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

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Acknowledgments:

Students:

Glenn Creighton (M.S. 2010)

Josh Cossuth (PhD student)

Chip Helms (M.S. 2012)

Andy Hazelton (PhD student)

Marc Austin (M.S. 2011)

Dan Halperin (M.S. 2011; PhD student)

Brad Reinhart (M.S. 2012)

Collaborators:

Stephen Durden (JPL), Rob Rogers (HRD),
Richard Blakeslee (MSFC), Chris Velden (CIMSS)

Publications

Submitted, in review:

Creighton, G., R. Hart, P. Cunningham, 2012: “A spatial filter approach to determining the role of convection on the evolutionof a mesoscale vortex.” *J. Atm. Sci.*

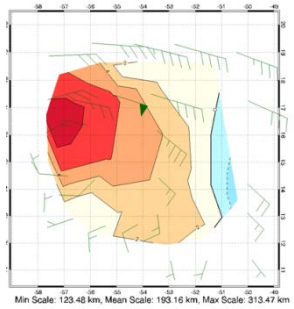
Hazelton, A. and R. Hart, 2012: “Hurricane Eye Slope as Determined by Using Airborne Radar Reflectivity Data: Composites and Case Studies.” *Wea. Forec*.

In Preparation:

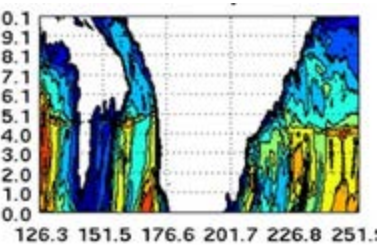
Halperin, D. J., H.E. Fuelberg, R.E. Hart, P. Sura, J. Cossuth, R. Truchelut, R. J. Pasch, 2012: “Evaluating tropical cyclogenesis forecasts from four global numerical models.” *Wea. Forec.*

Helms, C. and R. Hart, 2012: “The Evolution of Dropsonde-Derived Vorticity and Thermodynamics in Developing and Non-Developing Tropical Convective Systems.” *Mon. Wea. Rev*.

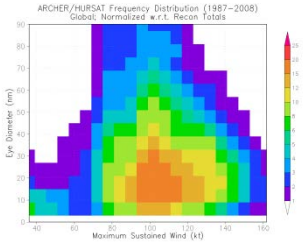
Outline



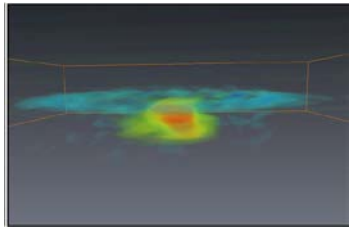
- Vorticity calculation and thermodynamic evolution during TC genesis (*Helms*)



- TC eyewall tilt and intensity (*Hazelton*)



- Objective TC structure definition and global climatology from satellites (*Cossuth*)



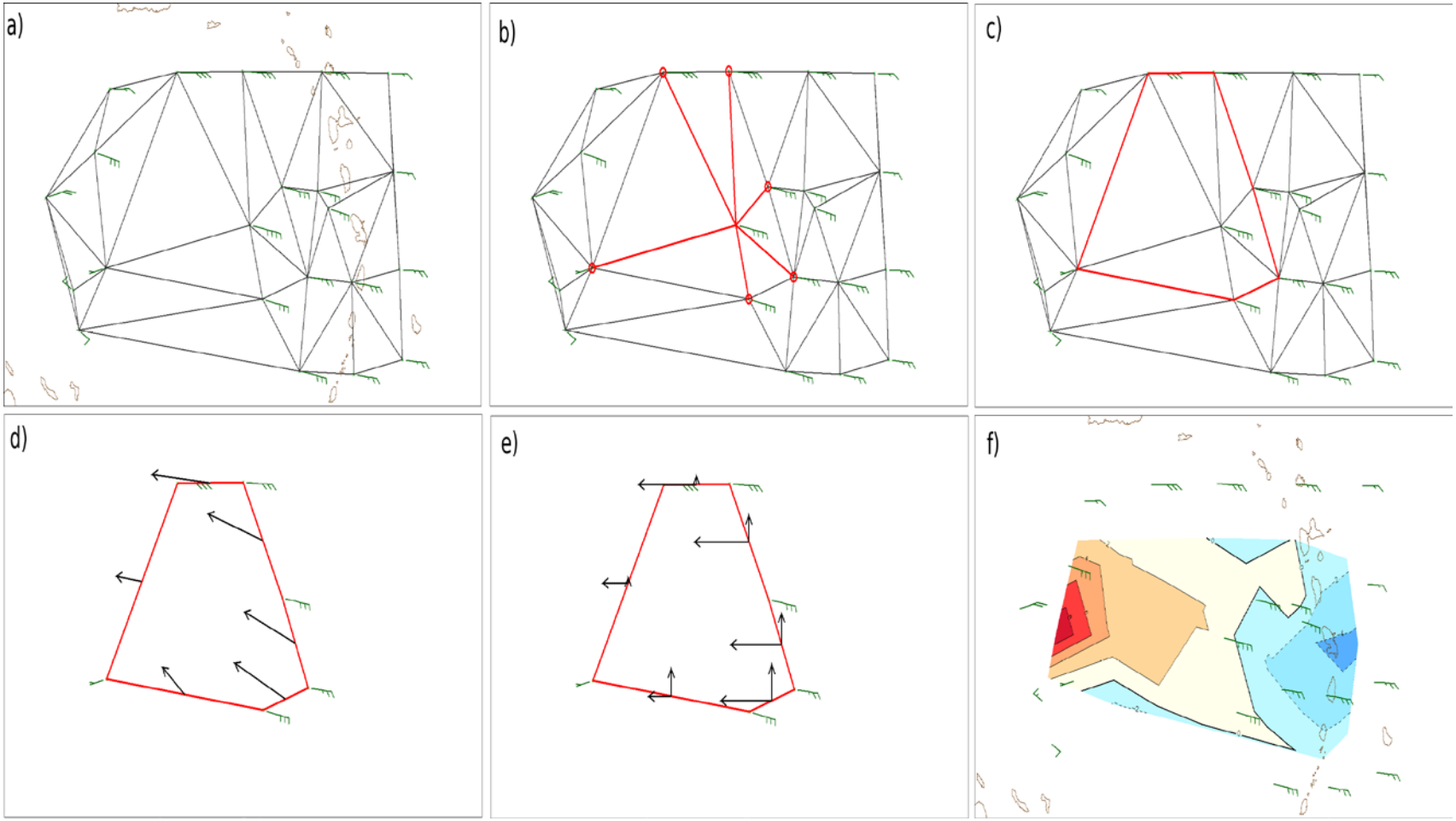
- New vortex-environment separation (*Creighton*)

Part 1: GRIP Dropsonde-Derived Vorticity and RH Vertical Structure (Helms and Hart)

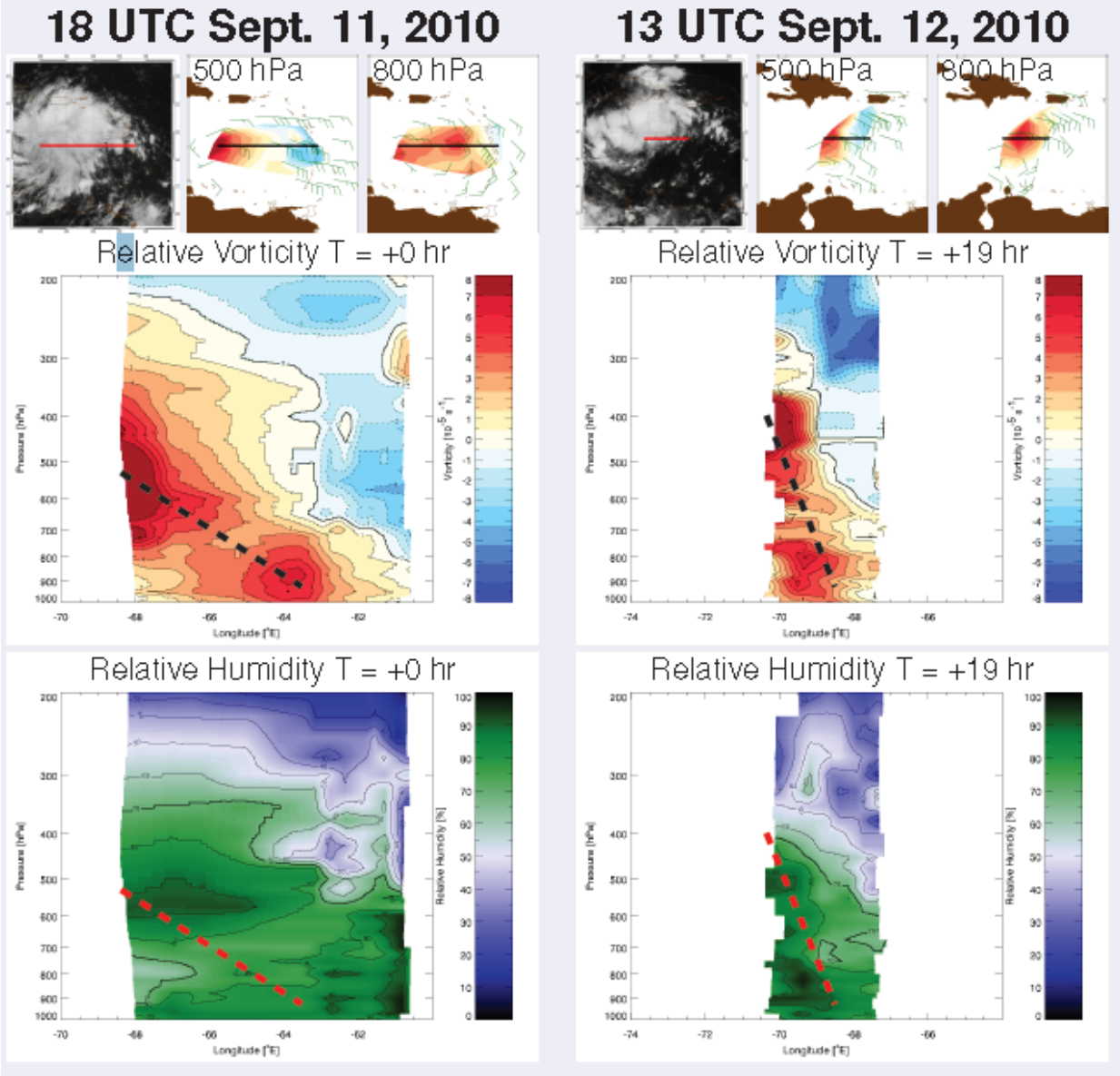
- First we build upon prior approaches to in-situ data to derive reliable vorticity estimates
  - Advect dropsondes to produce a time-space conversion (error-prone in accelerating flow)
  - Use Green's function to calculate vorticity from polygons generally larger than n=3

- 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)



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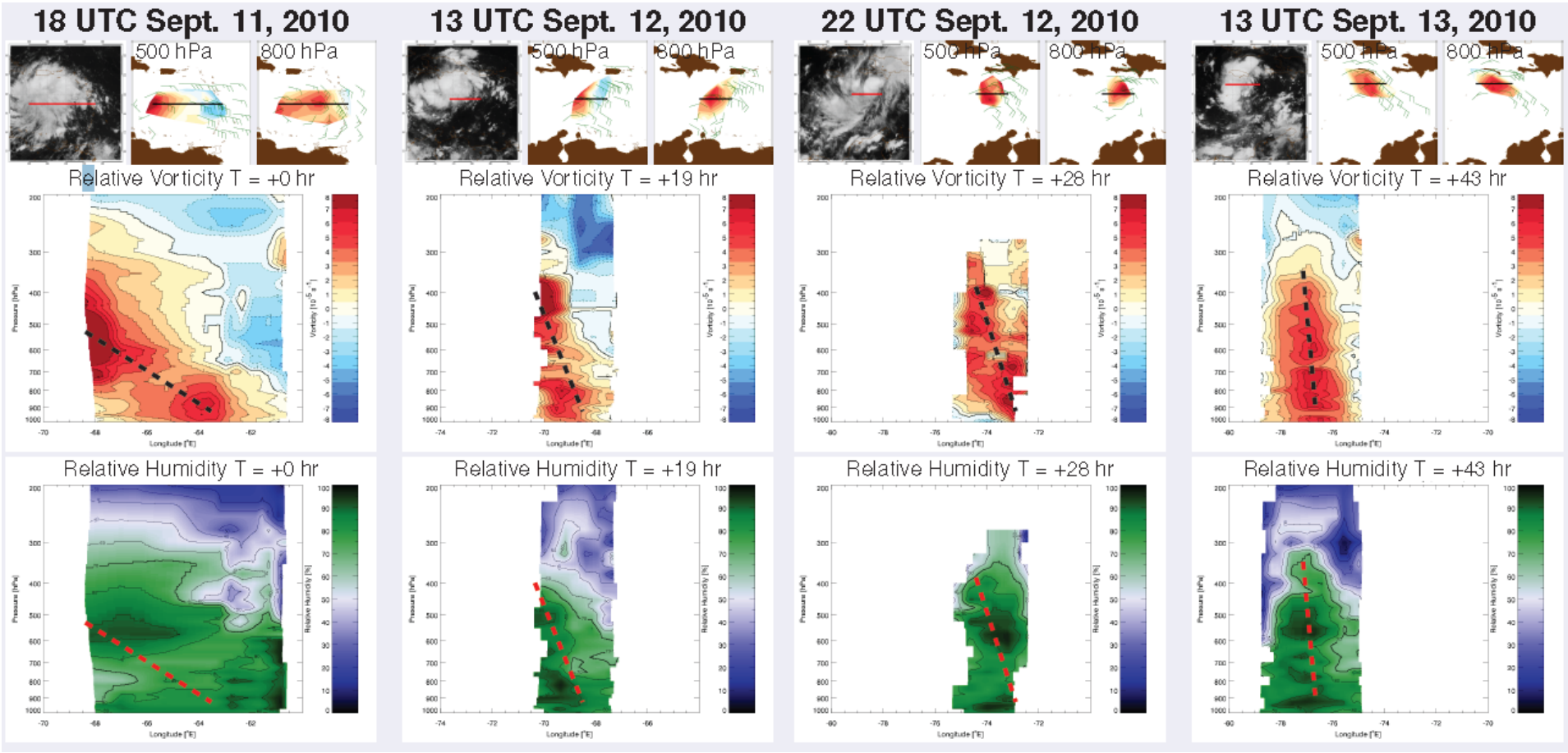
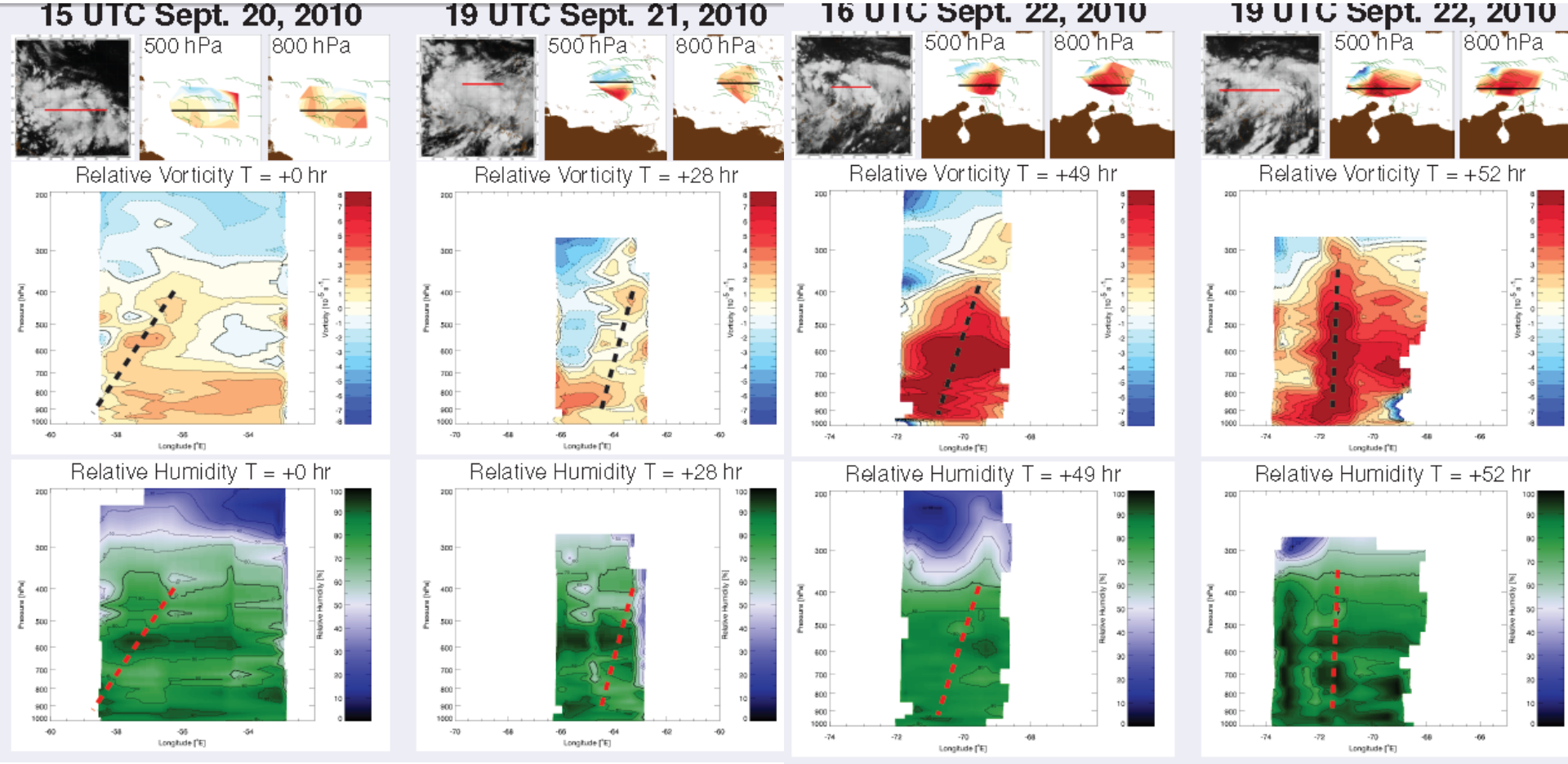
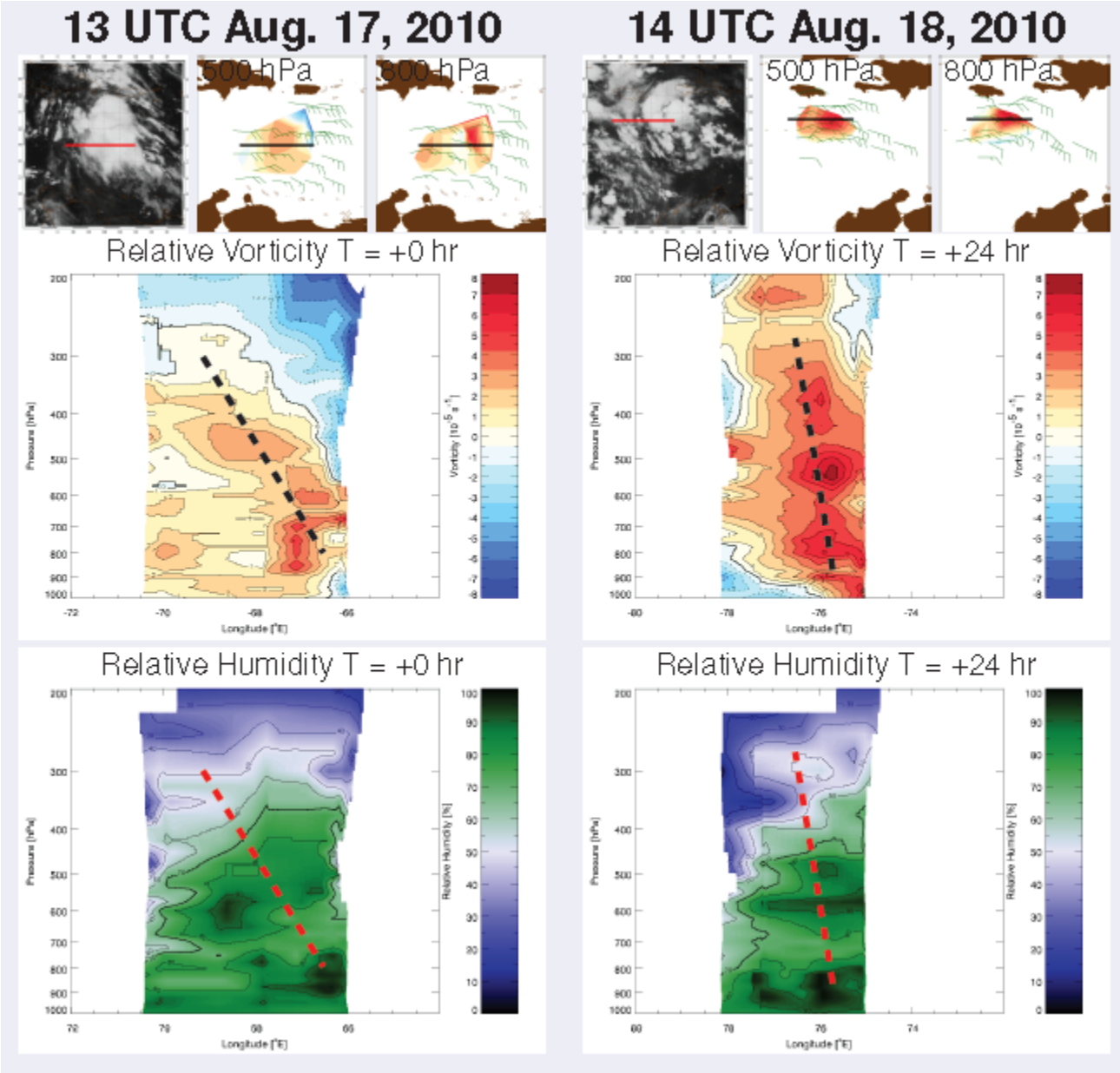


Developing Case 2 (PGI46L - Matthew)



Non-Developing Case (PGI27L)



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 <u>not</u> 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

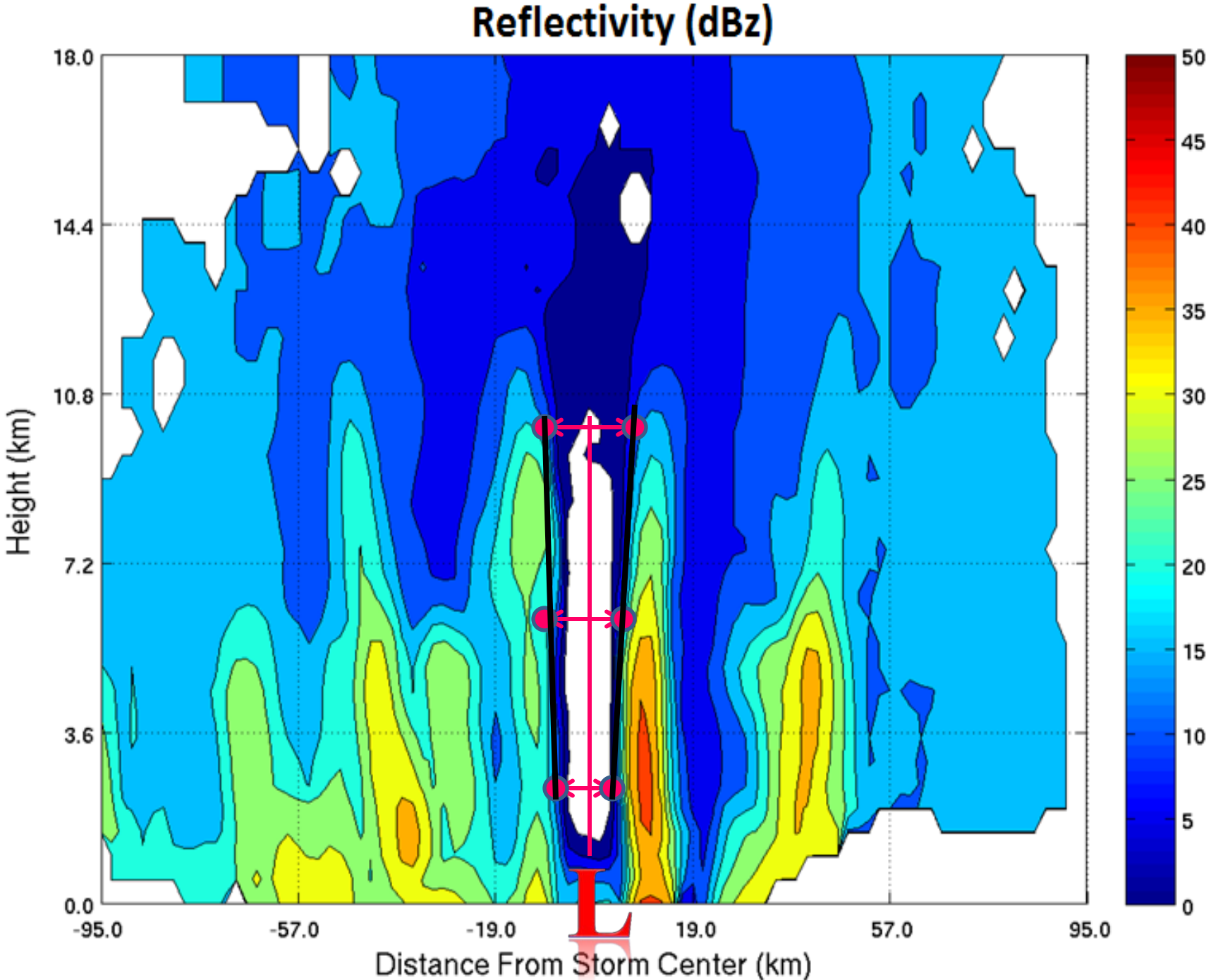
- Here we use the reflectivity to define the edge of the eyewall and find quite different results

Data/Methodology

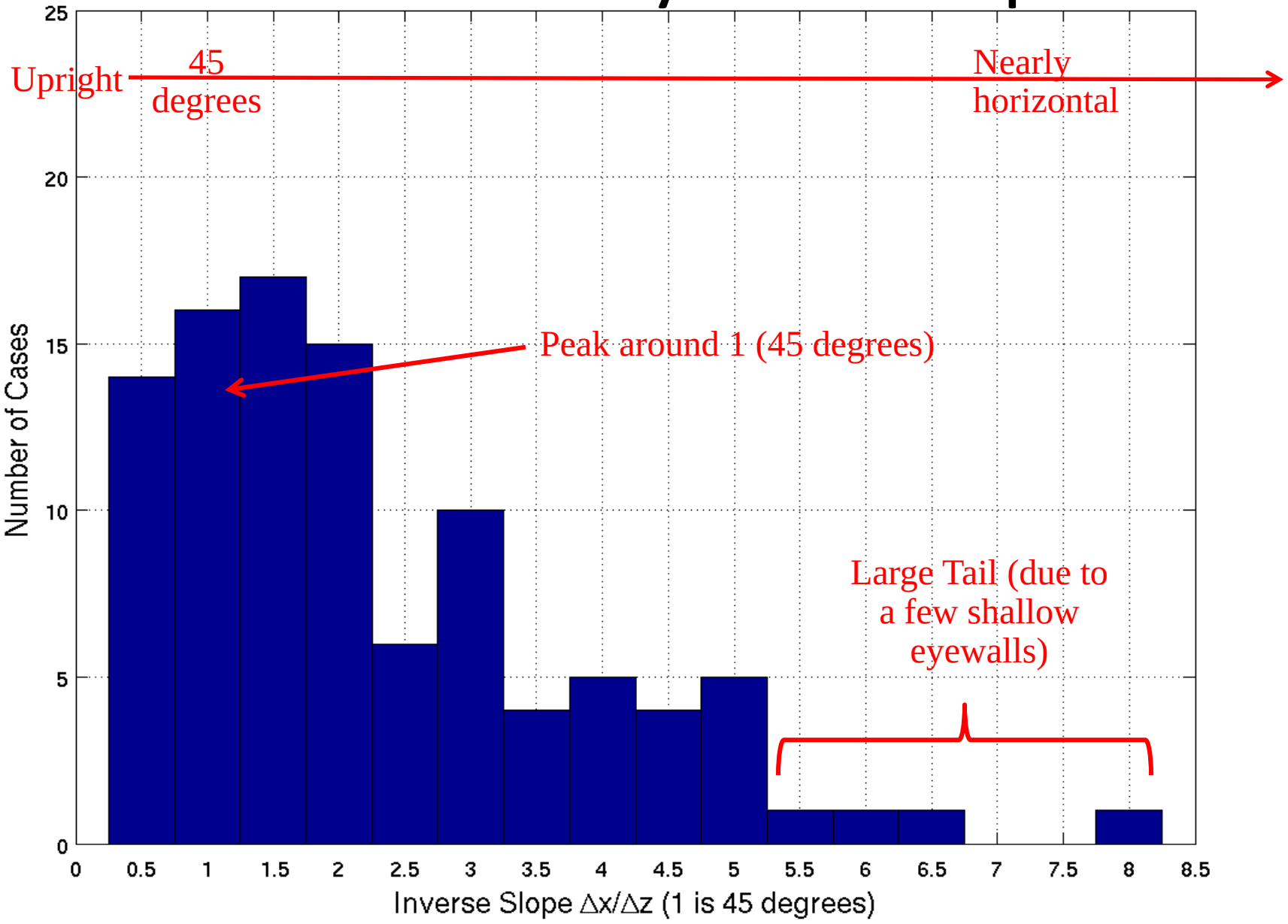
- In this study, we build a relatively large dataset of slopes based on radar reflectivity.
  - 100 passes from 17 TCs (2004-2011) from three sources
  - APR2 radar from the NASA-DC8 during the GRIP field campaign.
  - EDOP radar data from the CAMEX4 field campaign
  - Tail radar from the NOAA-P3 flights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


Reflectivity (dBz)
18.0
14.4
10.8
7.2
3.6
0.0
Height (km)
-95.0
-57.0
-19.0
19.0
57.0
95.0
Distance From Storm Center (km)
50
45
40
35
30
25
20
15
10
5
0
L

Distribution of Eyewall Slopes

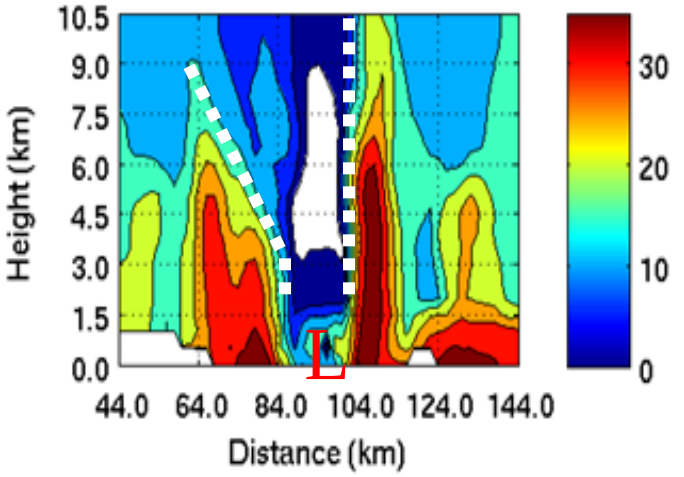


Noteworthy Features of Slope Distribution

-There were often differences in slope across the eye

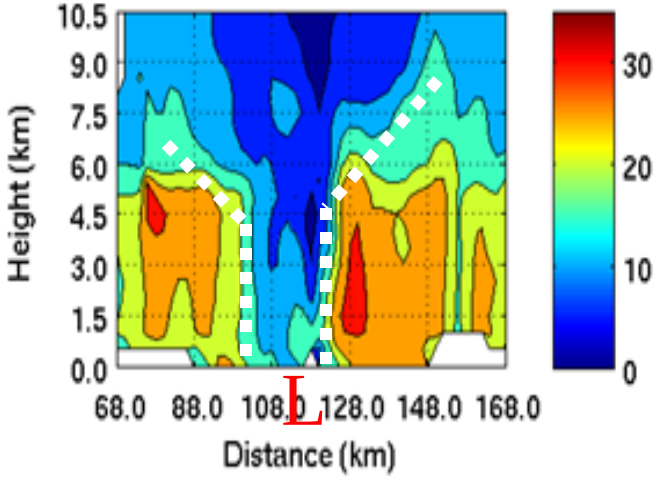
→ Average difference was 19 degrees (both for north-south and east-west cross-sections).

→ Is this mean shear or baroclinic beta-gyres induced?

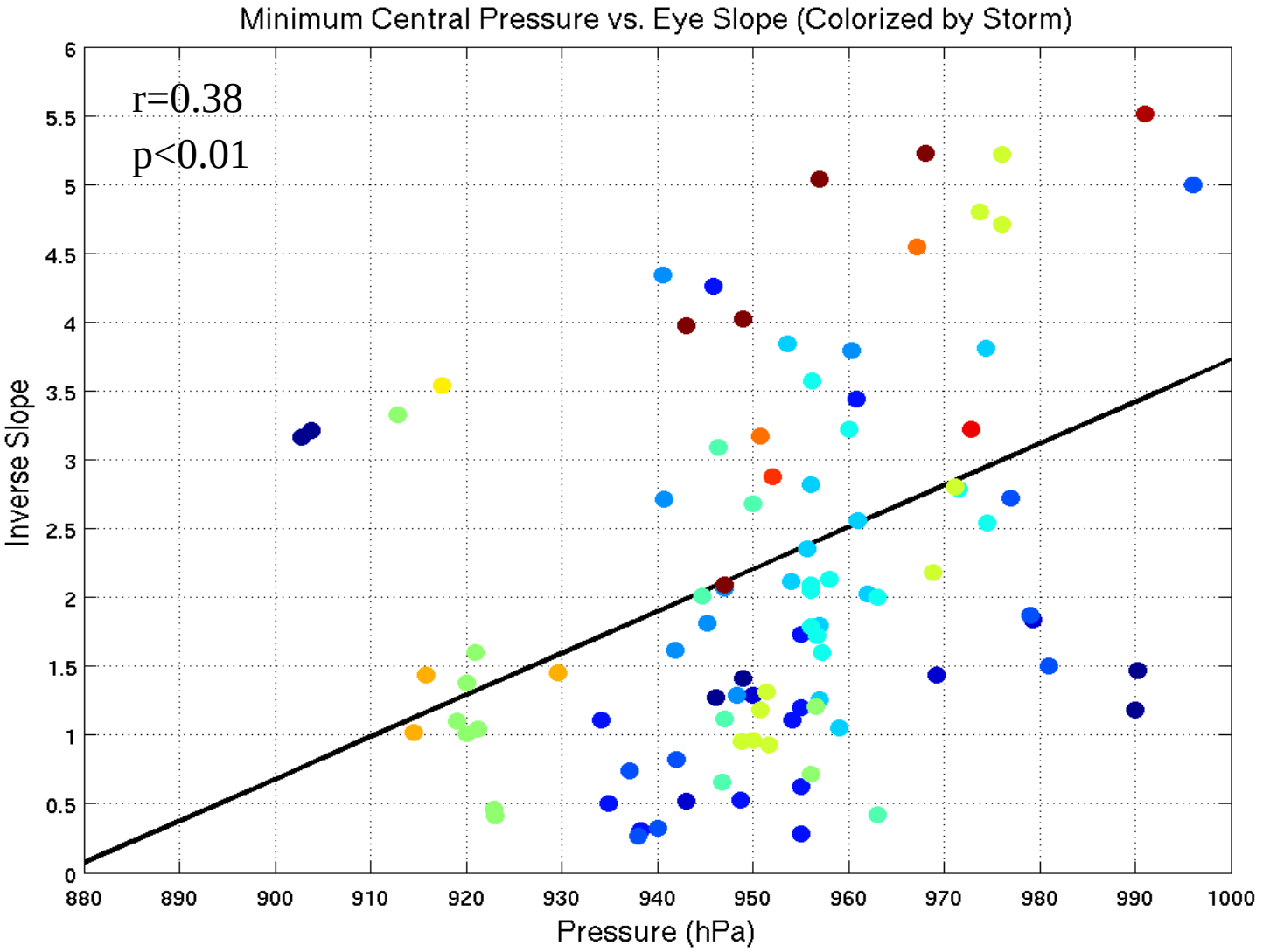


-Many cases were noted where the upper eye tilted more sharply than the lower eye.

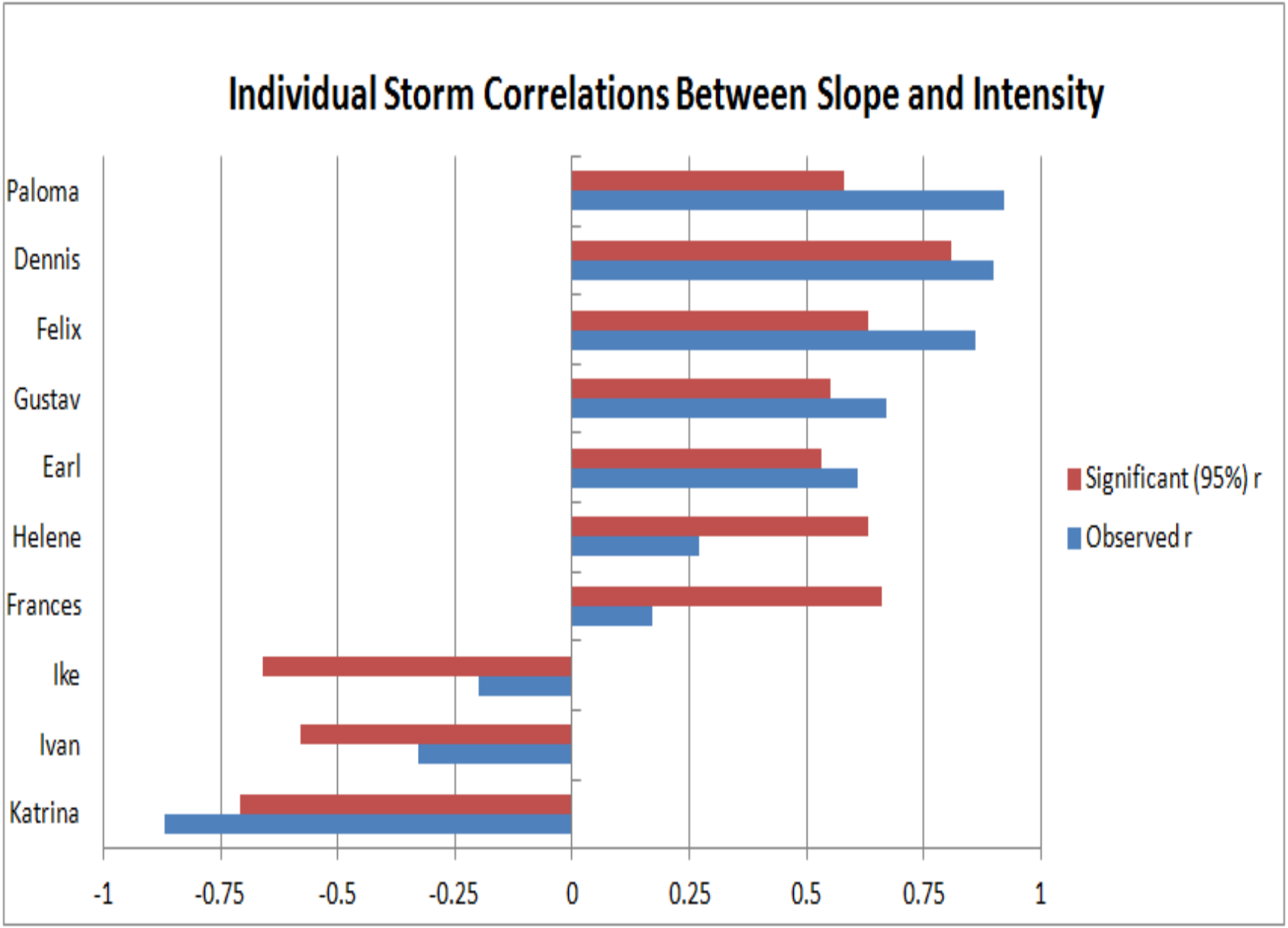
→ Actual physical tilt but perhaps also due to a loss of scatterers



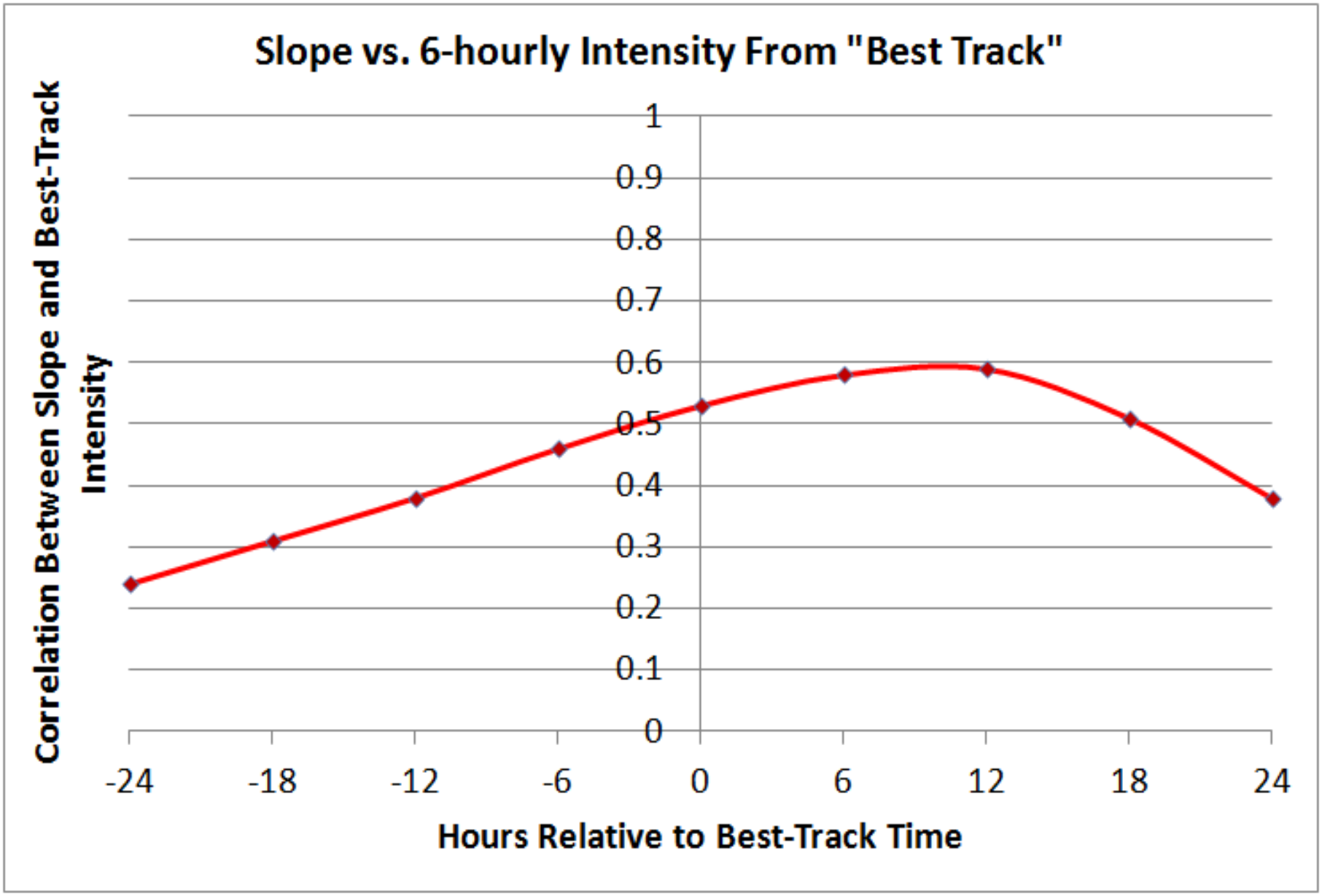
Relationship between tilt and intensity



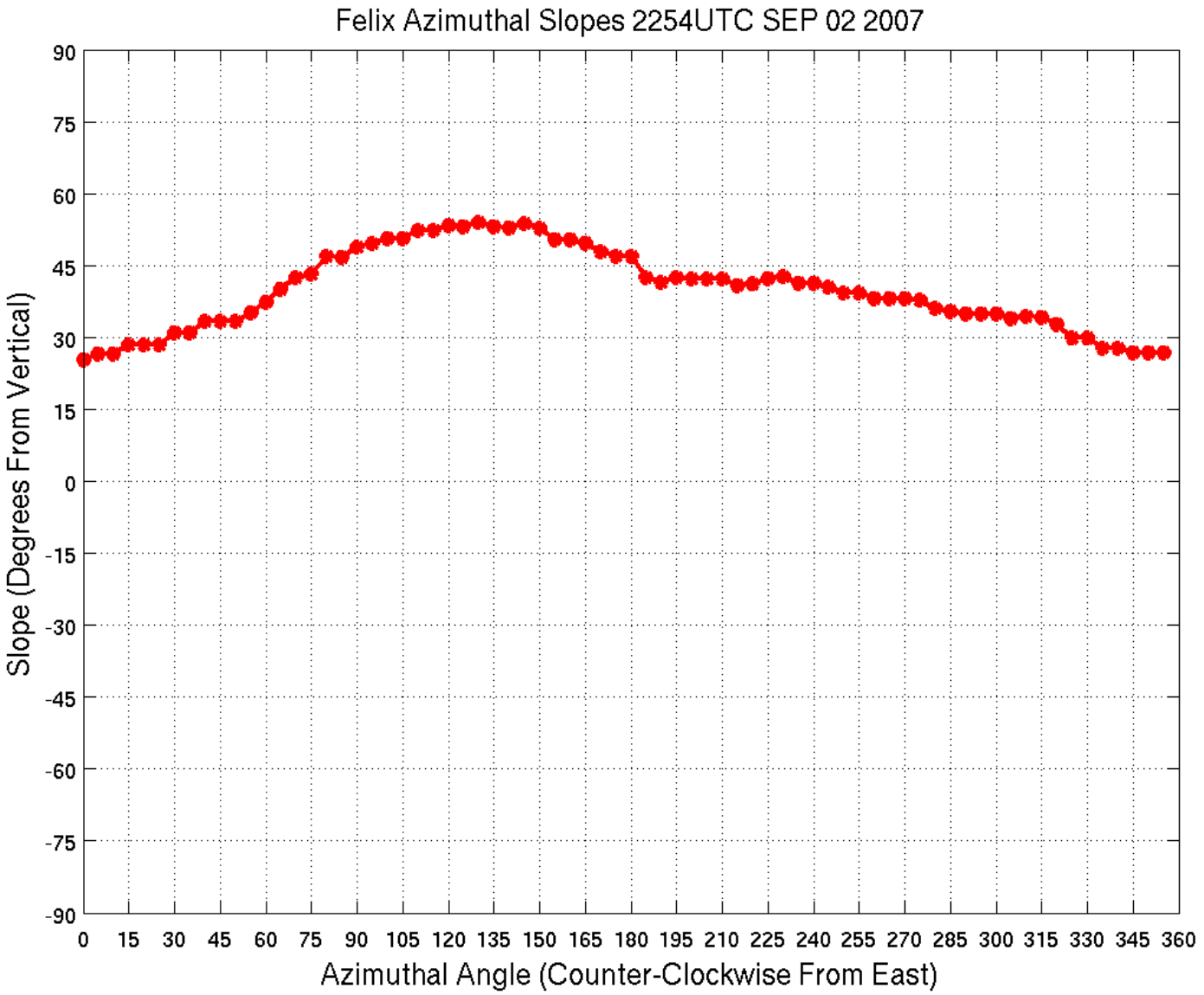
Variance: Examples of R(Slope, Intensity)



Pressure-Slope Lag



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

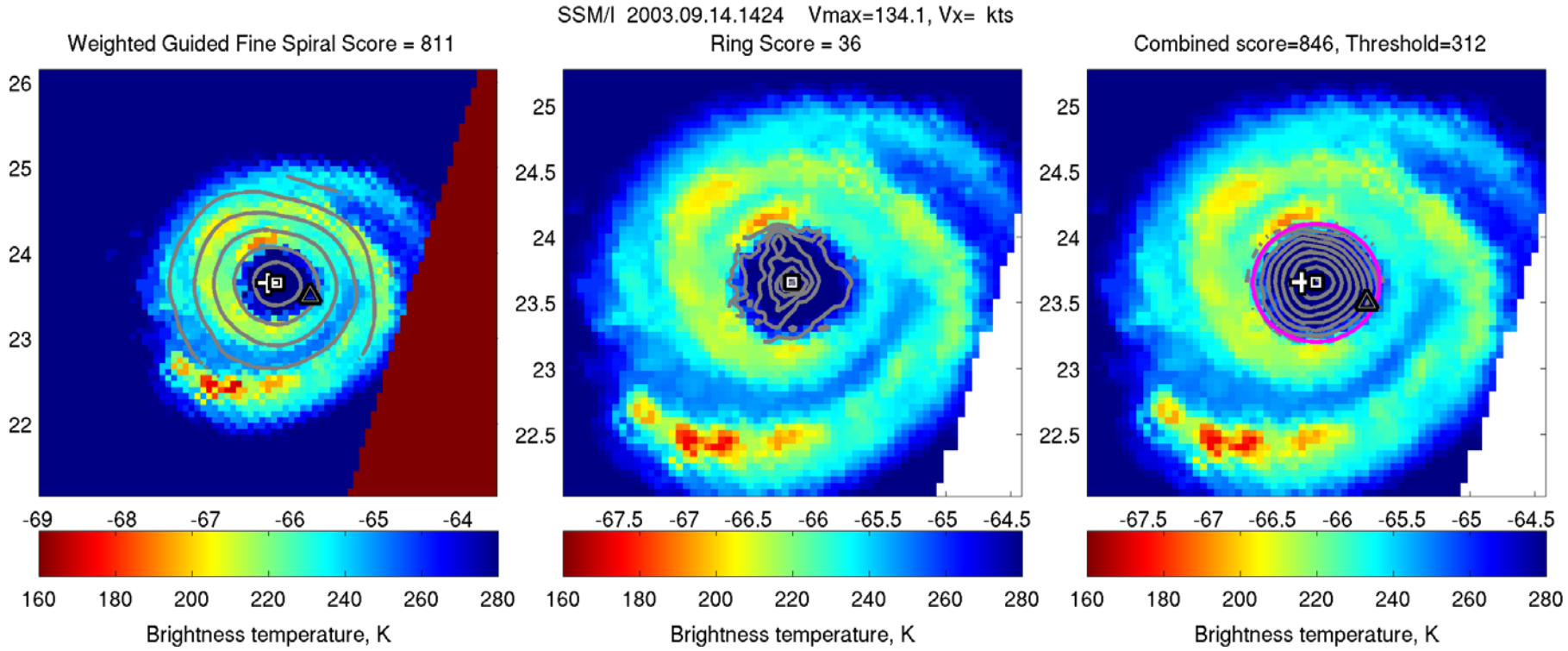
3: Global structure (Cossuth and Hart)

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

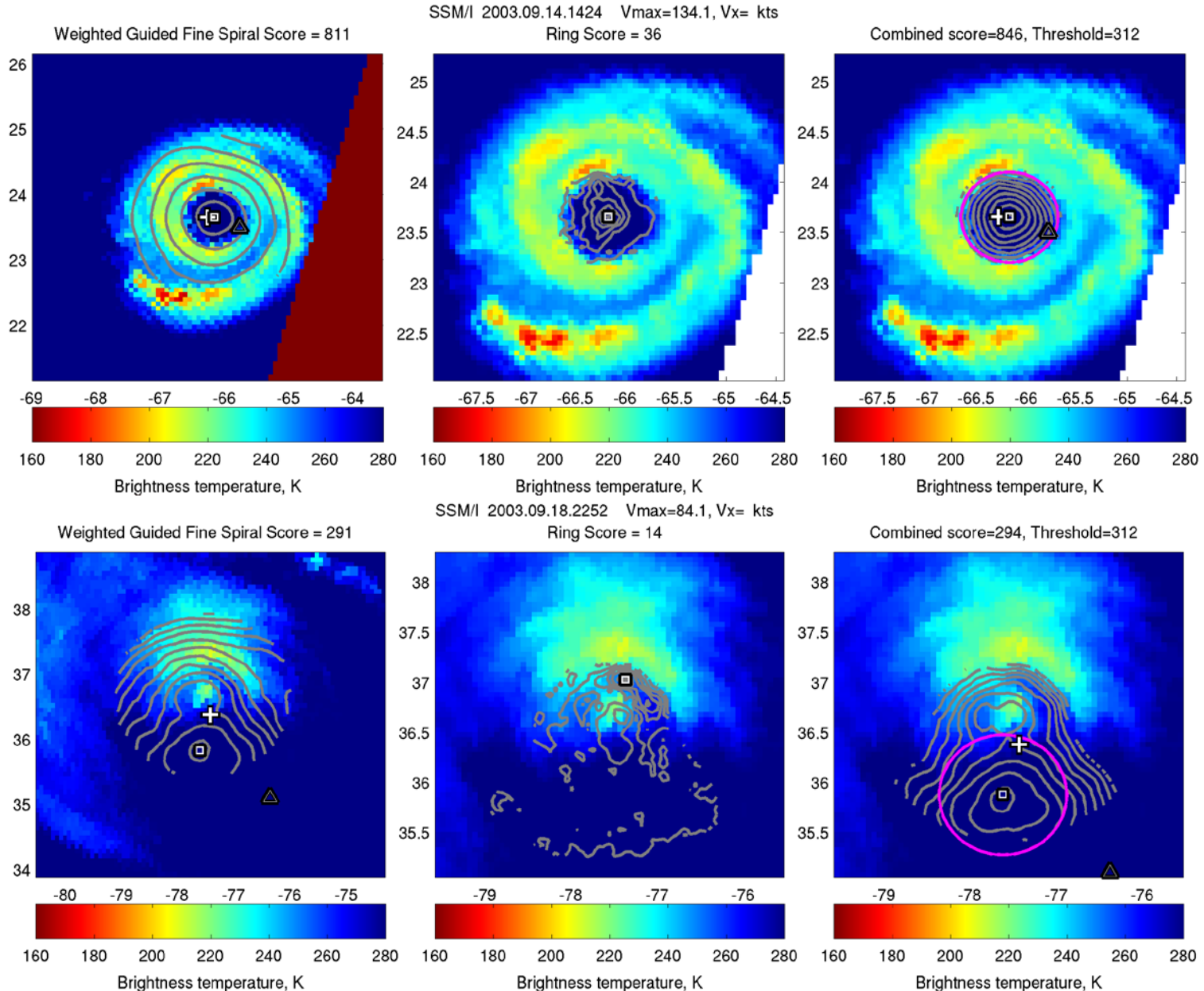
- Utilize the HURSAT satellite database (1987-2008) (Knapp 2010)

- Use ARCHER technique (Wimmers and Velden 2010) to objectively determine center and eye size

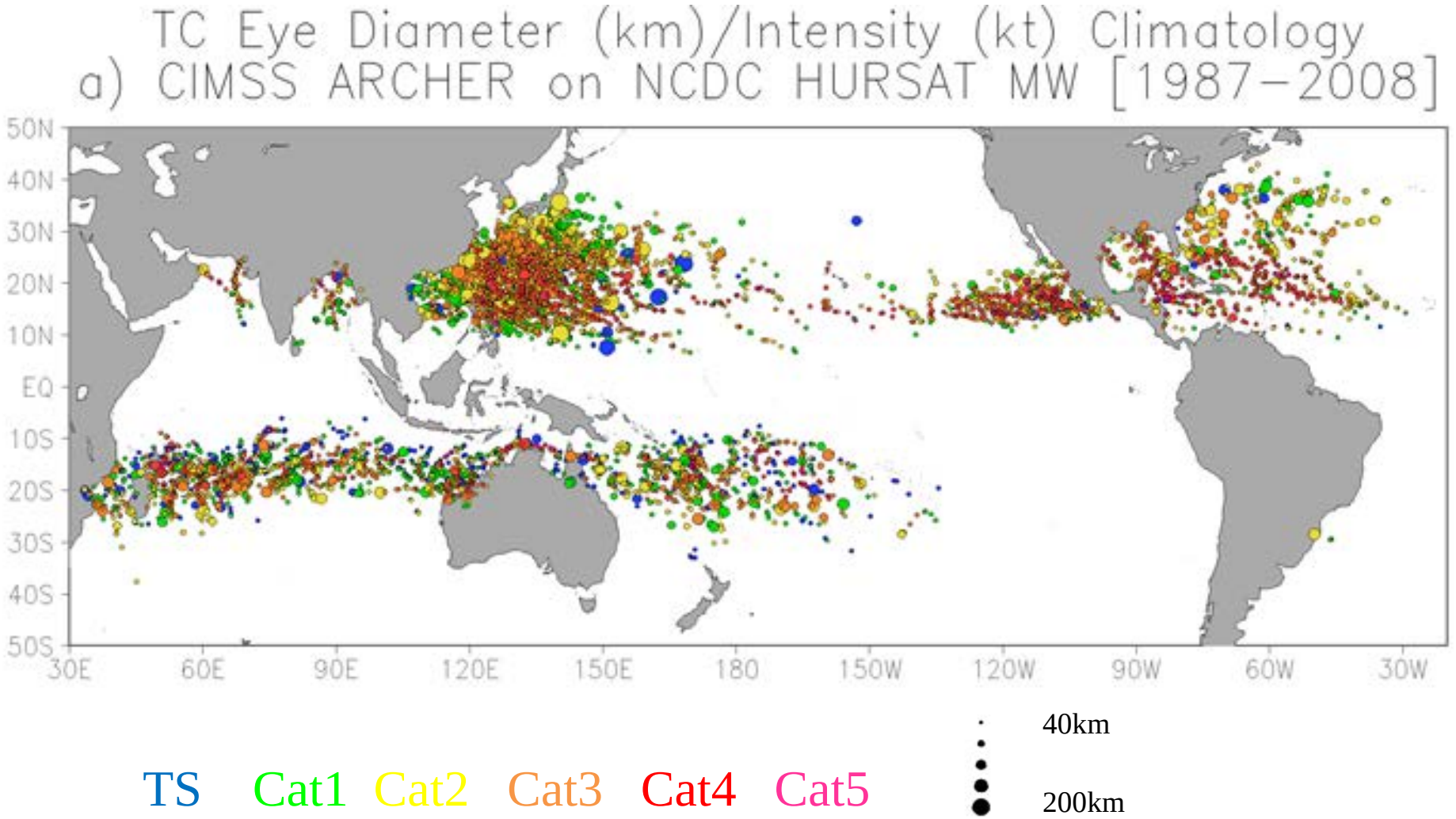
Example applications of ARCHER technique

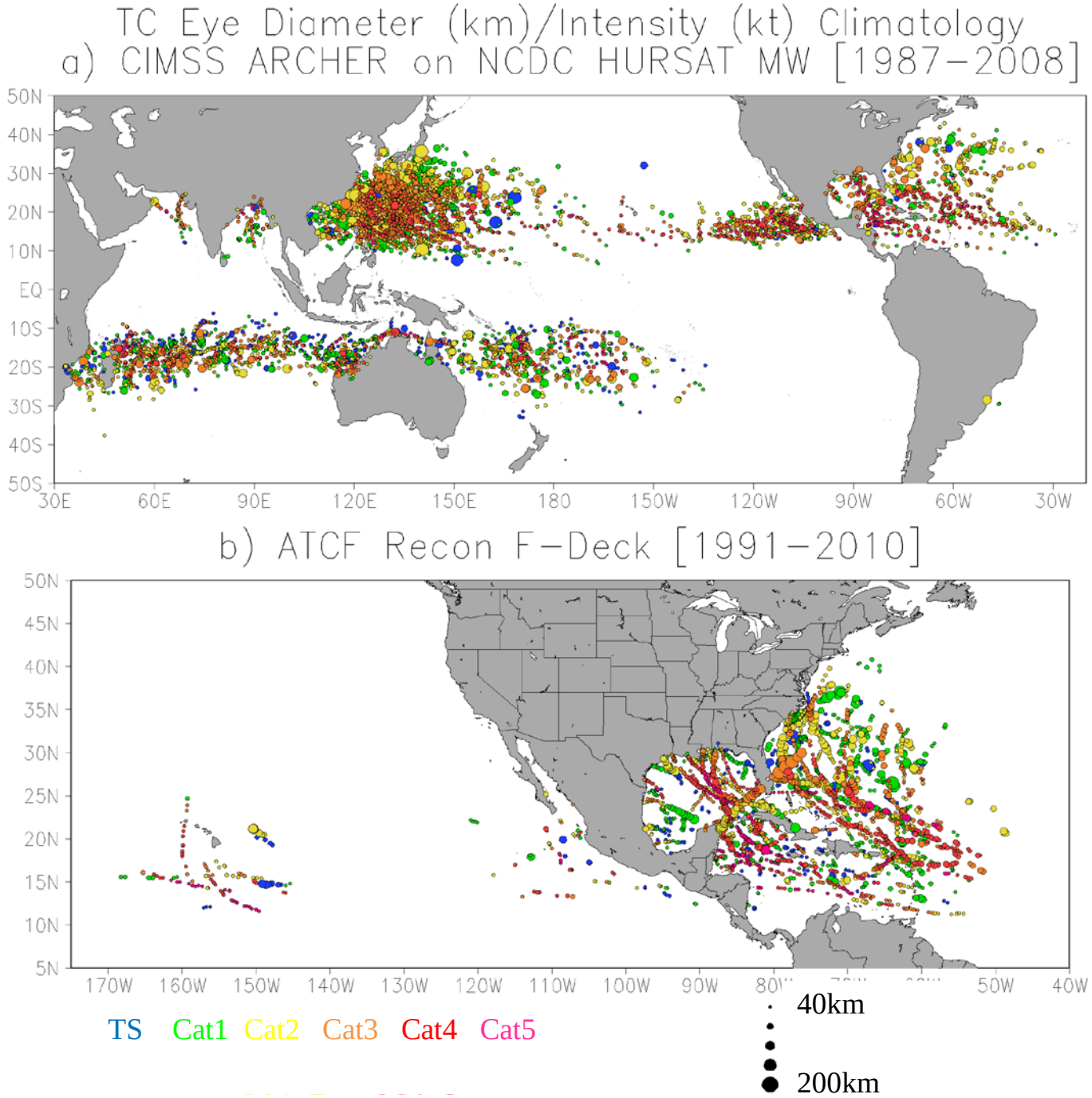


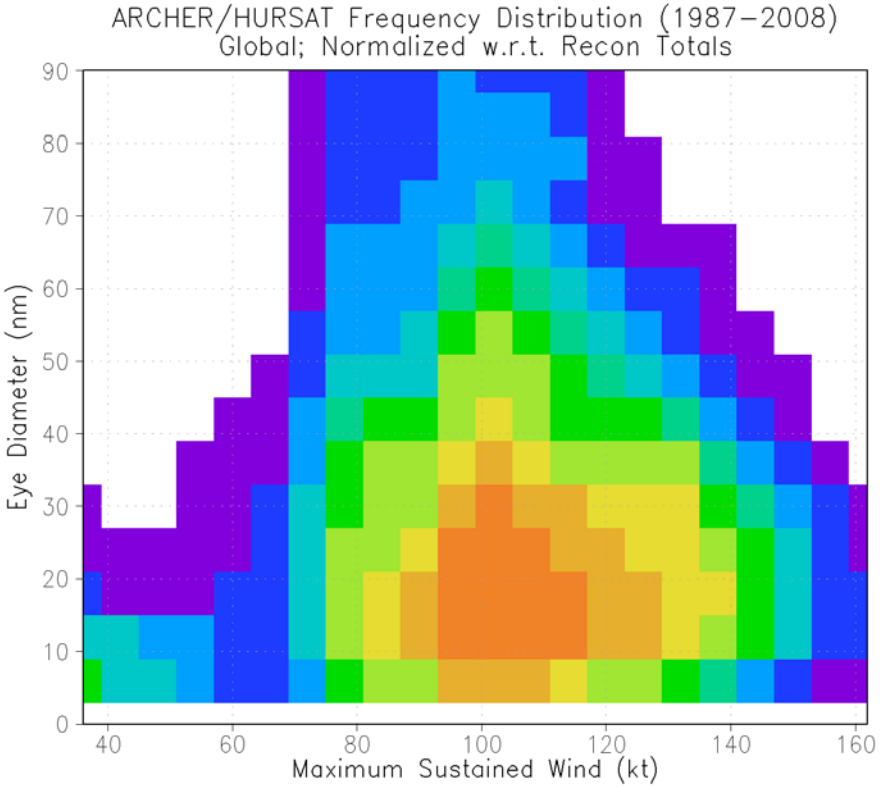
Example applications of ARCHER technique



Global satellite-based climatology of eye size and intensity

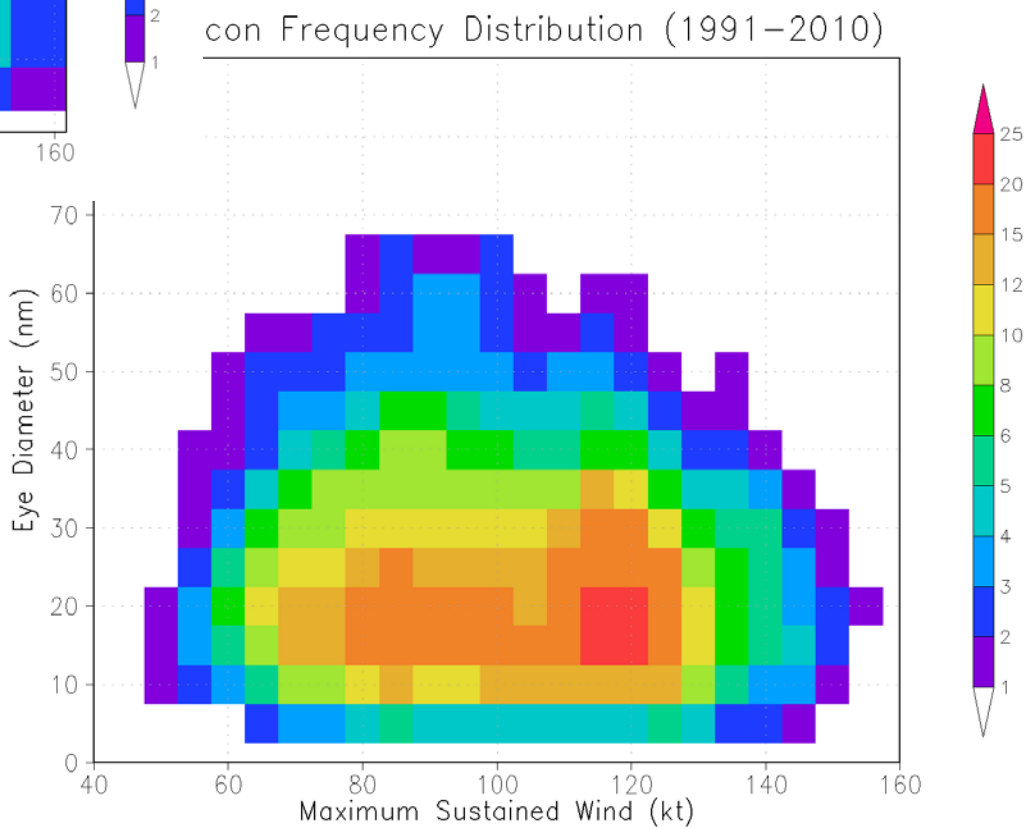



TC Eye Diameter (km)/Intensity (kt) Climatology
a) CIMSS ARCHER on NCDC HURSAT MW [1987–2008]
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
b) ATCF Recon F–Deck [1991–2010]
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
170W
160W
150W
140W
130W
120W
110W
100W
90W
80W
50W
40W
TS
Cat1
Cat2
Cat3
Cat4
Cat5
40km
200km



Global existence of satellite eye structure

- 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)

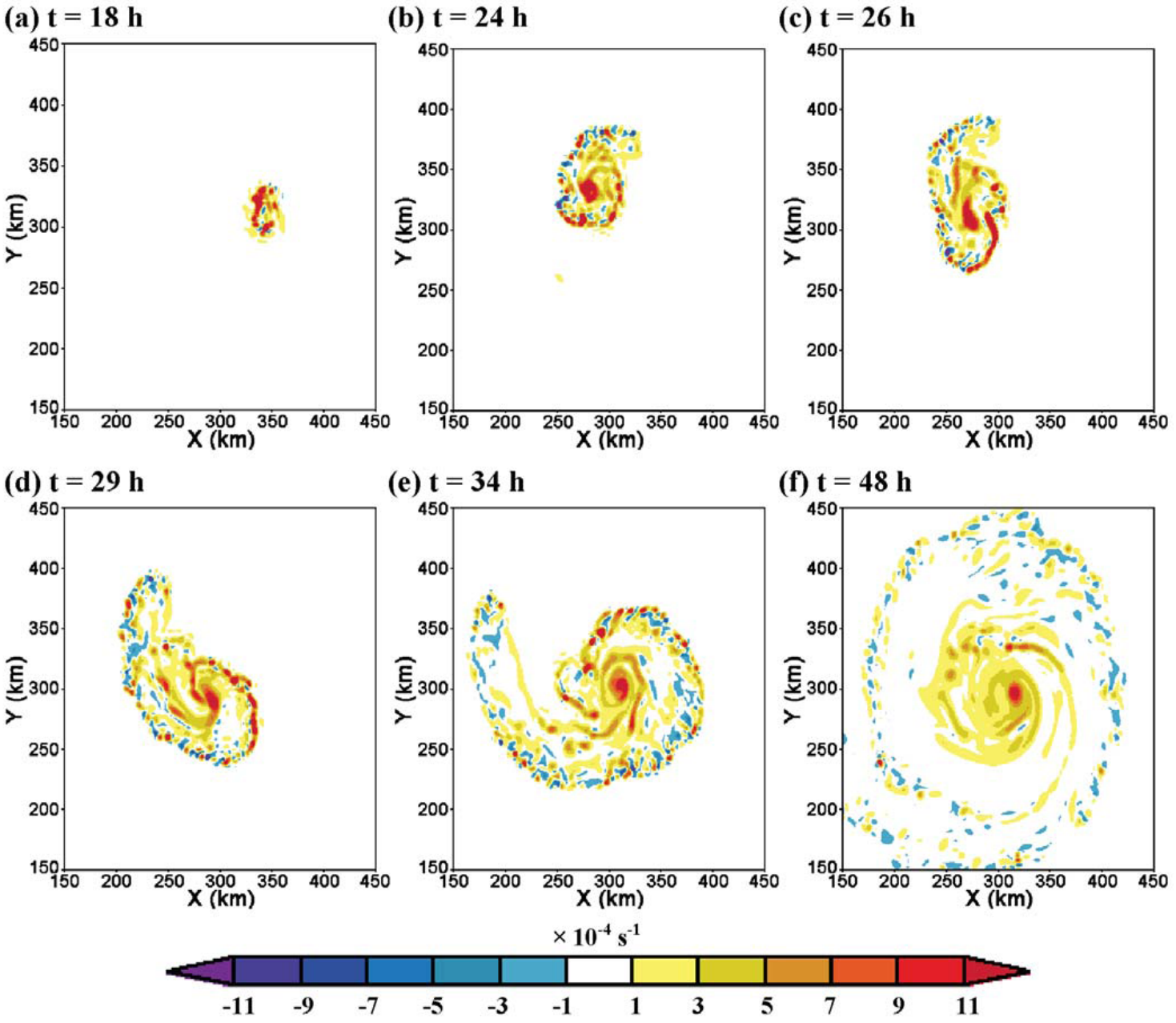
- Simulations of genesis often examine the evolution of vorticity and how the system grows from an upscale cascade

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

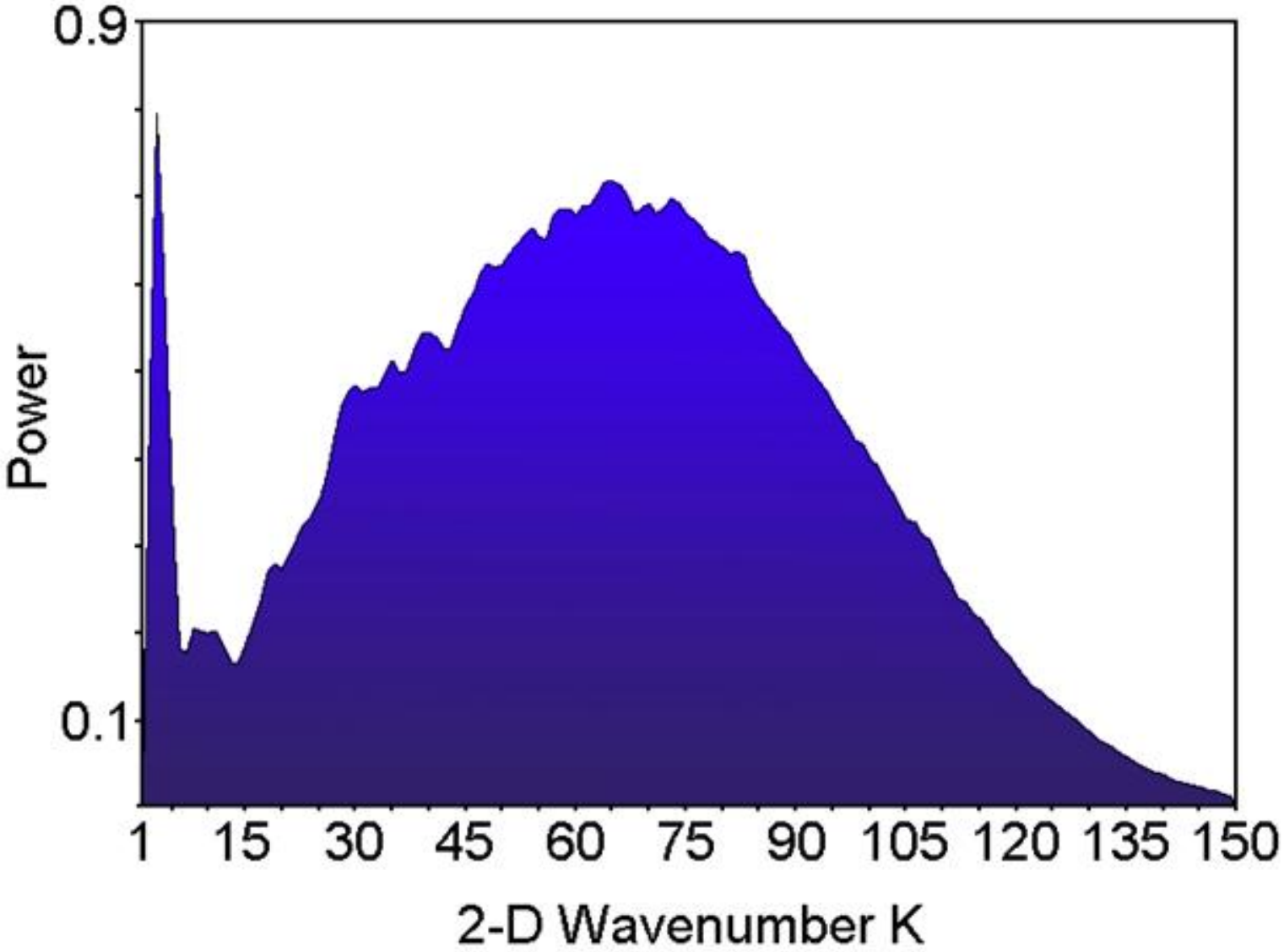
- This approach while elegant and simple is flawed, as the system itself has well-known asymmetries that should be considered part of the system, not the convective scale:
  - Wavenumber one beta-gyres
  - Wavenumber one and two asymmetries due to horizontal shear
  - Wavenumber one and two asymmetries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

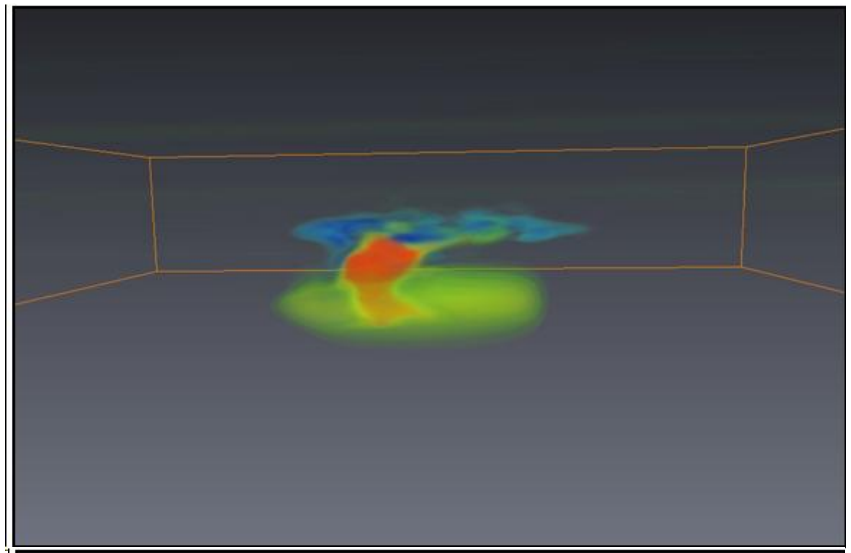
Vorticity evolution at 200m

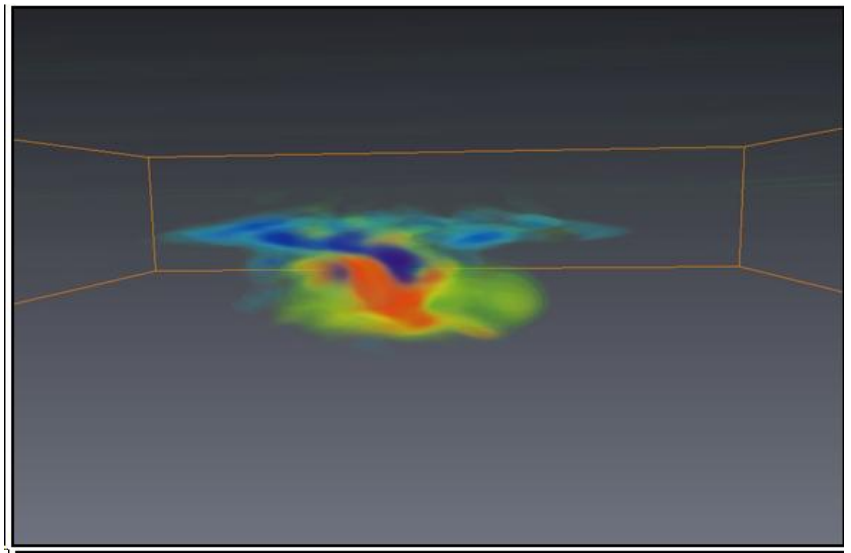


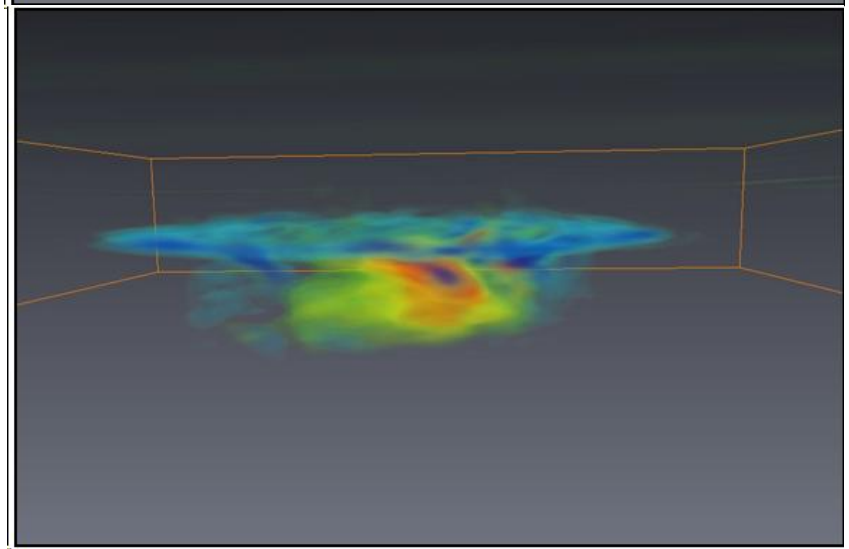
Power spectrum of vorticity at 200m for all times in the 48hr simulation

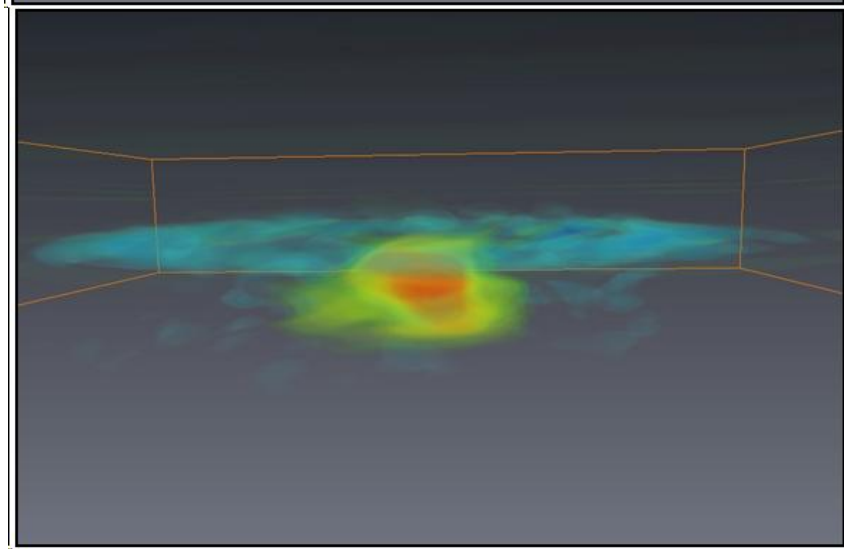


System-scale vorticity using filtering at 24, 29, 34, and 48hr









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