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TECHNICAL COMMUNICATION

# The Atlantic Coast Storm of March 1989

**Robert Dolan[a], Douglas L. Inman[b], and Bruce Hayden[a]**

[a]Department of Environmental Sciences
University of Virginia
Charlottesville, Virginia 22903 USA

[b]Scripps Institution of Oceanography
University of California, San Diego
La Jolla, California 92093 USA

**ABSTRACT**

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A severe northeast storm in March, 1989, resulted in major damage and beach erosion along the mid-Atlantic coast. Our hindcast analysis shows that this storm generated deep-water waves of 1.5 m or higher for 115 hours. In terms of erosion along the Virginia-North Carolina coast, it was one of the three highest, total-energy storms for the period 1942–1989.

**ADDITIONAL INDEX WORDS:** *Storm surge, wave hindcast, storm waves, sand transport during storms, Outer Banks of North Carolina.*

In March, 1989, a severe northeast storm caused serious beach erosion and millions of dollars of damage along the mid-Atlantic coast of the United States, from Ocean City, Maryland, to Cape Hatteras, North Carolina (Figure 1). In terms of total-energy, erosion, and damage it was one of the three worst mid-Atlantic storms during the period 1942–1989 (Figure 2).

We hindcast the storm using the method developed by C.L. Bretschneider as modified by BOSSERMAN and DOLAN (1968), and then compared the results with the established historical record of DOLAN *et al.* (1988). Based on the hindcast analysis, the maximum significant wave height (deep-water) during the storm period was 5.0 m; wave heights in excess of 1.5 m occurred for a period of 115 hours. Table 1 shows the wave heights and periods recorded by the U.S. Army Corps of Engineers, Field Research Facility (FRF) at Duck, NC. When corrected for shoaling and refraction, the FRF Waverider statistics are: 7 March, 3.9 m; 8 March, 4.5 m; 9 March 4.2 m; 10 March, 3.3 m; and, 11 March, 2.4 m. The difference between our hindcast wave heights and the Waverider data is that shoaling and refraction to the 23 m depth station of the Waverider result in an enhancement factor of about 1.14 for deep water wave conditions. Accordingly, the FRF Waverider data indicates a maximum deep water wave height of 4.8 m for the six hour average at 1900 hrs. on 7 and 8 March, and an average significant deep water wave height of 3.7 m for a period of 120 hours.

The track of the storm resulted in a fairly high wave setup along the Outer Banks of North Carolina. Using the method of RESIO (1974), the setup (water elevation above normal tides) was estimated to be 82 cm. Comparison of predicted vs. measured high tides at the FRF at Duck (Figure 3), gives a storm setup of 70 cm

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Table 1. *Wave height and period data recorded offshore from the U.S. Army Field Research Facility at Duck, N.C.*[a]

| March 1989 | | | |
|---|---|---|---|
| *Day* | *Hour* | $H_s$ *in meters*[b] | *T in seconds*[b] |
| 7 | 0100 | 2.2 | 9.5 |
| | 0700 | 3.1 | 7.1 |
| | 1300 | 3.8 | 10.6 |
| | 1900 | 4.2 | 12.1 |
| 8 | 0100 | 3.8 | 11.6 |
| | 0700 | 4.0 | 9.4 |
| | 1300 | 3.8 | 10.2 |
| | 1900 | 4.2 | 11.6 |
| 9 | 0100 | 3.8 | 12.1 |
| | 0700 | 3.9 | 10.8 |
| | 1300 | 3.7 | 11.1 |
| | 1900 | 3.4 | 11.6 |
| 10 | 0100 | 2.9 | 8.8 |
| | 0700 | 2.9 | 7.1 |
| | 1300 | 2.9 | 8.2 |
| | 1900 | 3.0 | 7.1 |
| 11 | 0100 | 2.4 | 11.6 |
| | 0700 | 2.3 | 12.1 |
| | 1300 | 1.8 | 11.6 |
| | 1900 | 1.7 | 11.6 |

[a] Measured by Waverider located 6 km offshore in water depth of 23 m.
[b] Significant wave height and peak-energy period. Deep water wave height is increased by a factor of about 1.14 above tabulated data because of shoaling and refraction to a deepth of 23 m. The average significant deepwater wave height was 3.7 m for the 120 hour period of this data.

Table 2. *Storm Setup, Vicinity of Oregon Inlet, March 1989*[a]

| Date March | Predicted Range[b] High Water (cm, MSL) | Measured Range[c] High Water (cm, MSL) | Storm Setup[d] (cm) |
|---|---|---|---|
| 7 | 75 | 120 | 45 |
| | 75 | 140 | 65 |
| 8 | 75 | 145 | 70[e] |
| | 85 | 130 | 45 |
| 9 | 75 | 125 | 50 |
| | 75 | 130 | 55 |
| 10 | 75 | 105 | 30 |
| | 85 | 110 | 25 |
| 11 | 65 | 75 | 10 |
| | 85 | 90 | 5 |

[a] Duck Pier is approximately 50 km north of Oregon Inlet.
[b] NOAA Tide Tables corrected to twice daily high tides at Kitty Hawk, 15 km south of Duck Pier.
[c] Data from U.S. Army Corps of Engineers Field Research Facility, Duck, North Carolina.
[d] Estimated from b-c.
[e] Relative to MSL the predicted vs measured high water levels at 07:42 EST were 75 cm and 1.45 cm respectively, and the following predicted vs measured low water at 14:12 EST were − 35 cm and − 20 cm respectively. This gives a predicted vs measured range of water level of 1.10 cm and 1.65 cm respectively.

(Table 2). In addition, 8–9 March 1989 were days of extreme (perigean) spring tidal range. Thus, the maximum water level during the storm was the sum of the perigean spring tidal elevation and storm setup. Data from Table 2, corrected to mean sealevel, suggest that the combination of perigean spring tides and storm setup raised the water level at Oregon Inlet about 1.5 m above mean sealevel.

The March storm spanned several tidal cycles so the erosive effect was spread vertically over a maximum section of beach; the water level ranged over 2.0 m, from −0.60 m below MSL at 12:30 EST on 6 March to +1.46 m above MSL at 07:42 on 8 March 1989.

The severity of the storm was not only due to the high wave action compounded by the perigean spring tides, but also due to its unusually long duration. Significant wave heights exceeding 1.5 m occurred for 115 hours, almost twice the duration of the average winter northeaster that impacts the Outer Banks. During the period 1942 to 1989, out of the 1,250 winter storms that impacted the mid-Atlantic coast only two other storms had longer durations (DOLAN *et al.*, 1988). The record shows that a storm in March, 1951, had a duration of 150 hours and one in February, 1969, had a duration of 170 hours. The probability of a storm with a duration of 115 hours, generating wave heights in excess of 1.5 m and up to 5.0 m, is about once in every 25 years. The storm record also reveals that 29 storms had maximum deepwater significant wave heights of 5.0 m or more during the period 1942 to 1989 with an average duration of 54 hours. Thus the storm of 1989 had more than twice the average duration of storms of similar magnitude. The model studies of RESIO (1974) are in agreement with the DOLAN, *et al.* (1988) record. Using the estimation procedure of RESIO (time during which maximum breaker heights equaled or exceeded 0.9 m), the duration of such storms averages 56 hours and the expected range of durations would be between 40 and 70 hours.

The erosion and transport of sand by storm waves is directly proportional to the energy-flux of the waves and their duration. For example, a three hour duration of the 5.0 m high waves expended 900 kilowatt hours per meter of coast length (kwH/m); in contrast, the estimated average 3.0 m high deep water waves

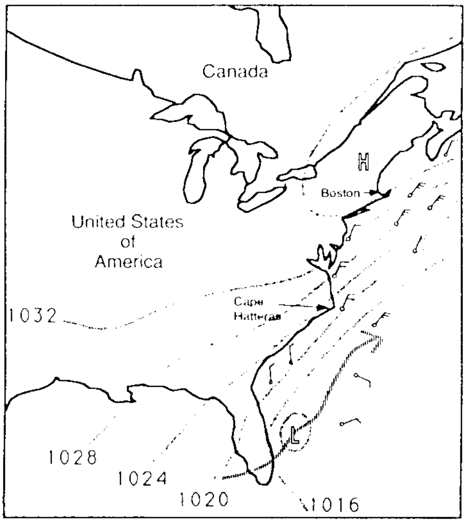


Figure 1. Pressure (in mb), wind field (each one-half barb is 5 knots), and track of the March, 1989, storm. The dashed arrow crossing Florida represents the storm track for the five days when significant waves were generated along the mid-Atlantic coast (March 7–11, 1989). The steep pressure gradient and persistent northeast winds arose mostly from the strong high pressure centered over New England for the entire period of the storm. The cyclone itself never deepened below 1012 mb. Position of low shown for 1200 Z, 9 March 1989.

persisting for 115 hours expended 11,500 kwH/m. These values are placed in perspective by noting that the annual average energy-flux of waves at Oregon Inlet on the Outer Banks is 2 kw/m, which sums to a yearly total of 17,500 kwH/m (INMAN and DOLAN, 1989, see Figure 20). This one storm had a power expenditure (and sand transport potential) equivalent to 66 percent of that for the average year.

The storm's total-energy of about 11,500 kwH/m would provide a longshore transport of sand of about 415,000 $m^3$ (INMAN and DOLAN, 1989, equation 6.3), assuming waves approach the shoreline such that the wave crest and shoreline make an angle of 10°). This estimate of 415,000 $m^3$ compares favorably with the measured storm erosion of 360,000 $m^3$ from the north end of Pea Island, Oregon Inlet, North Carolina (INMAN *et al.*, 1989).

## ACKNOWLEDGMENT

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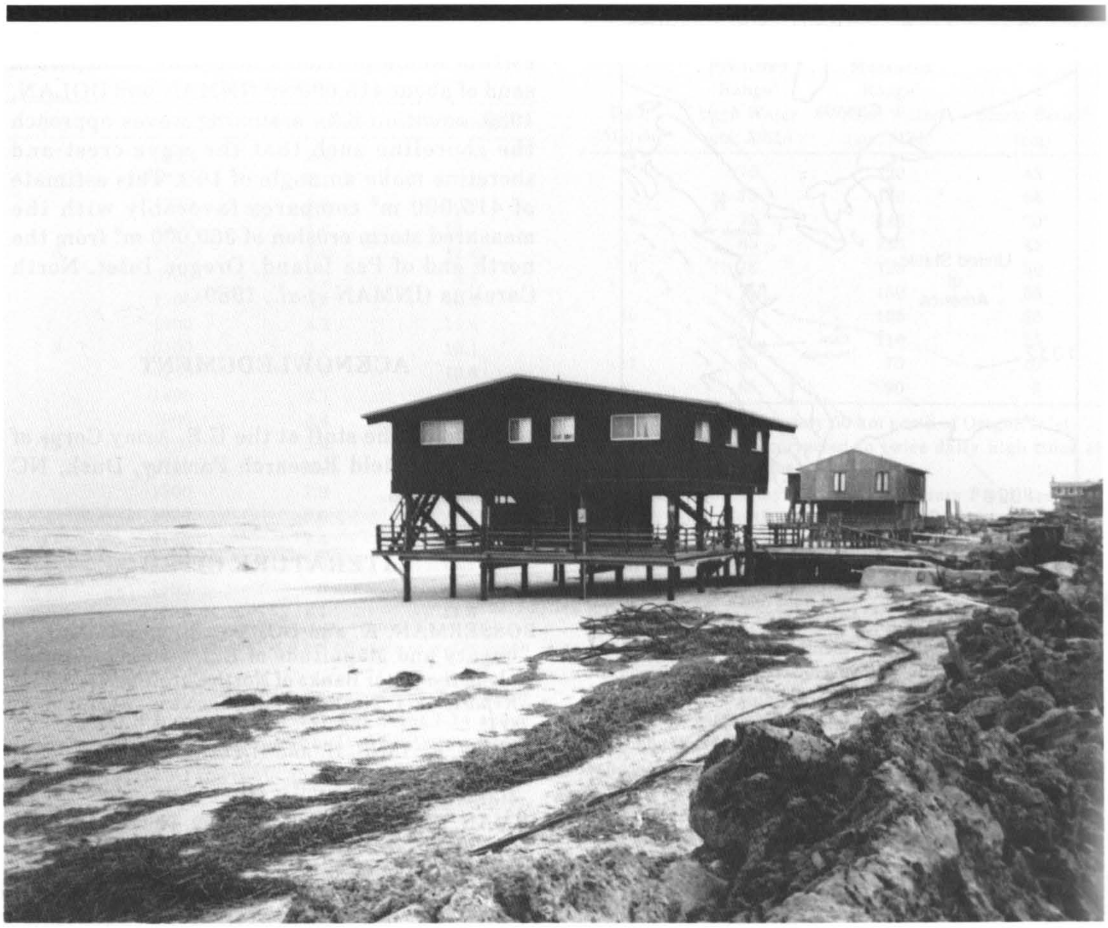

Figure 2. Property damage along Virginia coast during March storm of 1989. Photo of Sandbridge Beach, Virginia, by Susan Trossbach.

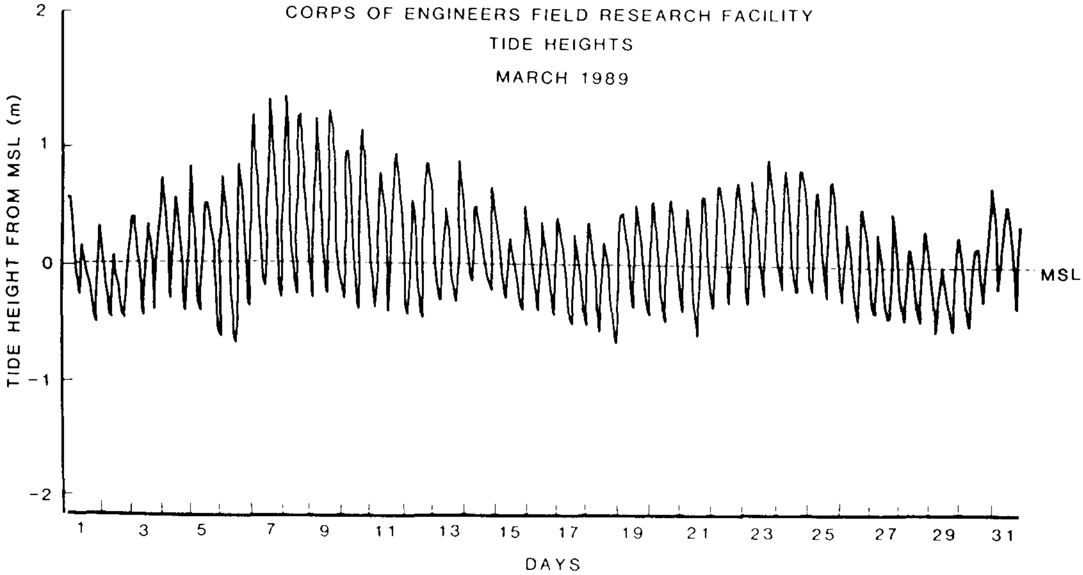


Figure 3. Tide heights as recorded by the U.S. Army Corps of Engineers at Duck, NC.