'indicatrice de diffusion par les particules, conserve entre 30° et 150°, la même forme aux diverses longueurs d'onde; c'est ce qui est d'ailleurs observé avec les eaux turbides pour lesquelles la diffusion moléculaire demeure pratiquement négligeable.
XIIa. MISCELLANEOUS PAPERS, MAINLY ON TIDES AND MEAN SEA LEVEL

Chairman: E. Lisitzin 3 October 1967

The following papers were given:

1. P. Hughes (U.K.) Submarine Cable Measurements of Tidal Currents in the Irish Sea
   The Seasonal Water Balance in the Ocean

2. E. Lisitzin (Finland) Sea Level Variations in Malaga
   Reasons for Long-term Changes in Sea Level

3. F.P. de Castilho and J. Berenguer E. Bernal (Spain)

4. P. Kaitera (Finland)

5. V. Neventa (Romania) (Paper given by C. Diaconu)
   Le méthode Monte-Carlo dans l'océanographie

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XIIa:1. SUBMARINE CABLE MEASUREMENTS OF TIDAL CURRENTS IN THE IRISH SEA

P. Hughes, Department of Oceanography, University of Liverpool, United Kingdom

The voltages induced on certain Port Office submarine cables in the Irish Sea due to water flowing over them are being studied in connection with investigations of water movements due to meteorological causes. The locations of the three cables are: (a) Comox Bay, Anglesey to Port Erin, Isle of Man; (b) Port Erin, Isle of Man to Nellychoran, N. Ireland; and (c) Donaghadee, N. Ireland to Portpatrick, Scotland. Direct current measurements with drifting drogues were made at various depths in a number of positions over the cables, to calibrate the voltage signals. Continuous records of water movement have been obtained in this way over a period of three years, except for short breaks due to cable faults. The tidal constituents were determined from hourly values on a monthly basis by Doedson's 29 day analysis, and annually by Doedson's yearly analysis. The principal lunar diurnal constituent M2 is the largest tidal term and it shows a marked annual variation of approximately 6%. The variation is shown to be highly correlated with the annual change of the electrical conductivity of the sea water.

The net transport of water into the eastern Irish Sea over the cables on a flood tide due to $M_2$ was found to be $84 \text{ km}^3$. This volume compares well with an estimate of $89 \text{ km}^3$ computed from Admiralty Chart 1824A, which gives co-range lines for $M_2$ in the same area.

Discussion of Paper XIIa:1

B. Setler asked if a similar calibration was made by Harle in the measurements in the Florida Current.

D. E. Cartwright asked whether similar variations could be measured in the $N_2$ tidal constituent.

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XIIa:2. THE SEASONAL WATER BALANCE IN THE OCEAN

Eugene Lisitzin, Institute of Marine Research, Helsinki, Finland

The paper describes an attempt made to determine the seasonal water balance in the ocean. Starting from the assumption that differences in the water quantity are greatest between late winter and late summer, and using all available records for the years 1957-1961, the deviations in sea level between March and September were computed. The results show that during this period an increase in sea level occurs in the northern hemisphere and a decrease occurs in the southern hemisphere. Taking into consideration the thermal contribution to water volume and the effect of changes in the distribution of air pressure over the ocean, it could be established that an increase of $1.6 \text{ cm}$, corresponding to $0.59 \times 10^{15} \text{ grams}$, is characteristic of the sea level in the world ocean between March and September. The mean error of the result may be estimated at 25 percent.

The question of where the water gained in September is stored in March can hardly be answered in detail. Some may be stored in the atmosphere, but most is gained from the northern hemisphere's winter snow cover in the arctic and sub-arctic regions. Estimates are available which indicate that the total snow
against the continental margins caused by the expanding of the rising material;
when the variations of the water and atmospheric pressure are pumping the mantle
material in certain zones into the sea floor.

The author has paid attention to the differences between the Auer-curve and
Fairbridge-curve concerning the long-term cyclic sea level variations. Fairbridge has
compared the changes in sea level with the alterations of the ancient
shore terraces below sea level, and the rise of sea level during the melting
phase of the glaciers may have hindered the rise of those terraces. Auer's
observations show the changes in sea level compared with the pulsating coastal
level when water amounts freed by the melting of the glaciers have brought about
the subsidence of sea floor and, respectively, the rise of the continental.

The eplanation periods dated by Auer occurred at the end of the long duration
of high sea pressure. This supports the hypothesis that also eogeneous movements
causing volcanic activity depend upon the sea pressure.

According to Batley there has been a fall in sea level of about 180 m
since Cretaceous in the low latitudes, and probably a greater rise in the high
latitudes. We based this opinion on the depth of the outer margin of the
continental shelf along the Atlantic and Pacific coasts of North and South America.

These observations become intelligible if one assumes that the increase of the
water volume has hindered the subsided sea floor to rise after the melting of
the glacier load in the high latitudes.

The author has made calculations which show that the forces mobilized by
sea level variations and by the expansion of the rising mantle material are
great enough to cause earthquakes in the present century.

Discussion of Paper XIA:4

P. Huül: I protest the question, comment les océans, de part et d'autre de
l'Atlantique, qui portent la trace de niveaux d'érosion concordants dans la zone
de basses et moyennes latitudes, peuvent être conciliés avec l'hypothèse exposée.

XIA:5. LA MÉTHODE MONTE-CARLO DANS L'OCEANOGRAPHIE

V. Roventi, Institut du Recherche Hydrotechniques,
Bucarest, Roumanie

On part de la similitude de la forme de l'équation de Laplace et celle de
l'équation des processus aléatoires en plan on dans l'espace.

On suppose ensuite que, pour une particule se déplaçant fortuitement en
plan, il existe des probabilités (m-1,n); P(m=1,n); P(m,n-1); P(m,n+1); (m-1,n);
(m=1,n); (m,n); permettant d'avoir à l'un des noyau du réseau.

La probabilité qu'une particule qui part des quatre noaux disposés symétriquement
par rapport au noyau central (m,n) aboutisse dans le noyau (m,n) est
exprimée par l'équation (1)

\[ P(m,n) = \frac{1}{4} [ P(m-1,n) + P(m+1,n) + P(m,n-1) + P(m,n+1) ] \]  

laquelle peut être écrite sous la forme

\[ P(m,n) = 2P(m,n) + P(m,n+1) + P(m,n-1) = P(m,n) - P(m,n+1) = 0 \]  

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Par une transformation à la limite on obtient de (2) l'équation de Laplace:

\[ \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0 \]  \hspace{1cm} (3)

En partant de cette similitude, J.H. Curtis a montré que la valeur approximative à un point donné M de la fonction V qui satisfait l'équation

\[ \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0 \]  \hspace{1cm} (4)

et qui, à la limite du domaine S à la valeur \( V_0 \), peut être trouvée sans en appeler à la fonction des points voisins.

Cet avantage a été combiné par l'auteur avec la marche au hasard de plusieurs particules. Ainsi, si (M) particules partent d'un point central (M), dans un point situé sur la frontière circulaire au rayon (r), aboutiront par unité de front (n) particules.

Cette méthode a été appliquée par l'auteur à la solution de l'équation de Stokes pour le calcul des courants totaux de la mer Noire.
At the Maritime Observatory Zingst are carried out recordings of the temperature of sea at several points normal to the shore line up to 500 m shore distance as well as measurements of heat budget components. According to coast type a typical temperature regime is formed in dependence on the yearly course of the net radiation. Strong horizontal temperature gradients exist in summer as well in winter. As mean values show, this nearshore anomaly is reduced extensively already in 500 m shore distance.

Under actual conditions the temperatures of the sea show a great variability in the shore area in time and space. The cause for this is to seek above all in advective processes. Local winds, the general wind field, changes of the sea level and currents in the open sea influence in a high degree the heat budget of the nearshore zone and by it the temperature conditions.

In this connection up-welling processes are of particular interest. They are dependent on the general wind field and take place in the cold season (warm water up-welling) as well as in the warm season (cold water up-welling).

By means of such temperature recordings at well selected points we are able to recognize circulation phenomena in the nearshore zone.

Some examples are described.

Temperature structure cross-sections and current determinations were made with the NEL thermistor chain in August 1964 and July 1966 west of the Hawaiian Islands. These indicate both cyclonic and anticyclonic migrating eddies that range between 70 and 140 kilometres in diameter. In the vortices, 120-metre vertical displacements of isotherms took place over distances of 70 kilometres and horizontal temperature gradients of 0.2°C per kilometre persisted over distances of 35 kilometres. In addition to isotherm depth changes of 6 to 10 metres every 1.1 kilometre, an internal wave probably generated by the wind-driven current passing over a lava ridge was found to be 37 metres in amplitude with a wavelength of 3.3 kilometres.

During the 1964 expedition only a counterclockwise rotating vortex about 140 kilometres in diameter was located. It was observed over a period of 11 days and was found to be moving 0.7 kilometre per day in a westerly direction. Current meters mounted on the thermistor chain at four depths showed currents that ranged between 0.4 and 0.7 knot on the periphery of the vortex. The direction of flow obtained from the current meters is in agreement with that obtained from the distribution of sigma-t surfaces.

During the 1966 expedition the same area was investigated and found to contain two smaller eddies; one of these was about 65 kilometres in diameter and rotated counterclockwise near shore. The other was located west of the first. It was about 90 kilometres in diameter and rotated clockwise. The current on the periphery of the vortices ranged between 0.6 and 1.8 knots. It is concluded that these eddies are formed in the lee of the islands during the period of prevailing trade winds, migrate west and northwest, and dissipate at sea while new eddies are formed in their place.
R.I. Tait: No, the salt finger phenomenon is essentially a molecular phenomenon. The driving force is provided by the difference in molecular diffusivities of heat and salt which gives rise to horizontal anomalies.

J.S. Turner: It may help this discussion about salt fingers if I show a photograph of the phenomenon produced in a laboratory tank. This can easily be done by pouring a little colored salt solution on the top of a tank of fresh water which is hotter at the top than the bottom.

XIB4: SOME HYDROGRAPHICAL OBSERVATIONS FROM THREE POSITIONS ON THE BRAZILIAN SHELF IN THE REGION OF CABO-FRIO-SANTOS, 1966
Ola M. Johannessen, Marine Sciences Centre, McGill University, Canada

Temperature, salinity and current measurements have been studied from three positions over three semi-diurnal periods on each station of the Brazilian Shelf in the region Cabo-Frio-Santos. Tidal rotary currents exist with a characteristic amplitude of half a knot for the upper layer, and the rotation is counterclockwise. The main direction of the tidal wave is toward the coast. The tidal current is much influenced by bottom friction, which causes variation of the directions of the axis of the tidal ellipse with increasing depth. Great internal oscillation is observed for the isotherms and isolines, particularly off the coast of Cabo-Frio. Here the range of the depth variation of the isotherms is as much as 30 m. in the boundary layer, depth to the bottom is 98 m. This seemed to be internal waves of tidal origin, but they might also be due to great horizontal gradients in the temperature and salinity field. The internal oscillations are also present at the two other stations further south on the shelf, but their range is less than half compared with the first one mentioned. The data also indicate that upwelling exists in the area off the coast of Rio de Janeiro. The T-S diagram shows that the station off the coast of Cabo-Frio is located in the Brazilian current. A characteristic mean velocity over a diurnal cycle is 0.5 knots. The direction of the current on the southern station, which is not located in the Brazilian current, gives an indication of a coastal counter-current to the Brazilian current.

XIB5: SOME OCEANOGRAPHIC STUDIES ON THE WEST COAST OF ENGLAND
S.H. Sharaf El Din, Oceanography Department, University of Alexandria, U.A.R.

The project is a complete surveying along the West Coast of England from North Wales to Morarcombe Bay area. Current, salinity and temperature measurements were taken at thirteen anchored stations during July and August of 1962, 1963 and 1964. Unfavorable weather conditions made it impossible to take any observations during the summer of 1964. The duration of set of measurements at any station was 25 or 13 hours. The current observations were taken using Kelvin Hughes and Roberts current meters. The salinity and temperature measurements were taken by N.I.O. and Wayne Kerr salinity bridge. The observations were further checked by collecting samples using an insulating water bottle of which the salinity was measured by N.I.O. thermostat salinometer. Hourly measurements were taken at about five depths between one meter below surface to one meter above bottom.

In order to study the effect of horizontal and transverse gradients of salinity on the mixing processes, measurements were taken from sampling stations. From these data the density current circulation was correlated to the river discharge. The resultant component of the residual flow at each station at different depths of surface to bottom was found to rotate in an anticlockwise direction. While in the upper layer the residual flow gives a near surface flow away from the shore, at the bottom layer, it is directed towards or parallel to the shore. The isolines showed a systematic increase towards the sea. The thermocline may be constructed as a result of different flows from the rivers and the sea.

XIB6: THE COMPUTATIONS OF WIND-DRIVEN CIRCULATION IN THE CASPIAN SEA

The computations of stream function are led to solution of the differential equation of the second order of the elliptic type with changeable coefficients, which depend on horizontal coordinates. Rotor and windengine divergency and both bottom relief and shape of the shore line are taken into account. The equation under consideration has a changeable parameter, that is very large for shallow water and very small for deep water. The computations were carried out on electronical computer ESM-2. The changeable parameter at higher order derivatives lead to some mathematical difficulties of the process of solving the task. The way of solutions was suggested by V.A. Masepakin. The eddy viscosity coefficient Az = 100 cm was taken. For the northern part of the Caspian sea with depths of about 5 metres, such order of the coefficient forced us to use asymptotic form of the main equation, in which the Coriolis parameter can be neglected. Besides, the real depth in the deep-water region was needed to be limited by the depth of 500 m., at the depths more than 500 metres a magnitude of the stream function becomes very small to control the error. The results of the calculations show the sign of the main circulation depends on the sign of wind stream rotor and a position of the circulation depends mainly on the bottom relief. In spite of the fact that water structure of Caspian sea is rather uniform one can find a variation of density field in connection with the change of the wind field.

Discussion of Paper XIB6
R.S. Gupta: The level of the Caspian Sea has gone down due to the excess of evaporation over precipitation and discharge. This has an effect on the density field — how is it affected? The Bay of Karabagar has a very high salinity. How does it affect the Caspian Sea?

B.A. Tareyev: The main cause of currents in the Caspian Sea is the wind. The currents do not depend on heat sources and sinks.

O.M. Johannessen: When the wind field changes rotation, how long does it take before the circulation in the Caspian Sea changes?

B.A. Tareyev: The circulation system of the Caspian Sea responds to every wind field change, with time response of a month for the seasonal variation.
XIb:7. COEFFICIENT DE FROTTEMENT DU VENT SUR LA MER DEPEUT DES PROFILS
DE VENT ET DES PROFILS DE COURANTS AU-DESSUS ET AU-DESSUS DE
L'INTERFACE

J. Gonella, Laboratoire d'Océanographie Physique
Paris, France

Grâce aux conditions météorologiques et océanographiques régnant à la bouée-
laboratoire (\(\gamma = 42^\circ.47^\prime\), N. - G = 87°.79\' E.) il a été possible de mettre en évi-
dence une spirale de courant analogue à celle d'Ekman, à partir d'observations
continues de vent et de courants (10, 25 et 75 mètres) effectuées du 12 au 21 mai
1966.

Le courant de dérive à chaque immersion est obtenu en éliminant le courant
de pente et le courant général du courant observé pendant la durée du coup de
vent (vent moyen sur 85 h. = 14 m./s.).

Les résultats sont les suivants:
- profondeur d'Ekman \(D = 143\) mètres.
- coefficient de viscosité turbulente de la mer \(\nu = 10^{-3}\) COH.
- coefficient de frottement du vent sur l'eau ("drag coefficient")

\[C_{10} = 23.10^{-4}\]

Par ailleurs, la mesure du \(C_{10}\) par la méthode des profils moyens de vent a
été effectuée dans la gamme de vitesse de vent allant de 2 à 22 m./s.; le \(C_{10}\)
croît avec la vitesse du vent.

Discussion Concernant Contribution XIb:7

O.H. Johannessen: This is really only the second quantitative verification
that the Ekman spiral really exists in Nature. R. Hunkins has shown the exist-

XlE. MISCELLANEOUS PAPERS, MAINLY ON CHEMICAL OCEANOGRAPH

Chairman: S.H. Fonselius
5 October 1967

The following papers were given:

1. M.V. Fedosev (U.S.S.R.)
   (Paper given by B.A. Skopintsev)
2. R. Sen Gupta (Sweden)
3. S.H. Fonselius (Sweden)
4. B.A. Skopintsev (U.S.S.R.)
5. Ph. Hisard et R. Plon
   (Nouvelle Calédonie)
6. H.R. Ensminger (U.S.A.)
7. J.D.H. Wiseman (U.K.)
8. C.D. Keeling (U.S.A.)
9. K. Grasshoff (F.R. Germany)

Some Distinctive Properties of the
Formation of Chemical Composition
of Ocean Waters
Biochemical Relationships and Inor-
ganic Nitrogen Equilibrium in the
Baltic
Analysis of Trace Metals in the
Mediterranean and Indian Ocean
Special Features of Sulphur Cycle
in the Black Sea Waters
La distribution du nitrite dans le
système des courants équatoriels
le long de 170°E
Sediments and Planktonic Foraminifera
of Tropical North Atlantic Cores
Indian Ocean Manganese Nodules:
Some New Chemical, Radiogenic,
Physical and Structural Observations
Which Have a Bearing on Their Origin
The Global Distribution of Carbon
Dioxide in Surface Ocean Waters
Chemical Indicators for the Circula-
tion of the Red Sea
XIC1. SOME DISTINCTIVE PROPERTIES OF THE FORMATION OF CHEMICAL COMPOSITION OF OCEAN WATERS

M.V. Fedoseev. VNIRO, U.S.S.R.

The regularity and quantitative characteristics of the perpetual process of chemical composition formation and micro-composition of the upper layers of sea waters in particular are of great interest in studies of natural and historical conditions of organic resources reproduction in the ocean.

The perpetual process of sedimentation in the ocean and permanent replenishment of the chemical composition of ocean waters from land control in the final analyses the provision of the productive photosynthesis layer with biogenic matter.

Denudation products of the upper layers of land are the primary source of maintaining the present level of biogenic capacity of photosynthesis layer in sea waters.

Proper evaluation of the significance of this geochemical process can't be based on a correlation between the water volumes of the whole ocean and annual river discharge, all the more on a correlation between the salt content in micro-composition of ocean waters and the amount of salt arriving from land.

The products of land denudation arrive directly into the upper layer of sea waters, and the relation between the biogenic matter content in river discharge and sea waters differs from that of the salt content in macro-chemical composition.

In the first place the biogenic matters rather than the salts of macro-composition pass into the sea bottom deposits.

Such are the main distinctive properties of the formation of chemical composition of the upper productive layers in the ocean waters which can be expressed by the following indices:

<table>
<thead>
<tr>
<th>Waters of the upper layer of productive photosynthesis (I)</th>
<th>Waters and different substances arriving into ocean from land (II)</th>
<th>Ratio (II/I) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water volumes n 1,4x10^7 cu km</td>
<td>n 35x10^3 cu km per year</td>
<td>0,25</td>
</tr>
<tr>
<td>Salt content n 4,8x10^14 ton</td>
<td>n 2,8x10^9 ton per year</td>
<td>0,002</td>
</tr>
<tr>
<td>Organic matter content n 45x10^9 tn</td>
<td>n 1,5-2,5x10^9 tn per year</td>
<td>3,3-5,6</td>
</tr>
<tr>
<td>Phosphates n 280x10^6 tn</td>
<td>n 2,5x10^6 tn per year</td>
<td>0,9</td>
</tr>
</tbody>
</table>

With relation to the whole water mass of the ocean the percentages will be a 100-fold decrease.

XIC2. BIOCHEMICAL RELATIONSHIPS AND INORGANIC NITROGEN EQUILIBRIUM IN THE BALTIC

R. Sen Gupta. Oceanografiska Institutionen, Göteborg, Sweden

In anoxic basins the oxidation of organic matter has so far been represented taking only the reduction of sulphate into consideration. Theoretical studies, however, show that anaerobic bacteria reduces nitrate prior to the reduction of sulphate. Hence, in representing the total redox reactants, the inclusion of ammonia gives a better representation of its relation to the total phosphate regeneration in stagnant basins.

Representing the total redox reactants as equivalent to AOU + 4S^0 + 3NH_4^+, where AOU represents the Apparent Oxygen Utilization, the values from the Gotland and the Landsort deeps in the Baltic are plotted against the total reactive phosphorus. For comparison, values from the Black Sea, the Bohuslän fjords (fjords of the northern part of the Swedish West coast), the Dramsfjord (Norway) and the Cariboo Trench (Gulf of Venezuela) have also been plotted in the same figure (the later two sets of literature data). Detailed analyses of the results show that the conditions for phosphate regeneration in periodically stagnant basins are almost the same. The region of the rapid increase in ammonia and phosphate together with a gradual increase of hydrogen sulphide concentrations in periodically stagnant basins corresponds to the "transition layer" in permanent anoxic basins (Black Sea). A surprising similarity is noted between the lines for the Landsort deep (fully aerobic basin) and the Cariboo Trench (fully anoxic basin). Calculating the equations for the linear least square regression lines it is found that in all the regions phosphate concentration is not a limiting factor for plant growth.

An attempt is made to study the state of equilibrium of the inorganic nitrogen compounds from measurements of the concentrations of nitrate-, nitrite-, and ammonia-nitrogen, using the parameter $pE$ [pE = log (I^-)] = E_r/(2.3 N/P) - E_r/59.156 at 25°C. The systems HNO_3 - HNO_2, NH_4^+ - NO_2, and NH_3 - NO_2 are applied for calculations. Studies are made of the variations of the three redox pairs in oxidizing and in reducing environments. In narrow basins, under oxidizing conditions, the system NO_2 - NO_2 is found to approach equilibrium values. From the proximity of the calculated values to the equilibrium values the system NO_2 - NO_2 - NH_4 is presumed to approach equilibrium conditions in marine environments independent of the general equilibrium condition controlled by the system O_2 - H^+ - H^+.

XIC3. ANALYSIS OF TRACE METALS IN THE MEDITERRANEAN AND THE INDIAN OCEAN

Stig H. Forsellius. Hydrographic Department, Fisby Board of Sweden, Gothenburg, Sweden

Few results of chromium analyses in sea water have been reported in the literature. The most reliable results seem to have been obtained by Ishibashi. The author used Ishibashi's co-precipitation method for some samples in the Mediterranean, the Red Sea and the Gulf of Arabia. The samples were taken with
non-metallic water samplers and in cases of surface samples with polyethylene bucket. Preliminary tests showed that about 75% of the Cr was retained on the filter paper in the sample was filtered. The slow and laborious filtering of the 50 l water samples was therefore omitted. The Cr values found were of the same order of magnitude as the values reported by Ishibashi in the Pacific.

Copper and zinc analyses using the Dithizon method by Koroleff were carried out in the eastern Mediterranean, the Suez Canal, the Red Sea and the Gulf of Arabia during the 11th cruise of Atlantis II in 1963. The results in the Mediterranean confirmed the earlier results by the author and Koroleff, which show that there is a maximum in the trace metal concentration in the "Intermediate Levantine Water". The Cr concentration was also high in this water. The water of the Great Bitter Lake in the Suez Canal had an extremely high trace metal content, 19-40 ug Zn/l and 2.7-3.9 ug Cu/l. This may explain the high concentrations of Zn and Cu found in the northern and central parts of the Red Sea. Layers with low Zn and Cu values were found in the Red Sea. In the Gulf of Aden and in the northern part of the Gulf of Arabia the distribution of trace metals was very complicated, probably due to mixing of different water layers originating from the Red Sea, the Persian Gulf and the Indian Ocean. More measurements of trace elements, especially from the Persian Gulf, are needed before any direct conclusions can be drawn regarding the distribution of different trace metals.

The results from a station in the middle of the Arabian Gulf shows the distribution of Zn and Cu from the surface down to about 4000 m. The Zn values are highest at the surface and decrease downward to around 1 ug/l. The Cu values at the contrary are low at the surface and reach a maximum of 0.43 ug/l at around 1000 m.

Generally it is concluded that it is difficult to draw any much reliable conclusions from these few measurements.

XII:4. SPECIAL FEATURES OF SULPHUR CYCLE IN THE BLACK SEA WAERS

R. A. Skopintsev, Institute of Biology of Inland Waters, U.S.S.R. Academy of Sciences, Marine Hydrophysical Institute, Ukrainian Academy of Sciences, U.S.S.R.

1. No likenesses have been observed between the S-SO_4 curves of vertical distribution and the Cl value ratio in the Black Sea waters plotted upon data of chemical analysis, on one hand, and the calculated data estimated on the basis of mixing of river waters of the Black Sea basin: a) the Sea of Marmara waters and b) deep waters of the Black Sea, on the other.

2. Whereas anal. plotted curve series of vertical distribution of Mg and Cl value ratio, as well as Ca and Cl shows practically complete likeness.

3. Comparison of all curves of vertical distribution of S-SO_4 and Cl with actual data of S-SO_4 and S-NO_3 concentration in a 0-2000 m. water column beneath 1 m permits to assume that the mentioned difference is conditioned:

a) by a process of sulphate reduction which develops not only at the bottom and the near-bottom sea layer, but also in the upper part of the hydrogen sulphide zone;

b) by the oxidation process of hydrogen sulphide in the intermediate zone spaced between the oxygen and hydrogen sulphide zones.

4. This is confirmed by the analysis of anal. plotted curves of carbonate alkalinity distribution and Cl value ratio in the Black Sea waters.

5. An approximate rate of the sulphur cycle in the Black Sea waters was calculated on the assumption of a dynamic equilibrium between entry and removal of essential S-forms.

XII:5. DISTRIBUTION OF NITRIDE IN THE SYSTEME DES COURANTS EQUATORIAUX LE LONG DE 170°E

Ph. Héard et D. Piton, Centre O.R.S.T.O.M., Noumea, Nouvelle-Caledonie

Quatre croisières ont été effectuées de novembre 1965 à septembre 1966, le long de 170°E entre 20°S et 5°N. Les nombreuses propriétés mesurées et la forte densité d’observations réalisées permettent a dernier de discuter la distribution du nitrite en fonction de la stabilité, de la température, de l’oxygène dissous, du nitrate et des pigments.

Deux zones d’accumulation de nitrates ont été observées l’une vers 5°S, l’autre au sud de l’équateur.

A 5°S, à une profondeur moyenne de 100 mètres, les teneurs en nitrite dépassent 2 mg/l et forment une sorte de poche de 50 mètres d’épaisseur; cette accumulation de nitrite est localisée au voisinage du sommet de la thermocline, au niveau du maximum de stabilité; elle est associée à des teneurs en oxygène telles que l’O/A.O. est d’environ 0.7 ml/l; au niveau de la poche de nitrite les concentrations en nitrate sont comprises entre 1 et 5 mg/l, on observe une atténuation marquée du gradient vertical de la température et du nitrate, et ce gradient vertical est également plus faible qu’au nord et au sud de cette zone. Parallèlement, la variation des teneurs moyennes en chlorophylle a de la couche euphotique est marquée par un minimum vers 5°S et le rapport de la phyto- phyline à la chlorophylle a semble plus élevé. La masse d’eau superficielle au dessus de la poche de nitrite est épulisée en sols nutritifs et pauvre en chlorophylle.

On observe à partir de 3°S un enrichissement des eaux superficielles et à l’équateur la concentration en nitrate à la surface atteint 2 mg/l; la deuxième zone d’accumulation de nitrite qui est observée à l’équateur est à une profondeur moyenne de 100 mètres; elle est moins épulée et est associée avec un maximum de chlorophylle a.

Ces observations ne permettent pas de conclure sur l’origine du nitrite; à l’équateur, la zone d’accumulation de nitrite peut être due à l’oxydation de la matière organique accumulée au sommet de la thermocline mais à 5°S, où les eaux superficielles sont épulisées en sols nutritifs et pauvres en chlorophylle, l’observation d’une poche de nitrite semble être liée à la présence d’une zone de convergence qui apparaît clairement dans la structure hydrologique et dans la distribution des sols nutritifs; on peut alors supposer que le phytoplancton se
of time a new layer of manganese material has been deposited around these previously fragmented nodules. The distribution of radiodanium in a fragmented nodule is discussed. Results of X-ray and electron probe are also given, and their significance discussed.

XIII.8. THE GLOBAL DISTRIBUTION OF CARBON DIOXIDE IN SURFACE OCEAN WATERS

Charles D. Keeling, Scripps Institution of Oceanography, La Jolla, California, U.S.A.

The distribution of carbon dioxide gas in surface waters of the Atlantic, Pacific, and Indian Oceans has been determined from 24 months of continuous measurements obtained on oceanic expeditions of the Scripps Institution of Oceanography in all three oceans, supplemented by 9 months of similar measurements and 55 discrete analyses obtained by other institutions in the Atlantic Ocean and near the west coast of South America. Most of the data represent summer conditions. In the Pacific and Atlantic Oceans pronounced belts of high concentration appear near the equator. The Pacific belt is far more extensive than the Atlantic, but the patterns are similar and both are clearly defined. In the Indian Ocean no belt of high pressure appears near the equator during the northern summer. The concentration diminishes southward from India to 30°S. In the subtropics of all oceans the concentration tends to be low except in coastal areas where upwelling occurs. In polar areas, patterns appear to be more complicated and are uncertain because the data are too few to establish seasonal variability. The data are displayed on a chart which is the first to be prepared for the world's oceans. Although details of the patterns are tentative in all cases, the chart should be useful in furthering an understanding of the exchange of CO2 between the atmosphere and oceans, and as a basis for planning future investigations.

XIII.9. CHEMICAL INDICATORS FOR THE CIRCULATION OF THE RED SEA

Klaus Gräfehoff, Institut für Meerestechnik, Universität Kiel, F.R. Germany

Based upon the hydrochemical measurements of R.V. "Meteor" during the I.T.O.R. a model for the circulation and of the water exchange between the Gulf of Aden and the Red Sea is proposed. The increase of salinity in the surface waters of the Red Sea from the south to the north is caused by evaporation only to about 1%. The remaining part can be traced to the admixture of water from below the pycnocline. Due to the temperature conditions special values for the rate of oxygen consumption are developed for the deep water (1500 m $0.33 \times 10^{-6}$ ml/l/sec). Through this it is possible to calculate the net transport of deep water from the north to the south, and the mean velocities of deep water currents. The residence time of the deep water is ca. 7.0 years. The vertical movement and exchange of the water is calculated by means of the distribution of dissolved inorganic phosphates. From the main figures of outflow and inflow, and from the distribution of salinity it is shown, that the balance of nutrients can only be obtained if additional nutrients are transported into the Red Sea from intermediate layers of the Gulf of Aden. The postulation of sporadic influx of water from below the thermocline into the Red Sea is confirmed by hydrochemical observations north of the Straits of Bab el Mandeb. Silicate has a special distribution in the Red Sea, and it is shown to be a valuable indicator for water masses.
The turbulent mixing of water from different levels in the Straits of Bab el Mandeb causes a relatively high biological activity as indicated by the sudden increase of nitrite and the deficiency of total carbon dioxide in the surface layers. The calcium carbonate saturation and transport is discussed by means of direct measurements of the calcium content, pH and alkalinity.

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XII. MISCELLANEOUS PAPERS, MAINLY ON OCEANOGRAPHIC INSTRUMENTS

Chairman: W.S. von Arx

3 October 1967

The following papers were given:

1. W.S. von Arx (U.S.A.)
2. G. Kallenberg (Denmark)
3. R.E. Banks (Canada)
5. J. Brooke and R.L. Gilbert (Canada)
6. P.E. La Violette and P.L. Chabot (U.S.A.)
7. P. O斯塔off (U.S.A.)

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Geodetic Measurements at Sea
Optical Scattering Measurements in the Sargasso Sea
Temperature and Sound Velocity versus Depth in the North Atlantic Measured with an Automatic Data Sampling System
Research on Regularities of Transport of Radioactive Contamination in the Oceans
The B.I.O. Rock Core Drill
A Comparative Study: Nimbus II Satellite Sea Surface Temperatures versus Historical Data in a Selected Region
On the Possibility of a New "Hot Hole" in the Red Sea
XII:1. GEODETIC MEASUREMENTS AT SEA
W.S. von Arx, Massachusetts Institute of Technology and
Woods Hole Oceanographic Institution, U.S.A.

Inertial systems have been developed to indicate the direction of local
gravity at sea, and an accelerometer adapted to measure the magnitude of gravity
from ships. These instruments permit (1) accurate (±0.2 n. m. i.) astronomical
navigation, (2) definition of the shape of a level surface across ocean reaches,
and (3) measurement of the departures of the physical sea surface from the
geoid.

Discussion of Paper XII:1

J. Lyman: Would the speaker comment on the possibility of using his system to
measure oceanic tides?
W.S. von Arx: Only the out-of-phase component of the tide would be seen
because the Geon system would itself respond to the astronomical forcing func-
tion.

XII:2. OPTICAL SCATTERING MEASUREMENTS IN THE SARGASSO SEA
G. Kullenberg, Institute of Physical Oceanography
University of Copenhagen, Denmark

A Neop-Argon CW laser beam was used as a source, and a horn sink to collect
the main beam. Forward scattered light was collected by a short cylindrical
mirror coaxial with the laser beam, which could be moved to intercept scattered
rays at various angles and direct them to a photometer detector.

The scattering function for Sargasso water was very strong at small forward
angles and very weak near 90°. Comparison of these curves with Moré’s curves
for the Mediterranean showed about equal small angle forward scattering but
stronger side scattering in Mediterranean water.

Discussion of Paper XII:2

H.G. Neuymin: To what minimal angle are you measuring the scattering?
G. Kullenberg: A few degrees.
G.F. Beardsley: What is the range and resolution of the laser small angle
scattering meter?
G. Kullenberg: (answer not caught by rapporteur)

XII:3. TEMPERATURE AND SOUND VELOCITY VERSUS DEPTH IN THE NORTH
ATLANTIC MEASURED WITH AN AUTOMATIC DATA SAMPLING SYSTEM
B.E. Banks, Naval Research Establishment, Defense Research
Board of Canada, Dartmouth, N.S., Canada

The output of three sensors (temperature, sound velocity and depth) is
recorded on deck in digital form for computer processing ashore. Paper tape
is used.

With this unit sound velocity can be measured as a function of depth (to
3000 m) with an error of 0.01 m. Errors in depth of the sensors are about
1 m/sec in sound travel time. When the ship is moving the sensors are found
to rise at a rate near 1 m/min owing to cable drag as the ship drifts.

Sound velocity measurements disagree with Wilson’s theoretical values by
amounts ranging from 0.7 to 0.1 m/sec.

Discussion of Paper XII:3

G.E.R. Deacon: Has the speaker compared his measurements with Matthews’
figures?
B.E. Banks: No.
M.J. Tucker: A depth accuracy of ±0.5 m may be expected in a smooth sea,
but in a rough sea I would expect the error to be larger since the echo tends
to come from the troughs of the waves, or sometimes from patches of seclusion
(bubbles) in the water giving a consistently smaller apparent depth.
R.E. Banks: That is so, our tests were made only in smooth seas.

XII:4. RESEARCH ON REGULARITIES OF TRANSPORT OF RADIOACTIVE CONTAMINATION
IN THE OCEANS
V.I. Belyaev, A.G. Kalevich and B.A. Belenko, Marine Hydrophysical
Institute, Ukrainian Academy of Sciences, Sevastopol, U.S.S.R.

Observed values of Sr90 and Cs137 made by Belenko from the research ship
Mikhail Lomonosov were compared with theoretical values for vertical component
of velocity computed by Kalevich’s method. Corrections for sinking of 1 mg
particles were made using Brookes equation. Good agreement of predicted and
observed concentrations were found in the North Atlantic Ocean and Black Sea.
(Observations of the Cs137/Sr90 concentration ratio also agreed well with
values reported by Brookes and by Miyake.) The authors suggest that owing to
turbulent diffusion the radio carbon method of age determination re-
quires a correction proportional to the depth of sampling and allowance for
biological activity.

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XID:3. THE B-1-0. ROCK CORN DRILL

J. Brooke and R.L.G. Gilbert, Bedford Institute of Oceanography, Dartmouth, N.S., Canada.

A deep sea rock drill driven by hydrostatic pressure has cut cores in hard rocky 2.5 cm in diameter and from 15 to 25 cm long in drilling times from 3 to 8 minutes. A core catcher and orientation marker have been provided.

Some 20 successful lowerings have been made during which it has been found that a diamond tooth drill is more effective than a diamond matrix drill, and that by adding lead weights to the feet and a pin to the assembly, that its stability on the bottom is satisfactorily improved.

Discussion of Paper XID:3

P. Dehlinger: Were the cores shown in the last slide sedimentary or igneous rocks?

J. Brooke: They were quartz sandstone, i.e. very hard sedimentary rock.

J.D.H. Wiseman remarked that the first attempt to make a hydrostatic pressure drill was made about 80 years ago by Prof. Jolly of Trinity College, Dublin. Dr. Wiseman then asked whether the age of the consolidated sediment from the mid-Atlantic Ridge had been determined (answer no) and pointed out the great scientific use of this deep sea rock drill.

XID:6. A COMPARATIVE STUDY: NIMBUS II SATELLITE SEA SURFACE TEMPERATURES VERSUS HISTORICAL DATA IN A SELECTED REGION


When clouds are absent the MMCR sensor on board the Nimbus II satellite can indicate approximate sea surface temperatures. Values measured along the Somali coast for May, August (southeast monsoon) and November (northeast monsoon) suggest an upwelling maximum during August. Satellite temperature measurements tend to be low compared with historical averages.

Discussion of Paper XID:6

P. Ostapoff: Are Nimbus radiation data available for May/June 1967?

P.E. La Violette: Yes, they are published regularly by NASA.
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