Avoiding recurrent catastrophes

The death of perhaps 15,000 people in Bangladesh last month was caused by cyclonic and tidal forces in concert. Prevention may be impossible, but better warning is essential.

THE tragic loss of life in the Ganges delta of Bangladesh two weeks ago will never be accurately quantified. Even in normal circumstances, the numbers of people eking out a living in the delta can only be guessed at; the numbers of those swept away by the tidal wave that filled the Bay of Bengal on 25 and 26 May will be counted only imperfectly. But tragedies like this recur at frequent intervals along this low-lying coast. What can be done to prevent them, or at least to mitigate their effects? Understanding the phenomenon must be a first step, which is why there is interest in a calculation of the interaction between wind-driven surges and the natural tide in the Bay of Bengal, published in the *Philosophical Transactions of the Royal Society* (**A313**, 507-535; 1985) by B. Johns of the University of Reading and associates from the Indian Institute of Technology at New Delhi: A.D. Rao, S.K. Dube and P.C. Sinha.

In the long run, accurate prediction of these tidal waves must be a prerequisite for avoidance action. Two weeks ago, the meteorological services did warn of impending trouble along the low-lying coast, although the argument continues whether the warnings might have been fuller. Too fatalistically, people also ask what value broadcast warnings may be to people too poor to own radio receivers.

The essence of the phenomenon that killed about 15,000 people in the Bay of Bengal is that by which a cyclonic pressure may create a surge of water elevation as it moves through shallow water onto the shore of an enclosed tidal basin. The first expectation is that the increase of water level and thus the risk of flooding will be greater when the arrival of a cyclone coincides with high tide. But by now it is accepted that the interaction between the tides and the wind-driven surge is not linear. The whole may be greater (and more damaging) than the sum of the parts.

Johns *et al.* have provided a valuable snapshot of where the modelling of tide/surge interactions now stands, and also of what remains to be done. The paper sets out to model retrospectively the tidal wave that hit the low-lying coastal strip of the Indian state of Orissa, on the west of the Bay of Bengal on 3 and 4 June 1982. When more is known of the track of the cyclone that drove last month's tidal wave onto the coast of Bangladesh, the same mathematical apparatus may be used to reconstruct that sequence of events as well.

The technique is in principle straightforward. First, the bottom topography and the coastline of the bay are represented by smoothed curves. This is the idealized but still realistic basin in which the water is driven by the forcing of tidal oscillations in the Indian Ocean, and by the surface winds of cyclones. But because of the large volume of water in the several mouths of the Ganges, one elaboration of the model puts a series of 200-km stretches of water at the head of the bay.

The hydrodynamic equations for the motion of the water in the bay are simplified to the case of a flat surface, although the Coriolis forces associated with rotation are allowed for. The coupling between the Indian Ocean and the bay is supposed to be determined primarily by the astronomical tides, whence arises the most immediate difficulty of the model: by what conditions should the interaction be represented on the boundary, taken as an imaginary line running east from the Sri Lankan coast? In principle, if there were enough tidal stations around the bay, it would be possible to determine this external forcing function accurately, simply by running the model and comparing its predictions of the tides with observations of them in normal circumstances. In the event, the data are so sparse that Johns *et al.* can do no more than represent the tidal effect of the Indian Ocean on the bay by means of a regular sinusoidal variation of height with constant phase along the whole length of the arbitrary boundary. If catastrophic surges in the bay are to be predicted accurately, this needless simplification must be avoided, from which it follows that much better tidal data must be collected from many more stations in the bay.

Incorporating cyclones in the model is also an empirical process. The chief physical effect is that of cyclonic winds on the sea surface. Johns *et al.* represent the Orissa cyclone by a wind-field modelled to allow for decreasing velocity with increasing distance from the centre, but fitted with the crude meteorological data available for the cyclone. By their account, the predicted height of an induced surge in the Bay of Bengal will depend sensitively on the wind-field pattern out to 100 km or so from the centre of the storm, which points to another obvious difficulty: because there is at present no way of inferring precise wind-speeds from synoptic meteorological data, real-time predictions are, for the time being, uncertain.

In the circumstances, it is remarkable that the model functions as well as it does. By forcing the movement of the mass in the bay by the crude representation of the effects of the external tide, as well as by the Orissa cyclone following its measured track, Johns *et al.* conclude that the average height of the tidal wave in June 1982 may indeed have reached 8 m at some parts of the coastline. But given the unavoidable arbitrariness with which the constants specifying the wind-field must be chosen, the real proof of the pudding is that the model seems to have reconstructed the sequence of events correctly.

The Orissa inundations of 1982 turn out to have been interesting in their own right (but perhaps they all are). According to the model calculations, not much seems to have happened to the level of water off the Orissa coast (except for a gradual rise totalling 2 m in a day) until the centre of the cyclone made its landfall on the afternoon of 3 June. Thereafter, however, the computer calculations bear out such anecdotal evidence as there is that the largest elevation of sea-level occurred some hours later, further to the north-east. During this interval, the model shows, it is almost as if a tidal wave was moving steadily along the coast from the point of landfall, at first increasing with height. The tidal and cyclonic effects are not additive, which is what would be expected of solutions to a set of equations which are inherently nonlinear, but the result is that some odd things can be expected. The times of maximum inundation may differ by several hours from those of high tide. Parts of the coast far from the point of landfall may be inundated twice.

Directly, none of this has much to do with last month's tragedy. Indeed, the physical scale of these phenomena is so great that outright avoidance is clearly beyond reach. The only realistic way of mitigating recurrent damage on last month's scale is that there should be more accurate warnings, and that better use should be made of them. Much might be done by running the model of Johns *et al.* not merely on those cyclones which turn out to be damaging, but on the much larger number of meteorological depressions in the Bay of Bengal which turn out to be relatively benign, for then it might be possible to build up a kind of taxonomy of dangerous cyclones. But for such an exercise to be worthwhile, better tidal observations are essential.

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