and install a planetarium that incidentally provides the institution that buys it with a completely controlled environment for large-group instruction. The domed structure has controlled temperature, controlled lighting, and controlled sound, and constitutes a hemispheric screen on which anything can be projected. We also produce standardized tests, and are working on a system of evaluation for establishing their validity. McGraw-Hill, of course, is not alone in these efforts. Random House and L. W. Singer are now part of RCA; Holt, Rinehart and Winston is part of CBS; the American Book Company is part of Litton Industries. On and on it goes. I am convinced that this movement will produce a quiet revolution that will greatly benefit education in this country and throughout the world.

Still another force, and one about which there is great talk, is the application of the systems concept to instruction and instructional materials. There is nothing complicated or mysterious about this. It simply means that more than ever before we are defining the objectives of instruction for a given person for a given subject, and then utilizing in a rational manner all the tools available in the wide field of instructional material to meet that objective.

Finally, there is the need for education in the vast and developing world of emerging nations. All the means and materials I have talked about will be used in resolving the issues and solving the problems that this challenge presents. In addition, the transmission of information by satellite and by other microelectronic means will surely become increasingly important.

All these trends, together, make the world of publishing, as we have called it in the past, not only an exciting challenge, but one that needs—that demands—a high order of intelligence, talent, and dedication, to say nothing of financial resources.

Deep-Sea Tides: A Program

Walter H. Munk and Bernard D. Zetler

Tidal mathematicians have traditionally stood along the coastlines and looked longingly to sea, speculating on what the tides are offshore. They have seized upon the tide records obtained at a few island outposts and have expended great effort in producing cotidal charts of the oceans, with lines connecting points at sea at which the time of high water is thought to be simultaneous. The patterns on these charts have been quite complex, the most interesting feature being the locations of amphidromic points. These are the geographic positions where theoretically there is no tide, the cotidal lines radiating about them in various directions, with the tidal amplitude presumably increasing with distance from the amphidromic point. Inasmuch as the response of the ocean basins to the tide-producing forces is frequency-dependent, the more ambitious mathematicians have drawn their charts for each of the large tidal constituents, both diurnal and semidiurnal. Despite the application of the best techniques and all available data in their efforts, speculation has been an important ingredient in the completed charts, and one is forced to the conclusion that the best is none too good.

It appears as though modern technology has caught up with the problem and that there is hope of obtaining within a relatively few years objective measurements of the tide at positions on grids spanning the oceans. This is exciting in itself, but even more exciting is the anticipated solution of many other geophysical problems as a by-product of the program.

Several different engineering groups are developing tide gages for deep-sea measurements. Snodgrass (*1*) has built a self-contained capsule that is dropped to the sea floor, records absolute pressure *in situ*, and is subsequently recalled by acoustic signals from a surface vessel. Some success has already been achieved with the instrument, but many failures have demonstrated need for greater reliability—which entails duplication of critical circuits, quality control of individual components, long periods of pretesting, and pretesting under severe environmental conditions.

The U.S. Coast and Geodetic Survey has made some successful measurements of the tide at depths slightly less than 300 meters over the Atlantic continental shelf; it has an active developmental program underway to increase the depth potential of the gage and to improve its reliability. Martin Vitousek, University of Hawaii, has been involved in related research—the recording of tsunamis; although some problems are different in that he needs more frequent observations over a shorter period, there is significant similarity in the development program.

The effort has not been confined to the United States. Eyries, Service Hydrographique, Paris, has successfully tested a differential gage that is connected by wire to a surface buoy that transmits an analog signal to a nearby vessel. The Snodgrass and Eyries gages also record temperature because it is required for correction of pressure readings, but of course the temperature records are of great interest in themselves. Other foreign tidal authorities have shown marked interest in the program and stand ready to cooperate in an international program when the required instruments become available.

At a tide symposium (*2*) in Paris in 1965, an international working group on deep-sea tides was formed to organize systematic measurements and analyses of deep-sea tides. When the group met again in Moscow in 1966 to review the program, representatives of 11 nations attended and expressed some interest in the program; an associated committee (*3*) was formed to deal with theoretical problems related

Dr. Munk is with the Institute of Geophysics and Planetary Physics, University of California at San Diego, La Jolla; Dr. Zetler, with the Institute for Oceanography, Environmental Science Services Administration, Silver Spring, Maryland.

to deep-sea measurements of tides. The working group met again in January 1967 (*4*) to participate in sea trials of the Snodgrass gage. Eyries organized the symposium on deep-sea tides held in conjunction with the meetings of the International Union of Geodesy and Geophysics in Switzerland during the fall of 1967. In short, the growing interest in the program promises much for the future.

Field tests of the Snodgrass gage so far have been oriented toward development rather than scientific results. The first field program for the latter purpose, with plans to occupy the North Pacific semidaily lunar (M_2) amphidrome with three instruments, will stay on the bottom for 1 month. Each capsule will record *fluctuations* in the bottom pressure to the nearest millimeter of water; fluctuations in temperature to the nearest 10^{-5}°C, and horizontal current with a resolution of 1 millimeter per second. If a gage is properly positioned at the M_2 amphidrome, the M_2 amplitude will yield the continuum of energy rather than the tidal line; furthermore, the lunar semidaily tide, observed on either side of the amphidrome, will be opposite in phase. Inasmuch as the ocean's response is frequency-dependent, the solar semidaily tide (S_2) should exceed the M_2 tide at the amphidrome, and the various amplitudes and phases for S_2 at the four locations should point toward the probable location of the S_2 amphidrome.

Previous tests have shown an increase in temperature of the order of 0.05°C in the bottom few meters of some basins off the coast of California; it is not clear how this unstable gradient can persist. Furthermore, the records contained intermittent quiescent and active periods, with a time scale that is roughly tidal. For these reasons a special effort will be made to study bottom temperature gradients and intermittent turbulence during the tests. One capsule is being modified to shorten intervals in the recording system for data sampling, and there will be special movable arms on the transducer mounting to permit careful examination of the bottom meter of water. A special-purpose winch is planned, so that the capsule can be lifted off the bottom in a predetermined program to obtain the vertical temperature profile to a very high degree of precision. Finally, a camera system will be incorporated to monitor the installation and, if possible, observe the motions of the water by stereo photographs of particles drifting near the sea floor. Plans for 1968 include an equatorial station for measuring both tides and planetary waves, and measurements between Australia and Antarctica to obtain some information on Antarctic tides.

The tentative plans of the working group for coverage of the world's oceans include a 1000 by 1000-kilometer grid (10 degrees by 10 degrees at the equator) involving a total of 300 stations. Measurements are to be made at least hourly for 1 month (certainly for no less than 2 weeks) to the nearest centimeter of depth of water or better. Nevertheless, results from programs such as the North Pacific amphidrome test will be scrutinized carefully for the possibility of establishing a variable grid, based on preliminary theoretical results, with a maximum of information content per unit. We visualize two types of expeditions for obtaining the tidal records: (i) ships of opportunity, primarily devoted to other purposes, dropping tide instruments on the way out and retrieving them on the way back; and (ii) tidal expeditions primarily devoted to the program but serving also other needs and opportunities. A ship should be able to plant eight instruments approximately 3 days apart and then start to retrieve the first almost as soon as the planting is completed. On this basis eight stations are established and retrieved within 2 months; since most of the time is spent in cruising, there is ample opportunity for other measurements.

The scientific objects of the program include both increased understanding of global tides and other related geophysical phenomena; the former are listed first:

1) Theoretical calculations of global tides are now being performed by Perkeris and Hendershott for the true depths and boundaries of the world's oceans. So far both investigators have assumed perfectly reflective boundaries, but it appears that ultimately one must allow for absorption over the continental shelf. The availability of an ocean-wide grid of tidal observations for comparison with theoretical calculations will provide some evaluation of the need for a modified boundary premise; it will also permit reliable estimates of the proportion of total tidal energy (3×10^{19} ergs per second) dissipated within the oceans.

2) From knowledge of the global tides (beyond the continental shelves) it may be possible to infer tide predictions on a shelf for which land-based tide records are not available. In the case of highly nonlinear tides, existing predictions may be improved by knowledge of offshore tides; thus the nonlinear modification may be separated from the astronomic tide. The dynamic numerical computations will use depth and friction as parameters; for tides in rivers and bays the effective width will be an added parameter. Ultimately, coastal tides will be predicted from an initial two-dimensional tide "field" in the open sea.

Although at the moment one cannot envisage all related geophysical objects of the program, the following appear to be possible:

1) For geophysical measurements on land, the tidal frequencies cannot be interpreted without allowance being made for the effect of oceanic tides on a global basis; this point applies to measurements of gravity, magnetic field, and so on.

2) The previous item includes calculation of the dissipation of tidal energy in the world's ocean. The residual energy, 3×10^{19} ergs per second minus ocean dissipation, would give important information concerning the plastic properties of the solid Earth.

3) The fluctuating tidal currents flowing in Earth's magnetic field generate electric potentials that can be measured with suitable electrodes on the sea bottom. The generated potential depends also on the conductivity within Earth; with the tides known, the effective conductivity can be estimated for various tidal frequencies (and hence effective depth). These estimates in turn give information about the distribution of temperature in Earth's upper mantle. Horizontal temperature gradients within Earth, particularly beneath the ocean boundaries, are associated with a stress field that may be responsible for the principal belts of volcanic and seismic activity.

4) Barotropic signatures of passing storms, which will be superimposed on tidal fluctuations as measured with bottom-pressure recorders, represent an interesting problem of air-sea dynamics. It would be especially interesting to have long series of simultaneous observations of horizontal currents at great depth (away from surface noise). Planetary waves, which are so prominent in the atmosphere, have not been

convincingly demonstrated in the oceans, perhaps because they are poorly generated or poorly transmitted, or because the observations have not yet measured the proper variables. Such measurements are simply not available at this time. Well-documented current flow near the bottom would provide a far better reference for geostrophic computations than do theoretical levels of no motion; estimates of mass transport could thus be significantly improved.

5) We have already mentioned a sharp increase in temperature in the bottom few meters of the oceans. The existence of a warm bottom layer had been reported earlier by Van Herzen and coworkers from measurements with a geothermal probe. Is this warm layer maintained by greater density because of higher content of salt or of sedimentary particles? In fact, in the measurements of temperature gradients in sediments, what is the role of tidal "pumping" of interstitial water? For these studies as well as of the intermittent turbulence, long, reliable records of temperature are necessary; we hope they will be supplemented by measurements of heat flow.

6) Finally the observations may be helpful in explaining the origin of internal waves of tidal frequencies, and, if tsunamis are generated during periods of tide observations, they may be well documented if the time period of the observations is short enough. In any case, the instrumental development can be used in a tsunami-measurement program.

Thus the proposed program has applications in much of Earth's environment, air-sea dynamics, various ocean-wave phenomena, and the anelasticity and stress fields of the solid Earth. The bottom of the sea is perhaps the least explored of the "accessible boundary layers" on this planet, and we may be in for some surprises.

References and Notes

1. F. Snodgrass, Scripps Inst. of Oceanography, Univ. of California at San Diego, La Jolla.
2. Sponsored by UNESCO and the Intern. Assoc. for Physical Oceanography.
3. W. Hansen (Germany) and S. S. Voit (U.S.S.R.) are joint chairmen.
4. At La Jolla, California.

NEWS AND COMMENT

Social Sciences: Expanded Role Urged for Defense Department

A study group appointed by the National Academy of Sciences has advised the Department of Defense (DOD) to increase its support and use of research in the social and behavioral sciences. The Department "must now wage not only warfare but 'peacefare' as well," the panel states in its report. "Pacification, assistance, and the battle of ideas are major segments of the DOD responsibility. The social and behavioral sciences constitute the unique resource for support of these new requirements and must be vigorously pursued if our operations are to be effective."

Among its specific recommendations, the Academy group urged the Department to appoint an "eminent behavioral scientist" to lobby in Congress in behalf of Defense's social and behavioral science programs. Alluding to the aversion of some younger scholars toward defense-related research, it recommended that "publicity concerning the distinguished behavioral scientists who have long-term commitments to the DOD should be disseminated as a way of reassuring younger scientists and improving our research image." In reference to current proposals for reducing U.S. military support of social science research in other countries, it urges "strenuous efforts . . . to insure that the Department of Defense is not excluded from the innovating influences on policy planning and strategy in universities after foreign area studies are transferred to civilian agencies." And, as part of a "research strategy for military agencies," it urges the Department of Defense to undertake "studies of military establishments of allied nations carried out by foreign social scientists. . . ."

These and other recommendations are contained in a 53-page document titled "Report of the Panel on Defense Social and Behavorial Sciences." The document, which is now being narrowly circulated for comments, resulted from a meeting held from 5 to 14 July at Williamstown, Massachusetts, at the request of John S. Foster, Jr., director of Defense Research and Engineering. Foster's request was addressed to Frederick Seitz, chairman of the Defense Science Board, which is the Department's highest ranking science advisory group; Seitz is also president of the Academy, which selected the membership of the panel. Serving as chairman of the panel was S. Rains Wallace, president of the American Institutes of Research, a nonprofit organization that conducts research under contract to the Defense Department and other government agencies. In 1965 and 1966, prior to taking his present position, Wallace was chief of behavioral and social science research in the Defense Department office now headed by Foster. Other members of the panel were Peter Dorner, of the Council of Economic Advisers; Harold Guetzkow, Northwestern University; Michael Pearce, the RAND Corporation; A. Kimball Romney, Harvard; Roger Russell, Indiana University; and Eugene Webb, Stanford. Listed as a member of the panel, though he attended only one day of the meeting, is Gene Lyons of Dartmouth, who is heading a comprehensive study for the Academy on all social science activities of the federal government.

As is the case with virtually all studies produced by Academy panels, the findings in this case do not necessarily reflect the view of the Academy, nor is the recipient of the report obliged to regard it as more than an advisory statement. However, in view of the interlocking relationships of some of the key figures in the study, it is reasonable to assume that the panel's conclusions are receiving serious attention in the Department of Defense.

Foster's request to Seitz asked that the panel direct its attention to four topics: (i) "High Payoff R & D Areas," defined, in part, as "areas of social and behavioral science research in which it would be reasonable to expect great payoffs over the next three to ten years";