Using GRIP and related datasets for improved analysis of TC structure, genesis, and intensity change

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Acknowledgments:

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Submitted, in review:


In Preparation:


Outline

- Vorticity calculation and thermodynamic evolution during TC genesis (*Helms*)
- TC eyewall tilt and intensity (*Hazelton*)
- Objective TC structure definition and global climatology from satellites (*Cossuth*)
- New vortex-environment separation (*Creighton*)
Part 1: GRIP Dropsonde-Derived Vorticity and RH Vertical Structure (Helms and Hart)

• First we build upon prior approaches to in-situ data to derive reliable vorticity estimates
  – Advect dropsondes to produce a time-space conversion (error-prone in accelerating flow)
  – Use Green’s function to calculate vorticity from polygons generally larger than n=3

• Analyze vorticity and its relationship to moisture for developing vs. non-developing systems
Sample dropsonde field from GRIP and resulting steps for vorticity
Developing Case 1 (PGI44L – Karl)

18 UTC Sept. 11, 2010
Relative Vorticity T = +0 hr

13 UTC Sept. 12, 2010
Relative Vorticity T = +19 hr

Relative Humidity T = +0 hr

Relative Humidity T = +19 hr
Developing Case 1 (PGI44L – Karl)
Developing Case 2 (PGI46L - Matthew)
Non-Developing Case (PGL27L)

13 UTC Aug. 17, 2010
Relative Vorticity T = +0 hr

14 UTC Aug. 18, 2010
Relative Vorticity T = +24 hr

Relative Humidity T = +0 hr

Relative Humidity T = +24 hr
Part 1: Summary

• Initial tilt of vorticity exists in all three cases
  – The sign of the tilt varies with case

• The uprighting of the vorticity column occurs in both developing and non-developing cases

• In the three cases examined, the mid-level RH was significantly different (developing vs. non-developing), consistent with much recent work including Nolan (2007)

• However, in other cases not shown here, the moisture was not a significant discriminator. See Poster for more detail.
Part 2: Eyewall tilt and Intensity (Hazelton and Hart)

• Eyewall slope has been predicted since the earliest theoretical models of axisymmetric balance (warm-core vortex that weakens with height requires outward sloping M-surface)

• Shea and Gray (1975): relationship between RMW & intensity

• Stern and Nolan (2009): used airborne Doppler to show little relationship between the same

• Here we use the reflectivity to define the edge of the eyewall and find quite different results
Data/Methodology

• In this study, we build a relatively large dataset of slopes based on radar reflectivity.
  – 100 passes from 17 TCs (2004-2011) from three sources
  – APR2 radar from the NASA-DC8 during the GRIP field campaign.
  – EDOP radar data from the CAMEX4 field campaign
  – Tail radar from the NOAA-P3 flights from HRD

  – Thanks to Stephen Durden at NASA JPL for information about APR2 radar data, Rob Rogers and HRD for their data and interpretation, and Pete Black for his feedback

• Our study examines the relationship between the slope of the edge of the eye and TC intensity, rather than the relationship between the RMW slope and intensity.
Distribution of Eyewall Slopes

- Peak around 1 (45 degrees)
- Large Tail (due to a few shallow eyewalls)

In the chart:
- The x-axis represents the inverse slope $\Delta x/\Delta z$ (1 is 45 degrees).
- The y-axis represents the number of cases.
Noteworthy Features of Slope Distribution

- There were often differences in slope across the eye
  → Average difference was 19 degrees (both for north-south and east-west cross-sections).
  → Is this mean shear or baroclinic beta-gyres induced?

- Many cases were noted where the upper eye tilted more sharply than the lower eye.
  → Actual physical tilt but perhaps also due to a loss of scatterers
Relationship between tilt and intensity

Minimum Central Pressure vs. Eye Slope (Colorized by Storm)

$r=0.38$
$p<0.01$
Variance: Examples of $R$(Slope, Intensity)

Individual Storm Correlations Between Slope and Intensity

Paloma
Dennis
Felix
Gustav
Earl
Helene
Frances
Ike
Ivan
Katrina

-1 to 1 on the x-axis represents the range of correlation values, with significant correlations indicated by red bars and observed correlations by blue bars.
Pressure-Slope Lag

Slope vs. 6-hourly Intensity From "Best Track"

Correlation Between Slope and Best-Track

Intensity

Hours Relative to Best-Track Time
Ongoing work: Examine all azimuths rather than just two transects
Part 2: Summary

• There does appear to be a stat. significant relationship between edge of eye slope and intensity as defined here
  – The contrast with Stern and Nolan (2009) may be due to the different definitions for slope and their physical meanings (RMW vs. edge of indirect circulation in eye?)

• The relationship is optimized for a lag of about 12hr implying forecasting potential but requires further refinement

• A significant non-zero mean across-eye tilt differential may suggest either mean shear for cases examined, tilt due to (baroclinic) beta-gyres, or both

• Poster this afternoon has example case studies, including Earl
3: Global structure
(Cossuth and Hart)

• New datasets and techniques permit us to for the first time arrive at global climatologies of eye structure and its relationship to intensity

• Utilize the HURSAT satellite database (1987-2008) (Knapp 2010)

• Use ARCHER technique (Wimmers and Velden 2010) to objectively determine center and eye size
Example applications of ARCHER technique
Example applications of ARCHER technique
Global satellite-based climatology of eye size and intensity

TC Eye Diameter (km)/Intensity (kt) Climatology

a) CIMSS ARCHER on NCDC HURSAT MW [1987–2008]

TS    Cat1    Cat2    Cat3    Cat4    Cat5

40km

200km
TC Eye Diameter (km)/Intensity (kt) Climatology

a) CIMSS ARCHER on NCDC HURSAT MW [1987–2008]

b) ATCF Recon F-Deck [1991–2010]

TS    Cat1  Cat2  Cat3  Cat4  Cat5

40km

200km
• Atlantic existence of recon eye structure
Part 3: Summary

• New software has allowed for objective (but not perfect) center location and eye size determination from satellite data

• This has permitted the first global climatology of TC structure and its existence including regions without recon.

• Ongoing work to examine relationships between intensity and structure, and to define new objective measures of structure

• With one focus of HS3 the improvement of TC modeling, it would be interesting to see what WRF and HWRF have as comparable phase space of structural existence
  – The need for more robust measures of verification other than intensity and track
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Part 4: Vortex-environment separation
(Creighton, Hart, Cunningham)

• Simulations of genesis often examine the evolution of vorticity and how the system grows from an upscale cascade

• However, classic approaches nearly all involve the separation of the system from the convective scale through a simple symmetric-asymmetric approach.

• This approach while elegant and simple is flawed, as the system itself has well-known asymmetries that should be considered part of the system, not the convective scale:
  – Wavenumber one beta-gyres
  – Wavenumber one and two asymmetries due to horizontal shear
  – Wavenumber one and two asymmetries due to vertical shear

• Here we demonstrate a spectral gap in vorticity power spectrum of WRF simulations that provide an alternative separation point for storm-vs-convective structure
Vorticity evolution at 200m

(a) $t = 18$ h

(b) $t = 24$ h

(c) $t = 26$ h

(d) $t = 29$ h

(e) $t = 34$ h

(f) $t = 48$ h

$\times 10^{-4}$ s$^{-1}$
Power spectrum of vorticity at 200m for all times in the 48hr simulation
System-scale vorticity using filtering at 24, 29, 34, and 48hr
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