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ONSHORE AND OFFSHORE WIND FLOW REGIMES AT THE LANDFALL OF HURRICANE ISABEL (2003)5

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1. INTRODUCTION

On 18 September 2003, Hurricane Isabel made landfall on the North Carolina coast. Several university and non-profit groups had deployed portable Doppler radars and wind towers in the region to study the convective and mesoscale structure of the windfield at landfall. During and just after landfall the Aircraft Operations Center flew NOAA 42RF in a combined Ocean Winds and Hurricane Windfields at Landfall experiment. In addition to the standard flight-level data, NOAA 42RF collected data from the tail Doppler radar, Simultaneous Frequency Microwave Radiometer (SFMR), Imaging Wind and Rain Airborne Profiler (IWRAP), and several Global Positioning System (GPS) dropsondes that were deployed near the coast.

To estimate hurricane intensity over the ocean forecasters must estimate the surface winds by application of reduction factors to winds measured by airborne reconnaissance or research aircraft. Powell et al (2003) recently hypothesized that flight level wind speed reduction factors derived for open ocean may need to be modified near the coast in high winds. There are very few measurements in this regime, though, so HRD has added a module to the Landfall experiment to deploy sondes near the coast in high winds in legs perpendicular to the coast line. Of course, opportunites for this are rare, and it will take data from many storms to have confidence in new reduction factors that might be derived.

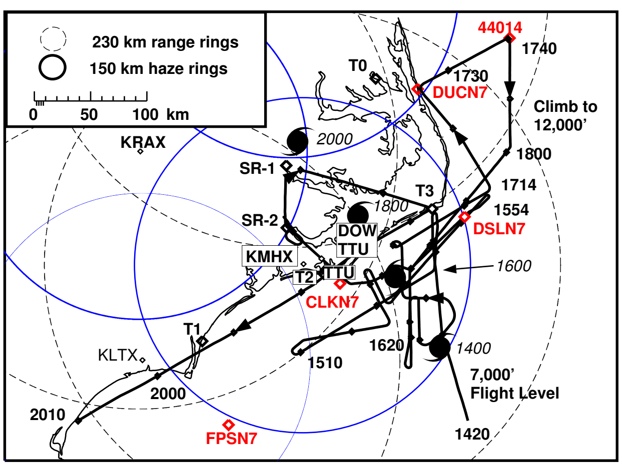

Figure 1. NOAA 42 flight track during landfall of Hurricane Isabel, 18 September 2003. The locations of radars and portable wind towers are also shown. Range rings correspond tp 150 (solid) and 230 (dashed) km. Hurricane symbols are NHC operational fixes from KMHX data.

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2. HURRICANE ISABEL

The center of Hurricane Isabel crossed the North Carolina coast about 1600 UTC. Figure 1 depicts the NOAA 42 flight track, as well as the locations of the Clemson/University of Florida towers (T0-T3), Texas Tech and U of Oklahoma radars (SMART-R2 and R1), Texas Tech wind towers (TTU) and the portable Doppler radars from the Center for Severe Weather Research (DOWs). The hurricane moved through the center of the array, but the maximum winds were almost 100 km N of the center. As the storm moved west of Cape Hatteras an inner eyewall seemed to redevelop.

From 1420 to 1714 the aircraft flew patterns for the Ocean Winds experiment, with many penetrations of wind maxima to gather IWRAP data. At 1714 the aircraft truned and headed north along the coast, just skirting a rainband (Fig. 2). At 1725 the aircraft turned at the DUCN7 CMAN station. Wind tower T0 was located at Elixabeth City, just downwind from DUCN7. From 1725 to 1740 4 sondes were deployed to measure possible changes in the boundary layer. At the conference we will present analyses from the data collected along this leg. The Doppler data will be analyzed to estimate the mesoscale wind fields, and then the sonde data and remotely sensed surface wind data will be examined in this context to describe possible changes in surface wind reduction ratios.

3. DATA ANALYSIS

The flight track from 1714 to 1800 UTC (Fig. 2) was beyond the useful Doppler range of the KMHX WSR-88D radar (175 km) so the Doppler wind fields will be derived using only the airborne Doppler data. In 2003 NOAA 42 had a dual beam antenna, composed of flat plates canted 20° fore and aft of the axis of rotation. Thses data are edited and then combined to estimate the three- dimensional windfields using the variational technique of Gamache (1997). This pseud-dual Doppler method can be applied in two ways. First,

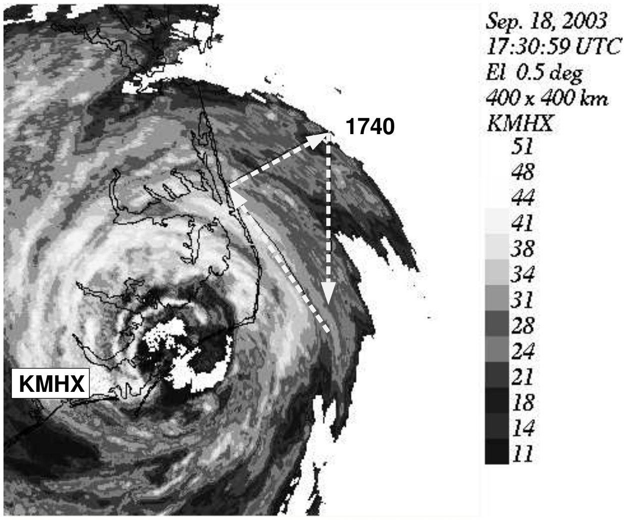

Figure 2. Reflectivity sweep from KMHX WSR-88D at 1730 UTC, 18 September 2003. Gray dashed line indicates NOAA 42 flight track from 1714 to 1800 UTC.

mesoscale analyses can be generated for regions within 40 km of the flight track. This technique will map out the winds along the rainbands. A limitation of the method is that winds can only be retrieved reliably above 0.5 - 1.0 km.

Recently Gamache (personal communication) has modified the technique to retrieve winds beneath the aircraft at much higher vertical resolution, down to 100m above the surface. We will test this technique and apply it in the offshore flow also.

Uhlhorn and Black (2003) describe estimation of surface windspeeds by SFMR. The estimates result from a regreesion equation using microwave brightness temperatures in different frquency bands from the sea surface. Comparing SFMR and GPS sonde 10 m winds showed that above 15 m/s the errors are probably less than 1 m/s, although biases have been noted that varied by storm quadrant, a possible result of variations in the surface waves. SFMR estimates are not valid in coastal surf zones, buit should be valid within near the coast in tropical storm force winds.

Esteban-Fernandez et al (2004) describe instruments develpoed by the University of Massachusetts to estimate vertical profiles of the the total wind below an aircraft. A 4 beam flat plate antenna scans continuosly below the aircraft. Using algorithms similar to the Velocity Azimuth Display Technique (VAD, Browning and Wexler, 1968) data from the four conical scan are combined to yield high-resolution estimates of the boundary-layer windfield. This instrument holds great promise for mapping subtle changes in the boundary layer in onshore and offshore flow in hurricanes.

The highest resolution vertical profiles come from the GPS sondes. The sonde data will used to anchor the dual-Doppler and IWRAP profiles, and the SFMR data will provide the surface wind estimates. From this, for at least one portion of a landfalling storm, we should be able to examine any change in reduction factors. These thechniques can also be applied to other parts of the storm, such as the legs at DSLN7, closer to the maximum winds observed in the storm.

Future plans include Doppler analysis of the inner core that redeveloped as the storm moved north of KMHX (Fig. 3). The aircraft penetrated this inner feature around 1908 UTC.

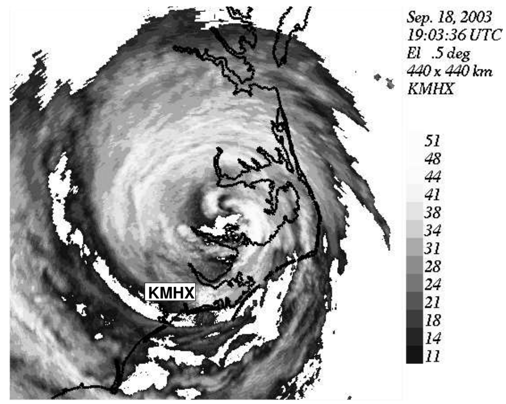

Figure 3. Reflectivity sweep at 1903 UTC, 18 September 2003, from KMHX WSR-88D.

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4. ACKNOWLEDGMENTS

The dedication of the flight and technial staff at NOAA's Aircraft Operations Center made this research flight possible. Flights in hurricane landfall are always difficult to plan for and we appreciate how the crew kept up with our changing plans - especially after they had four previous days of flying challenging CBLAST patterns in Isabel. Thanks to the Tropical Predcition Center for supplying some of the GPS sondes dropped off the coast and the hourly operational storm positions. The National Climatic Data Center supplied Archive Level II Doppler data from the WSR-88D radars.

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