Real-time Directional Wave Spectra from the NOAA Wide Swath Radar Altimeter

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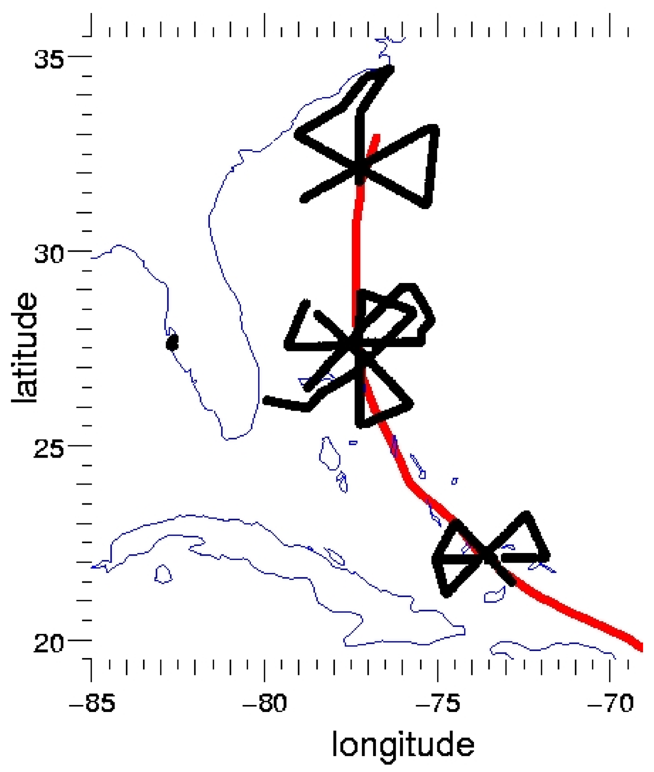
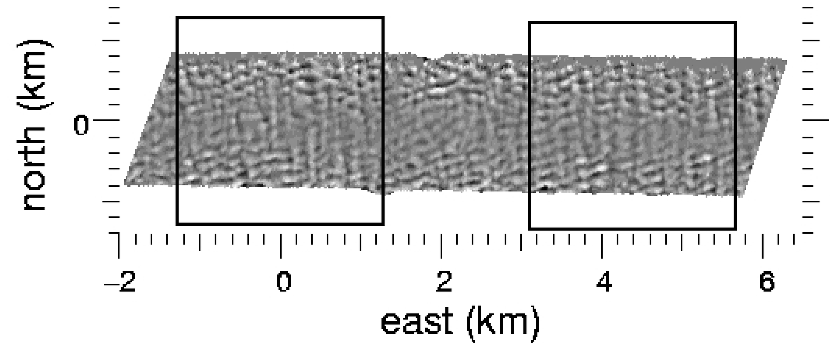
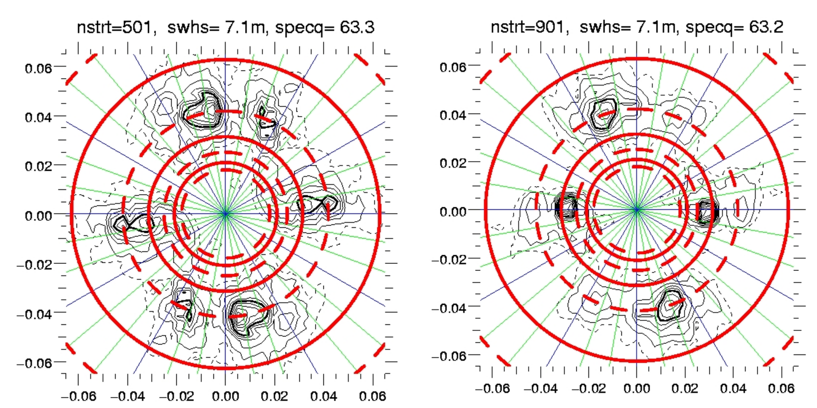
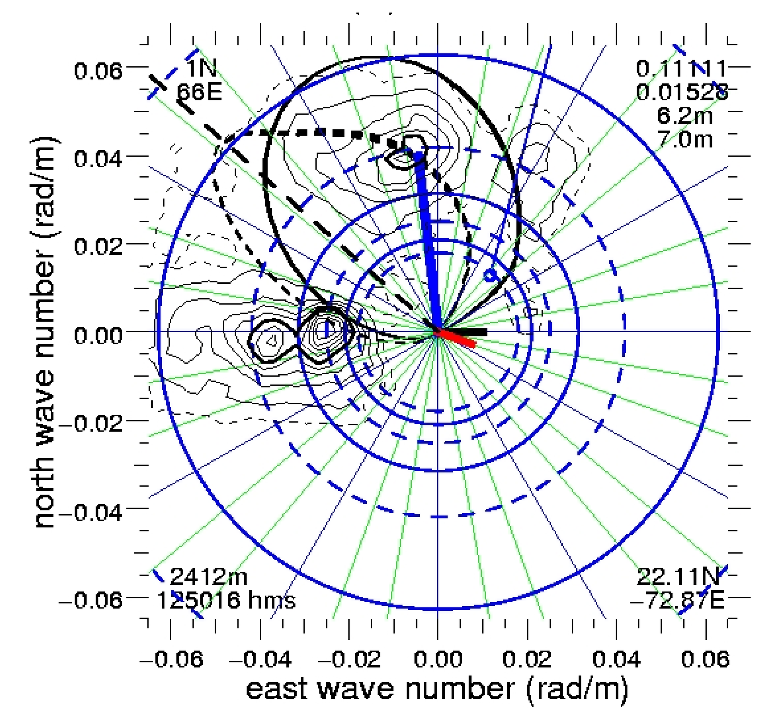
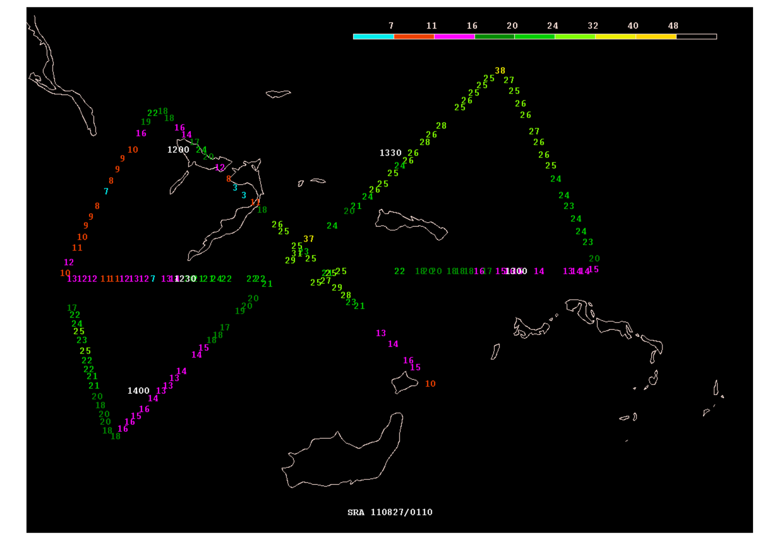
Wide Swath Radar Altimeter (WSRA) reconnaissance flights were made on 24, 25, 26 August 2011 as Hurricane Irene traveled from the Turks and Caicos Islands, through the Bahamas, and approached the shore of North Carolina. The WSRA generated real-time maps of sea surface topography and processed the topography into directional wave spectra. The 7.7 km grey-scale coded segment of wave topography shown was acquired on 24 August while the aircraft was directly east of the eye. Elevation data points within square boxes 2.56 km on a side are interpolated to a uniform grid and transformed by a two-dimensional FFT into encounter directional wave spectra. This complex wave field in the hurricane right rear quadrant is composed of three different wave systems. Since the two-dimensional FFT cannot determine which of two opposite directions each wave system could be propagating in, it puts half the energy in each direction, resulting in six spectral lobes instead of three. The WSRA processing doubles the spectral energy everywhere, deletes the artifact lobes, and Doppler-corrects the encounter lobes to produce the actual directional wave spectrum, displayed in the larger image.

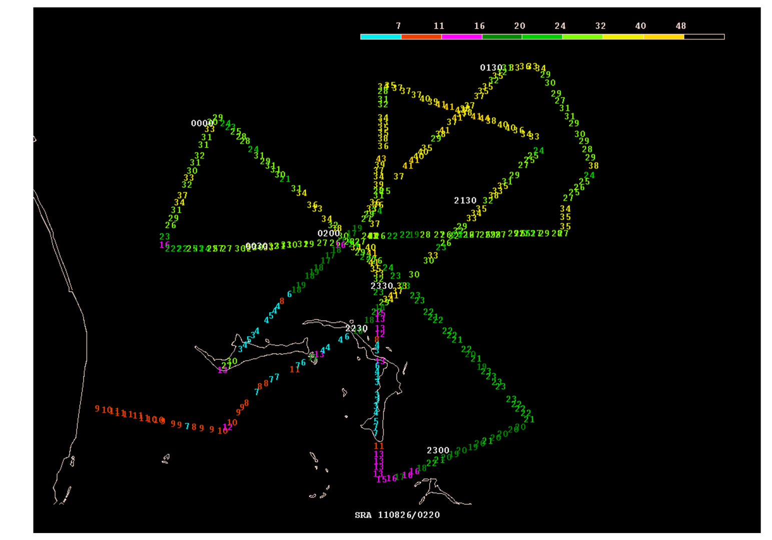


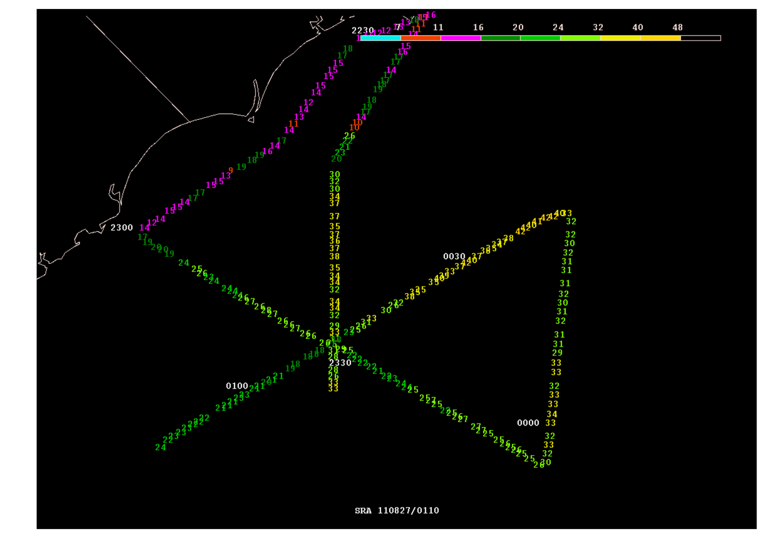








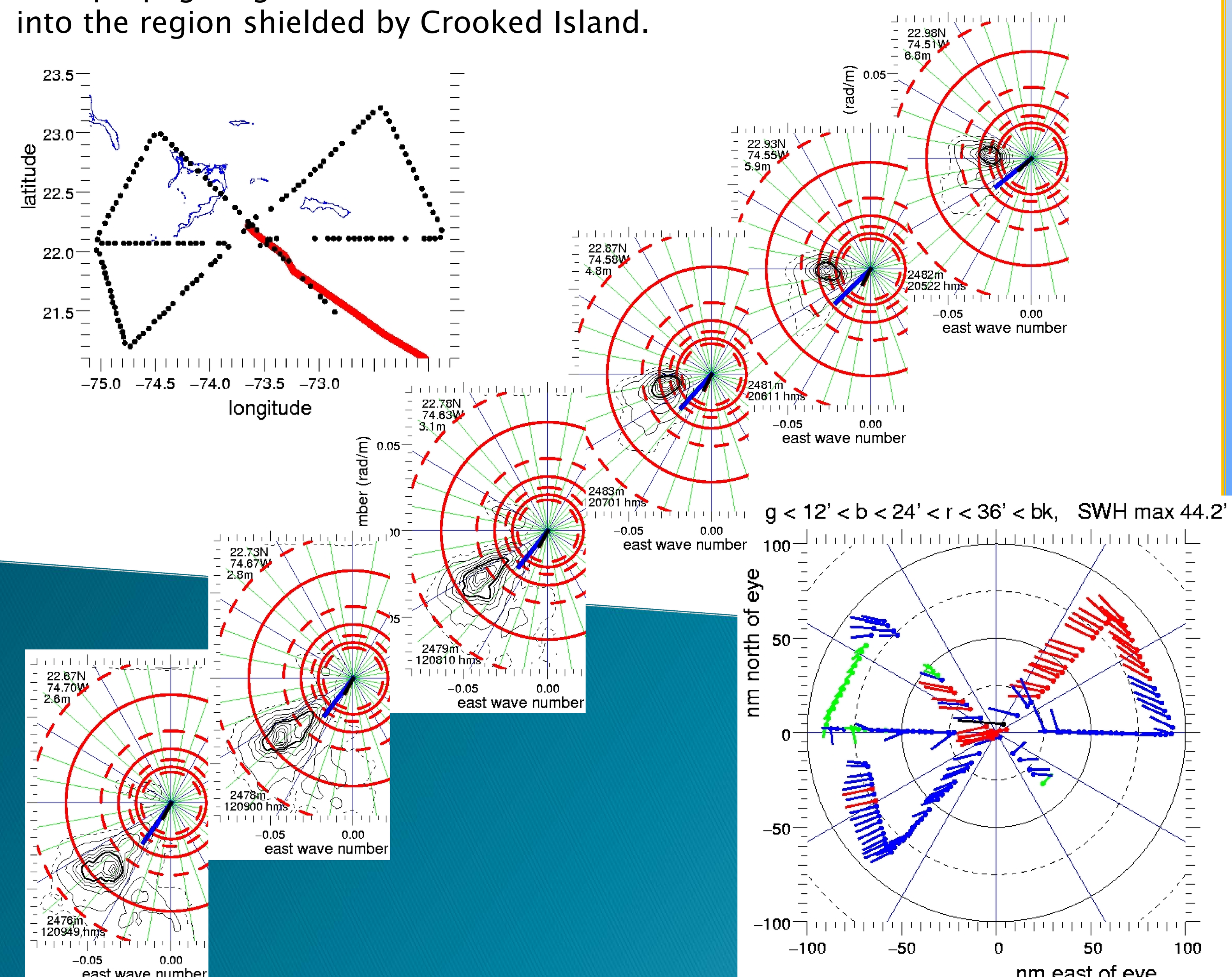




Wave spectra and other extracted parameters were transmitted from the aircraft via satellite link to an FTP site at the NOAA Aircraft Operations Center (AOC). A software script running on the Joint Hurricane Testbed (JHT) server at the National Hurricane Center (NHC) automatically pulled the WSRA data from the AOC computers. Software executed on the JHT server converted the WSRA data into NAWIPS format to enable forecasters to superimpose the wave height information onto their other hurricane displays. The three images above, displaying wave height in feet, were generated by Jose Salazar at NHC from the NAWIPS format data.

WSRA observations are used to verify and improve the numerical wave models which forecast the short and long term evolution of a hurricane's wave field.

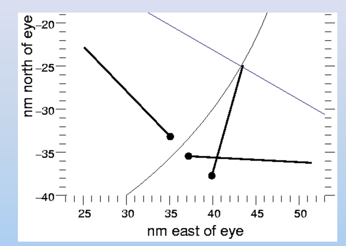
The black dots in the left panel below show geographical locations of the WSRA spectra which correspond to the circles showing the storm-relative locations in the right panel. Color-coded radials extend from the circles in the dominant wave propagation direction a distance proportional to the significant wave height (SWH). The eye of Irene was at about 22°N, 73.35°W and the dominant waves where the rapid decrease in wave height occurred at about 22.8°N, 74.6°W were west propagating swell. The decrease occurred as the aircraft track transitioned into the region shielded by Crooked Island.

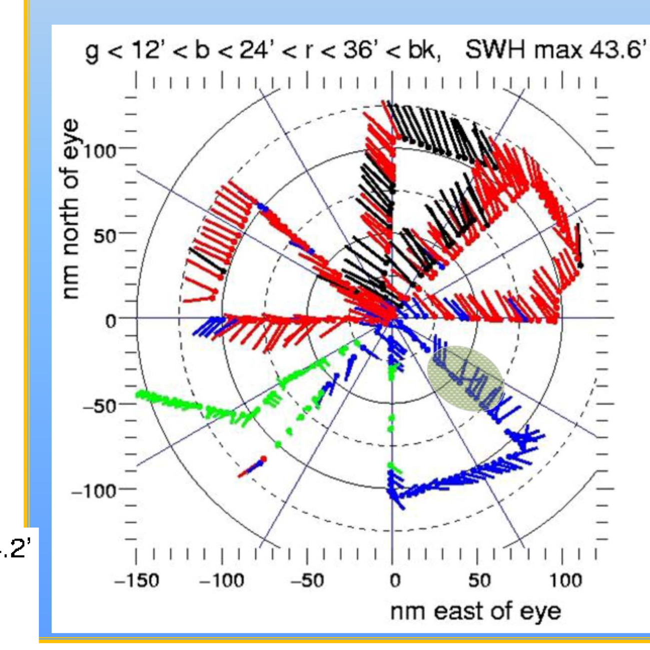


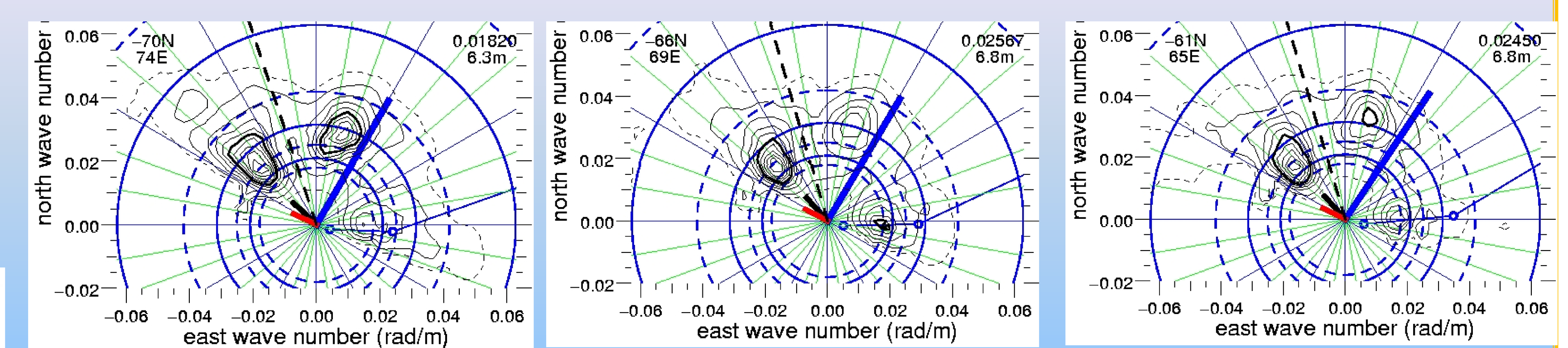
The six directional wave spectra shown above demonstrate the wealth of wave field information the WSRA provides. The short black radial indicates the aircraft track and the blue radial indicates the downwind vector at the aircraft altitude in m/s times 0.001. The wind was about 28 m/s towards the southwest. The SWH decreased monotonically over the six spectra: 6.8, 5.9, 4.8, 3.1, 2.8, 2.6 m. The solid contours span from 0.9 to 0.1 of each peak spectral variance density with the 0.5 contour bold. The dashed contour is at the 0.05 level.

The effect of the shallow water near the island is apparent in the first three spectra. The swell wavelength shortens and the propagation direction refracts counterclockwise. The first three spectra show waves propagating in the downwind direction whose energy density is at the 5% to 10 % relative to the spectral peaks. The peak spectral variance density decreased by a factor of 17 over the six spectra and the downwind spectral energy is comparable in all of them. Little of the swell remains in the last three spectra and the dominant waves have wavelengths of about 130 m and propagate near the downwind direction.

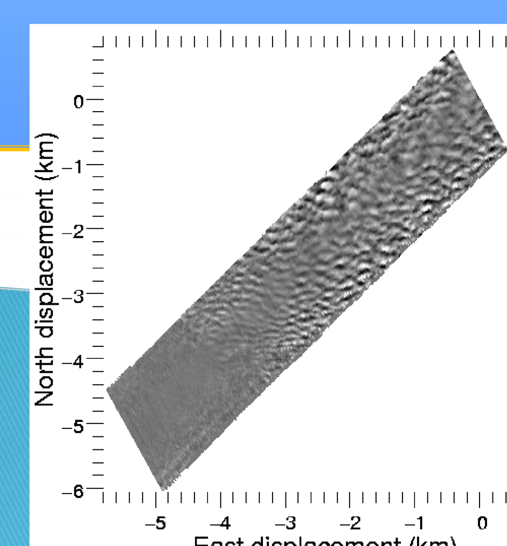
The WSRA directional wave spectra below are nearly identical, but the wild fluctuations in the dominant wave propagation direction apparent within the green oval southeast of the eye in the storm-relative wave height display below because the three wave systems had comparable energy and were trading dominance.







The region of wave heights below 12' (green) to the southwest of the eye was due to sheltering by Grand Bahamas on one leg (red oval on geographic plot) and shoaling water on the other leg (blue oval). The WSRA wave topography is shown below as the aircraft track approached the outlying islands at 27.1°N, 78.1°W.



The wave field display in the top left panel below is uncharacteristic in that the wave height about 150 nm directly north of the eye is lower than expected considering the waves northeast of the eye exceed 40' and are propagating in that direction. In this instance the explanation is not sheltering by islands but bathymetry. The bottom left panel shows that the flight tracks north of the eye went into the shoaling water around Cape Lookout and Onslow Bay.

The top right panel below shows a subset of the wave spectra locations in Onslow Bay superimposed on bathymetry where green indicates water depths of 16, 24 and 32 m and red represents depths of 20, 28 and 36 m. The bottom right panel shows the dominant wavelength diminishing with depth for those locations.