NEWS AND VIEWS

Sea Level and Natural Disasters

At not infrequent intervals the sea rouses itself with sufficient force to bring about catastrophes that make a fair bid to rival mankind's own efforts to undo himself. It is natural that oceanographers and meteorologists in particular should study the processes involved in the expectation that understanding will contribute to the alleviation of a substantial amount of human (and economic) suffering.

One such group of events, known as storm surges, is the subject of two communications by Das and by Flierl and Robinson on pages 211 and 213 of this issue of *Nature*.

These events would seem to an observer at the coastline like unexpected yet inexorable rises in sea level over the course of many hours, and are a consequence of severe atmospheric depressions moving in over the shallow continental borderlands. The effects are often critically dependent on the path and rate of progress of the depression and the topography of the seafloor.

The surface of the sea responds significantly on time scales spanning many orders of magnitude, and over much of this range the responses have a significant effect on man and his environment. The inputs that must be considered are those from the atmosphere, both synoptic and climatological, the gravitational attraction of the Moon and Sun, and geological events, again either climatological or sudden as in the case of earthquakes.

In part the catastrophes are a result of their unpredictability. The tides are, in their time scale and amplitude, of the same order as the storm surges. Yet because tides are a response to the known gravitational attraction of the Sun and Moon, they are essentially predictable and periodic. A "black box" approach of input, transfer function and response has proved to be adequate for many practical tidal problems in the past. At the same time their study allows the important dynamical processes and boundary conditions that contribute to the transfer function to be probed more deeply, and light to be shed on the less predictable events.

Another example of the unpredictable and catastrophic is to be found in the generation of tsunami waves by large seismic disturbances below or close to the seafloor. Once started their propagation is well accounted for in classical hydrodynamic terms, but their direct effect on the coastlines where they dissipate some of their energy is still a matter of intense scientific study and of serious consequence, particularly in the Pacific.

At higher frequencies, in the region of the spectrum dominated by the sea and swell waves, much theoretical and practical progress has been and continues to be made in our understanding. In consequence, the development of good forecasting techniques of value to the navigator and marine engineer is now possible.

At the lower frequencies, characterized by periods of decades to centuries, the water balance of the oceans as a whole and the response of the Earth's crust to the changing distribution of load on it create another class of problems.

The study of the part of the spectrum associated with

storm surges is being approached in current research from several directions. The approach in terms of a semi-empirical transfer function relies for its success on the good documentation of a substantial number of surges both as regards the meteorological input and the resulting surge. Even then good physical insight is needed to select an appropriately simple parameterization of the meteorological data. These data are only available for relatively few of those parts of the world that are subject to surges, although in the North Sea, for example, it was possible to pioneer the method in the 1930s. A second approach, involving statistical methods for the study of the extremes (tails) of probability distributions, is of significance in the long term planning and construction of sea defences. Again, a substantial number of historical data are required. It is of interest that many of the statistics studied so far for extreme surge heights fit rather well with Fisher and Tippett's extreme value distribution, showing a growth without limit albeit with decreasing probability and rapidly widening confidence limits. One physical interpretation of this result is perhaps that surge heights have never yet reached a state in which other physical constraints, such as non-linearities, depth of water and meteorological conditions, are limiting. Theoretical studies, though rarely directly applicable to the real ocean, have established, through simplified modelling, the important effects of the Earth's rotation and the non-linear interactions that can in real situations be significant enough to invalidate a simple linear additive solution of the combined surge and tidal problem. Moreover they provide the formalism necessary for perhaps the most promising attack on the prediction problem—by numerical or analogue solution of the equations of motion.

It is this approach that is adopted by the authors of the two communications in this issue along with many other oceanographers. It remains applicable even if the data from past surges are not substantial; but the meteorological input still needs to be well defined. Both authors remark on the difficulties of assessing the accuracy of the data, and this is reflected to an extent in the details of their conclusions.

Flierl and Robinson have adopted the view that what is most urgently required on the coastline of the Bay of Bengal is some immediate, though limited, oceanographic forecasting techniques to complement the meteorological predictions. In this approach they recognize the fallibility of detailed aspects of their numerical model, while extracting those parts of its results which can be used with some degree of confidence to predict the gross features, such as the maximum height, of the surge. This is expressed as a function of the path of the cyclone, its speed of progress and the wind speed.

In his contribution Das develops one particular model in more detail and tests it against one surge (the most disastrous). This to some extent reflects the considerable interest now being shown at several laboratories in the possibility of developing models of surges that are directly coupled to numerical weather predictions.—From a Correspondent.