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CDIP wave observations during Hurricane Matthew

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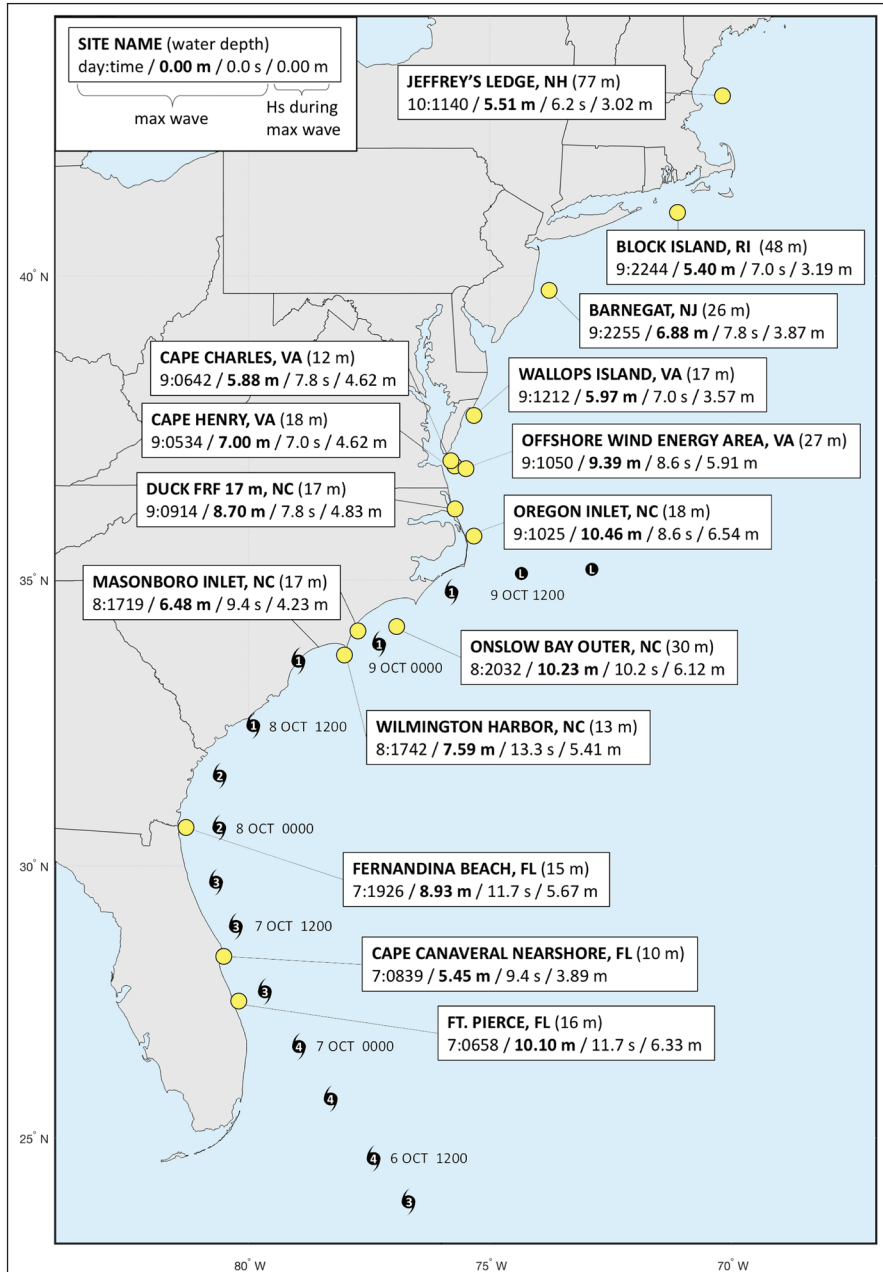


Figure 1. Wave buoy locations offshore eastern United States. Hurricane Matthew eye locations and storm intensities from NOAA's National Hurricane Center. All dates and times are UTC October 2016.

ABSTRACT

The Coastal Data Information Program (CDIP) recorded detailed information about the waves generated by Hurricane Matthew in October 2016. The wave field generated by the storm was measured by fifteen Datawell Directional Waverider moored buoys in the CDIP system. Significant wave height records and maximum individual waves are the focus of this report. The complete quality-controlled spectral and displacement data sets are publicly available at <http://cdip.ucsd.edu>.

Hurricane Matthew passed along the eastern coast of the United States from 6 October to 9 October 2016. It was the strongest storm of the 2016 Atlantic hurricane season, and the first Category 5 in the Atlantic basin since 2007. In addition to storm surge, beach erosion, and heavy rainfall, the speed and intensity of the storm generated extreme wave heights. A detailed record of these wave events was obtained by the Coastal Data Information Program (CDIP). CDIP is an extensive wave monitoring network along United States coastlines that is primarily funded by the U.S. Army Corps of Engineers (USACE). Several east coast sites analyzed in this report are cost shared with the U.S. Navy, industry, and National Oceanic Atmospheric Administration's U.S. Integrated Ocean Observing System (NOAA IOOS).

Waves generated during the storm's passage from the Caribbean to the North Atlantic were measured by CDIP's Datawell Waverider buoys moored at locations shown in Figure 1. These fifteen buoys span a north-south distance of ~2,000 km. (CDIP buoys offshore West Florida, in Cape Cod Bay, MA,

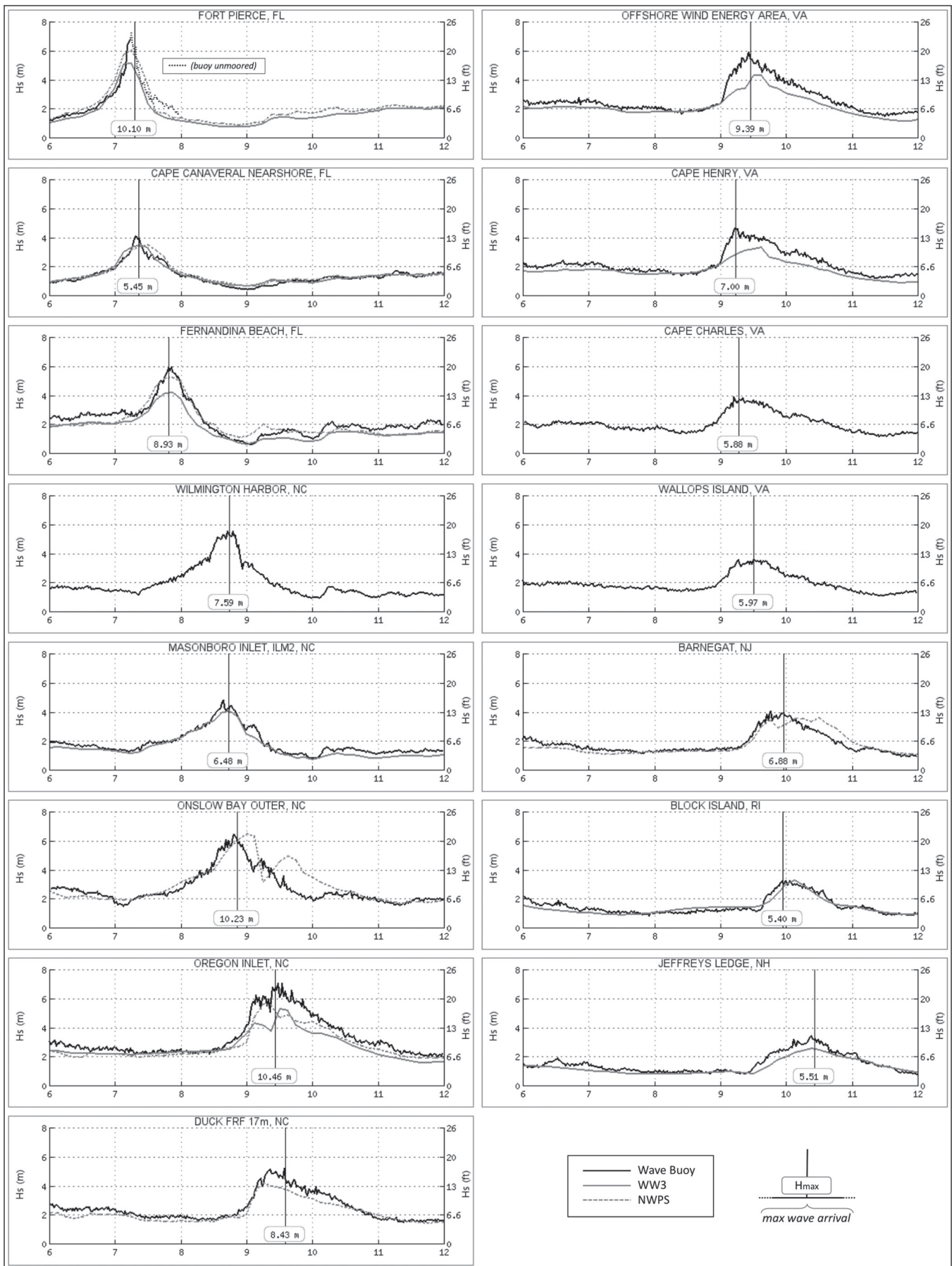


Figure 2. Significant wave height (H_s) measured by CDIP wave buoys 6-11 October 2016 (all times UTC). For each buoy, H_{max} arrival time and amplitude are indicated. Where available, NOAA's operational WW3 and NWPS predictions are shown. Buoys are displayed in order from south to north.

Table 1.**Maximum recorded wave heights during October 2016 Hurricane Matthew event (listed from south to north).**

Station name	UTC (DD-HH)	Hmax (m)	Tmax (s)	Hs (m)	Tp (s)	Dp (deg)	Delay (hr)	Hmax / Hs	Depth (m)
Fort Pierce, FL	07-06	10.10	11.7	6.33	11.76	069	1.19	1.60	16
Cape Canaveral Nearshore, FL	07-08	5.45	9.4	3.89	14.29	119	1.03	1.40	10
Fernandina Beach, FL	07-19	8.93	11.7	5.67	13.33	123	-1.36	1.57	15
Wilmington Harbor, NC	08-17	7.59	13.3	5.41	12.50	182	0.49	1.40	13
Masonboro Inlet, NC	08-17	6.48	9.4	4.23	10.53	134	1.58	1.53	17
Onslow Bay Outer, NC	08-20	10.23	10.2	6.12	9.88	158	0.84	1.67	30
Oregon Inlet, NC	09-10	10.46	8.6	6.54	9.09	355	-2.86	1.60	18
Duck FRF 17 m, NC	09-09	8.70	7.8	4.83	9.09	033	-4.72	1.80	17
Offshore Wind Energy Area, VA	09-10	9.39	8.6	5.91	8.33	028	0.21	1.59	27
Cape Henry, VA	09-05	7.00	7.0	4.62	7.14	044	0.09	1.52	18
Cape Charles, VA	09-06	5.88	7.8	3.64	10.53	104	1.49	1.62	12
Wallops Island, VA	09-12	5.97	7.0	3.57	11.76	139	-0.07	1.67	17
Barneгат, NJ	09-22	6.88	7.8	3.87	7.14	019	4.64	1.78	26
Block Island, RI	09-22	5.40	7.0	3.19	6.25	035	-1.46	1.69	48
Jeffrey's Ledge, NH	10-11	5.51	6.2	3.02	9.09	064	2.26	1.82	77

UTC: Universal Coordinated Time day and hour of Hmax arrival, October 2016**Hmax:** Amplitude (trough-to-crest) of largest recorded individual wave**Tmax:** Period of Hmax wave**HS:** Significant wave height at time of Hmax arrival**Tp:** Peak period corresponding to the measured Hs**Dp:** Peak direction corresponding to the measured Hs (meteorological convention)**Delay:** Time elapsed between Hs max and Hmax; Delay > 0 means Hmax occurred after Hs max**Hmax / Hs:** Ratio of Hmax to Hs during the time interval of Hmax arrival**Depth:** Water depth at buoy station

and at Rincon, Puerto Rico, although nearby, were not exposed to the primary hurricane-generated waves.) The buoys report their continuous wave observations in 27-minute segments via satellite transmissions. These data streams are converted into a variety of standardized data products by CDIP at the Scripps Institution of Oceanography, University of California, San Diego, and are available in near-real time at <http://cdip.ucsd.edu>.

Using a traditional measure of wave intensity, Hs (significant wave height, defined as the average height of the one-third highest waves in a given interval of time — in this case, approximately 27 minutes), the evolution of the storm wave height at each of the 15 buoy locations is shown plotted against UTC in Figure 2. All of the stations from Onslow Bay Outer, NC, south to Fort Pierce, FL, recorded

their greatest Hs values since initial deployment: Fort Pierce (9.8 years), Cape Canaveral, FL (9.4 years), Fernandina Beach, FL (10.4 years), and Masonboro Inlet, NC (7.7 years) all hit new maxima. The Fort Pierce buoy broke loose from its mooring during the initial storm surge and drifted east-southeastward prior to recording peak wave energy. Data from the first few hours after the buoy was free floating are included in Figure 2 as a dotted line (buoy within 50 km of the mooring location with intact sensors). Where available, predicted Hs values from NOAA's Operational WaveWatch III (WW3) model and the Nearshore Wave Prediction System (NWPS) are included for comparison. WW3 Hs values were generated from nine-hour hindcasts. NWPS values were acquired from the national server on 10 October 2016.

Because of the unusually energetic waves generated by Hurricane Matthew, the highest wave in each of the buoy records (Hmax) has particular significance. These values for the 15 locations are shown in Table 1, and were calculated as the maximum trough-to-crest (upcrossing) wave height in the buoy displacement record. Hmax arrival times are listed in Table 1 and Figure 1, and plotted in Figure 2. Note that Hmax did not occur simultaneously with maximum Hs for most buoys; the time offset between Hmax and the center of the 30-minute record that produced maximum Hs is listed in Table 1. Hmax/Hs ratios vary between 1.4 and 1.8 along the array, with a mean and median of ~1.6. The largest single wave that was recorded by this array of buoys during Hurricane Matthew was at the Oregon Inlet, NC, site measuring 10.46 meters.