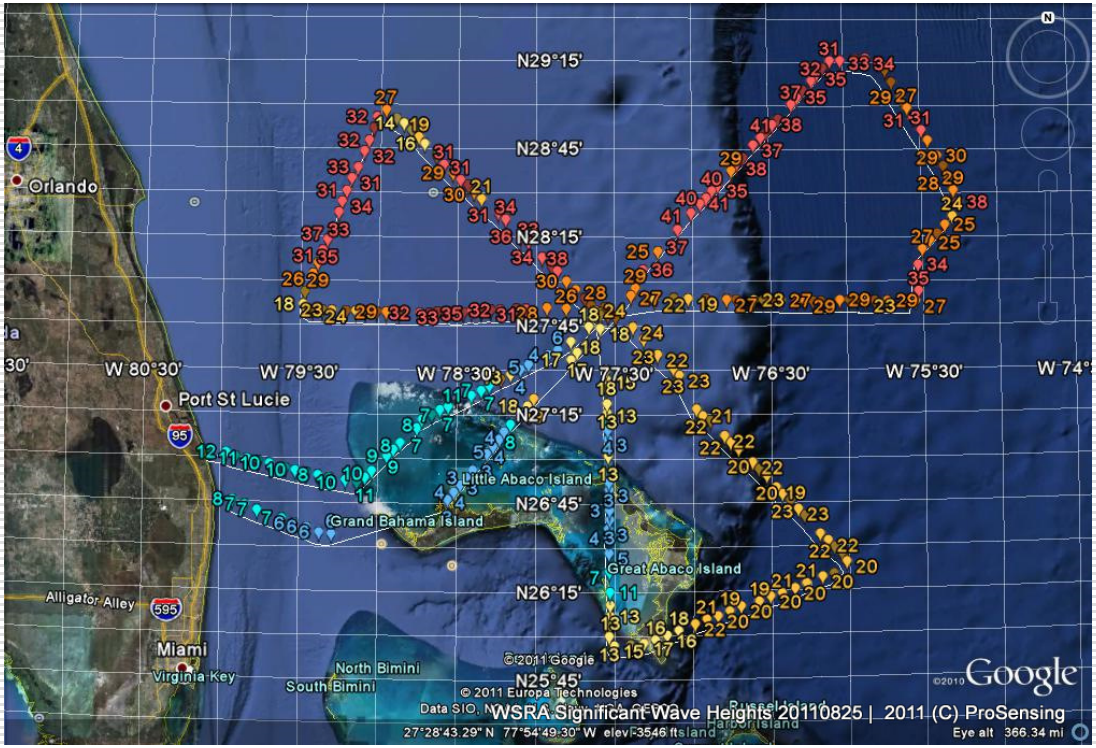
Algorithm optimization for real-time reporting of hurricane wave field data products measured with the NOAA Wide Swath Radar Altimeter



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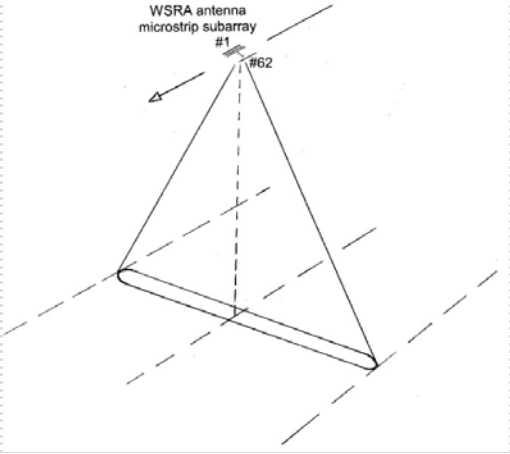
WSRA Technology:

- The WSRA is a digital beamforming radar with an antenna comprised of 64 narrow microstrip subarrays oriented in the along-track direction, and spaced at half wavelength intervals in the cross-track direction.

- The radar returns from sequential transmissions on each of 62 of the array elements are collected and coherently combined to produce 80 narrow beams spread over ±30º from the antenna boresight.

- Width of WSRA swath is about 3.46 km at the typical 3 km (10,000 feet) aircraft altitude.



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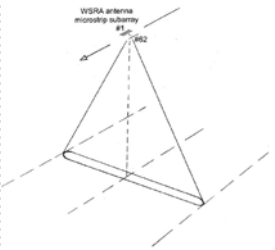
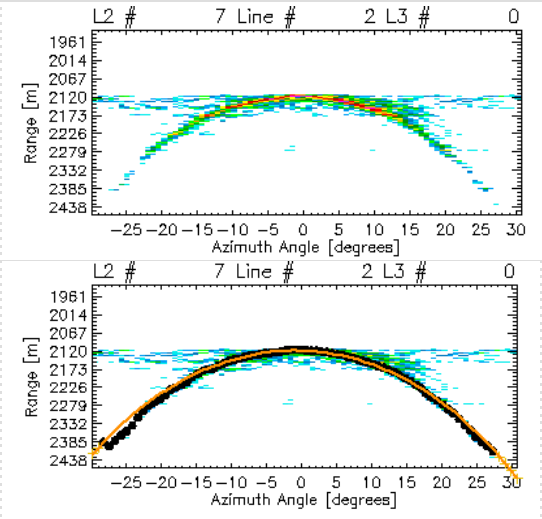
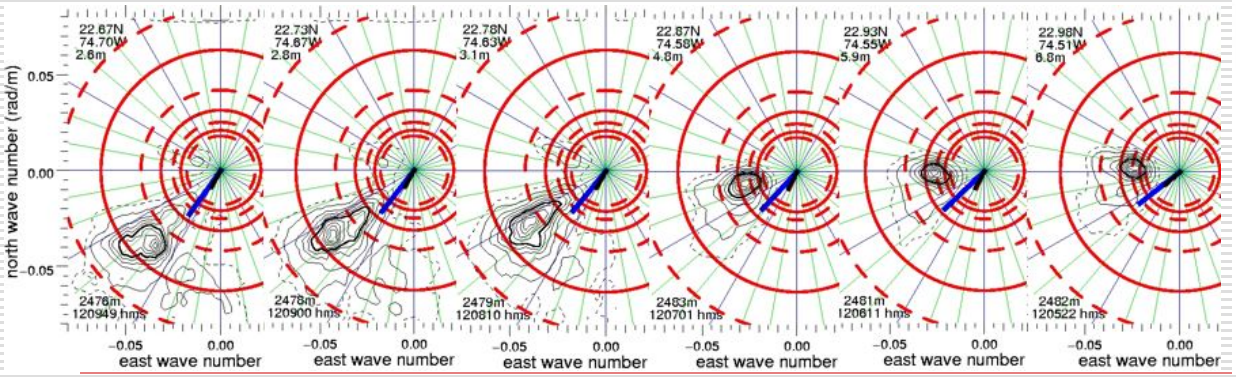


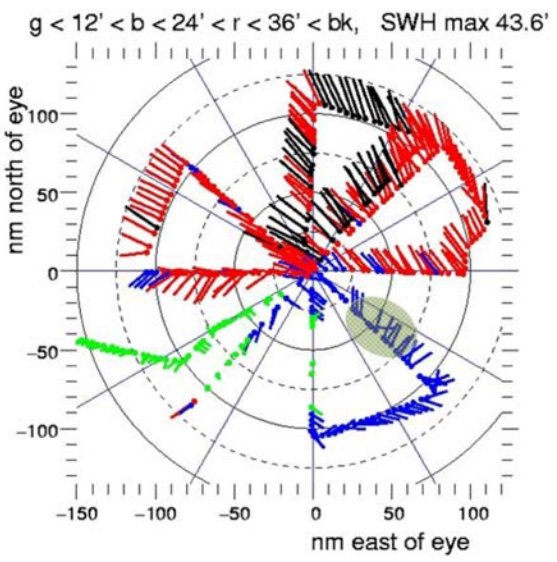
Operational WSRA Data Products



- **Mean Square Slope of the ocean surface**
- **Rain Rate**
- **Ocean Directional Wave Spectra**
- **Ocean Significant Wave Height**

4.5 minutes





SWH: 2.6m 2.8m 3.1m 4.8m 5.9m 6.8 m

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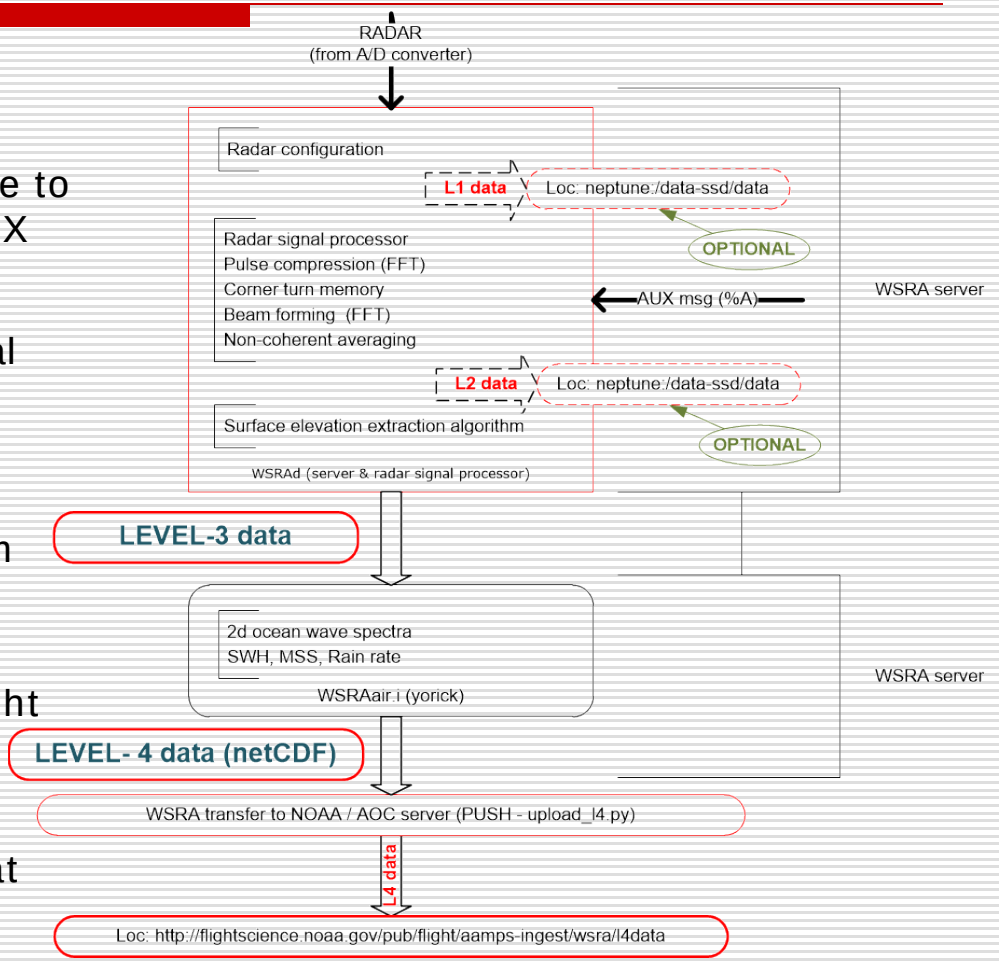
WSRA Data Flow

Processing, Transfer & Display => Real-time Reporting

In-flight processing highlights

- WSRA radar configuration is adaptable to changing aircraft flight level(using AUX INFO)
- Computationally intensive radar signal processing algorithm
- Radar return (Level-2 data)
- Surface elevation extraction algorithm
- Surface topography (Level-3 data)
- WSRA data products processed in-flight in real-time (Level-4 data)
- WSRA data products automatically transmitted from aircraft to FTP site at NOAA/AOC



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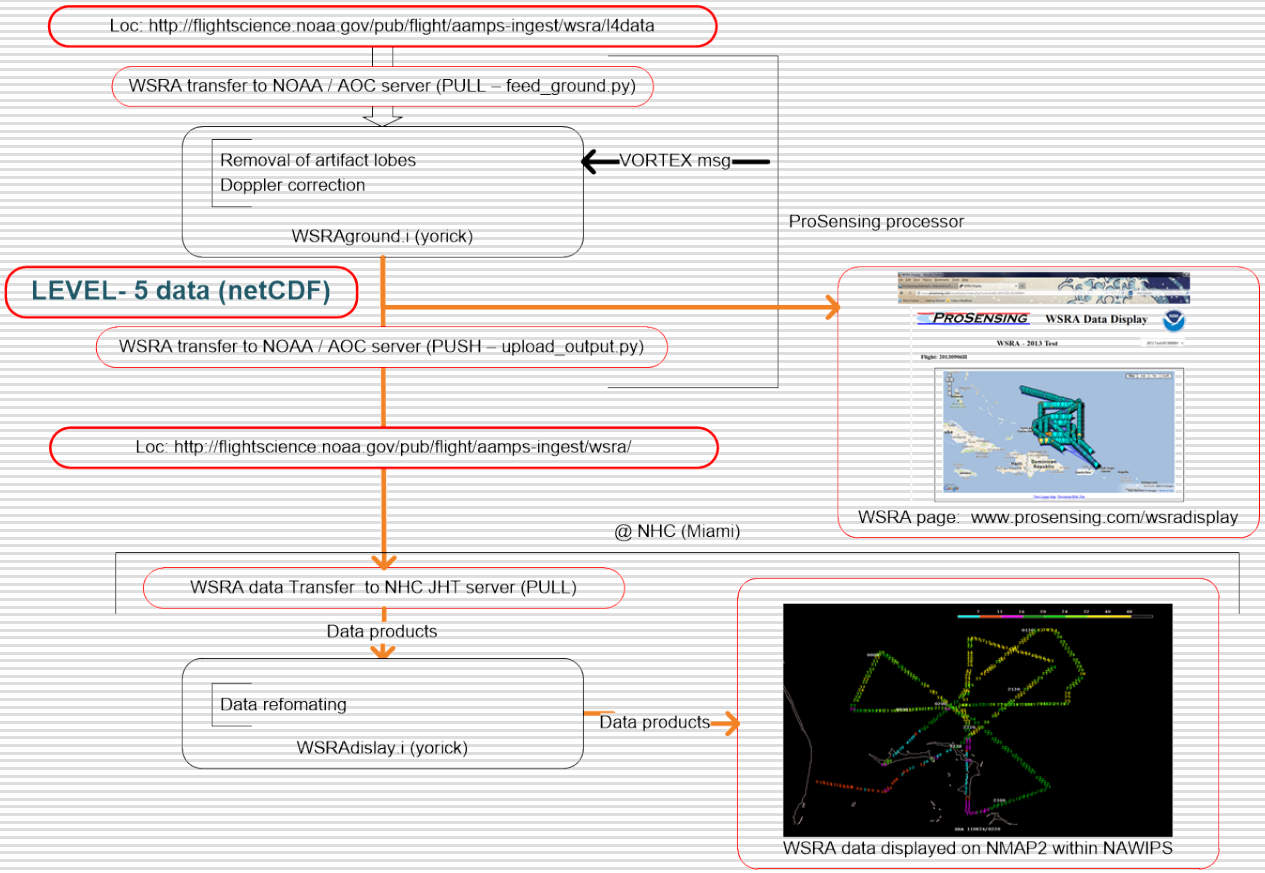
WSRA Data Flow

Processing, Transfer & Display => Real-time Reporting



Ground processing highlights

- Retrieves VORTEX messages via Internet
- Prediction algorithm of the general direction of the ocean wave field components (8) at each observation point using only information available in real-time: hurricane maximum wind speed, radius of maximum wind, and its track and forward speed.
- Resolve the 180° ambiguity of the ocean directional wave spectra
- Corrected WSRA data products automatically transmitted to NOAA NHC in Miami (in real-time)
- WSRA data displayed on NMAP2 within NAWIPS

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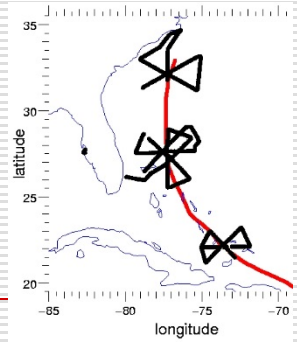
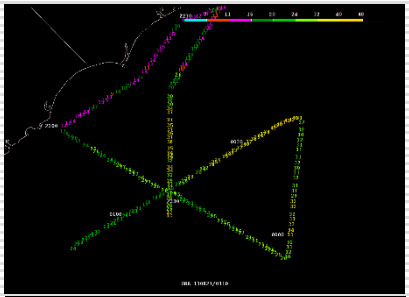
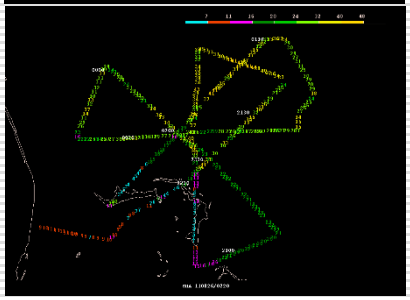
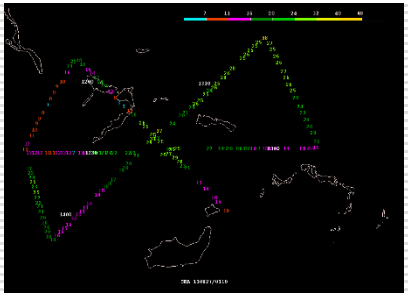
WSRA Operation Example

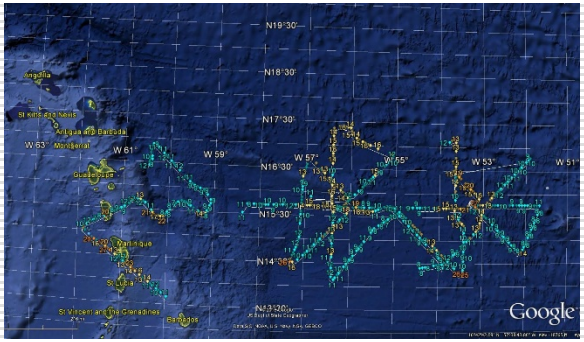


- Hurricane Irene (2011)
  - Three 12-hour missions on August 24th, 25th, & 26th
    - 20110824H
    - 20110825H
    - 20110826H
  - WSRA operated without ProSensing staff onboard the aircraft
  - After startup by NOAA AOC staff WSRA operated unattended for the entire duration of the flight
- Hurricane Danny (2015)
  - Three 12-hour missions on August 22th, 23th, & 24th









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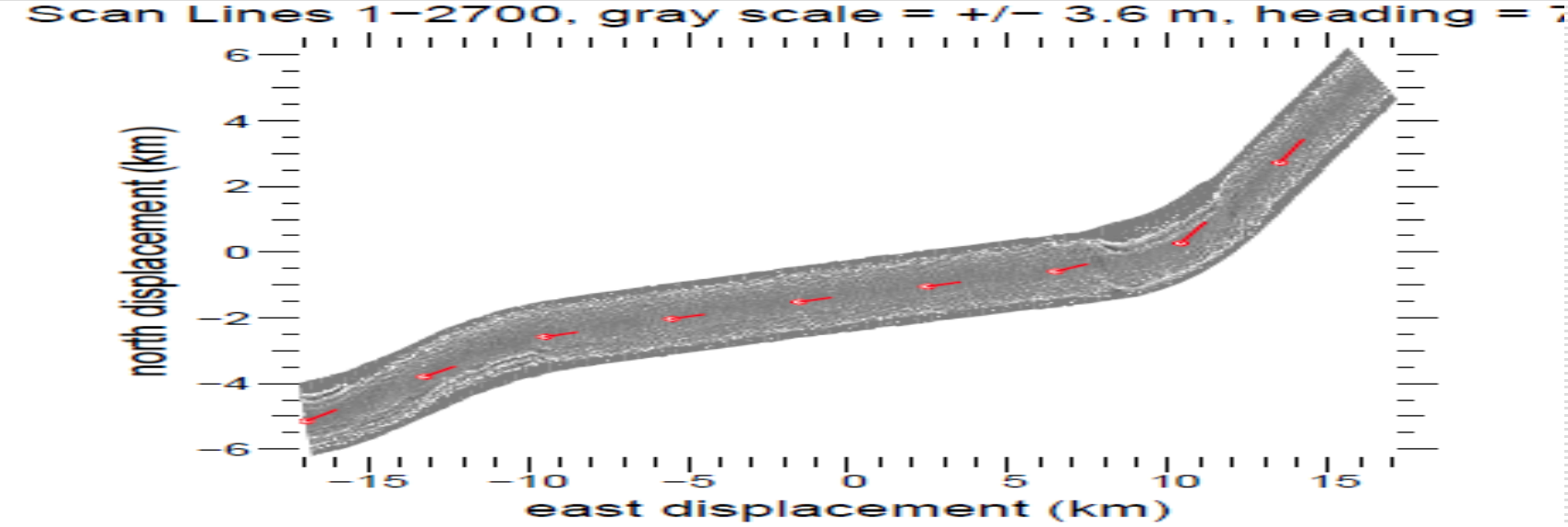
Archived WSRA Data Products

- Level-3 data Ocean Surface topography and backscatter power
- Data rate: 10 cross-track surface elevation lines per second
- Data volume: 10 G Bytes per hour
- Data stored on WSRA server computer onboard the aircraft.
- Data files are downloaded and archived at the end of the hurricane season



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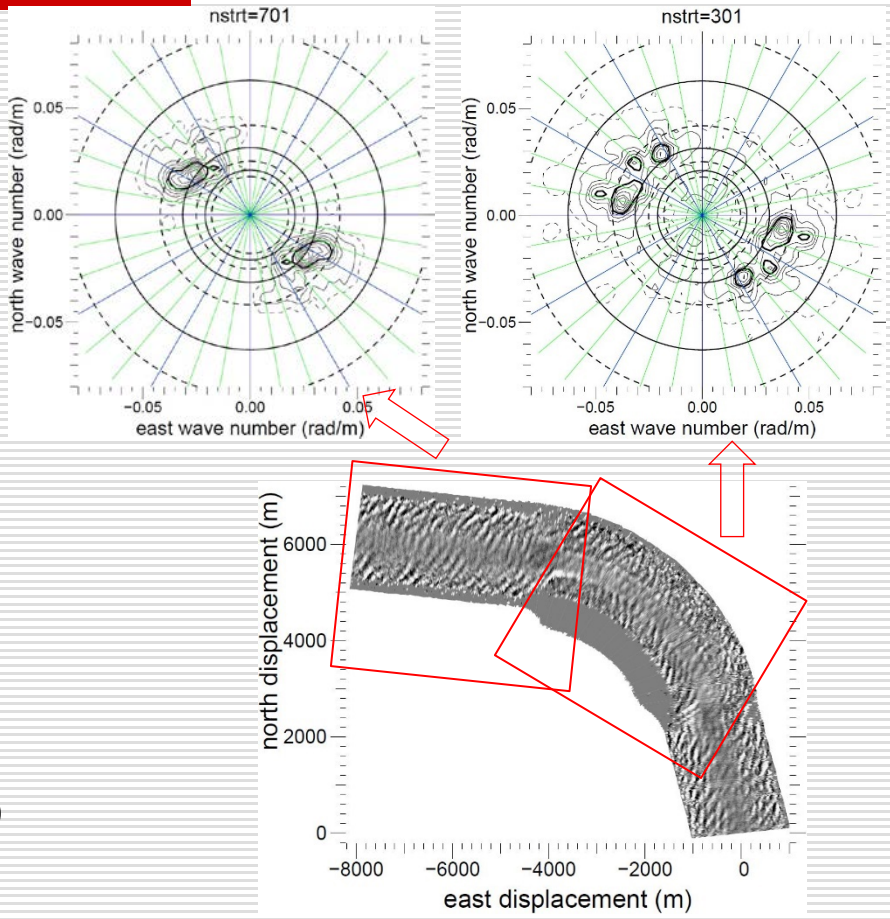
Improving the WSRA Ocean Surface Topography

- Anomalies in the surface topography are most visible during aircraft's high roll maneuvers.
- The differences between the two spectra—such as multiple artifact peaks and significant noise in the ocean wave spectra—are easy to observe.
- Ocean wave field over the small area shown would be uniform.
- These artifacts are a result of misplacement of WSRA surface elevation raster lines relative to each other.



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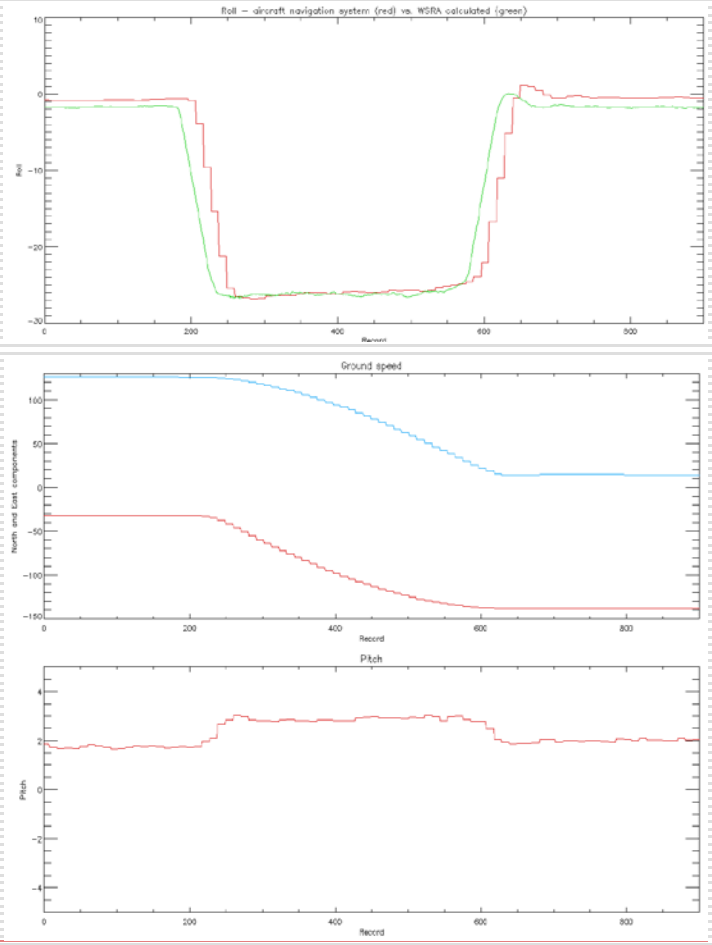
Improving the WSRA Ocean Surface Topography

- The instantaneous roll of the aircraft is computed from WSRA radar return
- INS aircraft data have update rate of 1 Hz, while WSRA raster lines are produced at 10 Hz rate
- WSRA server computer receives INS data with time lag of about 4 to 5 seconds.

- New improved algorithm:
  - calculate true instantaneous values for north and east ground speed components and pitch by removing the time lag and interpolating the 1Hz data to 10Hz data rate.
  - use the pitch value to improve the accuracy of the absolute location of raster lines calculation.



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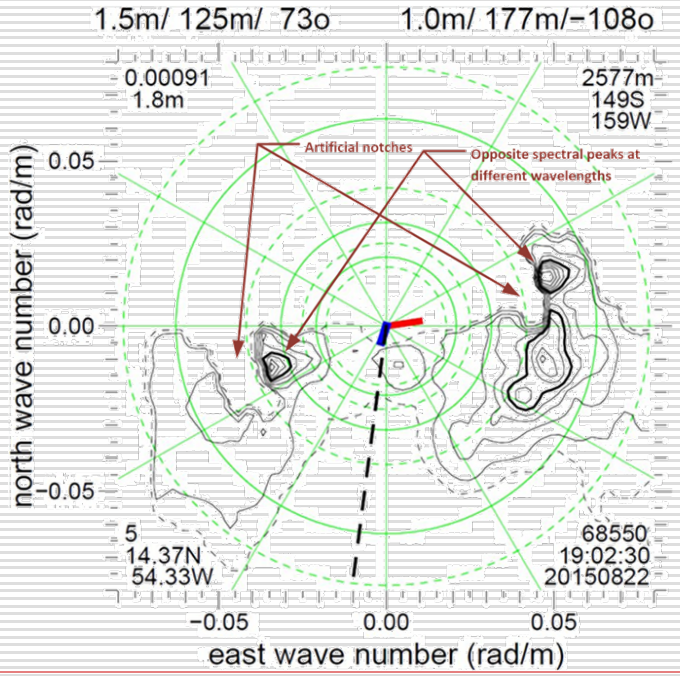
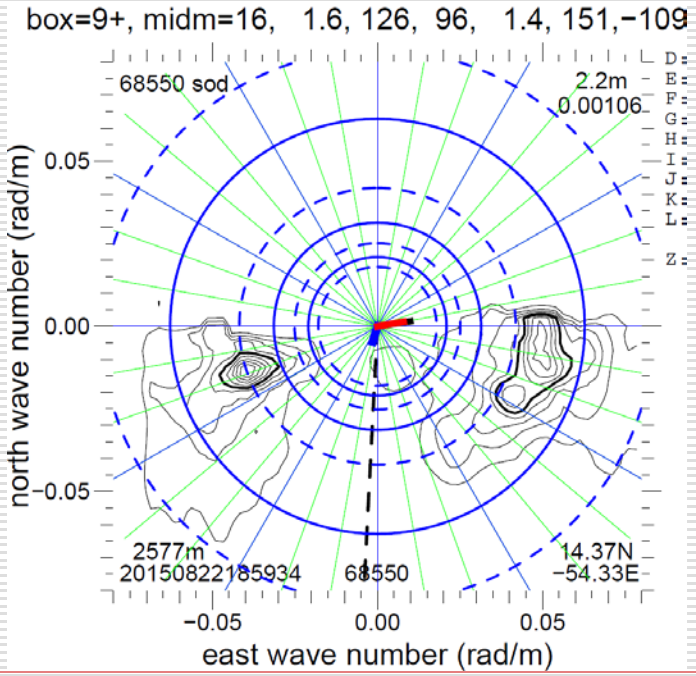
New methodology for removal of ambiguous artifact lobes in the directional ocean wave spectra (Level-5)

- Initial artifact lobe deletion algorithm predicted the wave component direction at each observation point inside a hurricane and found the spectral variance minimum within ±25° of the perpendicular to that direction, sometimes performing badly.
- New algorithm finds spectral peaks, selects the one closest to the predicted wave direction for that wavelength and deletes the opposite lobe as the artifact.





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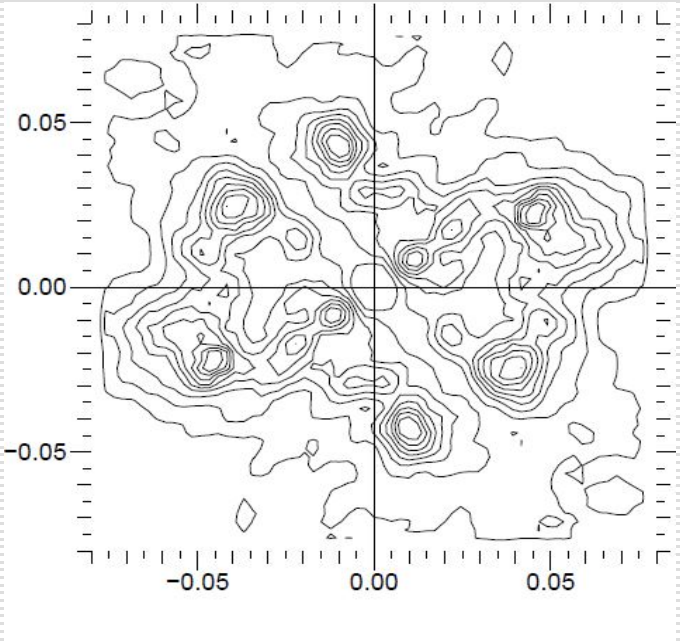
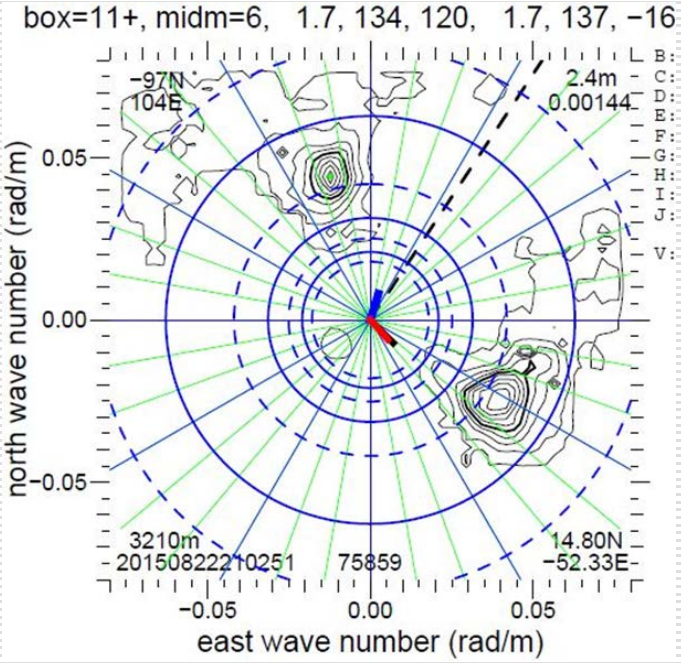
New methodology for removal of ambiguous artifact lobes in the directional ocean wave spectra (Level-5 data).

New methodology:

- focus on spectral maxima.
- spectral components for each ocean wave field spectrum would be transferred as a unit to the output spectrum rather than possibly being split into pieces.





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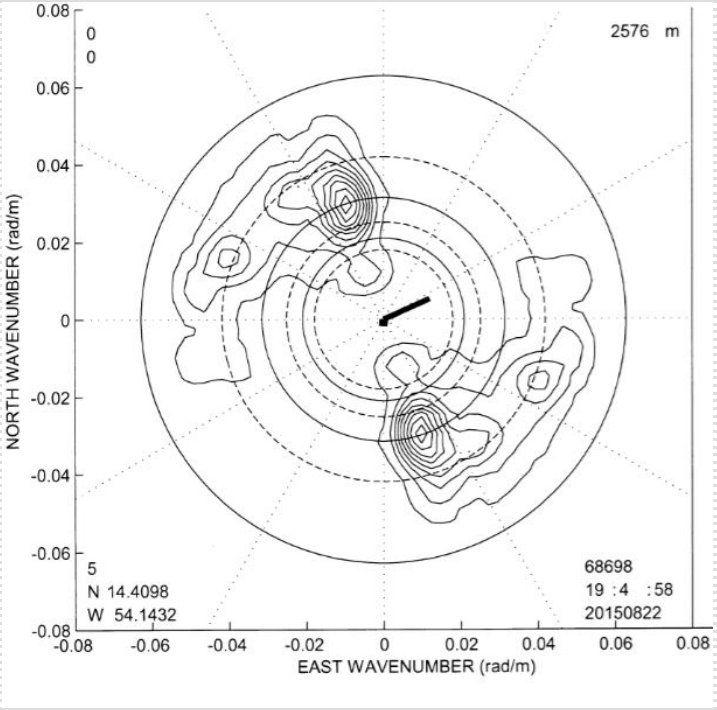
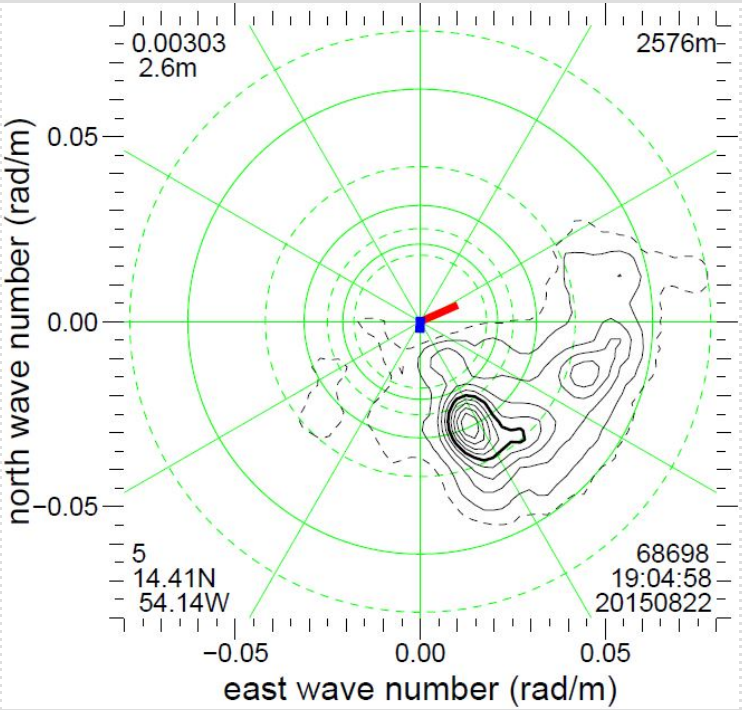
Archived WSRA Data Products

Level-4 data



Level-5 data



- Level-4 and 5 data available during recon flight on NOAA AOC FTP site
- Stored in self-descriptive netCDF format
- Data rate: 100 Byte/s
- Data Volume: 4 Mbyte per 12-hour reconnaissance flight

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Value of WSRA Data Product

- The WSRA directional ocean wave spectra—important information about the air-sea interface—are produced every 4 minutes and 16 seconds.
- That makes the WSRA a unique instrument that routinely documents the rapid spatial variation of sea surface inside the evolving hurricane.
- WSRA data users:
  - Hurricane forecasting
    - Real-time knowledge of the wave field parameters should improve the hurricane intensity forecast
  - Ocean Wave Models
    - verification and improvements using WSRA observations of temporal and spatial evolution of wave field
  - Storm Surge forecast
    - verification and improvements using WSRA measurement of storm surge of landfalling hurricanes
    - This WSRA measurement technique has been shown to be feasible, but has yet to be implemented