Coherent Turbulence in the Boundary Layer of Intense Hurricanes

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The IWRAP Radar

- **C- and Ku-band**
  - Two simultaneous beams for each band

- **Conical Scan Rate**
  - 60 RPM

- **30 m range gates**

- **SFMR Column**
  - 20 to 28° beamwidth

**3DVAR Wind Retrieval Algorithm**
Guimond et al. (2014) in JTECH; Guimond et al. (2018a) in JAS
The IWRAP Radar

Novel features of IWRAP

– Very high-resolution wind/reflectivity data
  • ~ 100 – 150 m along-track and 30 m range sampling
  • 3D winds/reflectivity/derivatives on ~ 200 m/30 m grid

– Quality data down to ~ 200 m height
  • Deep into boundary layer, swath width 1 – 2 km

– Extensive TC database (starting with 2003 season)
  • Many Cat. 4/5 storms sampled, focus on high wind regions
  • Continues to collect data
Understanding Sampling Characteristics:
Large Eddy Simulation of a Rapidly Intensifying Hurricane

Guimond et al. (2018b)

- Idealized numerical simulation of the rapid intensification of Hurricane Guillermo (1997) in East Pacific was conducted.

Initial conditions...

- Latent heat retrievals (Guimond et al. 2011) used as forcing, vortex based on Guimond et al. (2016).

- Dry dynamics, simple sub-grid model.

1) Grid spacing of 60 meters in x/y/z with arrays of size 2100x2100x210, time step of 0.1 – 0.2 seconds.

2) Up to ~ 20,000 compute cores at one time used on NASA Pleiades system.

- Data being used for Observing System Experiments (OSE) to test sampling strategies of various airborne radars.
Effective Resolution of IWRAP Wind Retrievals

Guimond et al. (2018b)

Antenna Pattern

\[ \bar{V}_r = (\bar{u}x + \bar{v}y + \bar{w}z)r^{-1} \]

\[ \langle f \rangle = \frac{\sum_{i=1}^{n} f_i w_i}{\sum_{i=1}^{n} w_i} \]

\[ w_i = e^{-\left(\frac{r_i}{R_k \tan(BW/2)}\right)} \]
• Peak intensity on 9/22 at 06 UTC, slow weakening during sampling, intensity of 914 hPa
• Concentric eyewall formation at ~ 9/22 00 UTC
• Didlake et al. (2011)... focus on asymmetric structure (pert. vorticity)
• Bell et al. (2012)... axisymmetric structure of concentric eyewalls
Eddy Momentum Fluxes 2030–2040 UTC Leg

- Lower = 0.20 – 0.50 km mean, Upper = 0.50 – 1.00 km mean
- Peak $v'w' = 55 \text{ m}^2 \text{ s}^{-2}$, Mean (eyewalls) $v'w' = \sim 1.0 – 1.5 \text{ m}^2 \text{ s}^{-2}$
- Peak $u'w' = 150 \text{ m}^2 \text{ s}^{-2}$, Mean (eyewalls) $u'w' = \sim 0.0 – 3.0 \text{ m}^2 \text{ s}^{-2}$
Typical Boundary Layer Roll Structure

$v'w'$ and $u'w'<0$

Morrison et al. (2005)
IWRAP Rita Data
Sept. 23, 2005 ~ 1700 – 2200 UTC

- Continued slow weakening during sampling, intensity of 930 hPa
- Merged eyewalls
1720 – 1730 UTC C-Band vs. Dropsonde

Horizontal Wind speed (m/s)
1720 – 1730 UTC C-Band vs. Dropsonde
1720 – 1730 UTC C-Band vs. Dropsonde

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1720 – 1730 UTC C-Band vs. Dropsonde

Horizontal Wind speed (m/s)
Summary/Conclusions
Guimond et al. (2018a), JAS – remote sensing work

• Effective resolution of IWRAP wind retrievals
  – ~ 1 km or 4-5Δx with Δx = 200 – 250 meters
  – Fully capable of resolving “large turbulent eddies” with scales on order of 1 km

• Rich spectrum of turbulent eddies ubiquitous in IWRAP data
  – Both inner, outer eyewall and transition region
  – Typical characteristics of coherent eddies
    • Radial wavelengths of ~ 1 – 3 km (mean of 2 km)
      – SFMR wavelengths (mean of 2.65 km), SAR wavelengths (2 – 3 km)
    • Depths from ocean surface to flight level (at least ~ 2 km deep)
    • Aligned with mean tangential wind, tilt consistent with radial flow structure
    • Maximum winds located in eddies (up to 90+ m/s), perturbations of 10 – 20 m/s

• Impacts for IOVWST community
  – Understanding (physics & measurement) of dropsonde and SFMR obs
  – Feedback to satellite scales (e.g. how to up-scale SFMR)
References


