



TECHNICAL COMMUNICATION

The "All Hallows' Eve" Coastal Storm—October 1991

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ABSTRACT

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An extreme Atlantic coast northeast storm that occurred in October, 1991 resulted in major damage along the entire eastern coast of the United States. The storm originated over the southcentral United States, progressed northeastward, and intensified south of Newfoundland. It strengthened as it combined with the remnants of Hurricane Grace, producing one of the strongest northeasters in the last 50 years. Our wave hindcast analysis for Cape Hatteras, North Carolina, indicates that this storm generated significant deep-water waves 1.5 m or higher for 114 hours with maximum significant wave heights of 10.7 m (35 feet)—higher than the infamous "Ash Wednesday" storm of March, 1962. The fetch extended over 3,500 km from Newfoundland to south of Miami, Florida.

ADDITIONAL INDEX WORDS: *Wave hindcast, storm climatology, storm waves, extratropical storms, northeasters.*

INTRODUCTION

In late October, 1991, an extreme northeast storm caused significant damage and beach erosion along the entire east coast of the United States. Our analysis indicates that this storm was one of the most severe Atlantic storms in the past 50 years (Photo 1). High waves and storm surge resulted in extensive damage along the Outer Banks, including over 10 overwashes of the coastal highway and the loss of several beach cottages. This analysis is somewhat similar to the study of a major northeaster in March, 1989 described by DOLAN *et al.* (1990).

METEOROLOGICAL CHARACTERISTICS

The cyclone formed on Saturday, October 26, as a small depression over the Kansas-Oklahoma border along a stationary front oriented southwest to northeast. By 7 a.m. on the 27th, the still weak system had moved rapidly northeast with the prevailing upper-air flow to a position north of Lake Erie. The coastal storm began in earnest by Monday morning, as the cyclone travelled out

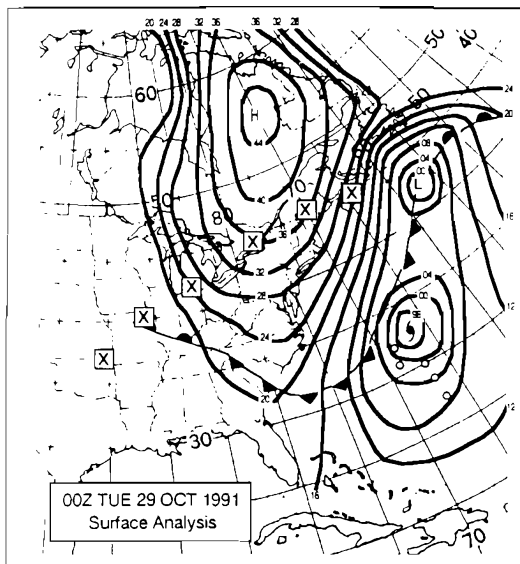


Figure 1. Surface weather map at 00Z Tuesday, October 29, 1991 (7 p.m. EST, October 28). Dark lines are isobars with 4 mb spacing (24 = 1,024 mb; 96 = 996 mb). Previous positions of the low pressure system and Hurricane Grace at 12 hour intervals are indicated by X's and open circles, respectively.



Photo 1. Dune Road in Westhampton, Long Island (New York) after the "All Hallows' Eve" northeast storm of October, 1991. Photo reprinted courtesy of *Newsday*/John H. Cornell Jr.

to sea south off Newfoundland with a cold front trailing it to the south. Although the storm's central pressure was still fairly high (about 1,015 mb), a strong high pressure system (1,045 mb) east of Hudson Bay produced a tight pressure gradient and moderate northerly winds and waves. This marked the beginning of the northeaster.

On Monday evening, October 28, the cold front had passed through South Carolina and the northerly winds behind the front began producing high waves (Figure 1). Also note that Hurricane Grace was located west of Bermuda at this time and moving toward the north. The storm's fetch was over 1,800 km and sustained winds within the fetch region were greater than 30 knots. Although these windspeeds are not particularly high for a major coastal storm, the long duration of sustained high windspeeds created unusually large deep-water waves.

By Wednesday morning, October 30, the remnants of Hurricane Grace joined the low pressure system which was located at 38°N, 60°W and had a central pressure of 983 mb. The anticyclone re-

tained its strength (1,042 mb) and had migrated slowly east to north of Maine. With the additional energy from Hurricane Grace, windspeeds jumped to over 40 knots and the fetch area extended from Newfoundland to south of Miami, Florida. Sustained 40 knot winds continued Wednesday and throughout Halloween, producing one of the greatest northeasters in the past half century (Figure 2). After combining with Hurricane Grace, the storm moved from west to east. As the anticyclone passed to the north of the low, strong onshore winds produced high waves along the New England and Mid-Atlantic coastal regions (Photo 2). Finally, by the afternoon of November 1, the storm began to fill (central pressure > 1,000 mb) and the high pressure system continued moving eastward and weakened.

WAVE CHARACTERISTICS

Significant wave heights and wave periods for this storm were hindcast for Cape Hatteras, North Carolina, using a procedure developed by Sverdrup, Munk, and Bretschneider (U.S. ARMY CORPS

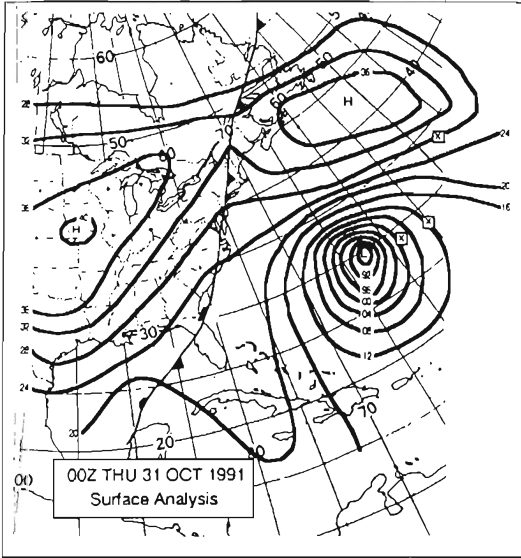


Figure 2. Surface weather map at 00Z Thursday, October 31, 1991 (7 p.m. EST, October 30). The storm retrograded, or moved from east to west, over the previous 36 hours.

MAXIMUM SIGNIFICANT DEEP-WATER WAVE HEIGHT FREQUENCIES

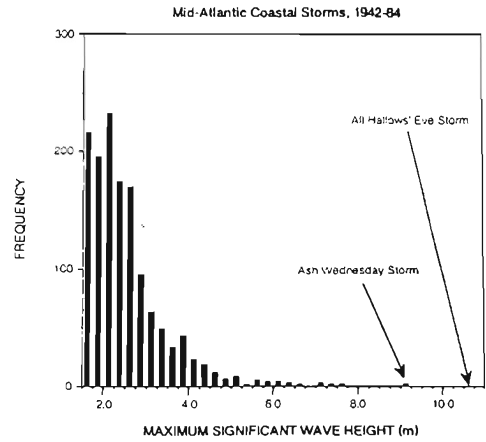


Figure 3. Comparison of hindcast maximum significant deep-water wave heights for the "All Hallows' Eve" storm and the "Ash Wednesday" storm to the overall wave height climatology of Atlantic coastal storms from 1942-1984. All wave hindcasts are determined for Cape Hatteras, North Carolina.



Photo 2. "All Hallows' Eve" storm waves along Nantasket Beach in Hull, Massachusetts. The storm caused damage from Cape Cod to Cape Hatteras. Photo courtesy of Tome Herde, *The Boston Globe*.

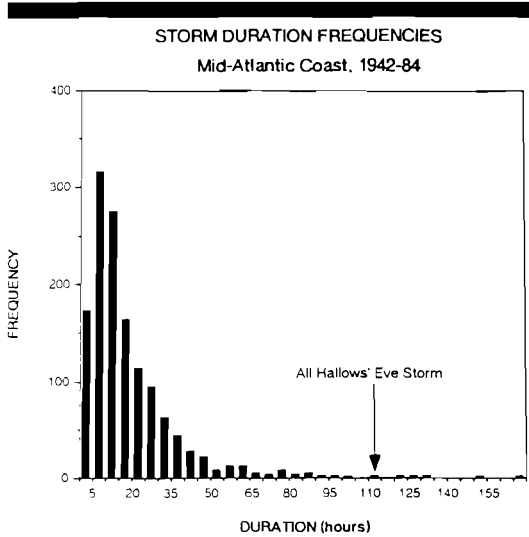


Figure 4. Comparison of the duration of the "All Hallows' Eve" storm to the durations of all Atlantic coastal storms from 1942-1984. Durations are determined as the period of time in which at least 1.5 m (5 ft.) deep-water waves are hindcast at Cape Hatteras, North Carolina.

OF ENGINEERS, 1984) and modified by BOSSERMAN and DOLAN (1968). These results are compared to a climatological data base of 1,347 Atlantic north-easters from 1942-1984 (DOLAN *et al.*, 1988). For inclusion, a storm must have produced at least 1.5 m (5 ft.) deep-water waves, a level which was experimentally shown to produce minimal coastal erosion along North Carolina's barrier islands (BOSSERMAN and DOLAN, 1968). Thus, the storm's duration was determined by the time period in which at least 1.5 m waves occurred.

Our hindcast results indicate that 10.7 m (35 ft.) significant deep-water waves occurred on the evening of October 30 and the morning of October 31. These waves are the highest in the past 50 years, easily surpassing the 9.1 m (30 ft.) waves hindcast for the famous Ash Wednesday Storm of March, 1962 (Figure 3). The All Hallows' Eve storm's 114 hour duration ranks it sixth longest in our dataset (Figure 4) and the longest wave period was 13.5 seconds. At the U.S. Army Corps of Engineers site at Duck on North Carolina's Outer Banks, the waverider 6 km offshore mea-

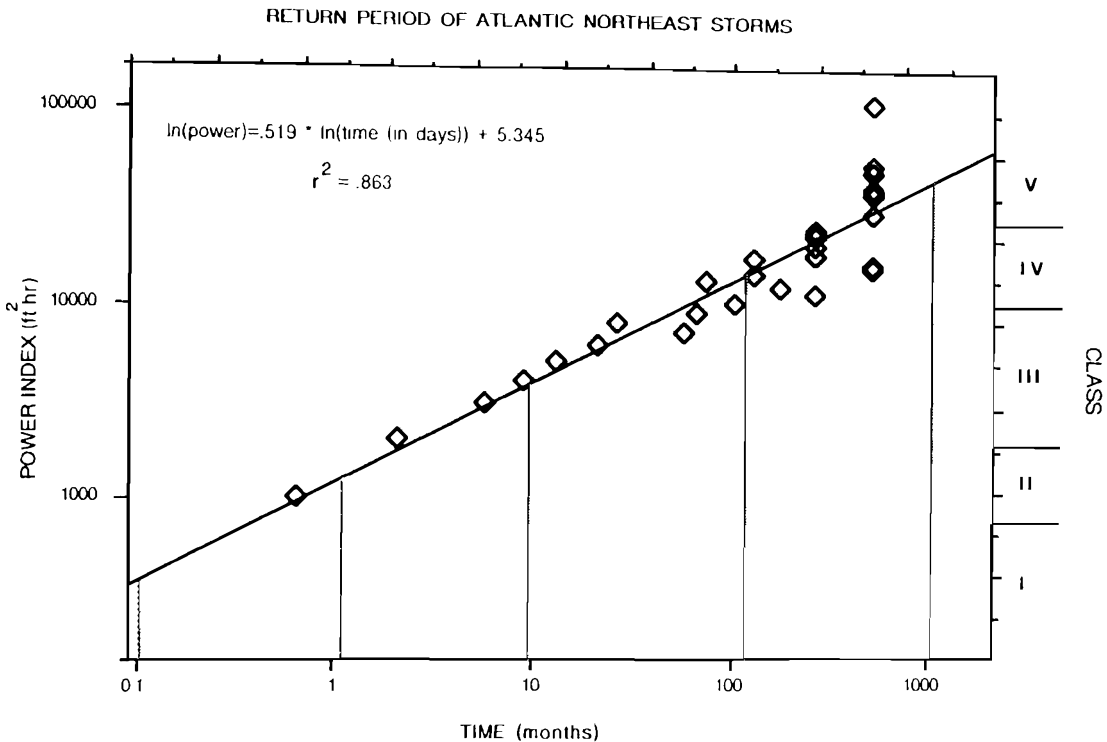


Figure 5. The return interval of Atlantic northeasters based upon a "power index." The five Dolan-Davis extratropical storm classes (DOLAN and DAVIS, 1992) are listed on the right axis. The "power index" is the product of a storm's duration and the square of maximum significant wave height.

sured 5.4 m (17.7 ft.) waves in 20 m water depth. Inshore, in 9 m water depth, the wave gage measured significant wave heights of 4.5 m (14.7 ft.). Analysis of a March, 1989 coastal storm for this region exhibited a similar ratio between deep and shallow-water wave heights, so the gage observations are comparable to our hindcast figures (DOLAN *et al.*, 1990). An unusual feature of this northeaster was not the magnitude of the wind but the long duration over which sustained 30 or 40 knot winds were acting. It was also somewhat unusual that clear skies and light winds occurred along the southeast U.S. coast during the times of peak wave heights, owing to the storm's distance and the extremely long storm fetch.

DOLAN and DAVIS (1992) developed a classification of Atlantic extratropical storms based on a "wave power index" which is simply the maximum significant wave height squared times the duration. These data for each storm in our 42 year dataset were stratified into five categories producing an extratropical storm intensity classification similar to the famous Saffir-Simpson hurricane scale (SAFFIR, 1977; SIMPSON, 1971). The "power index" for the All Hallows' Eve storm is over 12,981 m²hr (139,650 ft.²hr), the strongest storm on record, with a return period of 755 years (Figure 5). Although this was clearly a major storm event, this unusual return interval merely highlights the difficulty in extrapolating well beyond the range of existing data.

There has been some discussion regarding the role of Hurricane Grace in producing the extreme conditions. From surface weather map analysis, it is clear that most of the high waves were generated from the low pressure system south of Newfoundland, thus classifying this event as an extratropical rather than a tropical storm. High waves were generated beginning on October 28 as the cold front passed over the East Coast and

strong northerly winds developed. On October 29, before Hurricane Grace merged with the extratropical cyclone, sustained 30-knot winds were observed throughout the fetch area, which was already over 1,800 km. Thus, this system would have been a significant northeaster without the added energy from Hurricane Grace. However, when the two systems merged, a 10 knot increase in windspeeds was observed. Therefore, although the storm was largely extratropical, Hurricane Grace was responsible for making the "All Hallows' Eve Storm" of 1991 one of the most extreme northeasters in the past 50 years.

ACKNOWLEDGEMENTS

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□ RÉSUMÉ □

Une tempête de type extrême qui a eu lieu sur la côte NE des Etats Unis a considérablement endommagé toute la côte est des Etats Unis. La tempête avait pour origine le centre sud des Etats Unis, elle a progressé vers le NE et s'est intensifiée au sud du Newfoundland. Elle s'est renforcée en se combinant avec des reliques du hurricane Grace qui a produit l'un des plus forts NE (Northeasters) des 50 dernières années. L'analyse du spectre de houle du Cap Hatteras (Caroline du Nord), indique que cette tempête a engendré une houle en eau profonde de 1.5 m ou plus pendant 114 heures, avec une hauteur significative maximale de 10.7 m (plus haute que celle du "Mercredi des Cendres" de Mars 1962. Le fetch s'étendait sur 3,500 km depuis le Newfoundland jusqu'au sud de Miami en Floride.—Catherine Bousquet-Bressolier, *Géomorphologie E.P.H.E., Montrouge, France.*

□ RESUMEN □

En Octubre de 1991, se presentó una tormenta extrema, sobre la costa noreste del Atlántico, que produjo grandes daños en toda la costa este de los Estados Unidos. La tormenta se originó en la región centro-sud de los Estados Unidos, avanzando hacia el noreste

e intensificándose hacia el sud de Newfoundland. Su fuerza se combinó con el remanente del Huracán Grace, produciendo uno de los vientos del noreste más fuertes de los últimos 50 años. El análisis de la olas generadas para Cabo Hatteras, Carolina del Norte, indicó que la tormenta generó olas significativas en aguas profundas de 1.5 m o mayores, durante 114 horas, con alturas significativas máximas de 10.7 m, superiores a las ocurridas durante la terrible tormenta del "Miércoles de Ceniza", de Marzo de 1962. El campo de acción del viento se extendió por 3,500 km desde Newfoundland hasta el sud de Miami, Florida.—*Néstor W. Lanfredi, CIC-UNLP, La Plata, Argentina.*

□ ZUSAMMENFASSUNG □

Der extreme Atlantiksturm aus Richtung Nordost vom Oktober 1991 führte zu beträchtlichen Zerstörungen an der gesamten Ostküste der Vereinigten Staaten. Der Sturm entstand südlich der Landesmitte, wanderte nach Nordosten und verstärkte sich südlich von Neufundland. Er gewann weiter an Kraft durch die Verbindung mit dem auslaufenden Hurrikan Grace und entwickelte sich zu einem der stärksten Nordoststürme der letzten 50 Jahre. Die nachträgliche Wellenanalyse für Kap Hatteras in North Carolina ergab, daß dieser Sturm Tiefwasserwellen von 1.5 m oder mehr für mindestens 114 Stunden und maximale Wellenhöhen von 10.7 m erzeugte. Diese Wellen waren höher als die des berühmten "Ash Wednesday", Sturmes von März 1962. Der Fetch erstreckte sich über eine Entfernung von 3,500 Kilometern von Neufundland bis südlich von Miami in Florida.—*Ulrich Radtke, Geographisches Institut, Universität Düsseldorf, Germany.*