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HIGH RESOLUTION AIRBORNE RADAR MEASUREMENTS OF HURRICANE ISABEL

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Abstract

The Imaging Wind and Rain Airborne Profiler (IWRAP) is a dual-frequency, conically-scanning Doppler radar that measures high resolution profiles of rain's effective reflectivity Z_e and Doppler velocity, as well as surface wind vectors via scatterometry. IWRAP was flown aboard a NOAA WP-3D aircraft during the 2002, 2003, 2004, and 2005 hurricane seasons as part of the ONR's Coupled Boundary Layers Air-Sea Transfer (CBLAST) experiment, NASA's Ocean Vector Winds research, and the NOAA/NESDIS Ocean Winds and Rain experiments. We will start with a description of IWRAP and its capabilities. Following this we will introduce a new dataset available to the CBLAST community. We will finish with high resolution radar observations of Hurricane Isabel with an emphasis on the 3-D structure of the storm, especially in the atmospheric boundary layer (ABL).

1. Introduction

During the past four hurricane seasons the Microwave Remote Sensing Laboratory at the University of Massachusetts flew its Imaging Wind and Rain Airborne Profiler (IWRAP) aboard a NOAA WP-3D aircraft in collaboration with NOAA/NESDIS. There are myriad of objectives of these flights: determining Ku- and C-band geophysical model functions (GMF) in extreme environments (Fernandez 2005), determining the effects of rain on scatterometry, characterizing boundary layer winds in hurricanes (Fernandez et al. 2005), and others. Here we will highlight IWRAP's high resolution capabilities.

Table 1: IWRAP hurricane flights.

$Year$	$Name$	$Category$
2002	Lili	2 and 4
2003	Fabian	3 and 4
	Isabel	2, 4, and 5
2004	Ivan	4 and 5
	Jeanne	1
2005	Ophelia	TS and 1
	Rita	4 and 5

2. IWRAP

a. *Instrument*

IWRAP is a dual-frequency, conically-scanning, coherent radar operating at C- and Ku-bands (Figure 1). The instrument measures profiles of rain reflectivity Z_e and Doppler velocity with 30 m range resolution. It has the capability of being single- or dual-polarized depending on the antenna. In addition to being a profiling radar, IWRAP also functions as a scatterometer providing measurements of the surface wind vector. IWRAP was has been flown on the NOAA WP-3D since the 2002 hurricane season in varying configurations (i.e. single- versus dual-polarizations and various incidence angles). Table 1 shows IWRAP hurricane research flights aboard the NOAA WP-3D. A detailed description of the instru-

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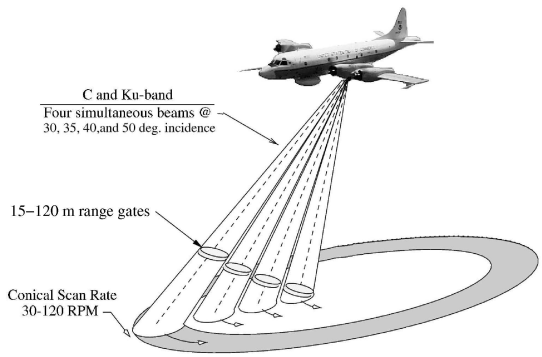

Figure 1: IWRAP configuration on NOAA WP-3D. The incidence angles during the 2003 hurricane season were approximately: 30°, 35°, 40°, and 50°. The azimuthal scan rate was 60 RPM.

ment and its capabilities can be found in Fernandez et al. (2005).

3. Data

Currently, a subset of IWRAP data is available via the CBLAST server (*http://cblast.ecs.umass.edu*). Data collected over the past four hurricane seasons is being further processed and quality controlled in order to make available a new dataset of profiles of reflectivity and Doppler velocity.

4. Hurricane Isabel

Hurricane Isabel developed into a major hurricane the second week of September 2003 with its maximum intensity on 12 September. Here we will focus on IWRAP data from this date.

a. *Scatterometry*

As a scatterometer, IWRAP infers surface wind speed and direction from measurements of surface backscatter represented by the normalized radar cross section (NRCS). Figure 2a and b show Ku- and C-band surface fore-looking NRCS measured during a NW-SE transect through the eye of the hurricane. Both frequencies show the expected NRCS behavior: areas of high wind speed have greater cross section. The difference in the two frequencies illustrates the primary complication of using Ku-band as the scatterometer frequency. That is, as passing through the southern eyewall, where rain was heavy, Ku-band was completely attenuated by rain in the atmosphere which completely obscured Ku-band's ability to sense surface winds.

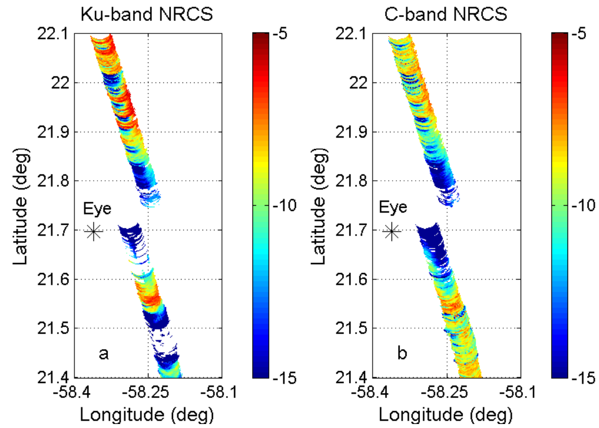

Figure 2: IWRAP measured a) Ku- and b) C-band NRCS at roughly 50° incidence angle during a transect through the eye of Hurricane Isabel on September 12. The transect is from top left corner to bottom right and spans the period 1841 to 1908 UTC.

b. *Airborne Profiler*

Profiles of reflectivity for the outbound portion of the transect are shown for Ku-band in Figure 3a and b. The tilt of the features depending on look direction is expected since the IWRAP antennas point at oblique angles and sample vertical features at different altitudes depending on distance. As the aircraft passed through the eyewall, heavy precipitation completely attenuated the Ku-band signal. Clear in the figure is kilometer-scale structure in the rain field. These fine-scale features are intense rain bands happening at very small scales that are not represented in most numerical models. C-band profiles (Figure 4a and b) also show fine-scale rain structure. However, the C-band signal is not significantly attenuated by the intense precipitation in the eyewall. It should be pointed out that the increase in reflectivity at a range of about 2,200 m is due to a nadir pointing sidelobe.

5. Summary

Data measured by IWRAP during the last four hurricane seasons present observations of the lowest few kilometers of the atmosphere at unprecedented spatial resolution. Measurements show the prevalence of intense fine-scale rain features associated with Hurricane Isabel's eyewall. The inclusion of these features is probably critical for accurately modeling hurricane evolution.

As mentioned, IWRAP data are currently being further processed, quality controlled, and put onto the CBLAST archive. A priority is making the data available to the hurricane community.

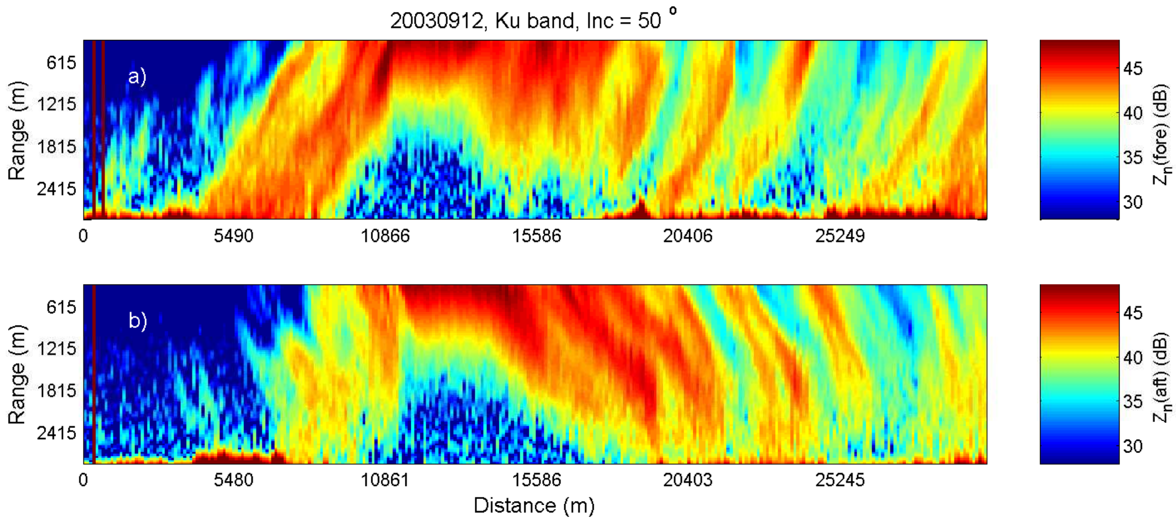

Figure 3: Profiles of reflectivity at Ku-band during the outbound portion of the leg shown in Figure 2. Panel a) is in the foreward look direction and b) the aft.

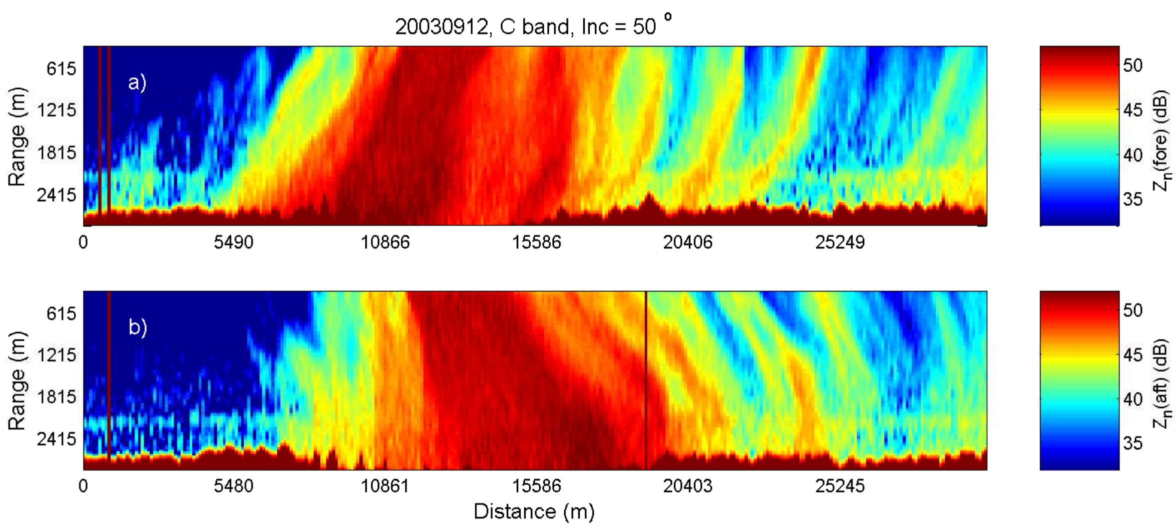

Figure 4: Profiles of reflectivity at C-band during the outbound portion of the leg shown in Figure 2. Panel a) is in the foreward look direction and b) the aft.

References

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