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Shoreline Orientation and Storm Surge*

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The storm surge is the deviation of the observed storm tide from the expected astronomical tide. Some authors (Pore, 1970) have differentiated between storm surges generated by hurricanes and extratropical cyclones, however this difference appears to be a function of magnitude of intensity rather than storm type. Four factors are generally considered in the generation of storm surges. These are: 1) the wind set-up, that is the stress of the wind blowing over the sea surface piles water up along the fetch; 2) the inverted barometer effect, which is the increase of the sea level surface elevation in a region of low barometric pressure. A pressure drop of one inch of mercury (33.86 millibars) yields a water level rise of approximately 13.5 inches (Pore, 1961); 3) the transport of water by waves into the near shore area. This factor is related to the wind set-up and might be dubbed the wave set-up; and 4) modification of the storm sea-level due to the shoreline configuration and bathymetry. Lateral constriction and shallowing of a bay cause an increase of the (astronomical or storm) tidal range.

Individual factors which determine the magnitude of the storm surge in relation to mean high water and hence the effect of the individual storm surge on the coast are the stage of the tide (spring or neap, ebb or full), the intensity of the storm, the speed of the storm's passage through the area, and the path of the storm in relation to the shoreline. Finally, the frequency of storms and surges affects the ability of the coast to recover and return to a "normal" state. The last in a series of closely spaces storms will be more destructive, all other factors being equal, than the first. The later storms act upon a battered, unprotected shore instead of one which might have been at the peak of an accretional stage. The earlier storms "soften up" the coast for the later storms. The two factors which I emphasize are the speed of a storm's passage through an area and the path of the storm in relation to the shoreline. Both of these factors greatly contribute to the generation of the wind and wave set-ups of the storm surge.

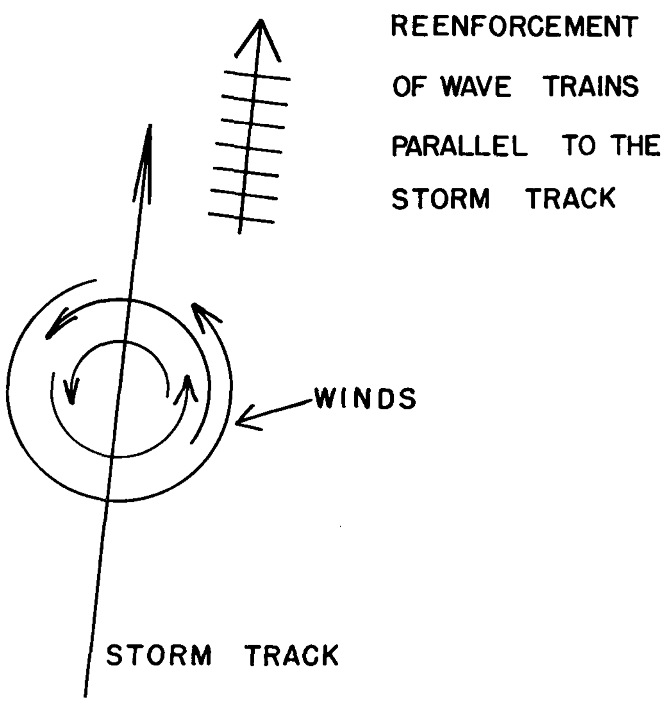

Figure 1. Schematic diagram indicating the reinforcement of wave trains parallel and to the right of the storm track.

The orientation of the shore with respect to the storm path is critical in determining the magnitude of the surge. A coast that faces perpendicularly into the storm track is subjected to a reinforced wind and wave set-up (Fig. 1). Due to the counterclockwise rotation of the winds about the storm center, only parallel to the storm track and to the right of the storm center do the winds blow along a constant path. This reinforcement is analogous to the Doppler Effect noted in other types of wave energy. Thus with a northerly trending storm track, a southward facing shore would receive the brunt of the storm surge. An easterly facing shore would not be subject to the reinforced storm, and a northerly facing shore would be protected, shielded, from the storm and surge.

* Manuscript received April 13, 1971.

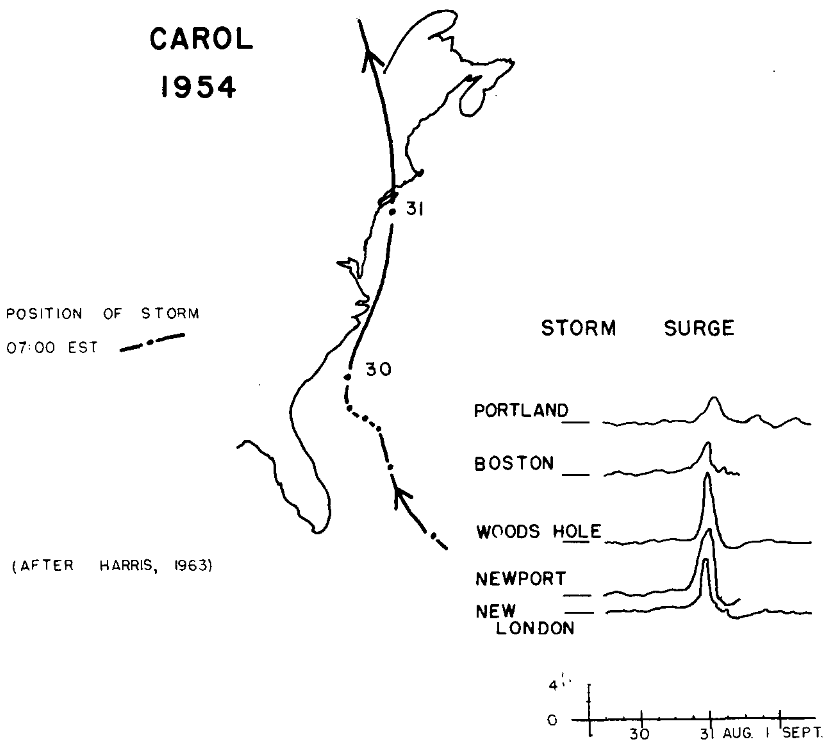

Figure 2. Storm track and surge profiles for Hurricane Carol, August - September 1954. The greatest surges occur on the south facing coast perpendicular to the storm track.

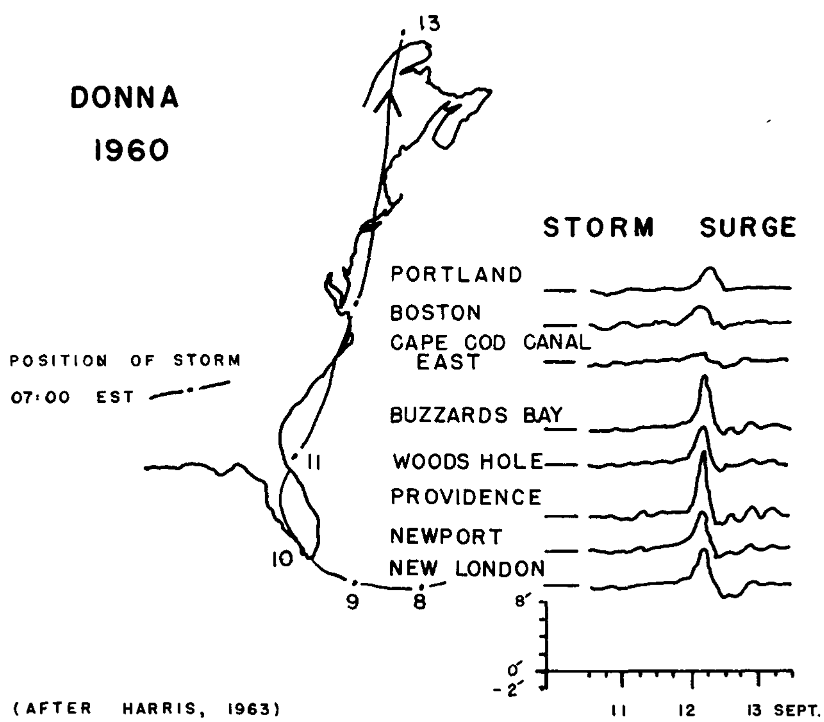

Figure 3. Storm track and surge profiles for Hurricane Donna, September 1960. Constriction of the water mass in Buzzards Bay causes an increase in the storm tidal range. The body of Cape Cod protects the east end of the Cape Cod Canal from the wind and wave set-ups.

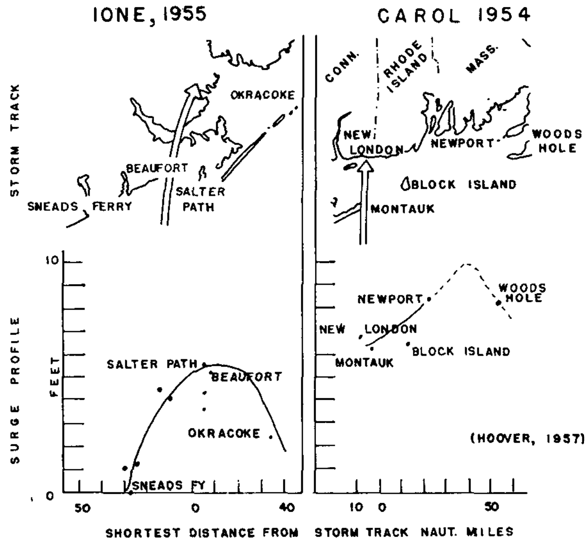

Figure 4. Storm surge offset from storm track, Hurricane Ione, 1955, and Carol, 1954. Greatest surge occurs east (right) of the point where the storm center crosses the coast.

During Hurricane Carol, August, 1954, (Fig. 2) Montauk, New London, Newport, and Woods Hole would be expected to have experienced and did experience greater tides than Boston and Portland. A similar pattern is seen in the storm surge that accompanied Hurricane Donna, September, 1960, (Fig. 3). Especially interesting to note is the relative height of the water surface at Woods Hole, Buzzards Bay, and the eastern end of the Cape Cod Canal, Massachusetts. The increased surge at Buzzards Bay reflects the constriction of the water prism as it moved up the bay from the relatively open shore at Woods Hole. The comparatively low surge at the eastern end of the canal is due, in part, to the northerly exposure that is protected from the wind and wave set-ups by the body of Cape Cod.

The reinforcement of both the wind and wave set-ups parallel to the storm track also results in the offset of the region of the greatest surge to the right (in the Northern Hemisphere) of the storm path. Examples of this occurrence are common along the hurricane-ridden southern Gulf Coast of the United States. Hurricane Camille, August, 1969, produced a surge of over 20 feet above mean sea level along a wide segment of the Louisiana-Mississippi coast. The greatest measured surge, 24.2 feet at Pass Christian, was slightly east of the point where the eye of the north moving hurricane crossed the coastline. This phenomenon also is observable in the recorded storm surges for Hurricanes Ione, 1955, and Carol, 1954 (Fig. 4). Jelesnianski (1966, 1967) computes a similar pattern for storm surge asymmetry.

A storm which moves quite rapidly does not have time to reinforce itself as greatly as does a slow-moving or stationary storm. The duration of the reinforcing winds parallel to the storm track is not as great for the rapidly moving storm hence the wind and wave set-ups are not able to develop to their greatest extent.

In conclusion, the orientation of the shore and the storm track and the speed of the storm through the area are major factors in the consideration of a storm surge. The greatest storm surge should occur slightly to the right of the point where the center of a slowly moving storm crosses a coast that is perpendicular to the storm track.

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