Mausam, (1983), **34**, 4, 399-404

551.515 : 551.513 (210.5)

Numerical simulation of storm surge envelopes associated with the recent severe cyclones impinging on the east and west coasts of India

S. K. GHOSH, B. N. DEWAN* and B. V. SINGH

Meteorological Office, New Delhi

(*Received 14 April 1982*)

सार — सन् 1975 के पोरबन्दर चक्रवात, सन् 1977 के आन्ध्रप्रदेश चक्रवात और सन् 1978 के पम्बन चक्रवात से उत्पन्न तूफानी महोमियों के अन्वालोप को कम्प्यूटर पर अनुकारित किया गया । तेज तूफानी महोमियों की स्थितियों और आकार से कम्प्यूटर प्राप्त प्रेक्षणों से काफी मेल खाते हैं ।

ABSTRACT. Envelopes of storm surges generated by the Porbandar cyclone of 1975, Andhra Pradesh cyclone of 1977 and Pamban cyclone of 1978 are simulated on the computer. The locations and the magnitudes of peak storm surges are found to be in good agreement with observations.

1. Introduction

Before the advent of high speed electronic computers, attempts at prediction of storm surges were made by empirical means or by the use of simplified mathematical models. Both the above procedures have obvious limitations. In spite of these limitations some important relationship between storm surges and meteorological parameters were found out by such studies. For example, Conner *et al.* (1957) found the correlation coefficient of 0.68 between the observed maximum sea level elevation and the lowest central pressure of hurricanes. Harris (1959) found a correlation coefficient of 0.75 between storm surge and two parameters, *viz.*, the central pressure and the distance of the 50 fathom (90 m) line from shore.

A more rational method of prediction of storm surges is, however, to formulate a set of differential equations governing the motion of the sea by incorporating various driving forces and bottom stress, and then solving the equation, numerically. But the principal equation of a unified theory of the hydrodynamic processes involved in storm surge generation, even in tensor notation (Fortak 1962) almost fills a page. This equation obviously is too complicated to admit numerical solution. We may therefore take recourse to a simplified version of momentum and mass equation by neglecting non-linear interactions, as was done first by Ekman (1905, 1923). Numerical solutions of such equations have been obtained on computers during the last two decades.

In India such a prediction model was pioneered by Das (1972). He conducted a numerical experiment and computed the peak storm surge generated by an idealized cyclone striking the coast of Bangladesh. Das *et al.* (1974) extended the above mentioned study for application to the coasts of West Bengal and north Orissa. They evolved a set of pre-computed nomograms with the help of which storm surges could be objectively predicted if storm parameters, *viz.*, pressure drop and storm speed are given. These nomograms, however, have limited applicability for storm intensity. Ghosh (1977) has evolved pre-computed nomograms with the help of which storm surges can be predicted on the east coast of India north of latitude 10 deg. north.

While prediction of peak surge is very important, it is also necessary to have an idea of quantitative dispersion of surge along the coast (*i.e.*, surge envelope) so that the coastal stretch upto which significant surge is expected can be estimated for the purpose of evacuation of population. Moreover, in order that a prediction scheme is considered reliable, it is necessary that the computed surges are verified with observations. In this paper an attempt is made to compute, with the help of a numerical model, the surge envelopes associated with a few recent cyclones impinging on both the east and west coasts of India, and the computer printouts of the surge envelopes are presented. The computed magnitudes and locations of peak surges are compared with observations.

In the recent years there have been three cases of significant storm surges associated with the following cyclones :

(*i*) the Porbandar cyclone of October 1975,

(*ii*) the Andhra Pradesh cyclone of November 1977,

(*iii*) the Pamban cyclone of November 1978.

*Meteorological Office, Pune

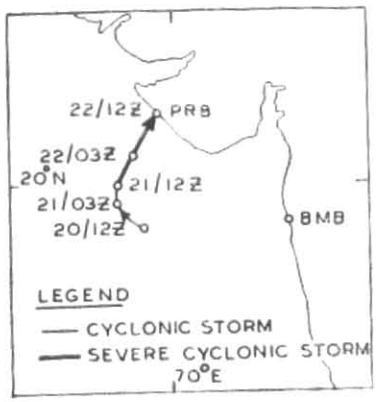

Fig. 1. Track of Porbandar cyclone of October 1975

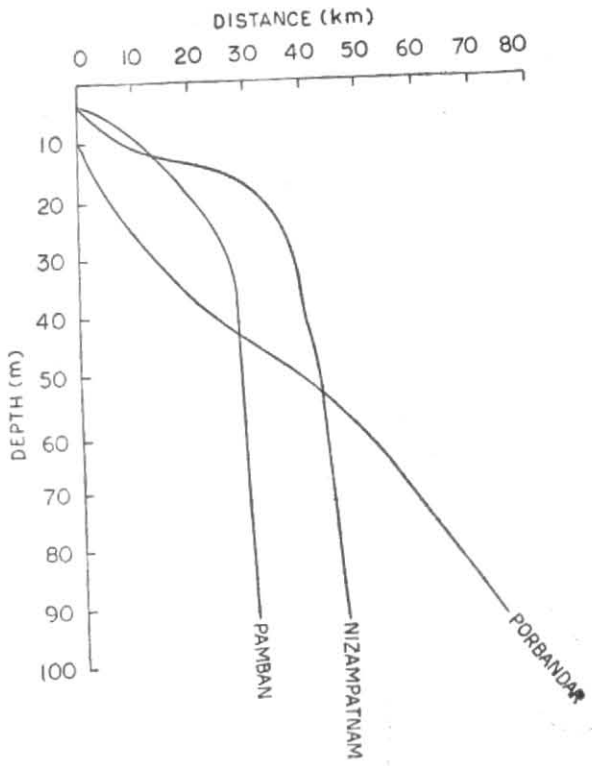

Fig. 2. Depth profiles near Porbandar, Nizamapatnam (Andhra Pradesh) and Pamban

The model used in the present study for numerical computations of storm surges is adapted from the works of Jelesnianski (1967, 1972) as modified for Indian coasts.

2. Discussion

(*i*) *Porbandar cyclone of October* 1975

The track of the cyclone is reproduced (Gupta *et al.* 1977) in Fig. 1.

The various meteorological parameters associated with the cyclone have been obtained from satellite cloud imagery and synoptic chart by Gupta *et al.* (1977). For storm surge computations the following input parameters have been obtained from the above paper and also from Mishra and Gupta (1976).

Pressure drop	= 66 mb
Angle of track relative to the coastline	= 63° E
Speed of propagation	= 32 kmph
Radius of maximum wind	= 40 km

The offshore bathymetry near Porbandar, an important input parameter required for storm surge computation, is obtained from marine coastal charts. The depth profile is given in Fig. 2. In this figure the depth of the continental shelf near Porbandar is plotted against the distance from the coast.

Using the numerical model for computing storm surges and the above input parameters we obtain a storm surge envelope as displayed on a computer output. Such an output of a graph displaying the envelope of storm surges generated by the Porbandar cyclone is shown in Fig. 3.

The graph is portrayed with asterisks. The horizontal scale of the graph is 960 km long; it represents the coast on a straight line. Highest local surge heights are printed at intervals of 12.8 km. Below this line are given linear distances to the right or left of landfall. The centre of the horizontal scale is tangent to the natural coast. This means the printed distances away from the basin centre are smaller than the actual curvilinear distances along the coast.

As can be seen from Fig. 3 the peak surge computed by the model is 2.5 m. No measurement of the storm surge generated by the cyclone is available. However, a post-storm survey estimated the peak surge to be about 3 m above mean sea level.

It may also be seen from the same figure that the location of peak surge, as computed, is to the right of the point of landfall of the cyclone.

(*ii*) *Andhra Pradesh cyclone of Novemebr* 1977

The storm track (Pant *et al.* 1980) is given in Fig. 4.

The parameters required for storm surge computations are given below :

The pressure drop just before landfall is estimated to be 97 mb (Ghosh 1981).

In the radar picture of 19th morning the 'eye' was very clearly seen. The diameter of the wall cloud

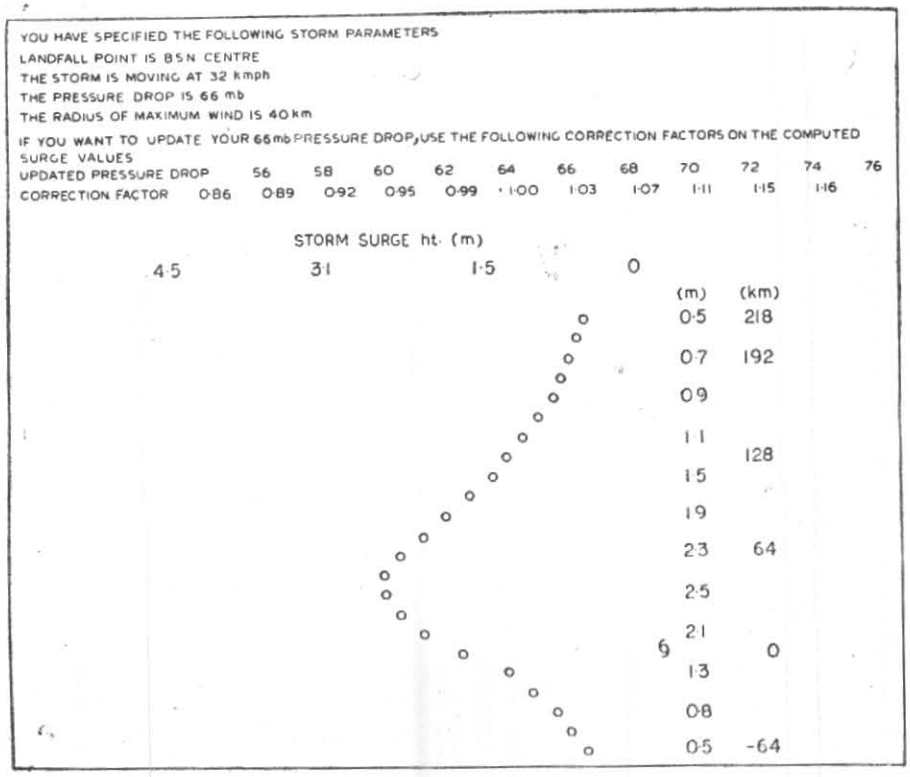

Fig. 3. Computed storm surge envelope associated with Porbandar cyclone of October 1975

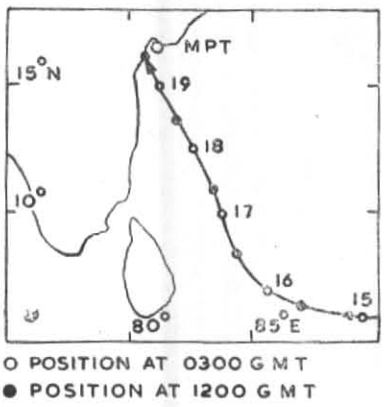

Fig. 4. Track of Andhra Pradesh cyclone of November 1977

which may be taken to represent the diameter of the ring of the maximum wind, (Gentry 1973), appeared to be about 90 km; so the radius of the maximum wind is 45 km.

The angle of track relative to the coastline is about 90 deg. and the speed of the cyclone is 15 kmph.

The depth profile near the point of landfall is given in Fig. 2.

With the above input parameters the computed storm surge envelope is as shown in Fig. 5. It is seen from this figure that the peak storm surge is 5.7 m.

According to the press report soon after the landfall of the cyclone the highest sea level elevation was about 18 ft, *i.e.*, 5.4 m (This estimate was mainly due to the fact that sea weeds were seen stuck on telegraph wires eighteen feet high). During the post storm survey it was found that the temple (on the roof of which many people took shelter) in a village called Sangameshwaram in Divi taluka was completely submerged by sea water. Height of the temple is 14 ft (4.3 m) above the ground level. The height of the base of the temple is not accurately known. Since the Spring Tide range near Divi is about 1.3 m

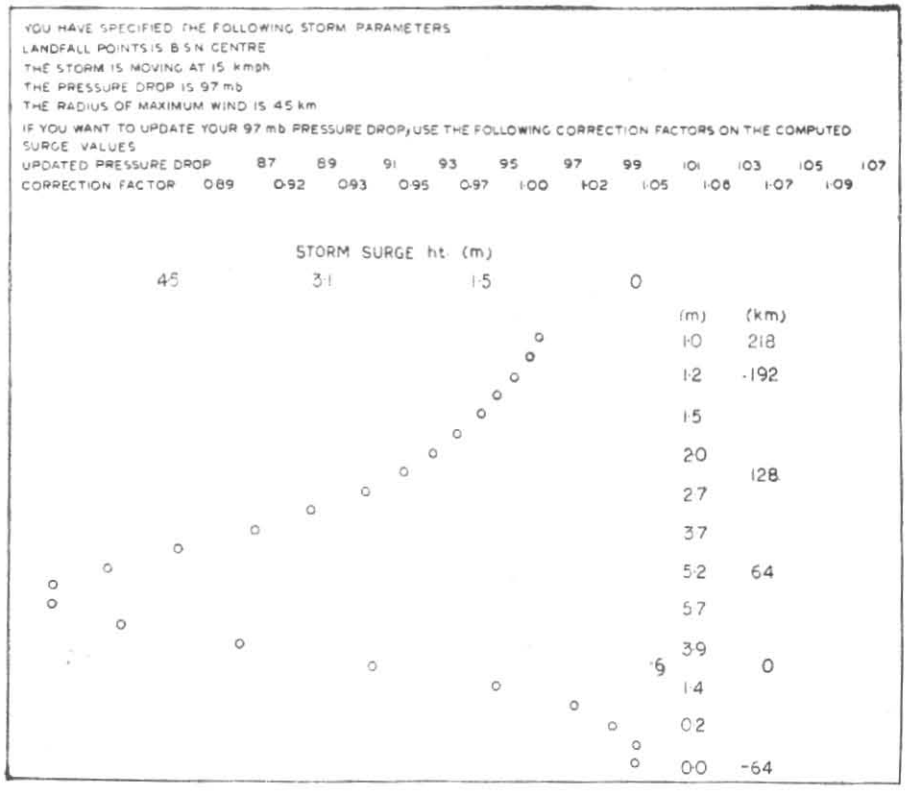

Fig. 5. Computed storm surge envelope associated with Andhra Pradesh cyclone of November 1977

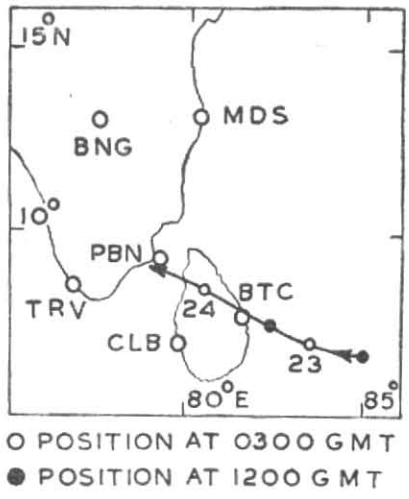

Fig. 6. Track of Pamban cyclone of November 1978

and it is unlikely that a temple has been constructed at a place flooded by sea water during Spring Tide the height of the base of the temple must be more than 0.7 m. Thus the peak sea level elevation must have been greater than 5 m. As the contribution of the astronomical tide to the total sea level elevation at the time of landfall was insignificant, the total sea level elevation was almost entirely due to storm surge. Thus it is seen that the computed peak surge is in excellent agreement with the observation. It may also be seen that the computed location of the peak surge is to the right of landfall which is borne out by observations (Plant *et al.* 1980).

(iii) Pamban cylone of November 1978

The storm track of the cyclone (Srinivasan *et al.* 1980) is given in Fig. 6.

The cyclonic storm was classified as T6 on 23rd in the Satellite Tropical Disturbance Summary from