Tropical Cyclone Structure from Downward Pointing, Conically Scanning Airborne Doppler Radar: IWRAP and HIWRAP

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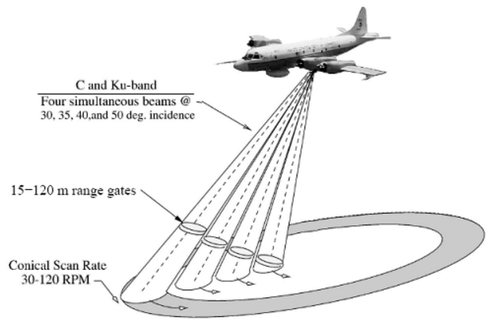
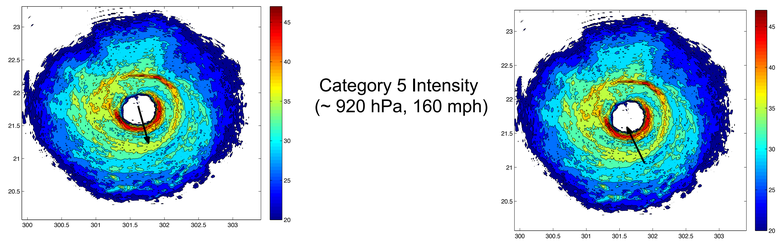
Imaging Wind and Rain Airborne Profiler (IWRAP)

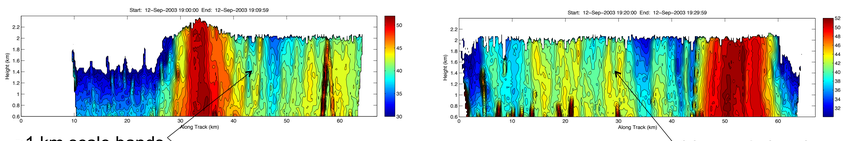


Above: The scan geometry of IWRAP flying aboard the NOAA P-3 aircraft (typical flight altitude of 2 – 5 km). The IWRAP instrument typically has four incidence angles, two frequencies per beam with range gates at 30 m and a scan rate of 60 RPM (along-track sampling every 100 – 150 m).

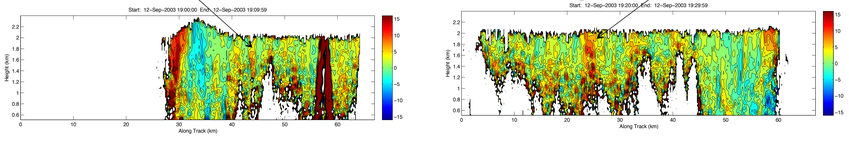
The Concentric Eyewall of Hurricane Isabel (2003)

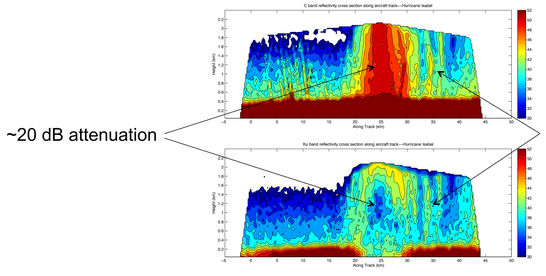


IWRAP Reflectivity



IWRAP Vertical Velocity



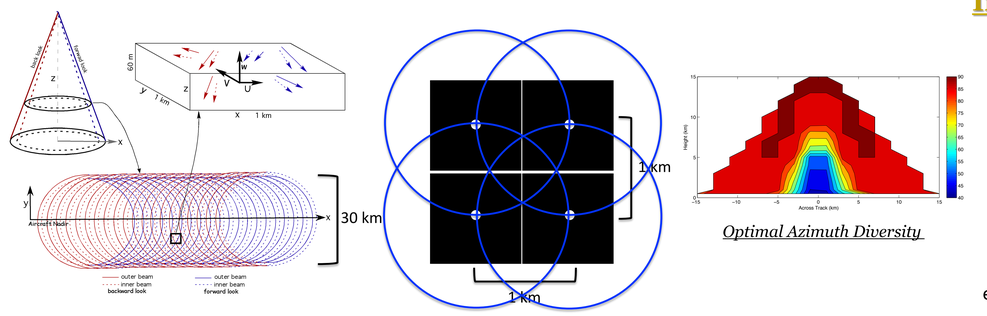


Above: A collection of radar products from Hurricane Isabel (2003) on September 12, 2003. The Lower Fuselage (LF) scans at C band (top) show a concentric eyewall structure of Isabel at an extreme intensity of the storm. In the following 12 h, the pressure increased 15 hPa due to the destruction of the inner eyewall (note downdrafts in the IWRAP retrievals) as the outer eyewall contracted. Below the LF images are plots of IWRAP calibrated reflectivity and retrievals of the vertical velocity at nadir along the flight track. The pulse-pair correlation coefficient was used to filter noisy regions of the Doppler velocities. In addition, attenuation in the eyewall of Isabel (C band and Ku band) is also shown. The grid resolution for the IWRAP data is 200 m (along-track) x 30 m (vertical).

Abstract

Downward-pointing, conically-scanning airborne Doppler radars provide a unique view of atmospheric and oceanic phenomena with their inverted cone geometry. A wind retrieval algorithm was designed to provide the three Cartesian wind components over the 3D swath of these radars. A retrieval simulator shows that the horizontal wind components can be provided to excellent accuracy over most of the swath. The vertical wind retrieval is more difficult, but can still be provided to acceptable accuracy over the inner-portion of the radar swath. Application of the retrieval algorithms to data from IWRAP in Hurricane Isabel (2003) and HIWRAP in Hurricane Karl (2010) and Tropical Storm Matthew (2010) highlight the unique abilities of these radars for tropical cyclone research and operations.

Three-Dimensional Wind Retrieval Algorithm



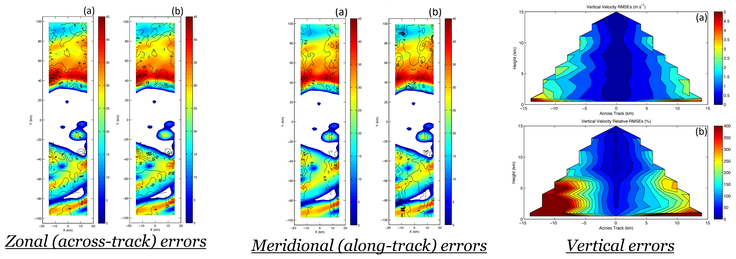
Direct Method: Least Squares (e.g. Lhermitte & Gilet 1976; Ray et al. 1980)

$$\mathbf{J} = \left\| W\left(y - \mathbf{E}x\right) \right\|^2 \xrightarrow{\min} \frac{\partial \mathbf{J}}{\partial \mathbf{x}} = 0 \qquad x = \left(\mathbf{E}^{\mathrm{T}} W \mathbf{E}\right)^{-1} \mathbf{E}^{\mathrm{T}} W y$$

Simulated Error Characteristics

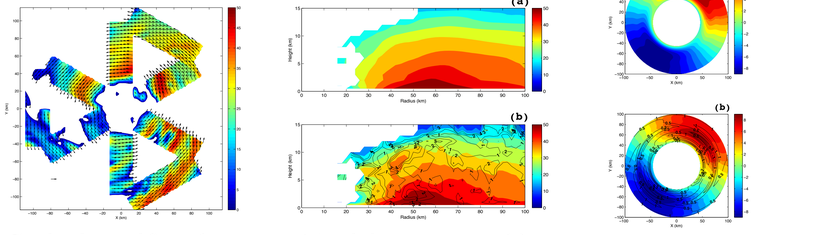
A 2 km numerical simulation of Hurricane Bonnie (1998) provided by Scott Braun

Cartesian Wind Component Errors



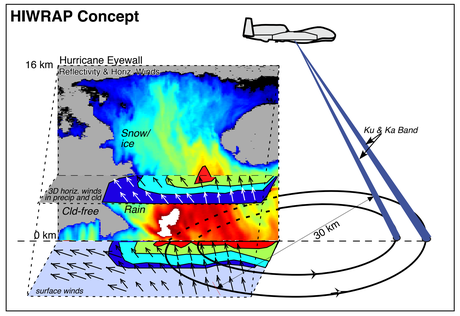
Zonal (across-track) errors | *Meridional (along-track) errors* | *Vertical errors*

Hurricane Structure Provided by HIWRAP



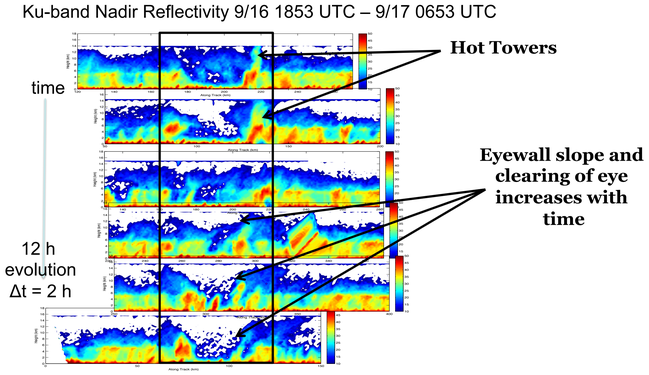
Simulated rotated figure-four flight pattern at 1 km height | *Azimuthal mean structure. (a) Model truth, (b) HIWRAP retrieval* | *Wavenumber one structure. (a) Model truth, (b) HIWRAP retrieval*

High-altitude IWRAP (HIWRAP)



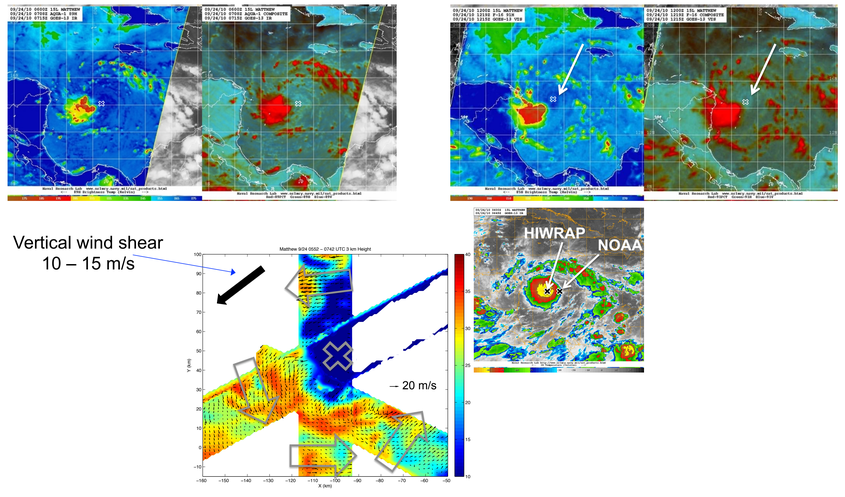
Above: The scan geometry of HIWRAP aboard the NASA Global Hawk UAV (20 km flight altitude). The HIWRAP instrument has two incidence angles (30° and 40°), two frequencies per beam with current range gates at 150 m and a scan rate of 16 RPM (along-track sampling every 600 m).

Intensification of Hurricane Karl (2010)



"Hidden" Circulation in Tropical Storm Matthew (2010)

Does Satellite Data Support NHC Center?



Acknowledgements

This research was supported by the NASA postdoctoral program administered by Oak Ridge Associated Universities and HIWRAP funding through HS3.