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3-D Atmospheric Boundary Layer Wind Fields from Hurricanes Fabian and Isabel

Daniel Esteban Fernandez[1], S. Frasier[1], J. Carswell[2], P. Chang[3], P. Black[4], and F. Marks, Jr.[4]
[1] Microwave Remote Sensing Laboratory, University of Massachusetts
[2] Remote Sensing Solutions, Inc.
[3] Office of Research and Applications, NOAA/NESDIS
[4] Hurricane Research Division, NOAA/AOML

1. Introduction

The University of Massachusetts (UMass), working with NOAA/AOML/HRD, NOAA/NESDIS/ORA, and NOAA/OMAO/AOC participated in the 2003 ONR CBLAST Hurricane Field Program and the NESDIS Hurricane Ocean Winds and Rain Experiment. UMass installed two instruments on the NOAA N42RF WP-3D aircraft: the Imaging Wind and Rain Airborne Profiler (IWRAP) and the Simultaneous Frequency Microwave Radiometer (SFMR). IWRAP is a dual band (C and Ku), dual-polarized pencil-beam airborne radar that profiles the volume backscatter and Doppler velocity from rain and that also measures the ocean backscatter response. It simultaneously profiles along four separate incidence angles while conically scanning at 60 rpm [1]. SFMR is a C-band nadir viewing radiometer that measures the emission from the ocean surface and intervening atmosphere simultaneously at six frequencies. It is designed to obtain the surface wind speed and the column average rain rate [2].

From the IWRAP measurements, the ocean surface wind field and vertical profiles of the atmospheric boundary layer (ABL) winds are mapped at very high spatial resolution. The ocean surface winds are retrieved using ocean scatterometry methods, while the vertical profiles of the ABL winds are derived from the Doppler measurements of precipitation. These are compared to coincident surface wind speed measurements provided by SFMR, flight level wind measurements, and GPS dropsonde winds.

2. Data Collected

During the 2003 hurricane season, a total of eight flights were flown during various phases of hurricanes Fabian and Isabel, where ocean surface winds of up to 72 m/s and ABL wind speeds in excess of 100 m/s were recorded. Most of the eye-wall penetrations were made at an altitude of roughly 2150 m. Table I summarizes these missions. Approximately one terabyte of IWRAP data were recorded during these flights, together with coincident surface wind speed and rain rate from the SFMR, as well as hundreds of dropsondes and buoy measurements. Note that SFMR provides wind speed and rate rate estimates continuously at 1 Hz. This translates to approximately 125 m spatial sampling.

TABLE I
IWRAP AND SFMR FLIGHT SUMMARY

Flight	Date	Description	Conditions
1	09/02/03	Fabian #1	Cat. 4
2	09/03/03	Fabian #2	Cat. 4
3	09/04/03	Fabian #3	Cat. 3
4	09/12/03	Isabel #1	Cat. 5
5	09/13/03	Isabel #2	Cat. 5
6	09/14/03	Isabel #3	Cat. 5
7	09/16/03	Isabel #4	Cat. 4
8	09/18/03	Isabel #5	Landfall, Cat. 2

3. Processing techniques and Results

In the presence of precipitation, such as during an eye-wall penetration, the radar's conical scan pattern permits deriving continuous 3-D wind profiles. For the Fabian and Isabel flights, C and Ku-band profiles were simultaneously acquired at approximately 30, 40, and 50 degrees incidence and range resolution of 30 m. The vertical profiles of the ABL winds can be derived using VAD techniques from each incidence angle and conical scan, or the Doppler measurements from each incidence angle can be mapped to a latitude, longitude, and altitude grid and the wind components derived for each volume pixel by taking advantage of the multiple azimuth and incidence looks provided by the multiple radar beams.

Figure 1 illustrates the VAD approach from the Ku-band measurements at 30 degrees incidence. For the first time, sub-kilometer continous retrievals of the ABL wind profiles within a hurricane have been generated. The series of profiles show the horizontal wind speed and wind direction from aircraft altitude down to 350 m above the surface. Below that altitude due to the off-nadir incidence angle, the ocean surface Doppler velocity influences the overall Doppler velocity measurement. Therefore, the resulting Doppler velocity becomes a weighted average of the volume (i.e. rain) and surface (i.e. ocean) Doppler velocities. The weighting is related to the ratio of the backscatter power associated to the individual components, and the surface contribution becomes more and more significant as the altitude decreases. Further analysis is required in order to quantify the surface contribution to retrieve the wind field at the lowest ABL heights. SFMR winds do, however, provide an estimate of the equivalent 1-min mean, 10 m level neutral stability winds.

Acknowledgments

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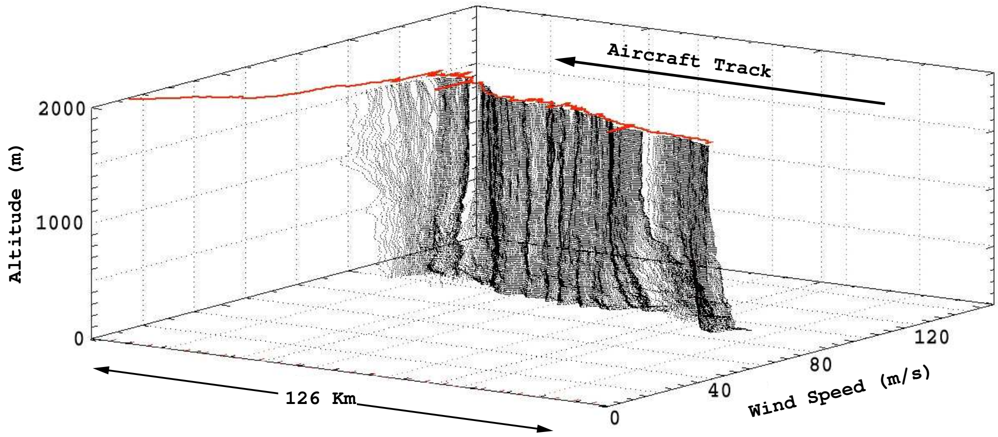
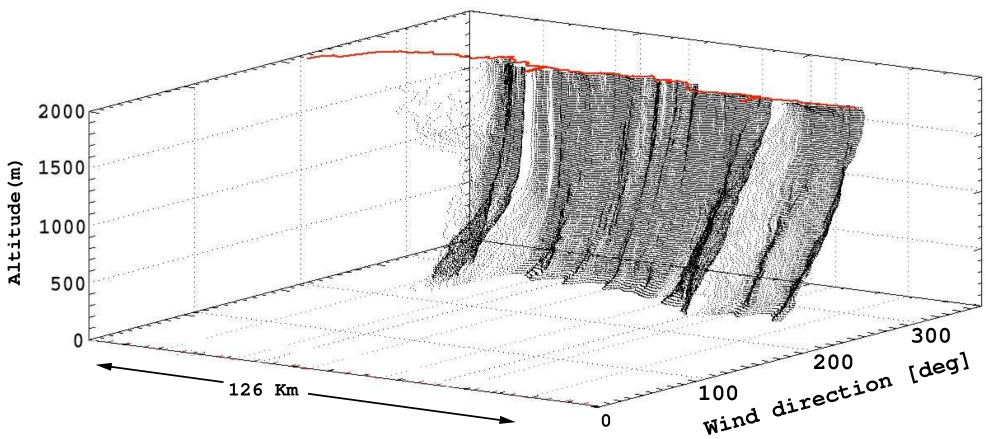
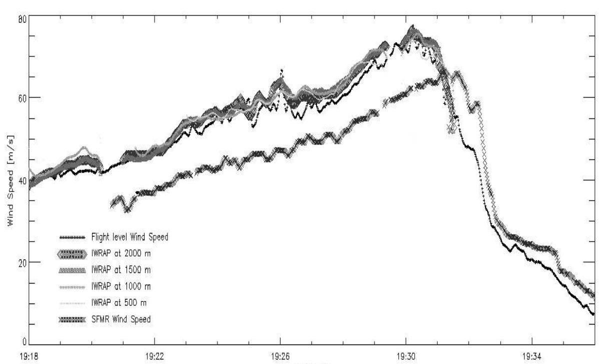


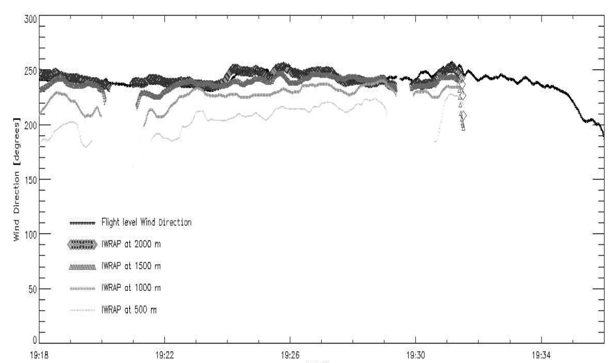
(a)



(b)



(c)



(d)

Fig. 1. (a) Horizontal wind speed and (b) Wind direction of a continuous set of profiles along the flight track. These measurements were retrieved from a precipitation event during an eye-wall penetration of Hurricane Isabel on September 12th, 2003, 19:18 to 19:36 GMT. The flight level wind speed and direction as measured by the on-board probes has been overlaid on top of the profile series. The SFMR wind speed is also overlaid at surface level. (c) and (d) show the horizontal wind speed and wind direction for four cuts corresponding to altitudes of 500 m, 1000 m, 1500m and 2000m.