Operational Use of Near-Real-Time Sea Surface Directional Wave Spectra Generated from NOAA Scanning Radar Altimeter Range Measurements

Edward J. Walsh, Principal Investigator
Code 614.6, NASA Goddard Space Flight Center, Greenbelt, MD 20771
office 303-497-6357, cell 303-579-7811, edward.walsh@noaa.gov

Year 1 Final Report – Year 2 Renewal Proposal

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ProSensing shipped the NOAA Scanning Radar Altimeter (SRA) to the NOAA Aircraft Operations Center (AOC) in mid-October 2007. Unfortunately, due to other commitments, AOC will not be able to install it on N43RF until May 2008 at the earliest, so there are no flight data available to analyze the system performance. Before shipping the SRA, ProSensing recorded data at 2360 m range backscattered from the library building that protrudes high above the UMass campus in Amherst, indicating that the digital beam forming antenna was functioning properly and the system had good signal level.

AOC is developing the Airborne Atmospheric Measurement and Profiling System (AAMPS), a new aircraft data communication network which will handle everything from the navigation data to the remote sensing systems. It will eventually be deployed on all AOC aircraft, but because one of the original contractors sold off a critical segment of their company, the development is running about a year late. Initial testing of various portions of AAMPS will be conducted during the 2008 hurricane season in parallel with the existing data system. But the new system will not be operational and AOC's highest priority is to duplicate and verify the performance of AAMPS to replace their present data system for all the standard aircraft remote sensing systems such as the tail Doppler radar, the belly radar and the dropsondes so the existing data system can be retired.

AAMPS will have an order of magnitude greater capability than the present aircraft data system. The SRA or any other new instrument will eventually be able to easily communicate with AAMPS and transfer data using a web browser and the Application Programming Interface (API) protocols now being developed. That capability will not be operational during the 2008 season but should be in place well before the 2009 season. There are two types of SRA data. The low volume header files that contain the sea surface mean square slope, rain rate, and the wave height, length and direction of propagation parameters extracted from the spectra, and the high volume directional wave spectra files. The directional wave spectra will not be able to be transferred to NHC during the flights until AAMPS is fully operational after the 2008 season. But John Hill (AOC) indicated that during the 2008 season flights the header files could be transferred using an existing aircraft satellite communication data link to an AOC server which would then relay them to NHC. Jose Salazar (NHC) has already designated an area on the JHT server to receive and process the SRA files using the analysis programs I have already developed.

The detailed description of the end-to-end simulation I developed to test the SRA processing software was presented in earlier progress reports and will not be repeated here. Jose Salazar was able to run on the JHT server the SRA display program I developed using dummy files I generated from a flight in Hurricane Humberto and produced Figure 1 below on a JHT computer display. As a result of interactions with Dan Brown, I developed different versions of the display program which will either automatically tailor the color bar to the range of wave heights observed or request an input to provide the end user maximum control.

Mark Willis indicated that it was important to get the SRA data into the N-AWIPS system so it could be used interactively with other data sets. Mark indicated they were able to view wave height data from the Jason satellite altimeter as a series of numbers and found the display of exact wave height values along the satellite track very useful. He sent an example from Hurricane Flossie and indicated that implementing something similar for the SRA would allow people to directly overlay the SRA observations on satellite images and wave model output, which he considered extremely important.

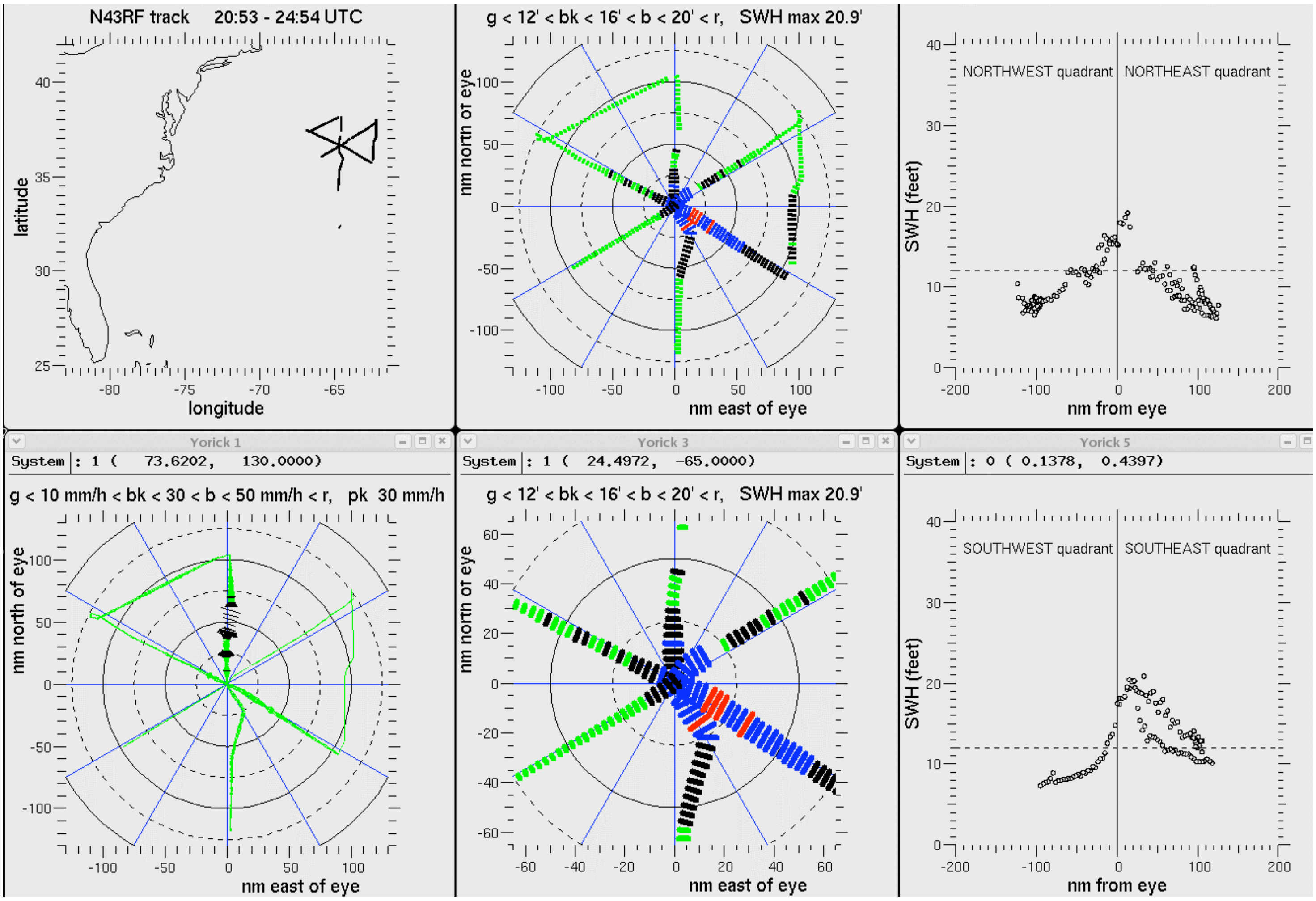

Figure 1.

Mark indicated that Chris Lauer was responsible for getting the Jason data into N-AWIPS so the forecasters would have the ability to view that data and any other data they wish to overlay. As a result of interactions with Chris, I was able to develop an SRA output file which mimicked the Jason data and Chris was able to plot SRA wave height data in N-AWIPS. The same could be done for the SRA rain rate data.

There is a significant difference between a satellite altimeter and the SRA that needs to be considered in the N-AWIPS display. A satellite passes over the hurricane in about a minute, essentially providing an instantaneous snapshot of the wave heights along its track. The downside of a satellite altimeter is that an encounter with a hurricane is relatively rare and even when it does, its very narrow swath will generally not pass directly over the eye. In contrast, the SRA provides excellent azimuthal coverage within about 200 km of the eye and includes several eye penetrations, but the storm generally moves significantly during the typical 5 hour data acquisition interval.

Figure 2 demonstrates the problem using the NASA SRA flight into Hurricane Humberto on 24 September 2001. The black line in the left panel indicates the NHC Best Track for Humberto. The blue dots show the locations of SRA directional wave spectra as they were acquired with the numbers indicating the order of the aircraft flight tracks. The red dots indicate the storm-relative positions of the SRA wave spectra corresponding to the eye position of Hurricane Humberto at the time of the last SRA observation (point 6). The largest position change was at point 1, the earliest spectrum, which moved to the north northeast by about 80 km.

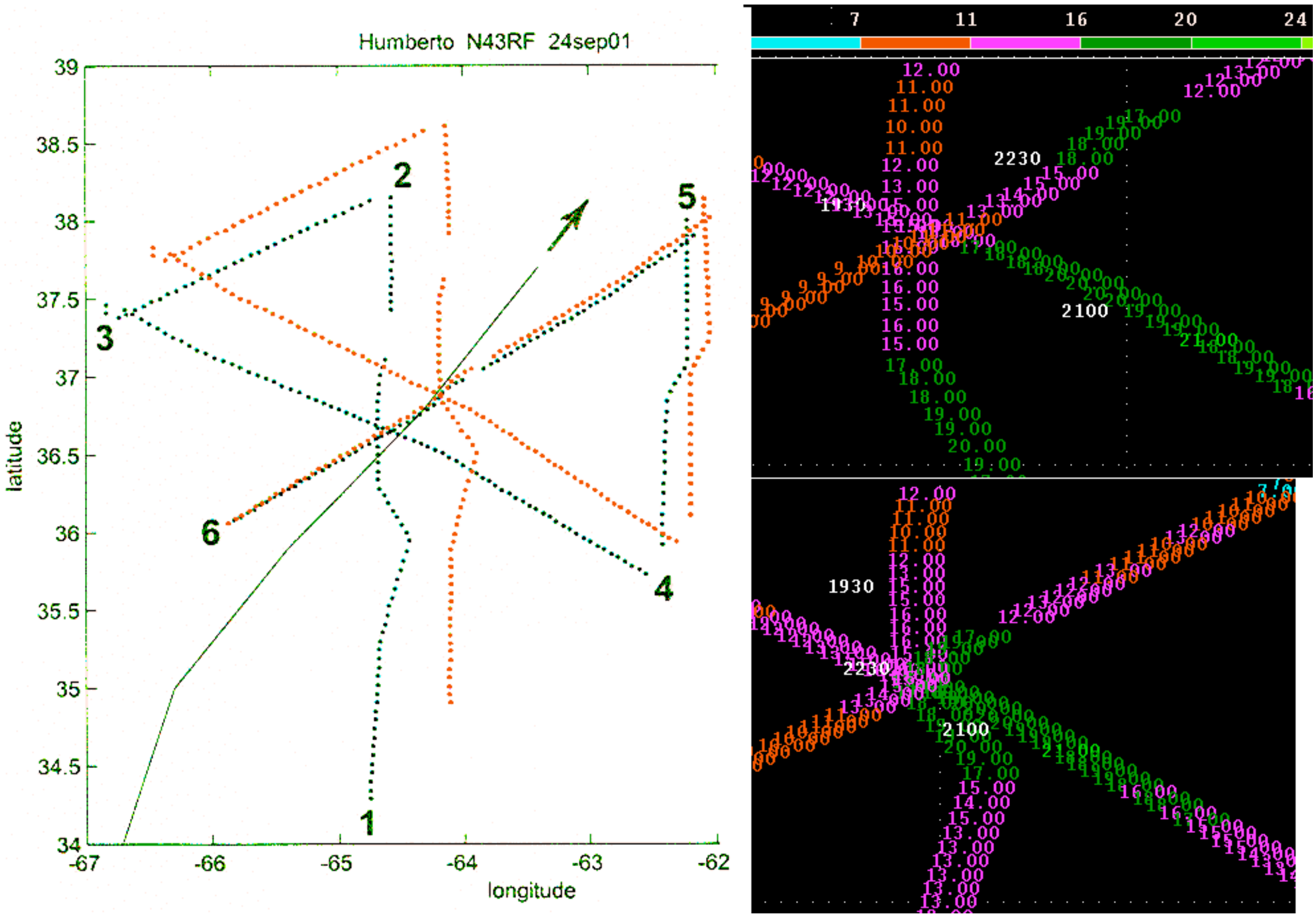

Figure 2.

I developed two SRA output files in the Jason altimeter data format and blow-ups of the N-AWIPS plots Chris Lauer produced from them are shown on the right side of Figure 2 for the vicinity of the intersection of the three eye penetrations, which were made at about 1930, 2100, and 2230 UTC. The white numbers are the UTC observation times. The colored numbers are the SRA significant wave height values in integer feet (the Jason altimeter quantity displayed). The color coding is indicated at the top right side of Figure 2. The top right panel is the plot where each SRA wave height was assigned to the latitude and longitude of the observation location (blue dots in the left panel). Because of the movement of the storm, this produced an inconsistent picture of the wave heights. The numbers are accurate, but the wave height at the intersection of the flight lines changed over the three hour measurement interval

In the bottom right panel of Figure 2, the lat and lons were assigned to the storm-relative positions (red dots in the left panel) corresponding to the time of the last observation. The storm-relative wave height values present a much more realistic picture since the wave field moves with the hurricane.

A potential problem could occur in the vicinity of land and shallow bathymetry which would modify the open water wave field variation. Both types of output files could be generated so that users could see the wave information presented storm-relative in the open ocean or as collected, superimposed on shorelines near land.

I suggested to Chris Lauer that both the Jason and SRA displays would be improved if the wave heights were plotted as integers instead of having the decimal points and two trailing zeros. Chris indicated that he didn't know how to modify the GEMPAK NMAP2 display. When I queried the Unidata GEMPAK support team they indicated that their GEMPAK guru recently left them for another position and they were struggling to juggle support coverage and come up to speed on the various packages that he was the expert on. They believed that there is an NMAP2 configuration file that can be adjusted/created that would allow plotting values as integers instead of floating point numbers, but they had not yet found the appropriate configuration file and were still looking. They suggested taking advantage of the GEMPAK community of users by joining the gembud@unidata.ucar.edu email list and posting a question there, but I have no experience with GEMPAK.

Chris Lauer indicated he had a lot on other things going on and I asked him to show Jose Salazar how to run the program he developed. I could then interact with Jose to mod the SRA display programs he already has running on the JHT server so they would generate SRA files that could be displayed in NAWIPS. Jose indicated that he would let me know when Chris got him up to speed.

As important as storm surge is, it is generally very crudely measured. Figure 3 indicates an additional capability for the NOAA SRA that I am trying to implement for the 2008 hurricane season. In the top panels, circles identify positions spaced at 25 km intervals along tracks flown by N43RF while it carried the NASA SRA during the landfall of Hurricane Bonnie on 26 September 1998. The thin lines indicate the North Carolina State University (NCSU) storm surge model contours and the thick dashed lines indicate the SLOSH storm surge model contours at the observation times. Dots indicate a piecewise linear approximation of the western edge of the Gulf Stream. In the bottom panels, dots indicate SRA storm surge values along the flight tracks. SLOSH surge values along the flight tracks are indicated by the circles connected by line segments. NCSU surge values are indicated by the curve without circles. The two models differ by about a meter over much of the flight line and the low-scatter SRA data generally fall between them.

Figure 4 suggests that much of the difference in the surge values of the models may have been caused by the different tracks they used for Hurricane Bonnie. The SLOSH track (dashes) was determined by a spline fit through the NHC 6-hour interval Best Track storm positions (X). NCSU used the eye locations (dots) at two hour intervals issued in the NHC advisories during landfall. Dashed radials extend from the 2100 UTC eye locations on the two tracks to Springmaid Pier and to the middle on Onslow Bay. Arrows drawn from the Springmaid

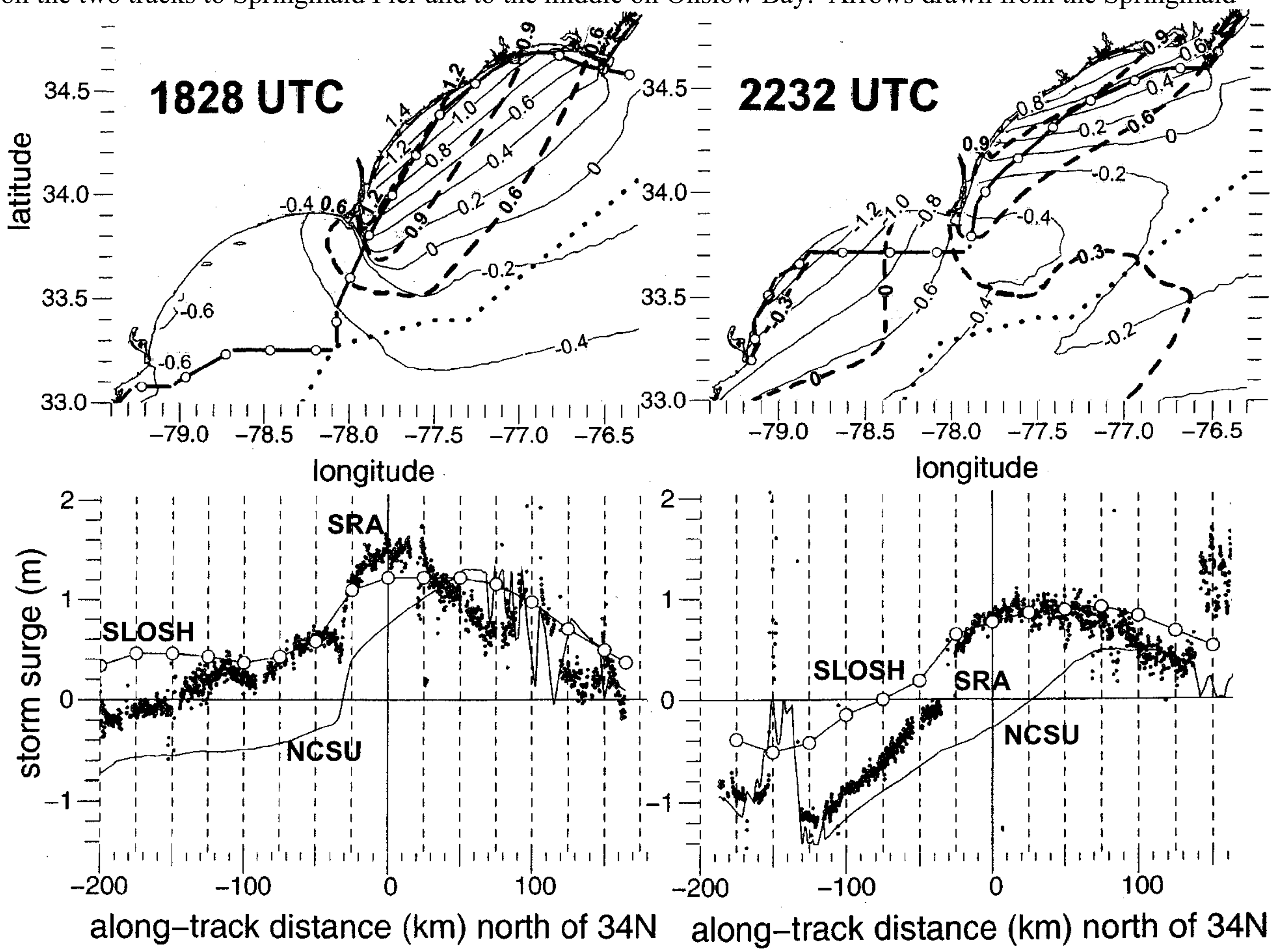

Figure 3.

Pier and Onslow Bay locations at right angles to the dashed radials provide a simple indication of differences in the local downwind direction caused by the track differences.

In the middle of Onslow Bay the downwind direction for NCSU would have been rotated 30° clockwise from SLOSH, which was greater than the 18° clockwise rotation in the surge elevation contours in evidence in the top panels of Figure 3. At Springmaid Pier the NCSU downwind direction would have been 21° closer to being perpendicular to the shoreline and presumably more effective in producing a depressed water surface. Halfway between Springmaid Pier and Cape Fear, the NCSU downwind direction would have been directly offshore while SLOSH would have been 33° from being perpendicular to the shoreline.

There was not much difference in the tracks prior to 1500 UTC, but then the NHC 2-hour advisories moved Bonnie forward too rapidly in addition to diverting it toward the west. The NHC 2-hour advisories placed Bonnie at 34°N at 2100 UTC while the SRA aircraft fixes (circles) suggested that it didn't reach that latitude until about 2300 UTC and the Best Track indicated 2400 UTC, a three-hour spread. In addition to the aircraft indicating a forward speed for Bonnie between that used by SLOSH and NCSU, two of the aircraft eye locations were between the tracks used by SLOSH and NCSU, suggesting why the SRA surge was generally between the two models.

If the aircraft had a survey quality GPS trajectory, the NOAA SRA could produce targeted measurements of storm surge that would provide an absolute standard to verify and improve numerical models. I am working with AOC to accomplish that goal.