ago. These inhabitants built irrigation systems, apartment houses, roads, and cities. Nevertheless, as Graf describes, they strove to adapt to the unique southwestern landscape rather than to dominate it. Whether or not this ethic is compatible with modern society is certainly debatable. There is no question, however, that in the long run neither adaptation nor dominance can succeed without sound scientific study of this sensitive landscape.

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Wave Dynamics

Ocean Wave Modeling. THE SWAMP GROUP. Plenum, New York, 1985. vi, 256 pp., illus. $49.50. From a symposium, Miami, May 1981.

The scientific prediction of surface waves may be dated from Sverdrup and Munk's 1947 *Wind, Sea, and Swell: Theory of Relations for Forecasting*. That report was stimulated by the need for the Allied forces to have sea and swell forecasts before the invasion of North Africa, and it appeared in classified form in 1943. The complete prediction comprises two essentially distinct parts, the prediction of the wind field, which is the province of meteorologists, and the prediction of the resulting response of the ocean surface, which is the province of oceanographers. The present monograph, like that of Sverdrup and Munk, deals with the latter problem.

The starting point is the transport equation

$$\frac{\partial F}{\partial t} + \mathbf{v} \cdot \nabla F = S_{in} + S_{nl} + S_{ds}$$

which governs the evolution of the surface-wave field in space (**x**) and time (t); $F = F(f,\theta;\mathbf{x},t)$ is the two-dimensional spectral density in frequency f and direction of propagation θ, $\mathbf{v} = \mathbf{v}(f, \theta)$ is the group velocity, S_{in} is the input from the wind, S_{nl} is the nonlinear transfer through wave interactions, and S_{ds} is the dissipation. This approach is distinct from that of Sverdrup and Munk, which was based on quasi-empirical relations between characteristic parameters of the wave and wind fields and antedated the introduction of statistical concepts (by Pierson, Neumann, and James in 1955) in the treatment of ocean waves. It became practical only in the early 1960's, after the theoretical studies of Phillips (1957) and Miles (1957), which provided a basis for the representation of S_{in}, and the discovery of resonant interactions by Hasselmann (1960) and Phillips (1960), which provided the basis for the representation of S_{nl}; the representation of S_{ds} was, and remains, empirical. It should perhaps be emphasized that these predictions are for deep water and that to extend them to water of a depth that is half, or less than half, of the wavelength would introduce further complications, especially if (as in coastal regions) the depth varies significantly.

The SWAMP (for Sea Wave Modeling Project) Group, which comprises 25 scientists from 11 institutions in the Federal Republic of Germany, Italy, Japan, the Netherlands, Norway, the United Kingdom, and the United States, has carried out a comparison of ten different models for the integration of the transport equation, using various parameterizations of the input terms, for seven hypothetical test cases. The first half of the present monograph discusses the various types of models and the principles on which they are based and describes the test cases. The second half presents the individual models and describes their predictions for some or all of the test cases.

There are (not unexpectedly) striking differences among the predictions of the models for particular test cases, and it is evident that we are not yet able to provide reliable forecasts of the surface-wave field induced by a strong front, let alone a hurricane. This is due in part to limitations in our basic understanding of the physics (the air flow over waves is turbulent), but the principal shortcomings of the models appear to stem from limitations in the parameterization of the nonlinear interactions (S_{nl}) and in the assumed form of the dissipation (S_{ds}). Nevertheless, much progress has been made, and the present ("second generation") models represent a significant advance over earlier ("first generation") models, in which nonlinearity was either absent or crudely represented and in which it had been necessary to increase the linear input S_{in} by one or more orders of magnitude over the theoretical values. Future ("third generation") models, already under development, will incorporate more sophisticated parameterizations of S_{nl} and may exploit our theoretical knowledge to its present limits, after which the lack of a rational model of dissipation and the effects of finite, variable depth are likely to present barriers to further progress.

We have come a long way from Sverdrup and Munk, but much remains to be done if we are to take full advantage of the data soon to be (if not already) available from satellite technology. The present monograph provides a valuable survey of the state of the art as of 1981.

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