Ongoing efforts to assist operational TC genesis and structure forecasting: developing new aids

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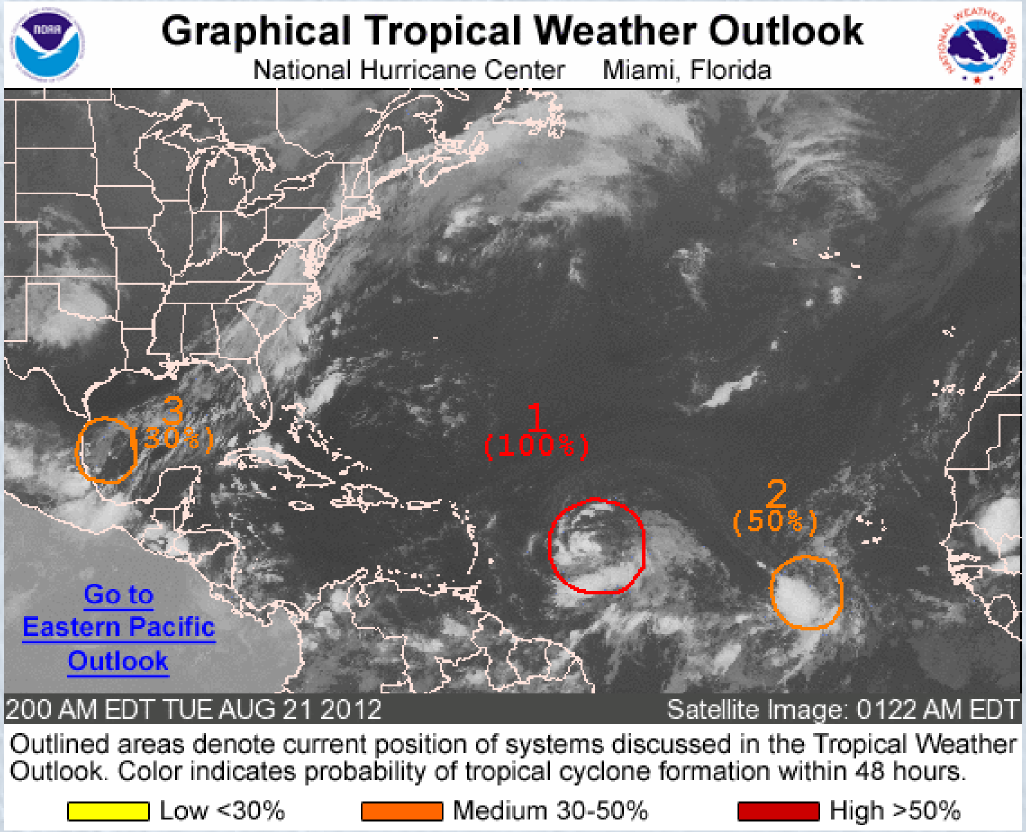
September 20, 2012

Scope of Presentation

- Tropical Cyclogenesis Guidance
  - Tropical disturbance database of operational Dvorak fixes
  - Using Dvorak classifications in other analysis schemes
  - Evaluating TC genesis from global model output
- Compiling a climatology of TC structure
  - Gathering and standardizing TC microwave data
  - Devising objective analysis techniques of the TC inner-core

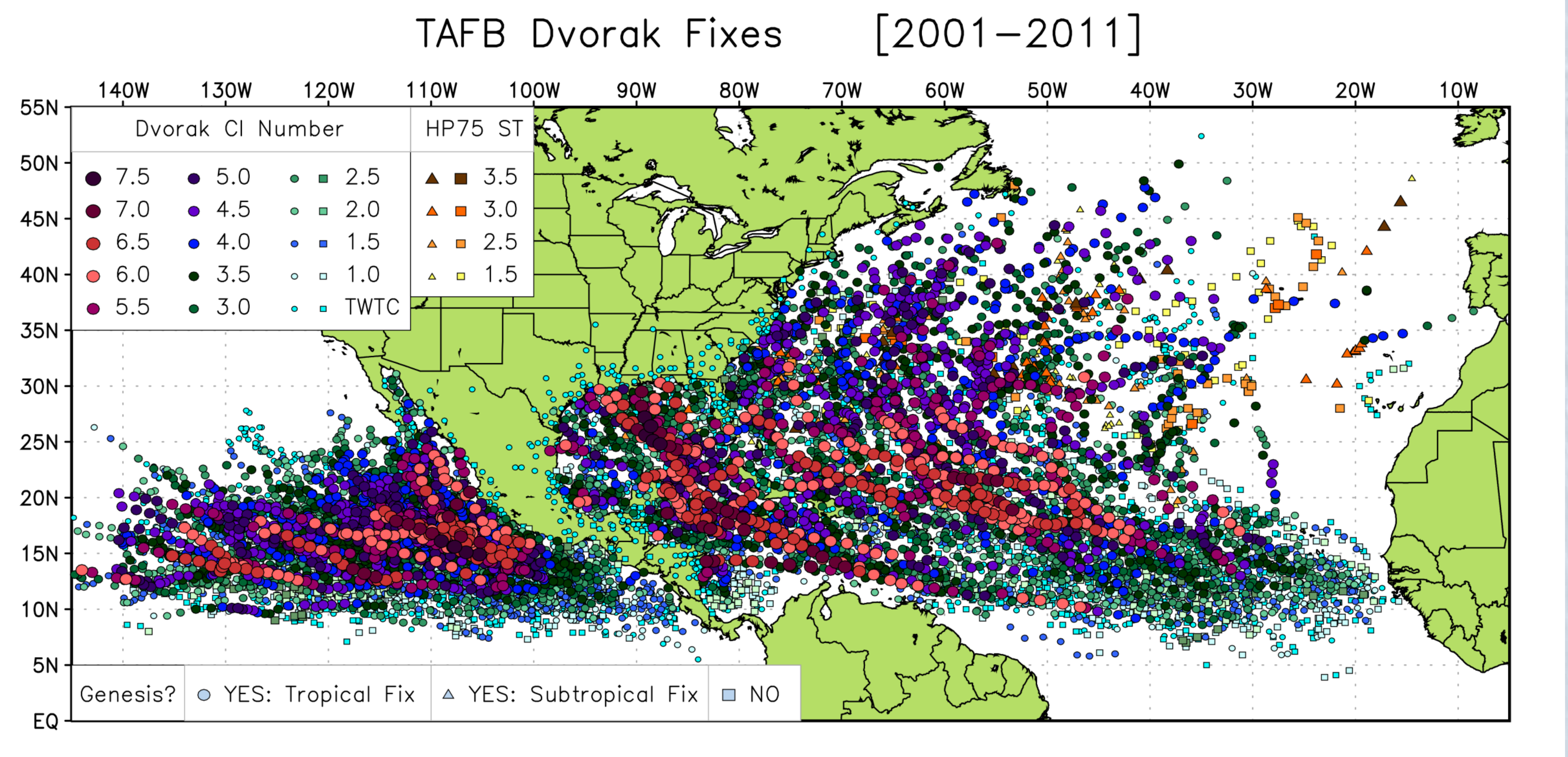
TC Genesis Motivation

- NHC routinely produces two probabilities of TC formation:
  - Public 0-48 hour probabilities in 10% intervals, as shown in the Graphical Tropical Weather Outlook
  - In-house experimental 48-120 hour probabilities in 10% intervals.
- Dvorak analyses:
  - Regularly performed by TAFB for tropical disturbances of interest
  - Estimate a tropical system's intensity by levels of organization
  - Routinely cited in TC discussions as a factor that influences intensity and genesis decisions

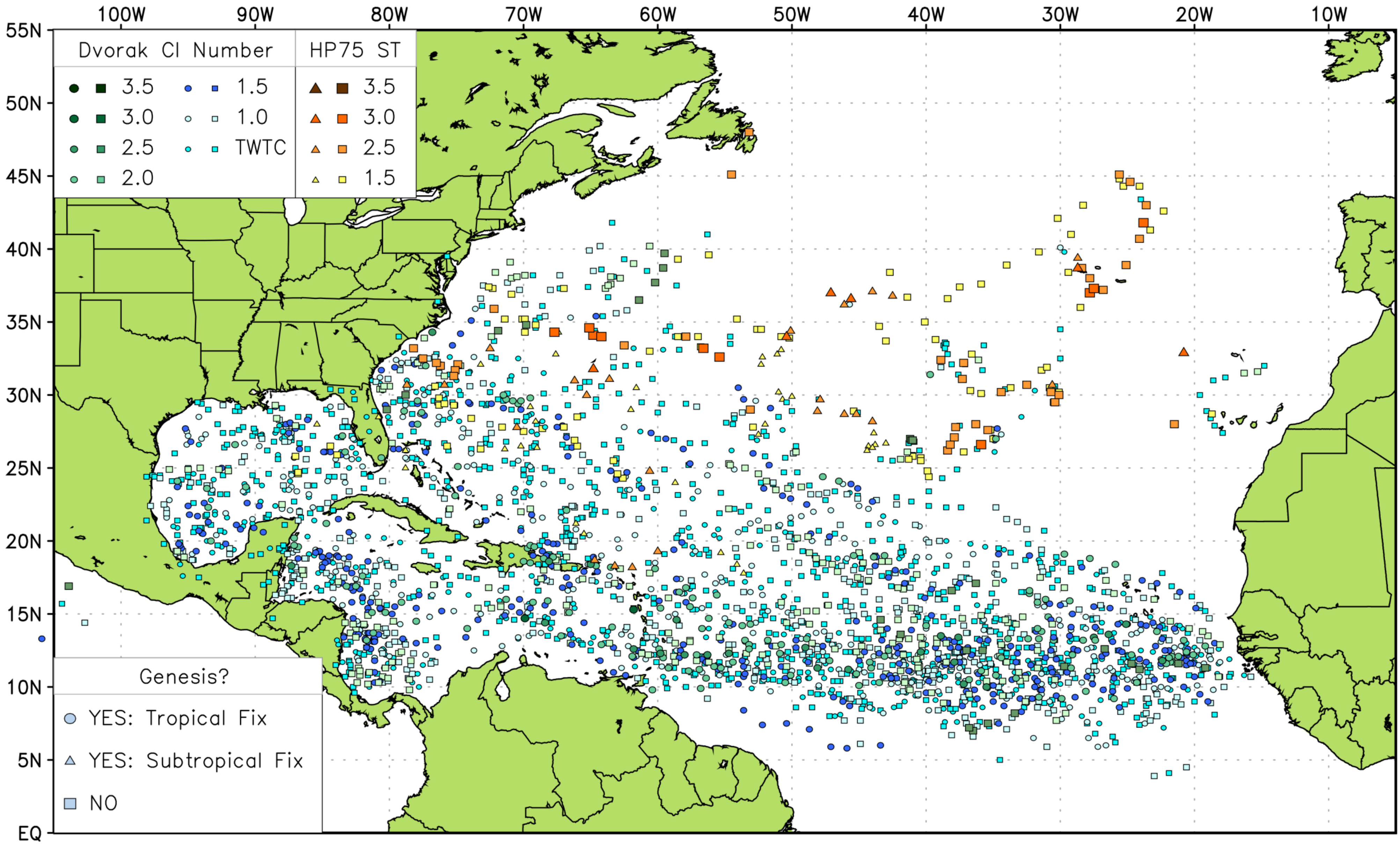


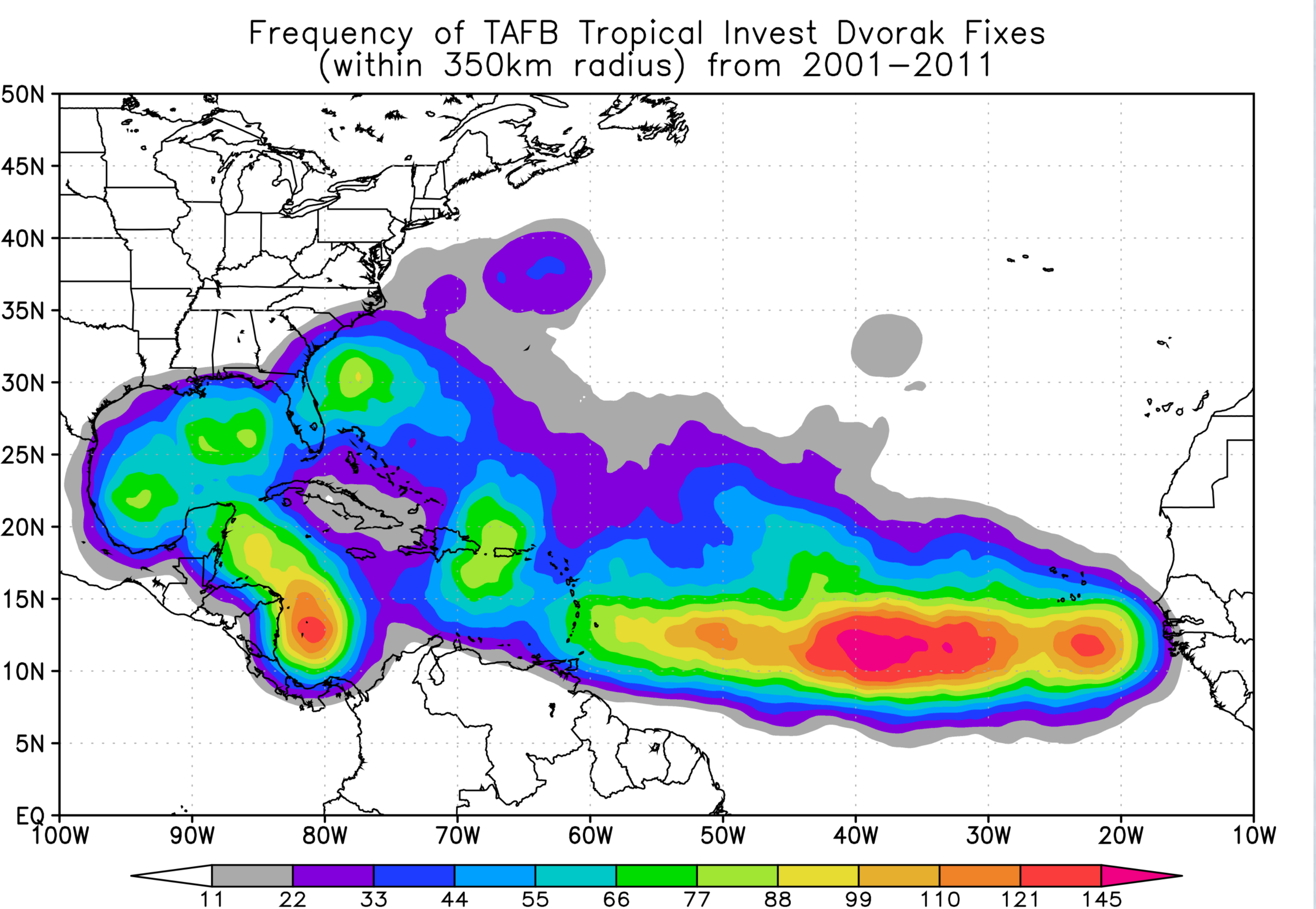
Dvorak Analysis Climatology

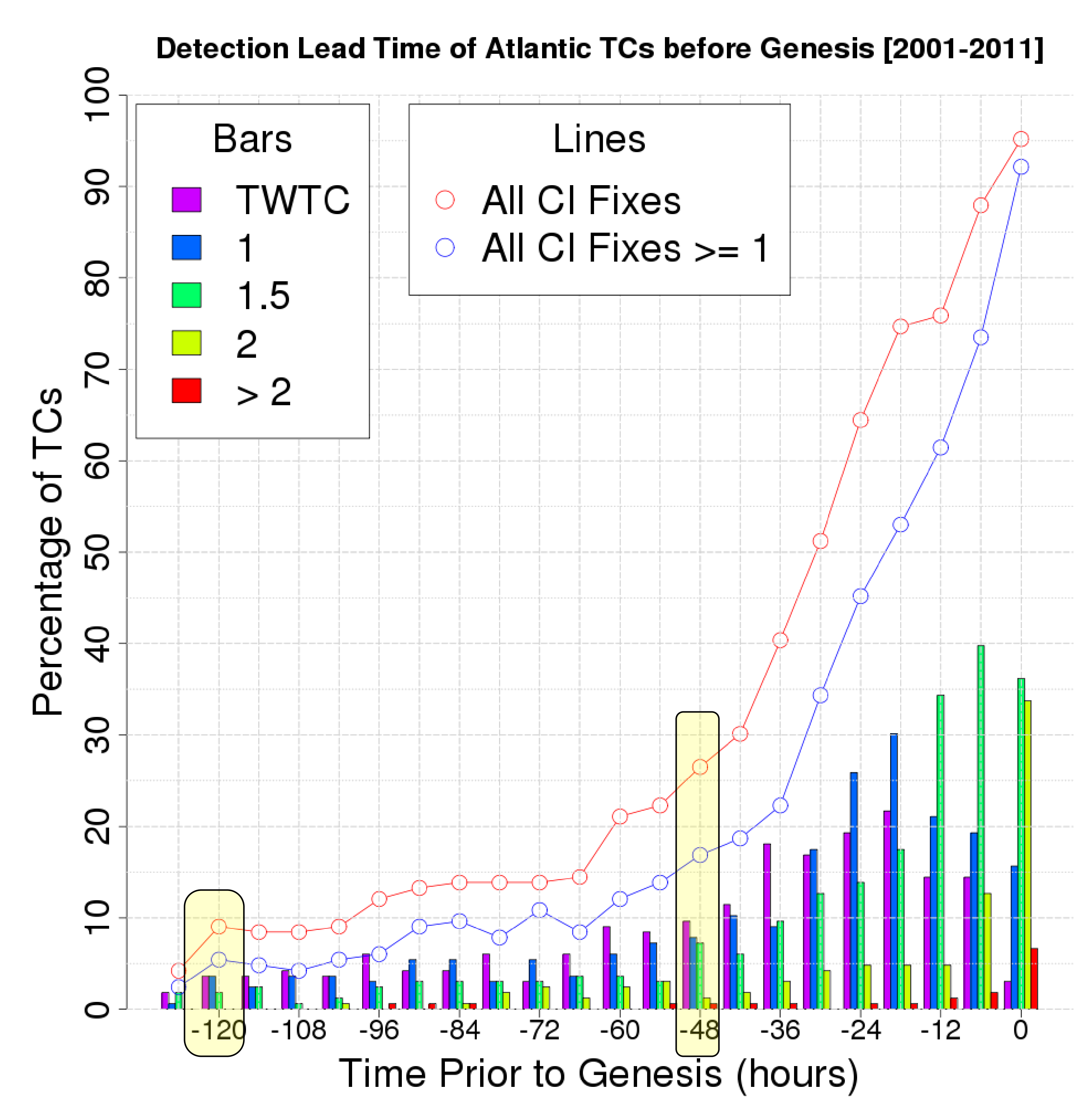
- In collaboration with Rick Knabb, Dan Brown, and Bob Hart
- For brevity, the following slides will only show the Atlantic



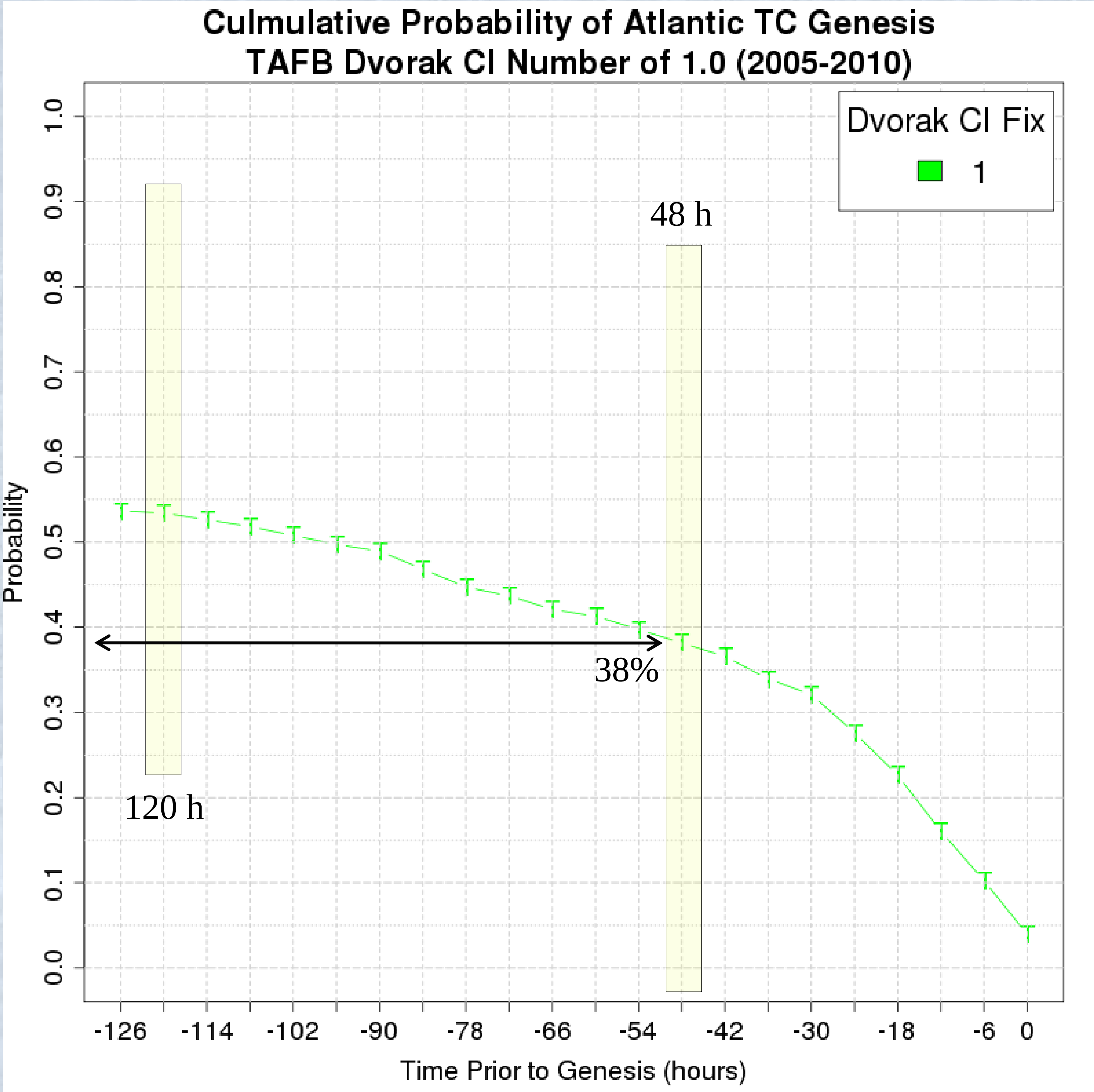
TAFB Atlantic Disturbance Dvorak Fixes [2001–2011]




Frequency of TAFB Tropical Invest Dvorak Fixes
(within 350km radius) from 2001–2011
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
100W
90W
80W
70W
60W
50W
40W
30W
20W
10W
11
22
33
44
55
66
77
88
99
110
121
145

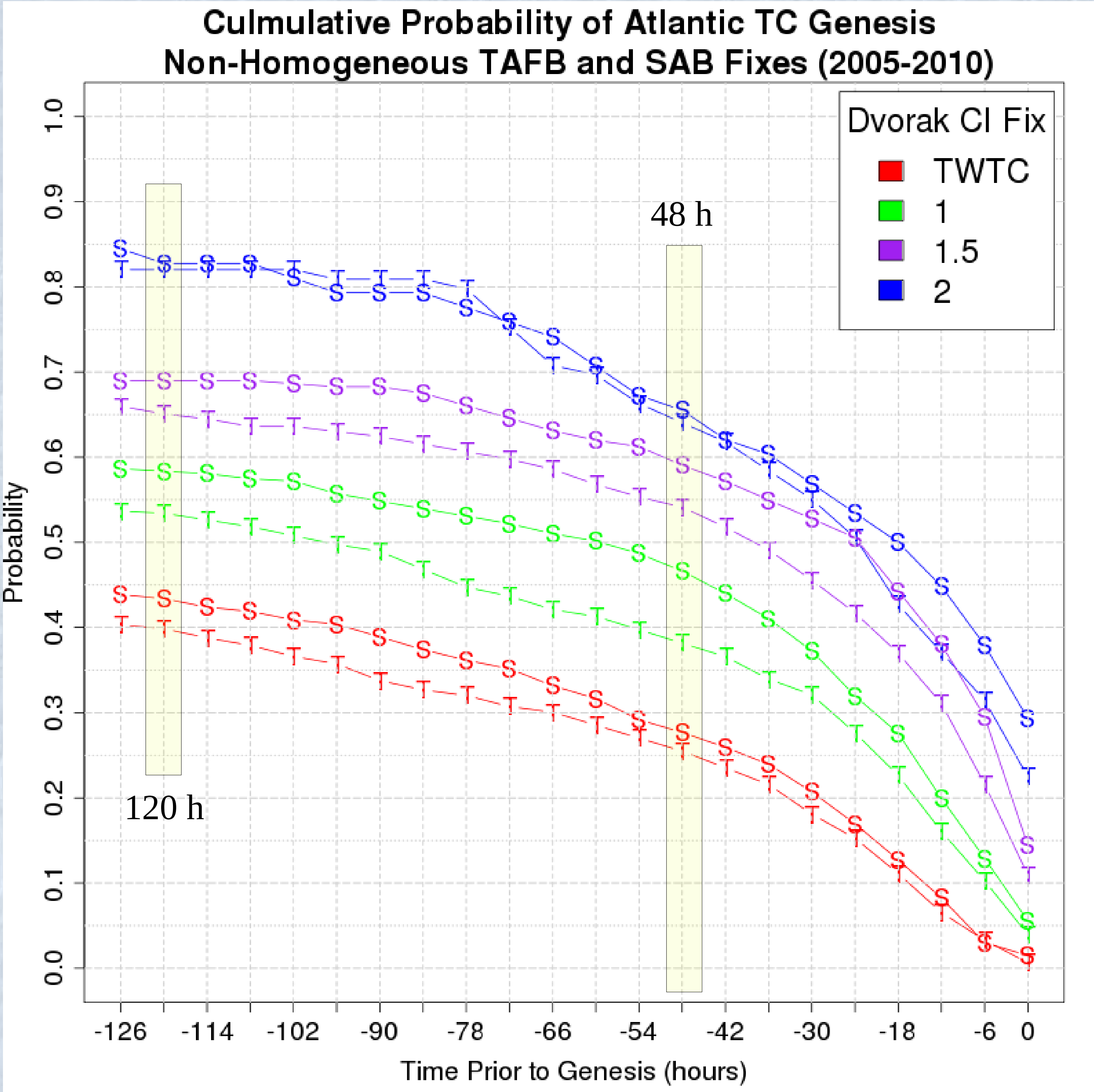


- Showing only TCs before genesis, this graph depicts how often Dvorak analyses are available.
- Only about 1/4 (1/10) of TCs have a Dvorak position or intensity at 48 h (120 h) ahead of best track genesis
- At genesis (0 h), there is a wide range of Dvorak fixes (mostly 1.5 and 2.0).



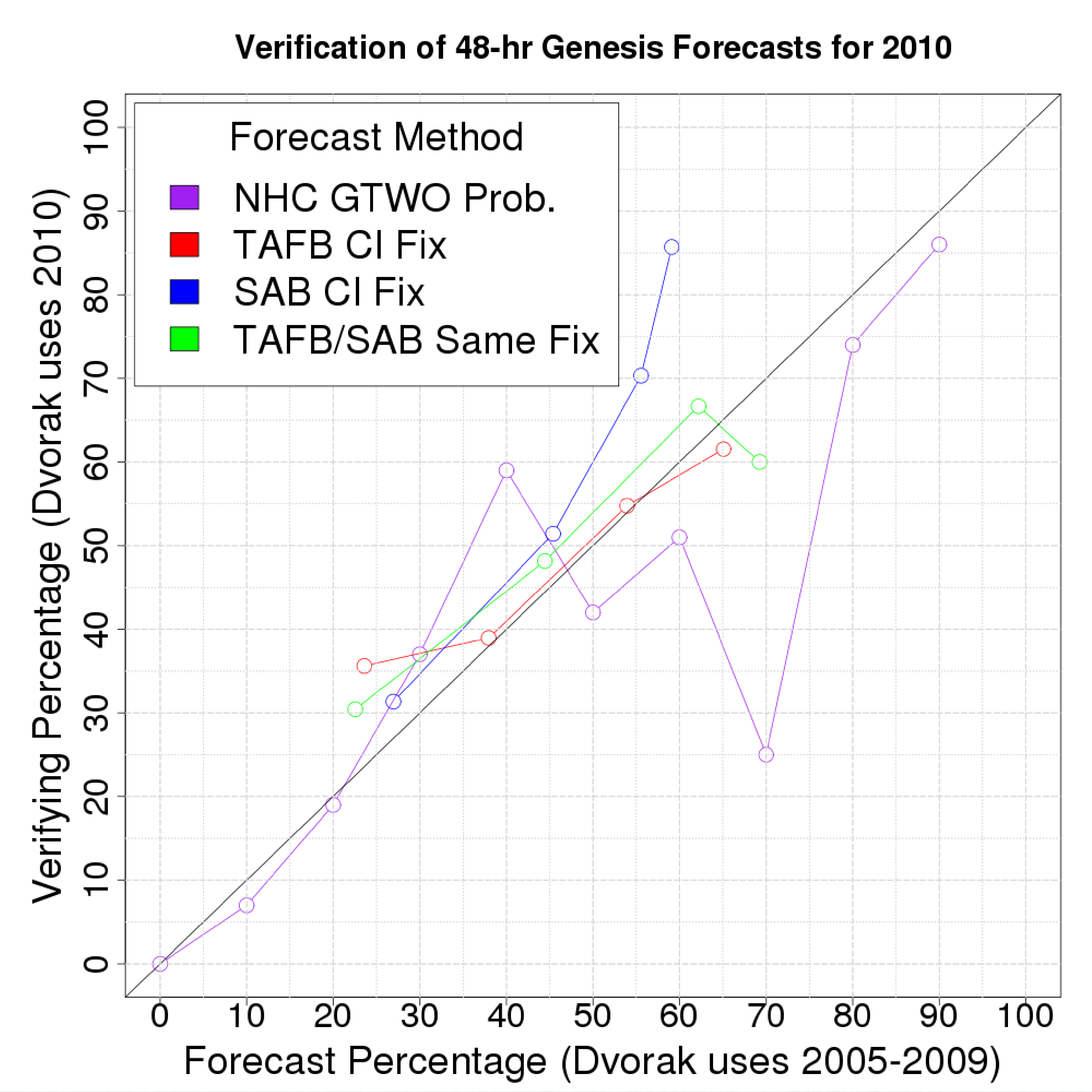
Example Graph:

- Each point shows the probability of genesis (on the ordinate) given a 6-hourly lead time (on the abscissa).
- In this case, the ‘T’ represents TAFB fixes while the green color corresponds to a CI number of 1.0.

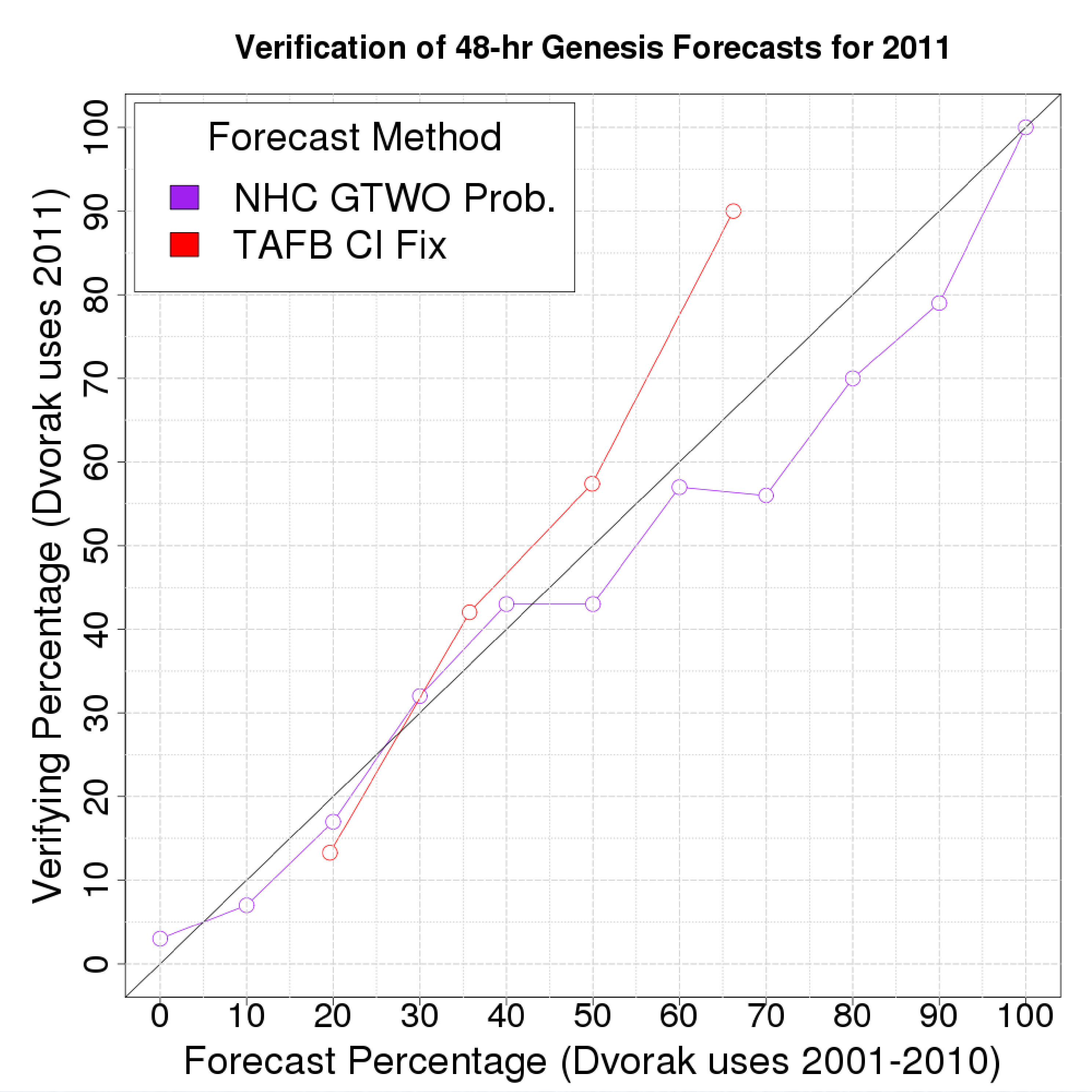


The probabilities of genesis from TAFB (T) and SAB (S) uses all available data from each respective agency.

SAB probabilities are generally higher either due to missing data or fewer Dvorak fixes (especially on non-developing storms).

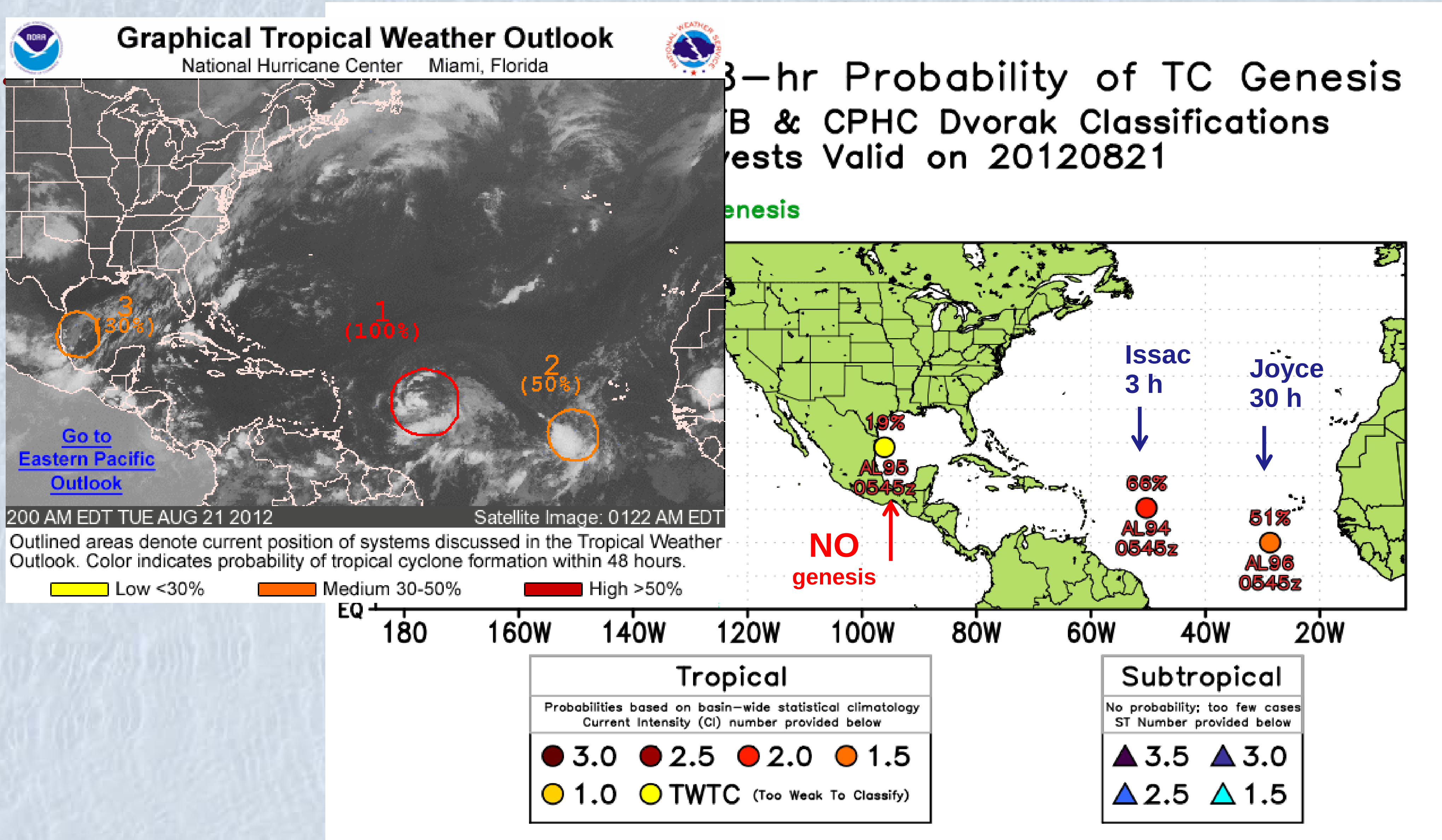


- Dvorak forecasts (especially from TAFB) show comparable skill to NHC forecasts.
- Probabilities using Dvorak analysis may be used to augment NHC performance in the more difficult middle percentage ranges.



- NHC performance very good in 2011
- Dvorak-based probabilities show a low bias for non-TWTC estimates.

Real Time Dvorak Guidance



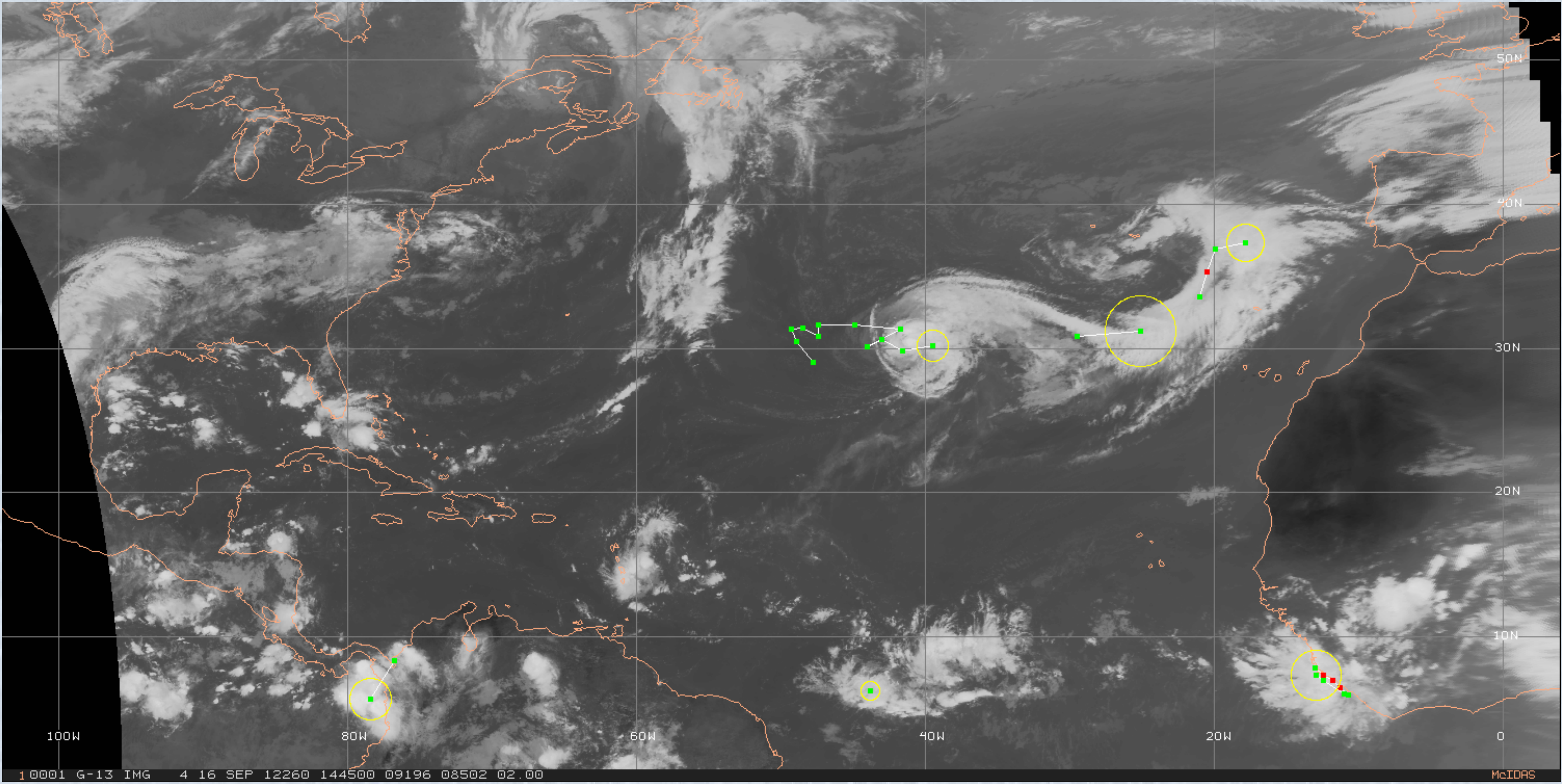
Dvorak as a predictor in the current JHT Statistical Genesis Scheme

- Collaboration with Jason Dunion, John Kaplan, Andrea Schumacher, and Mark DeMaria
- Disturbance-centric probabilities with data from operational Dvorak estimates, SHIPS, NESDIS TCFP product, and Total Precipitable Water.
- Table at right shows predictors with highest skill at differentiating developing and non-developing disturbances. (Dunion et al. JHT End of Year 1)

Predictor	Non-Developing	Developing	Dev - Non-Dev (sd units)
TNUM	0.85	1.38	1.06
DT24	-0.06	0.47	1.02
CNUM	0.89	1.41	1.00
DC24	-0.04	0.48	0.98
DT12	-0.06	0.32	0.97
DC12	-0.04	0.32	0.92
HDIV	-0.08	-0.23	-0.75
DV12	-0.16	0.03	0.68
DV24	-0.34	0.02	0.65
RVOR	1.54	2.31	0.64
VSHD	18.85	13.02	-0.61
MLRH	61.94	70.25	0.58
CPRB	0.27	0.43	0.55

CIMSS ADT Front-end

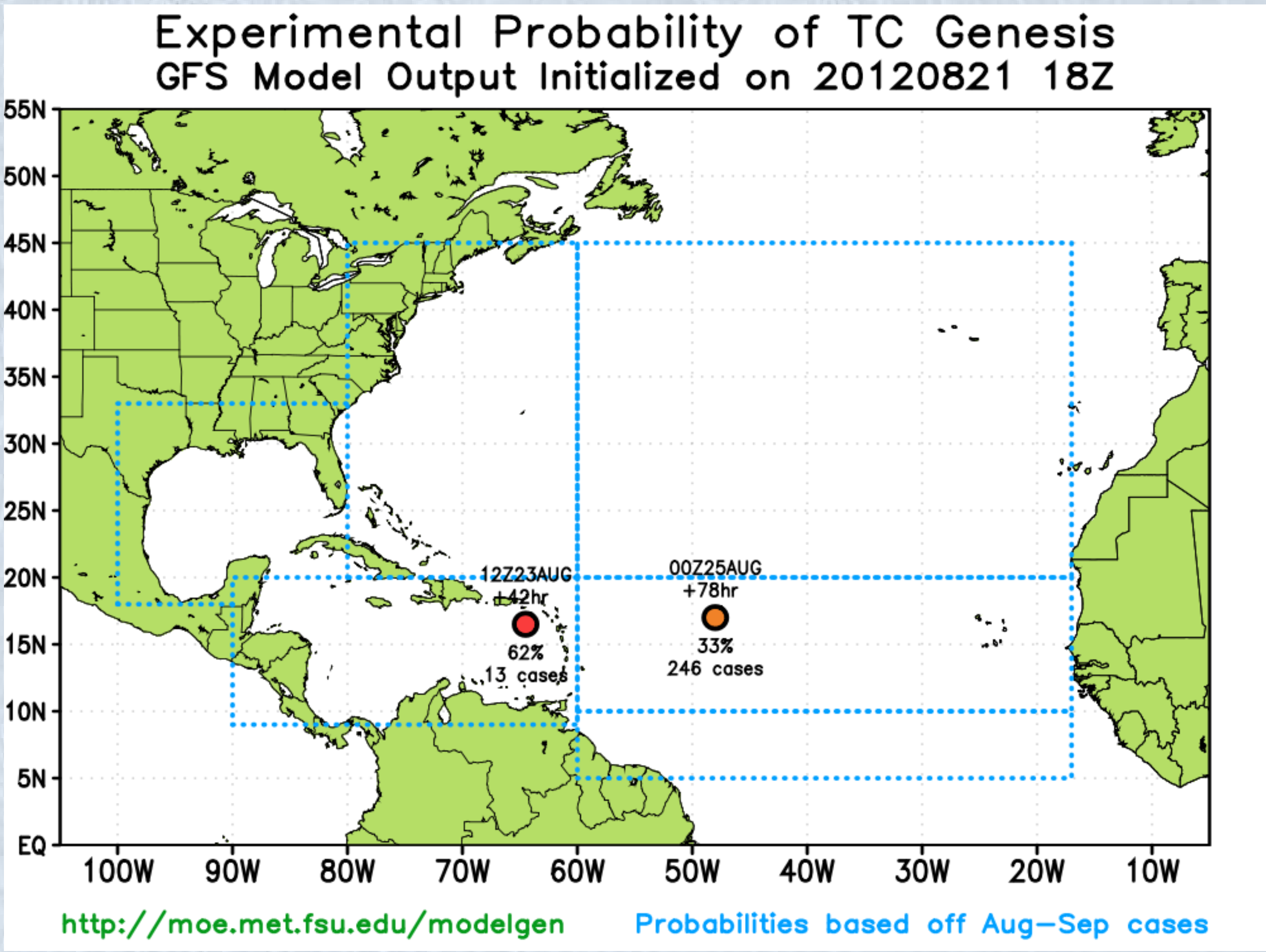
- Collaboration with Chris Velden, Tim Olander, Chris Hennon, Chip Helms
- Use operational Dvorak estimates to constrain an automated tracking and intensity estimation algorithm.



TC Genesis from Global Models

- Work by Dan Halperin; in collaboration with Henry Fuelberg, Bob Hart, Richard Pasch, Josh Cossuth, and Phillip Sura

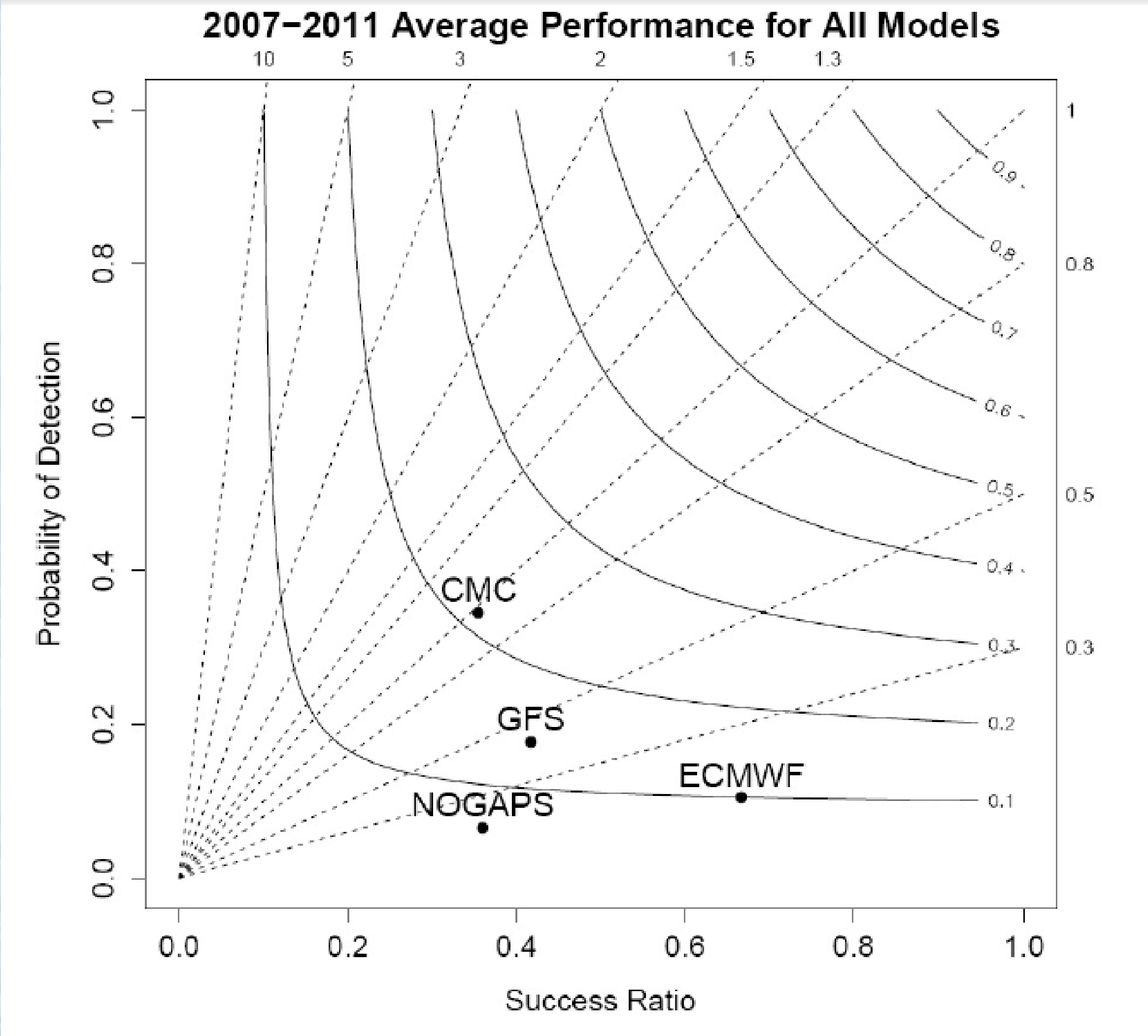
- Genesis guidance and verification using GFS, NOGAPS, CMC, UKMET, and ECMWF models
- Genesis defined by:
  - MSLP minimum
  - 850 hPa rel. vort. max.
  - 250-850 hPa thickness max.
  - 925 hPa wind speed
  - Criteria met for 24 hours
- Real-time probabilities available online at FSU



TC Genesis from Global Models

- Work by Dan Halperin; in collaboration with Henry Fuelberg, Bob Hart, Richard Pasch, Josh Cossuth, and Phillip Sura

- Dashed line represents bias = (hits + false alarms) / (hits + misses).
  - Lower values indicate an under-prediction of genesis frequency
- Solid curved lines show the Critical Success Index = number of hits / (hits + false alarms + misses)
  - Lower values indicate fewer genesis occurrences, given the total frequency of events
- Note: UKMET events currently being calculated

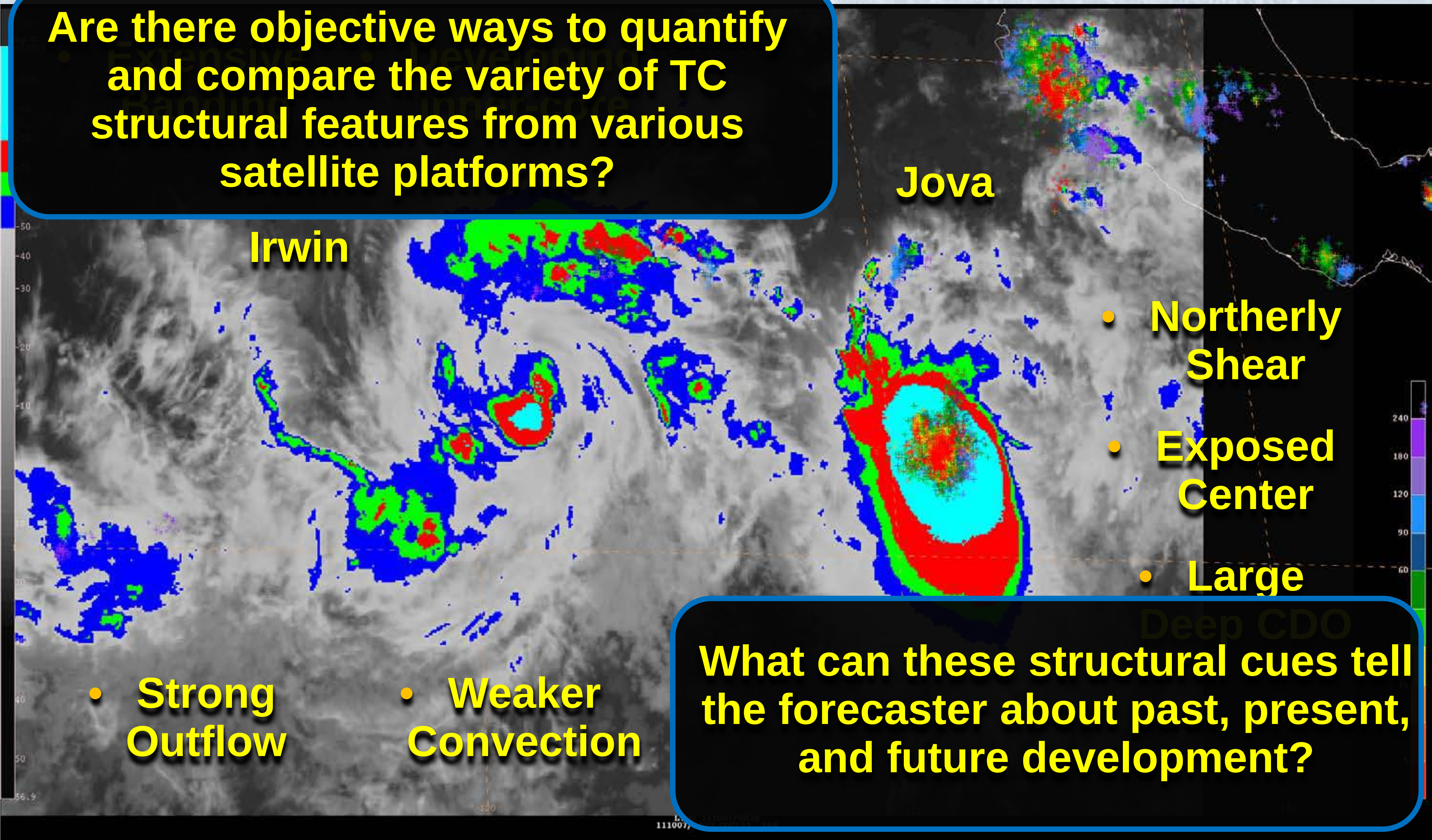


Switching Topics

- Tropical Cyclogenesis Guidance
  - Tropical disturbance database of operational Dvorak fixes
  - Using Dvorak classifications in other analysis schemes
  - Evaluating TC genesis from global model output
- **Compiling a climatology of TC structure**
  - **Gathering and standardizing TC microwave data**
  - **Devising objective analysis techniques of the TC inner-core**

Motivation

0030z, 7 October 2011 *Image Courtesy: Jack Beven, IHC 2012*



Motivation

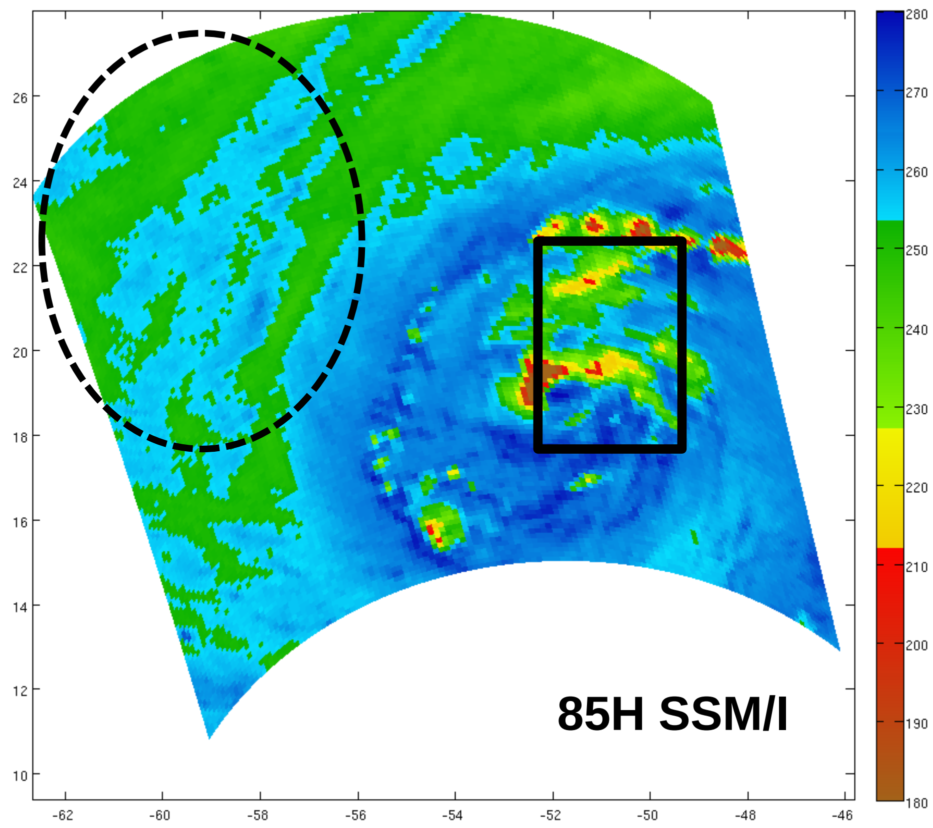
- **A comprehensive climatology of TC structural features does not yet exist.**
  - Archives of aircraft missions provide the largest repository of structural information on TCs (e.g. eye size, wind maxima, thermodynamic extrema, radar and microwave sensors)
  - Structural signals (e.g. Sitkowski et al. 2011) provide insight into TC evolution and intensity change, and is implicitly used (e.g. Dvorak technique, SHIPS, “annular” hurricanes)
  - The following shows our first steps towards:
    - Compiling a global database of TC microwave imagery
    - Objectively defining and delineating structural regimes in TCs using microwave frequencies.

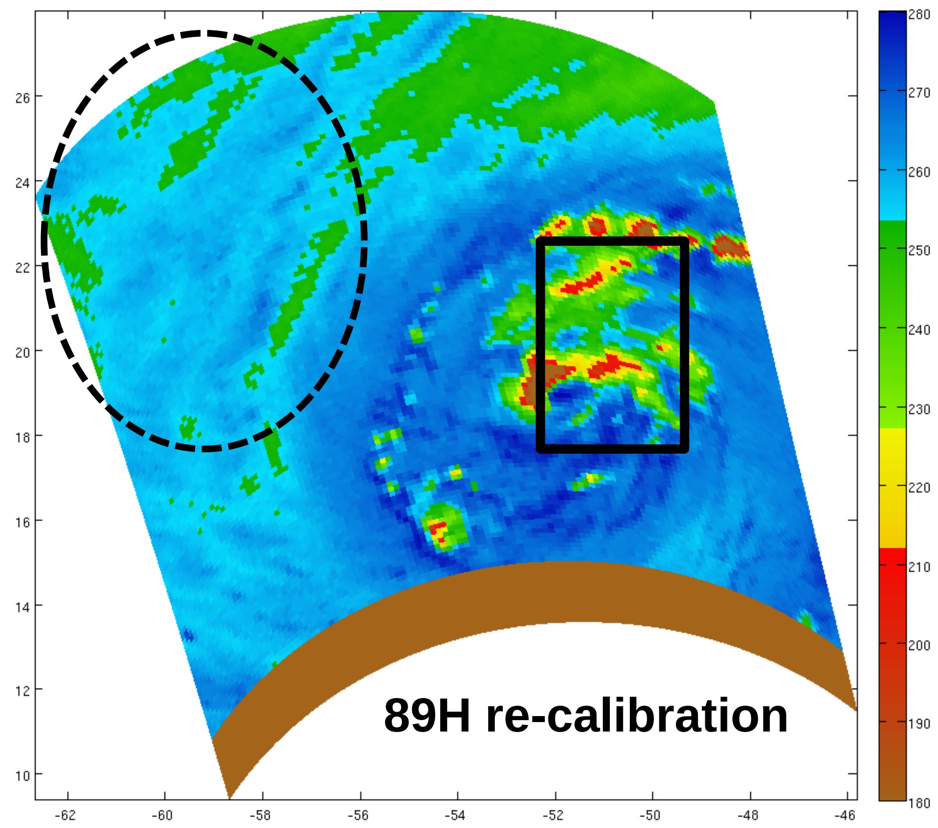
Methodology

- **Creation of a TC Microwave data archive**
  - **Data**: CSU SSM/I (F08, F10, F11, F13, F14, F15) and SSMIS (F16, F17, F18); NASA AMSR-E (Aqua); NASA TMI (TRMM)
  - **Processing:** Standardize ice scattering channels to 89GHz; Backus-Gilbert optimal interpolation to enhance resolution
  - In collaboration with NRL-Monterey: Jeff Hawkins, Song Yang, Kim Richardson, Mindy Surratt, and Jeremy Solbrig
- **Other data and techniques:**
  - HURSAT (Knapp 2008) TC-centered SSM/I (1987-2008; worldwide)
  - TC center first guess by linearly interpolated NHC/JTWC best track
  - ARCHER analysis (Wimmers and Velden 2010) applied to more precisely find satellite-based center location and eye/eyewall size
    - New center must pass an empirical threshold in order to be used
  - Later in presentation – efforts toward an objective eye/core size

Re-calibration to 89GHz

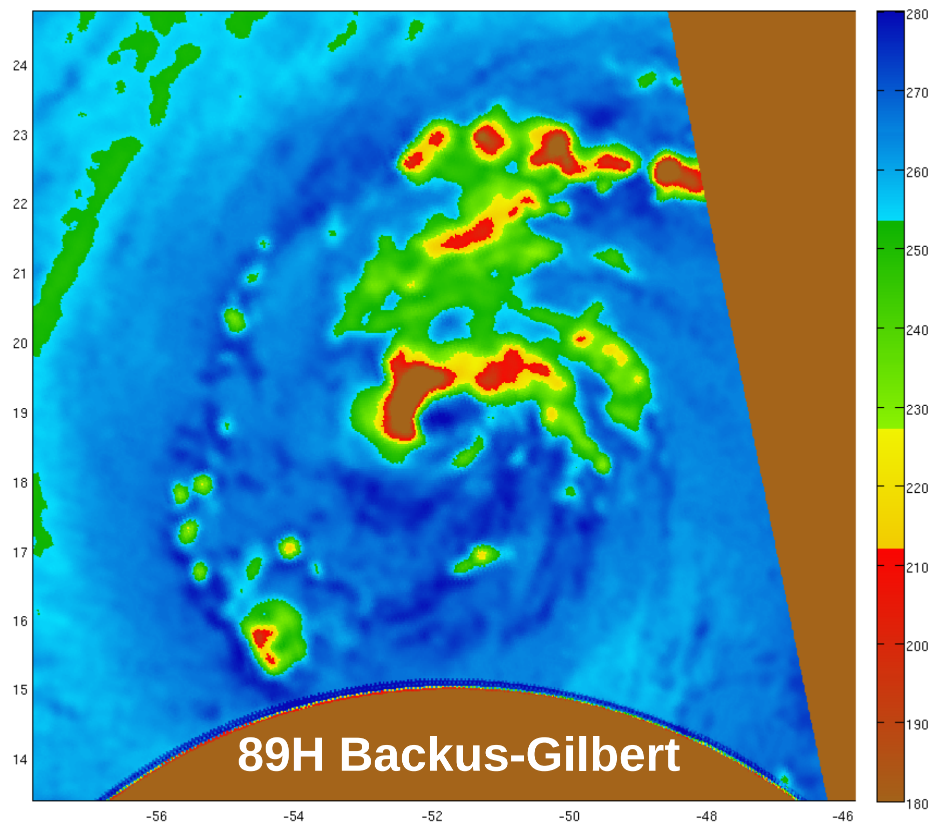
- Empirically derived coefficients (by Song Yang, NRL)
  - Uses coincident overpasses and radiative physics model
- Example case: Hurricane Felix (SSM/I F13; 10 Aug 1995)
  - Note deeper convective features, warmer environment signal

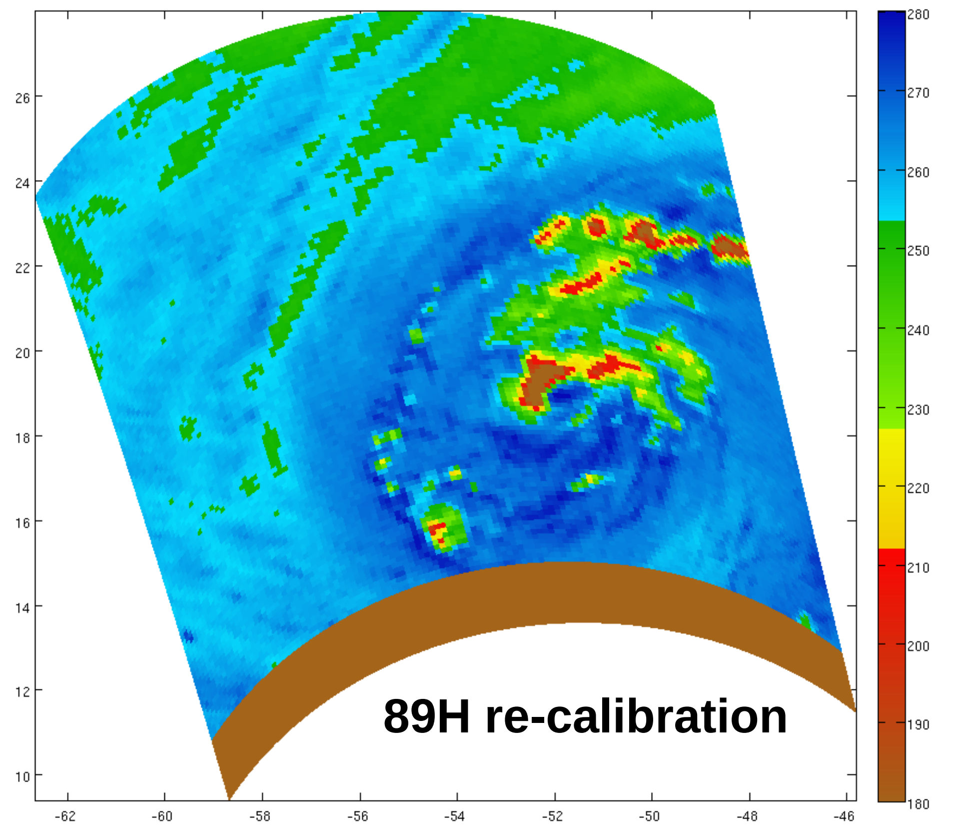




Backus-Gilbert Optimal Interpolation

- If observing platform has appropriate Nyquist sampling, can use antenna pattern coefficients to extract additional data from native resolution.
  - Data then resampled and interpolated to 1km resolution.

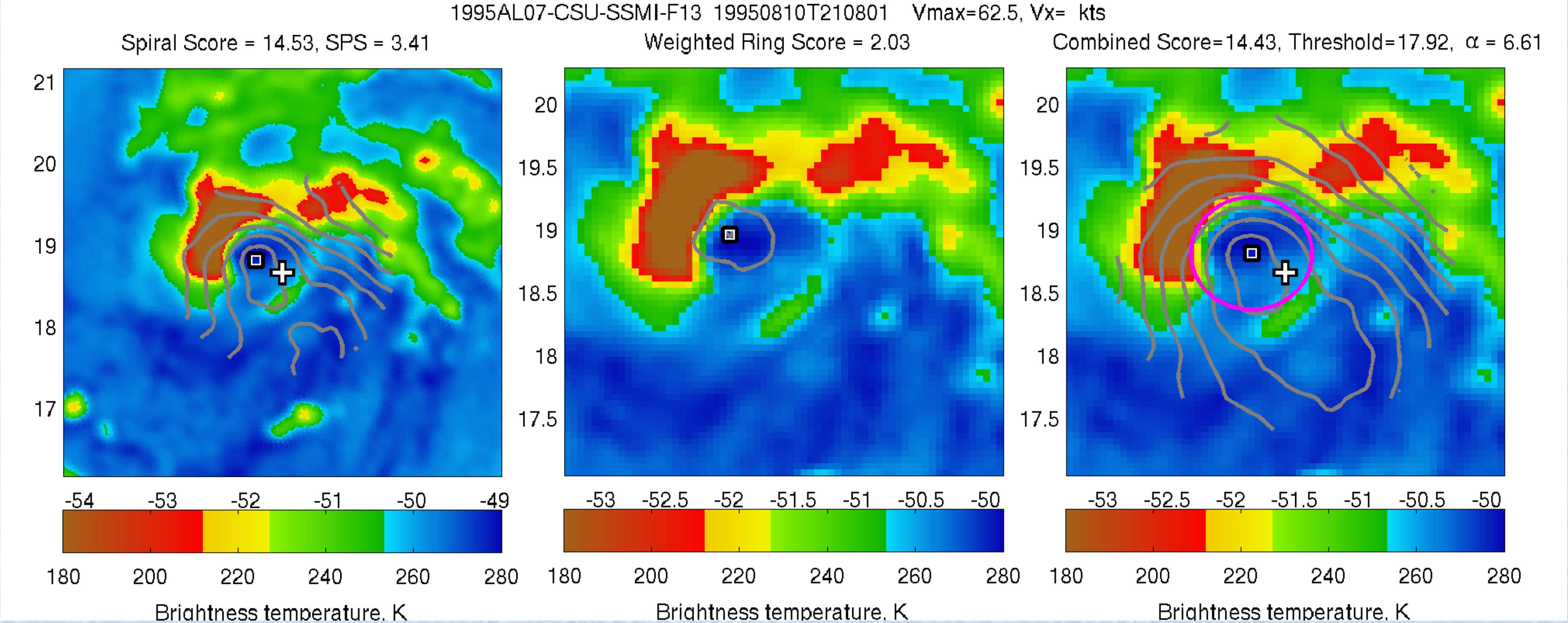




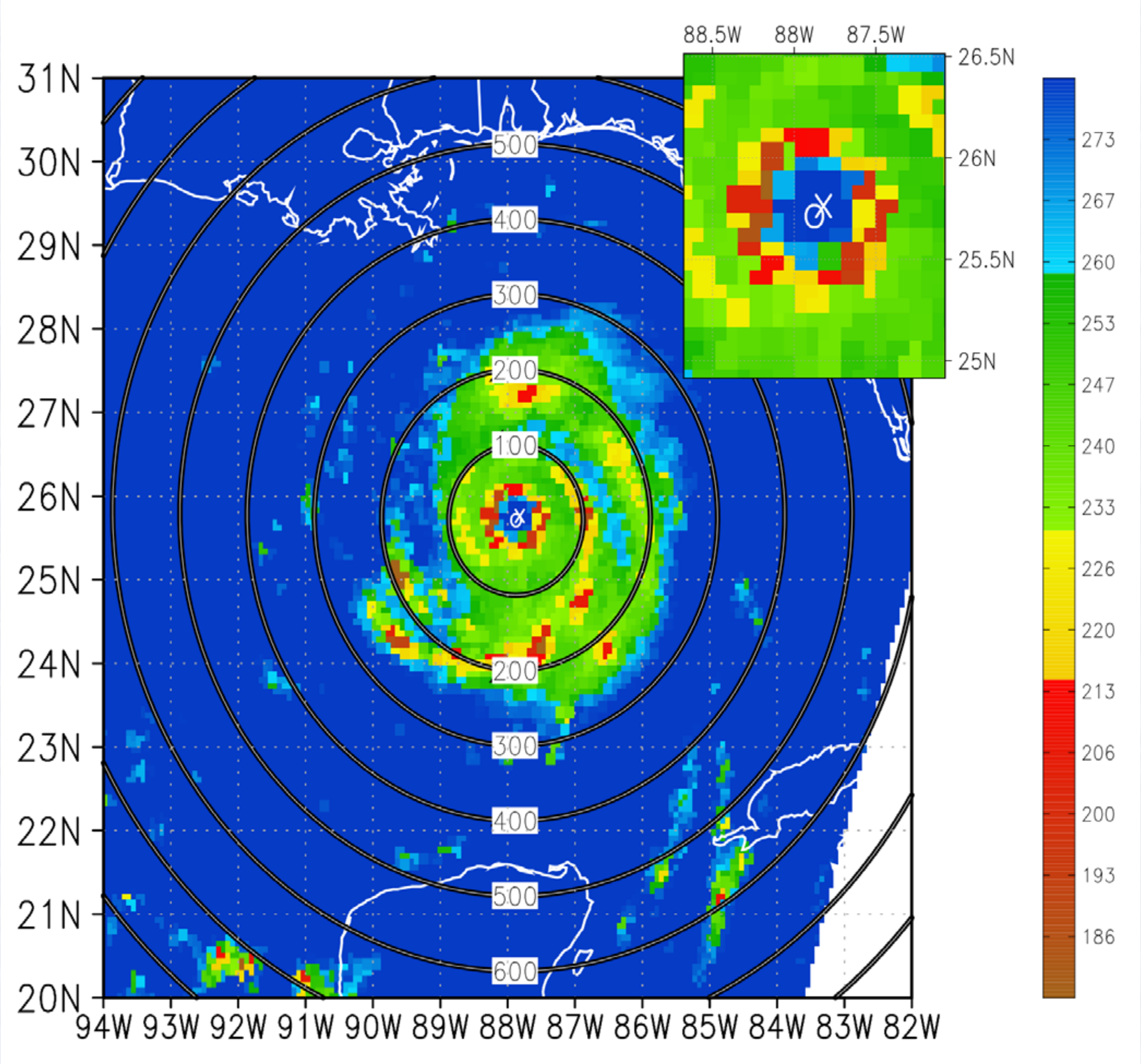
Applying ARCHER Technique

Wimmers and Velden 2010

- ARCHER versions are used in real-time TC products (e.g. ADT, MIMIC)
- Uses information in satellite image to determine TC center.
  - Spiral banding (left); Eye scene (middle); Final center (right)
  - Interpolated best track (plus sign); ARCHER-derived centers (square)



Eye Analysis Case

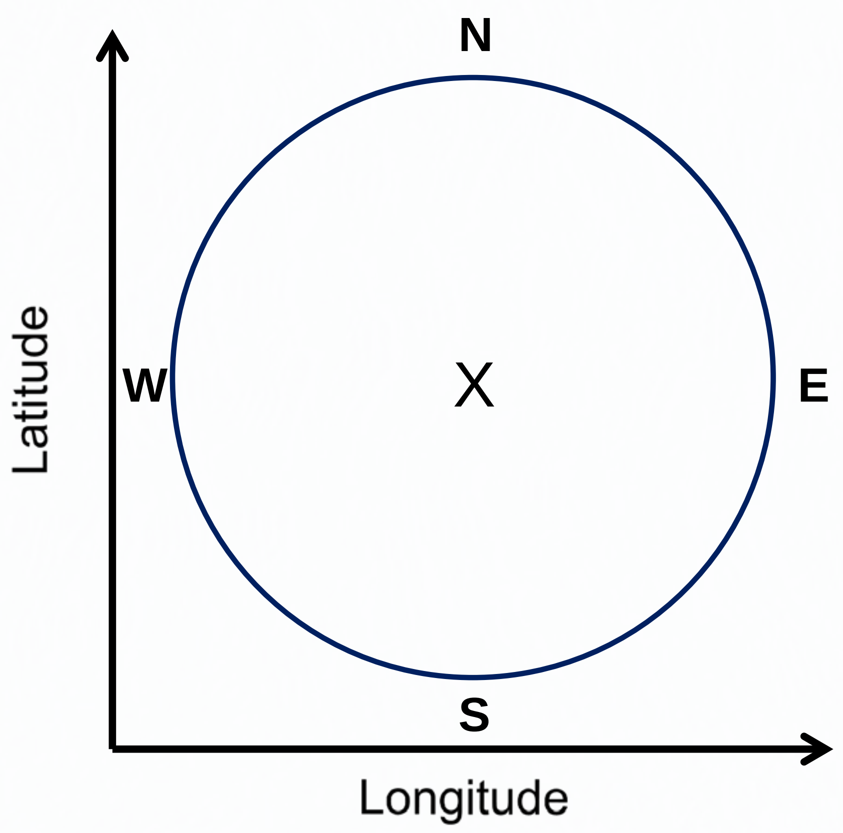


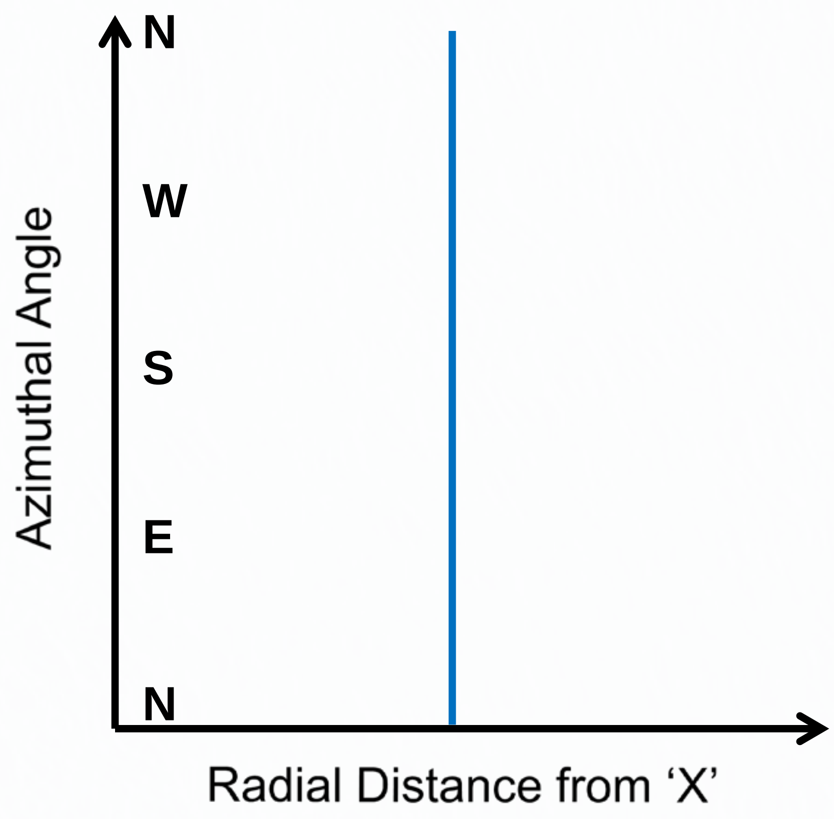
Hurricane Katrina

- 1244z, 28 August 2005 (~145 kts)
- HURSAT SSM/I
- 85GHz Polarization Corrected Temperature
- "X" = Linearly Interpolated Best Track
- "O" = ARCHER best guess

Eye/Eyewall Representation

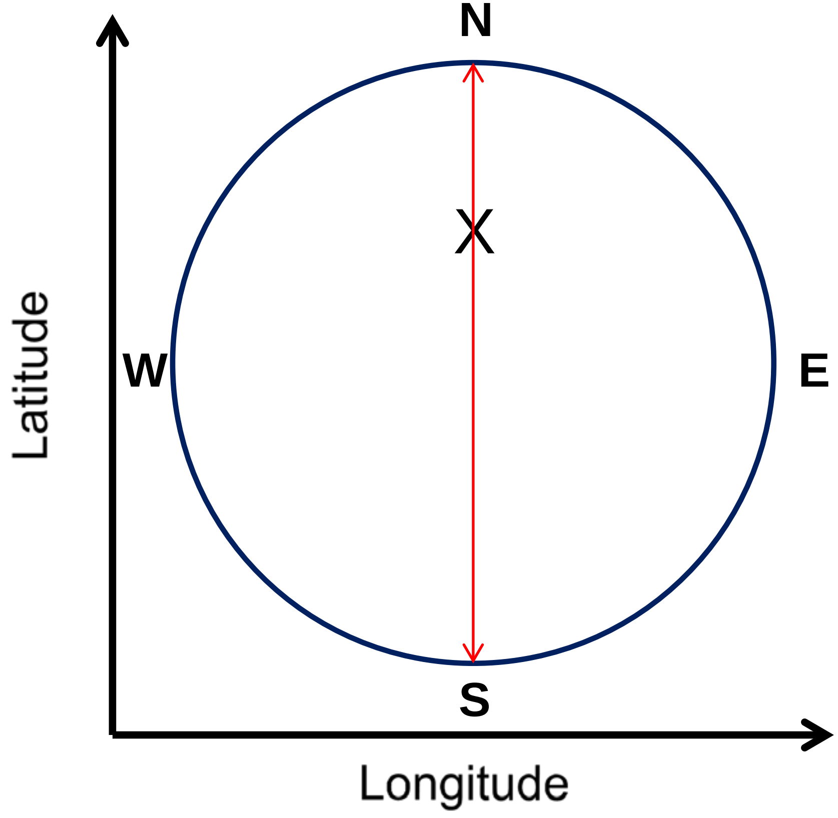
- Circular Eye with a ‘perfect’ center position
  - Appears as a straight line in polar coordinates

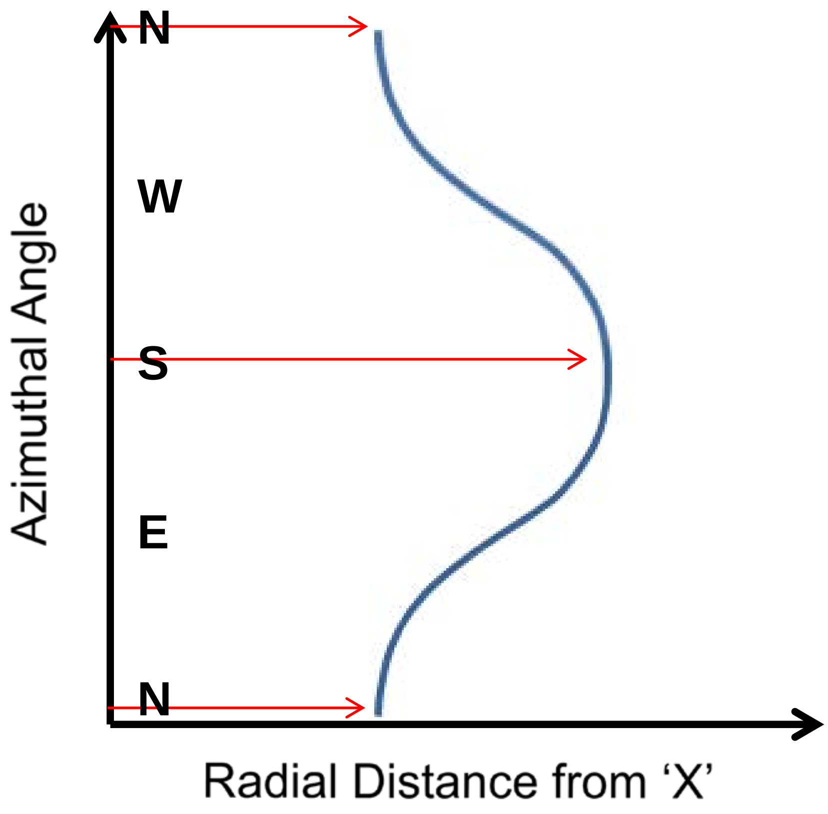




Eye/Eyewall Representation

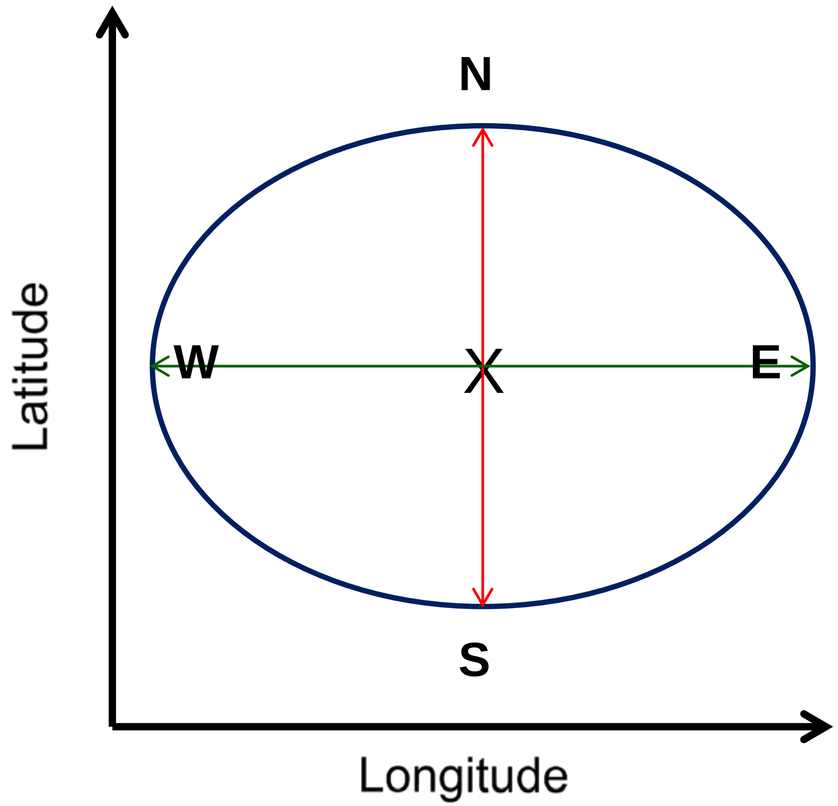
- Circular Eye with a displaced center position
  - Center displaced to the north
  - Wavenumber-1 asymmetry in polar coordinates

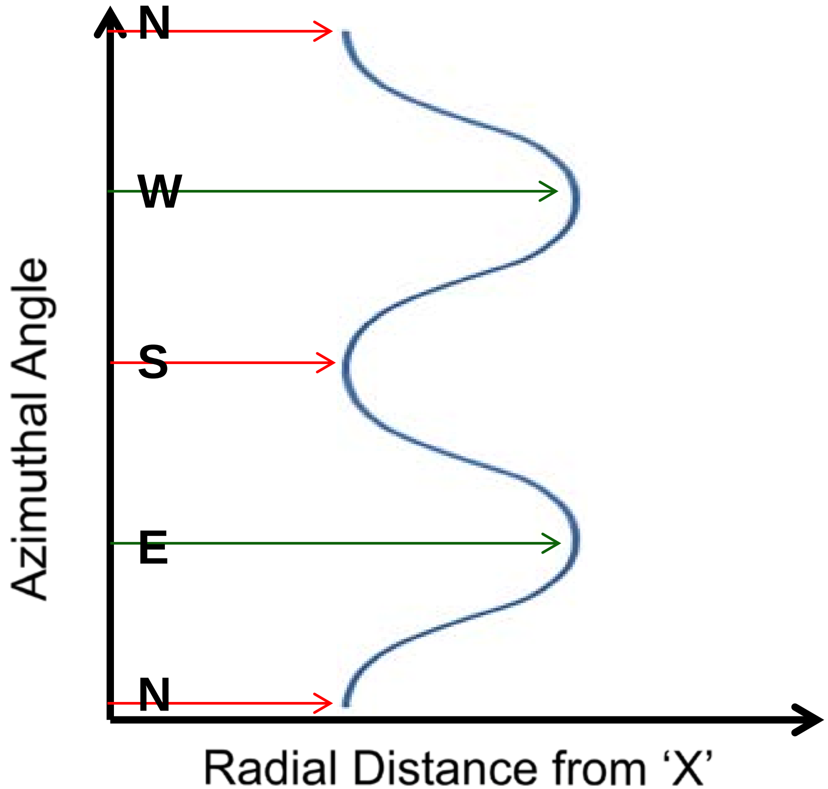




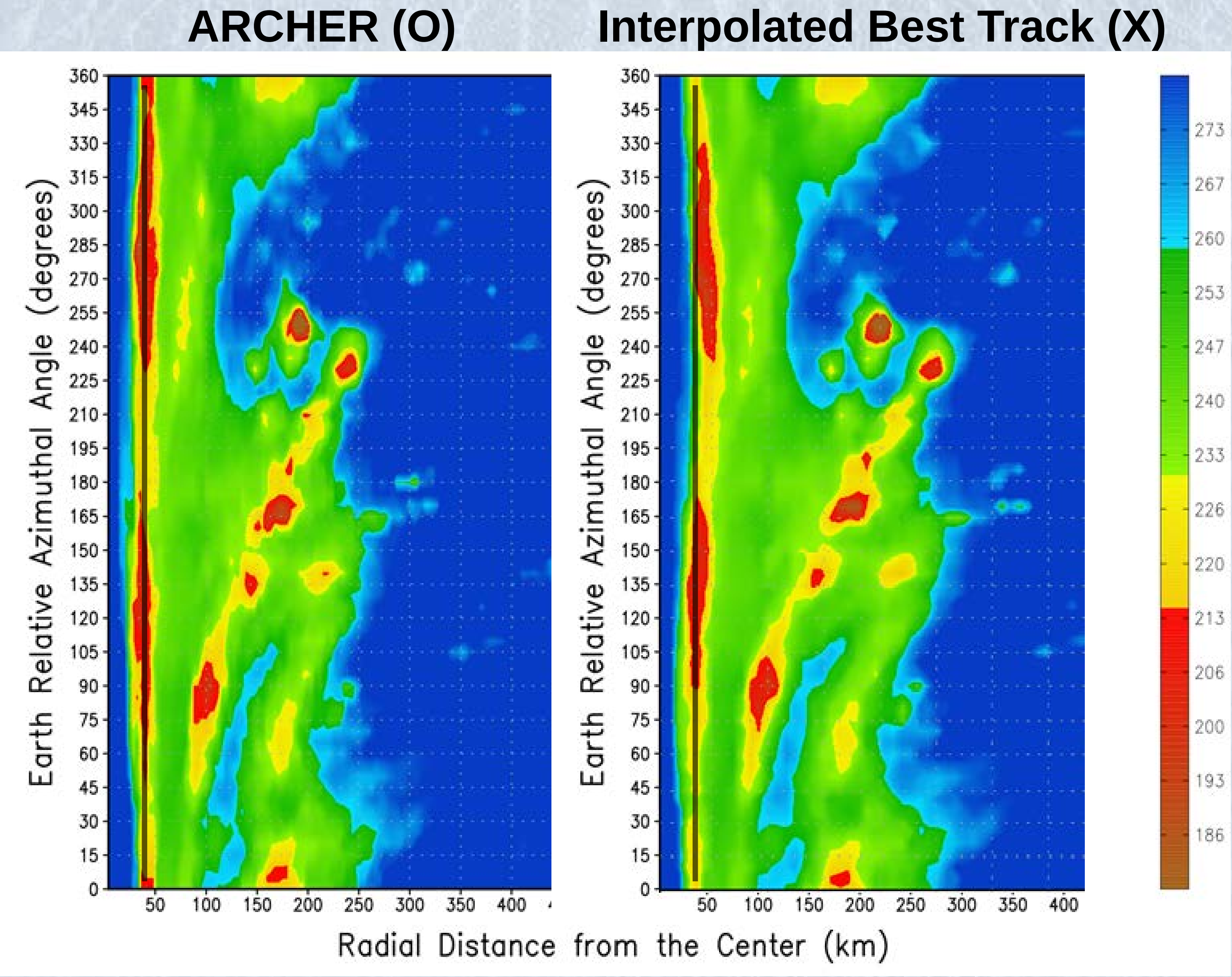
Eye/Eyewall Representation

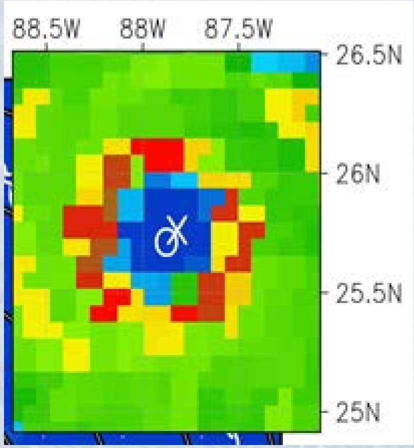
- Elliptical Eye with a ‘perfect’ center position
  - Long axis runs east-west; short axis along meridian
  - Wavenumber-2 asymmetry in polar coordinates





Importance of a Correct Center





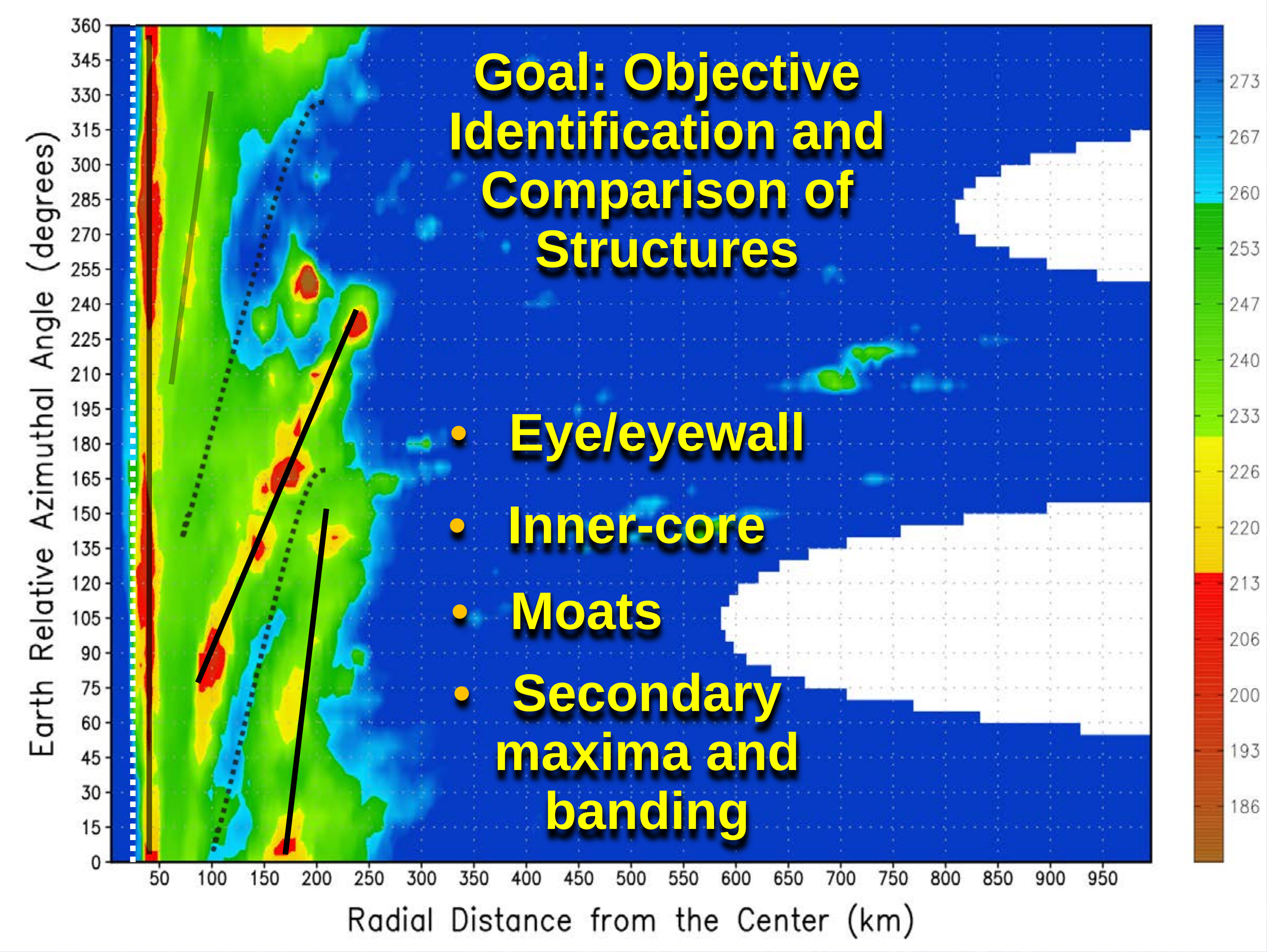
Hurricane Katrina

- 1244z, 28 August 2005 (~145 kts)
- 85GHz Polarization Corrected Temperature

Objective Structure Diagnostics

- The size inner eye/eyewall can be objectively defined by a Fourier analysis of its boundary.
  - Can even attempt to further correct the center position
- Obstacles:
  - Need a close center guess (ARCHER helps!)
  - Small features unresolved (limits of sensor resolution)
  - Defining a threshold for the eye/eyewall edge?
    - Brightness temperature value is sensor dependent
    - Another method not dependent of data magnitude?
      - Compare it to other features

Structural Feature Identification



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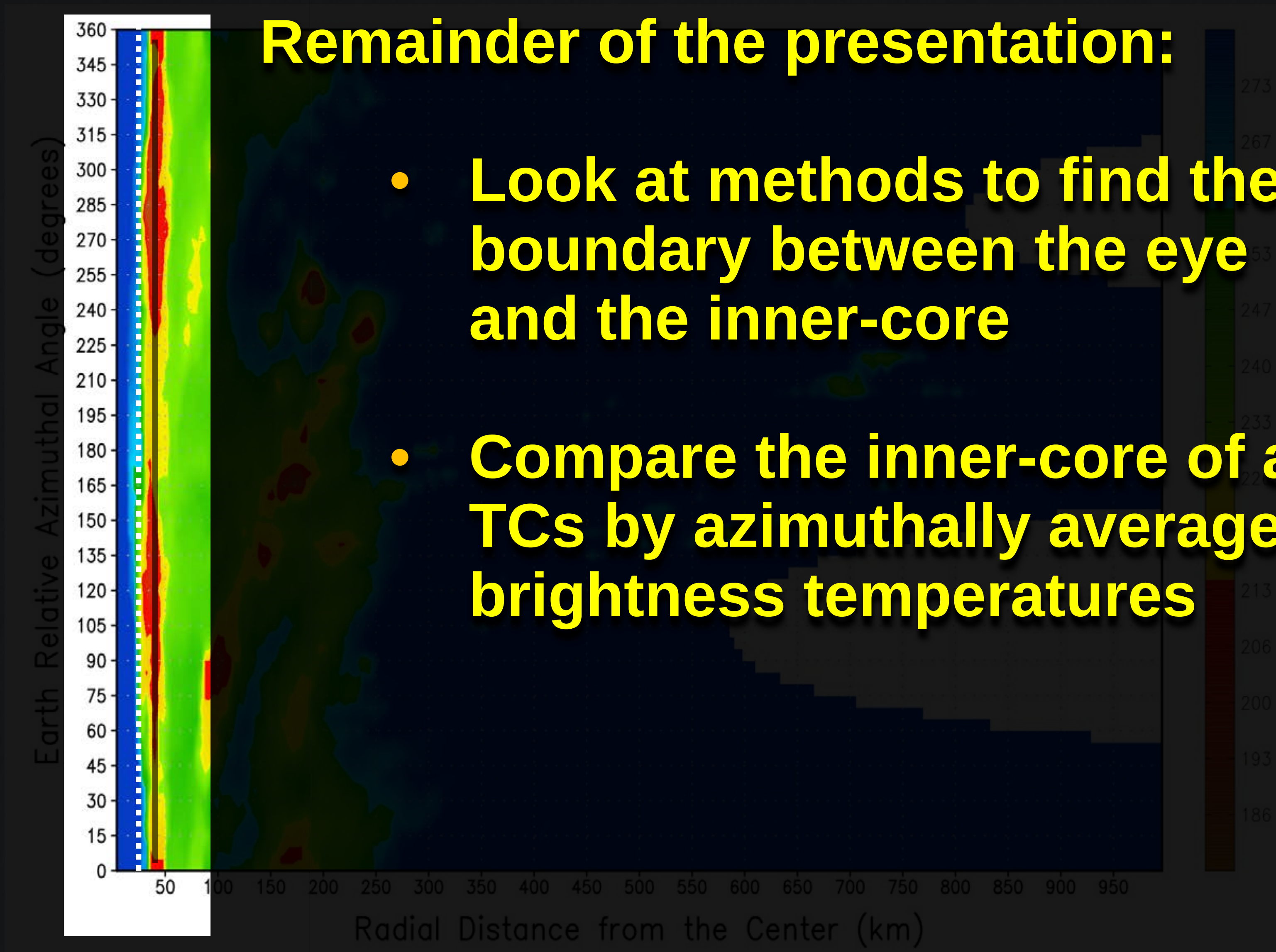
- Uses ARCHER best guess center
- (“O” from previous slide)

Structural Feature Identification



Remainder of the presentation:

- **Look at methods to find the boundary between the eye and the inner-core**
- **Compare the inner-core of all TCs by azimuthally averaged brightness temperatures**

Hurricane Katrina

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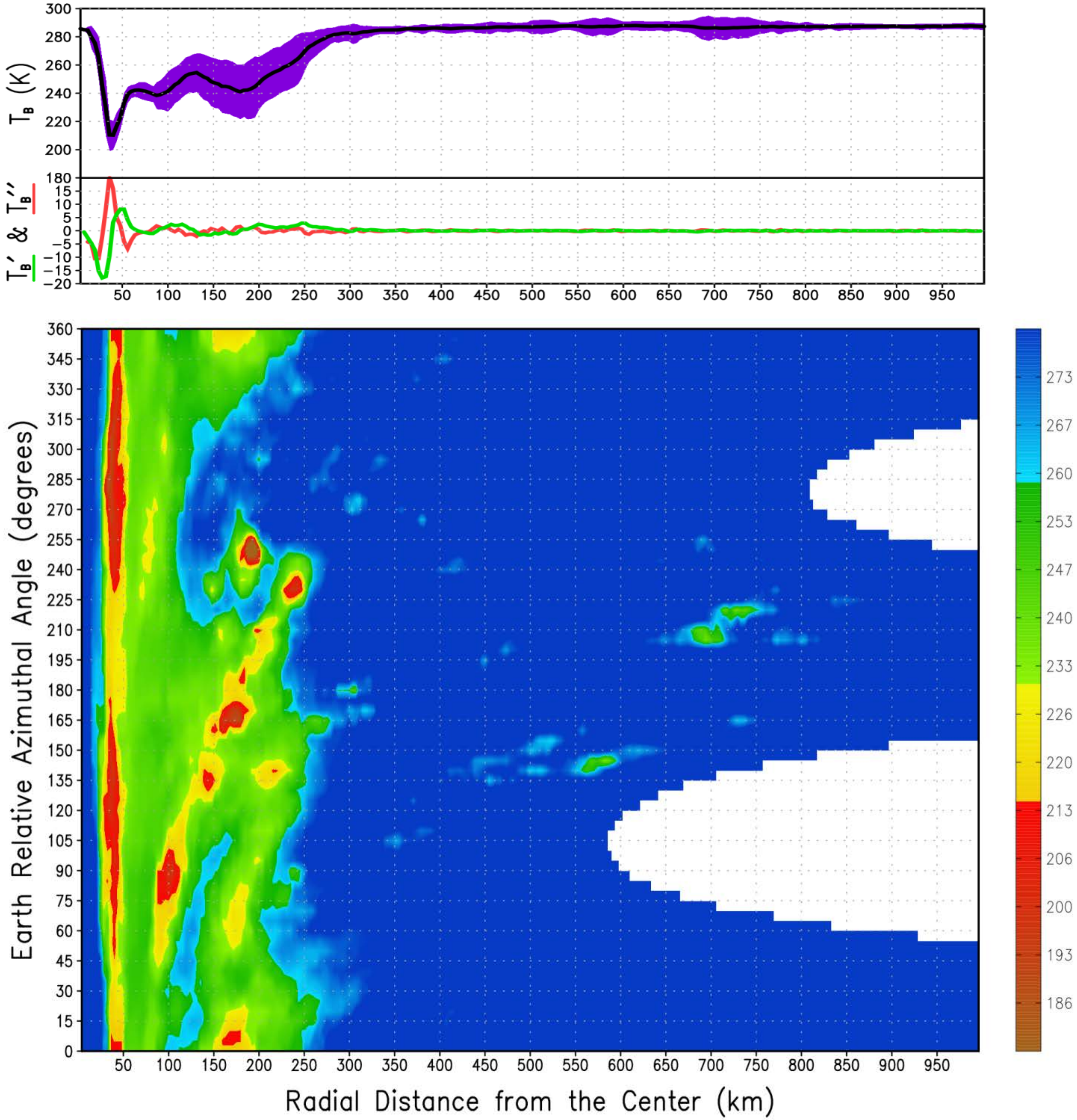
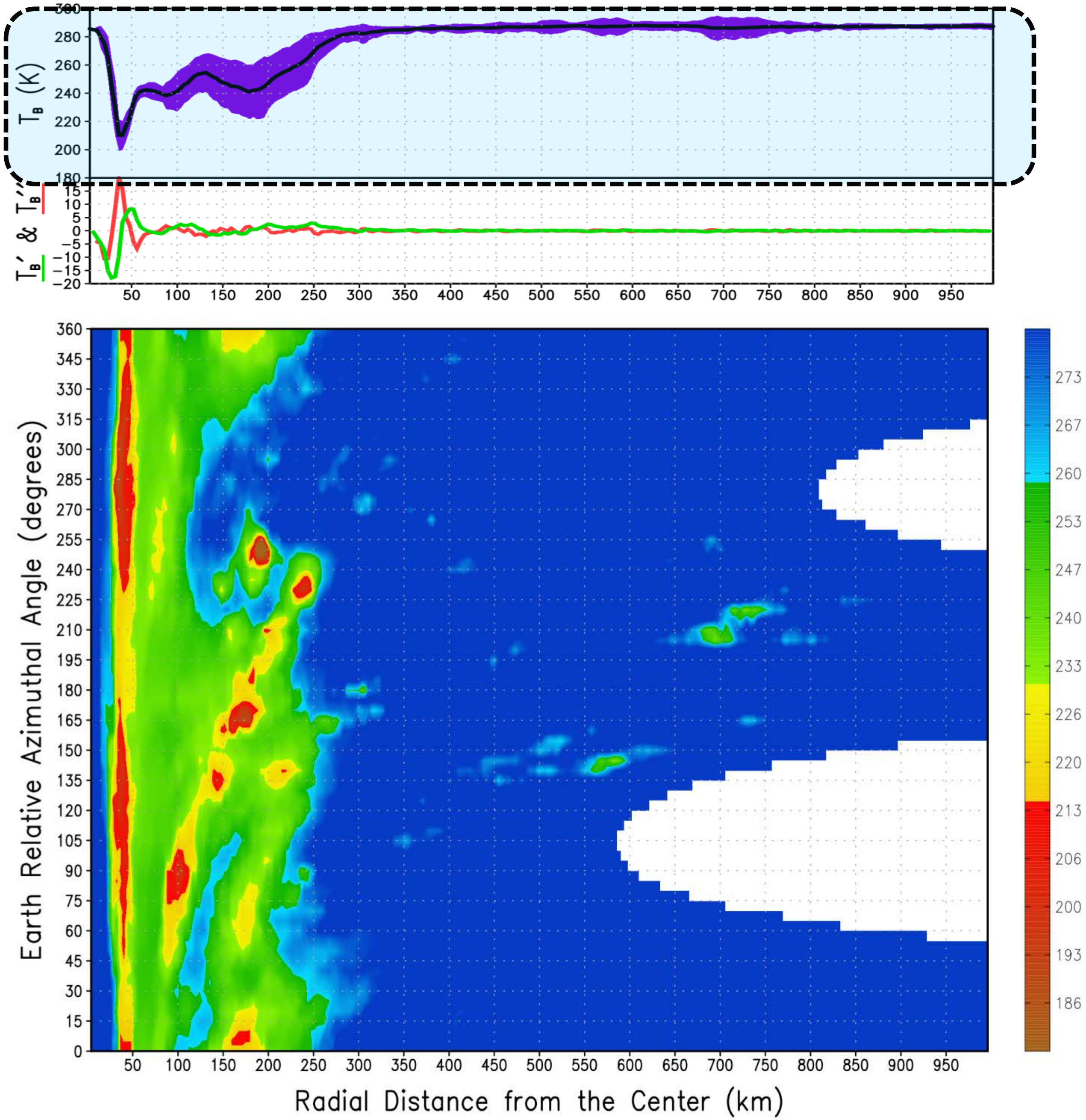
Using Polar Coordinates



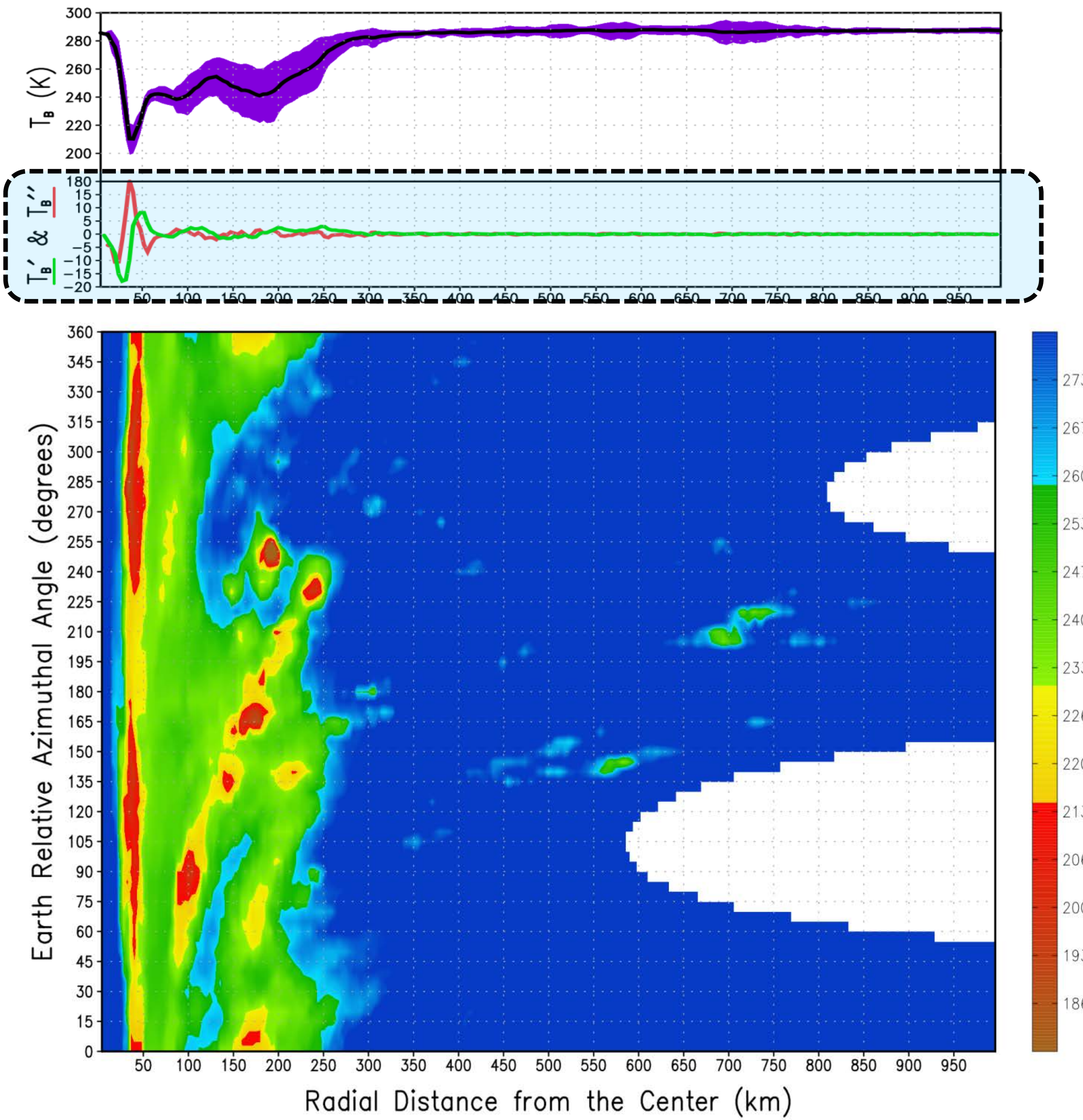
– Using the gradients of Brightness Temperature allows a sensor-invariant method of finding shape.

Using Polar Coordinates



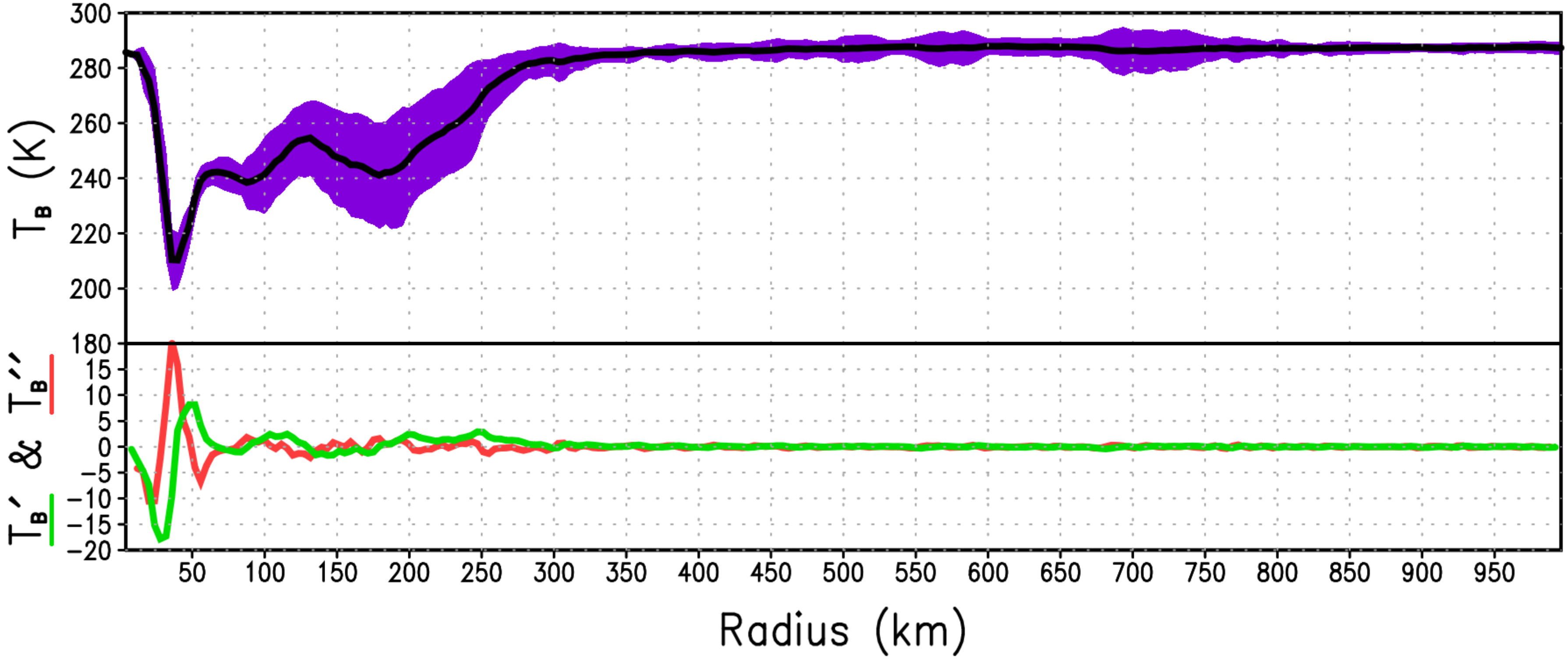
- Using the gradients of Brightness Temperature allows a sensor-invariant method of finding shape.
- Black line is the azimuthal average; purple shading about that line is the standard deviation

Using Polar Coordinates



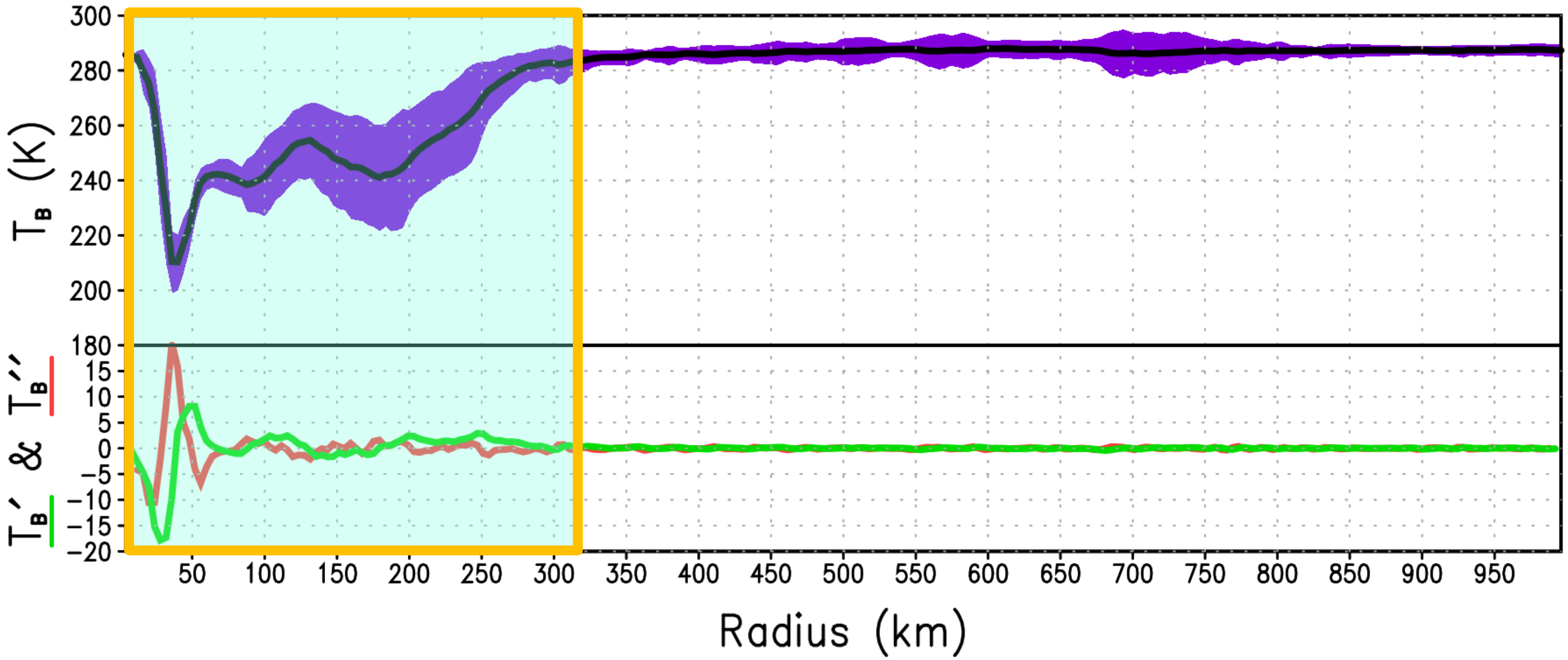
- Using the gradients of Brightness Temperature allows a sensor-invariant method of finding shape.
- Black line is the azimuthal average; purple shading about that line is the standard deviation
- First derivative is shown by the green line
- Second derivative is shown by the red line

Profile of Azimuthal Average



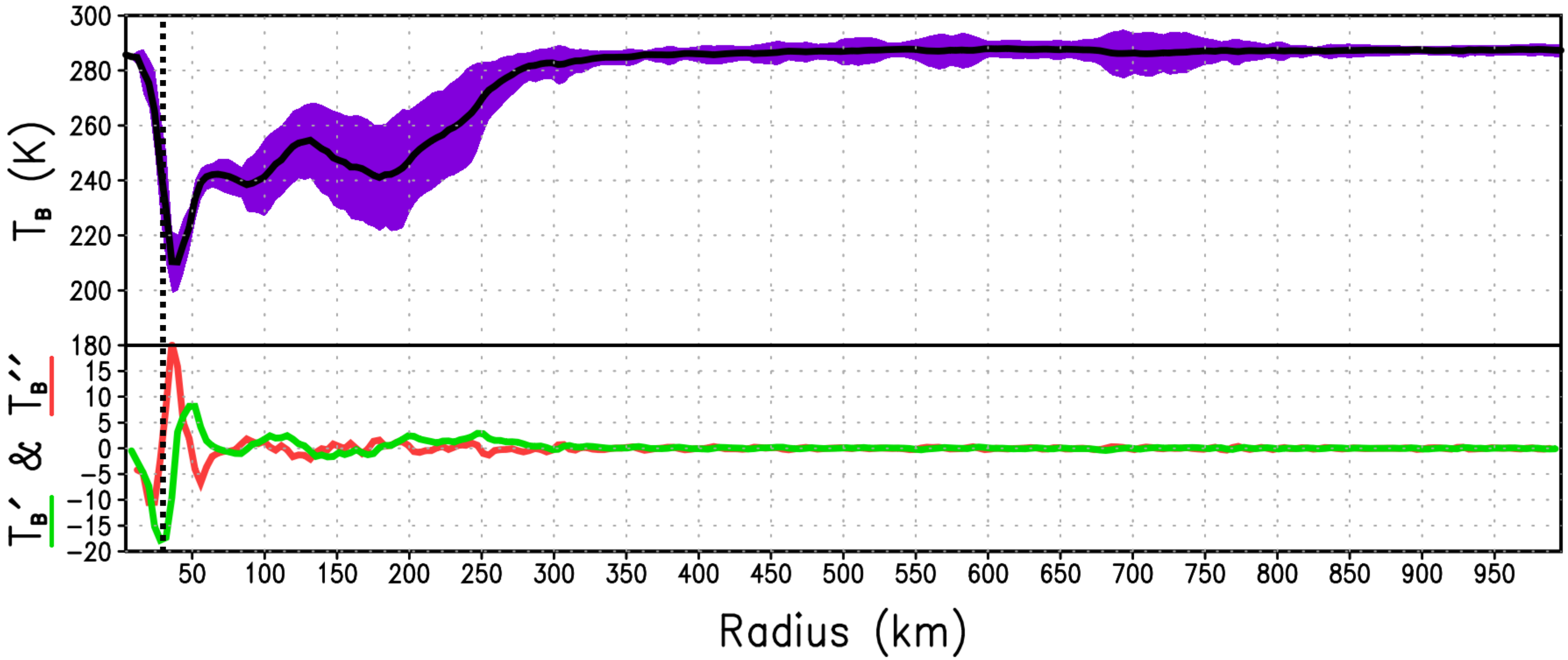
- Size relationships between can be seen in azimuthal average plots

Profile of Azimuthal Average



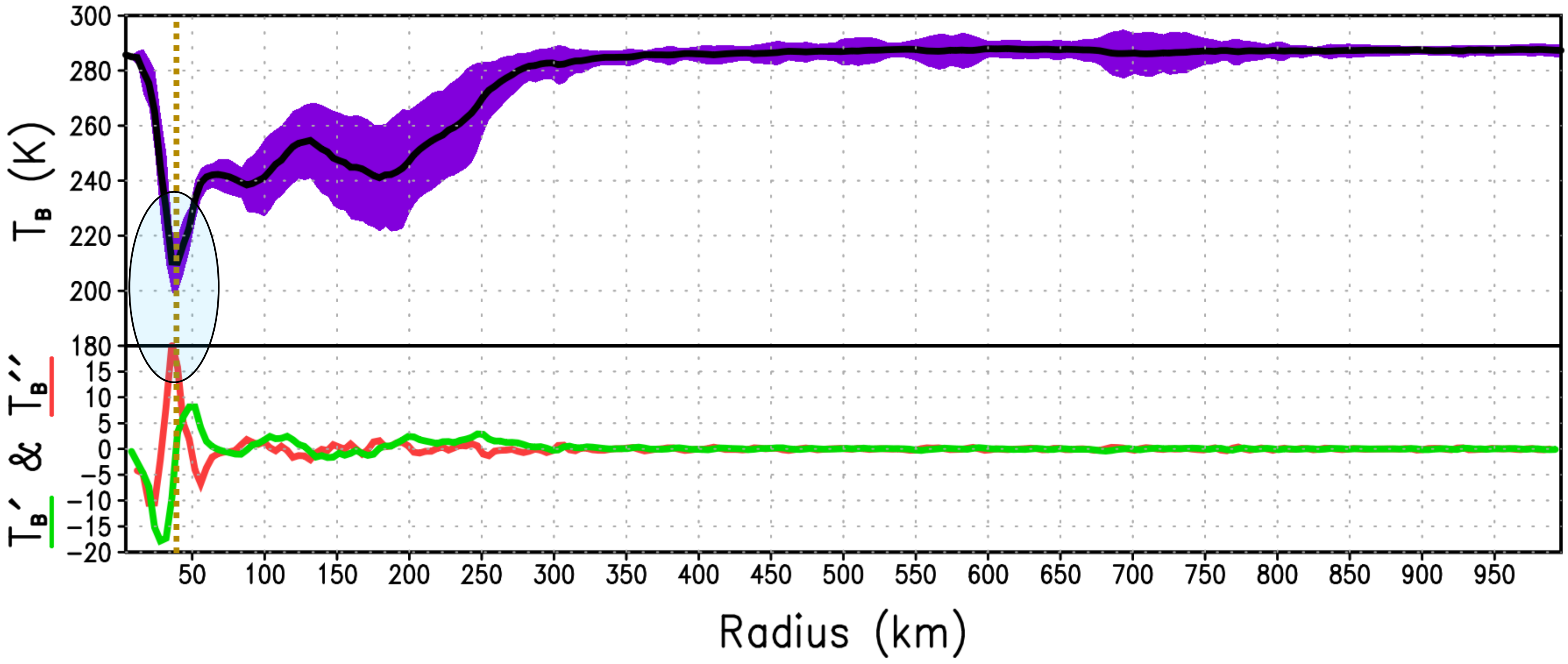
- Size relationships between can be seen in azimuthal average plots
  - A storm size metric can be defined (by variance or background temperature)

Profile of Azimuthal Average



- Size relationships between can be seen in azimuthal average plots
  - A storm size metric can be defined (by variance or background temperature)
  - It may be useful to define the eye size by the inflection point.

Profile of Azimuthal Average

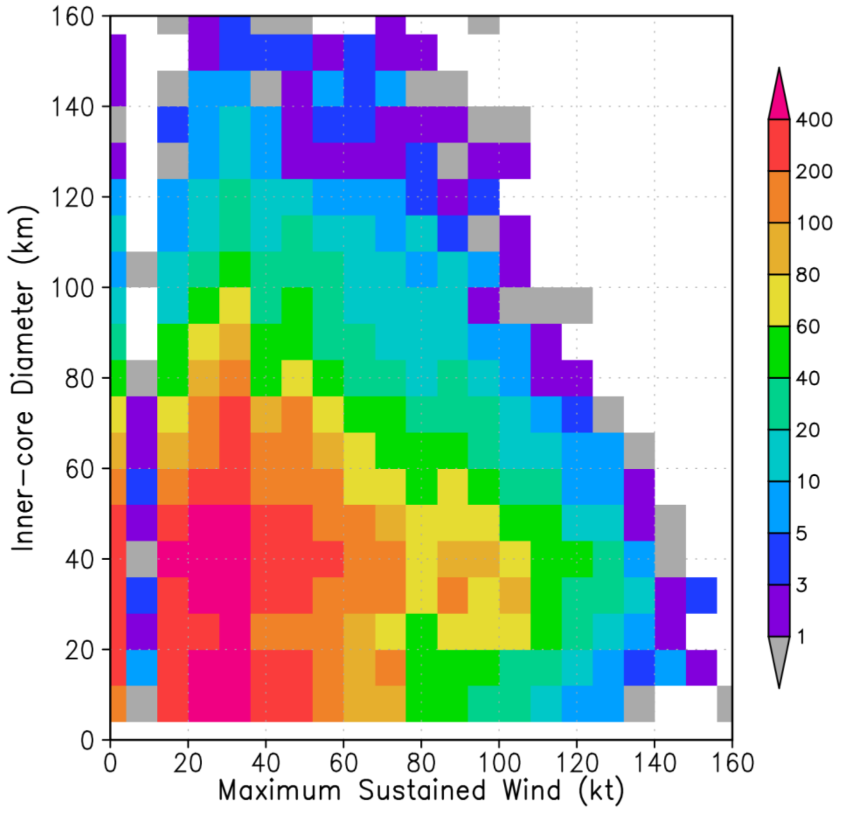


- Size relationships between can be seen in azimuthal average plots
  - A storm size metric can be defined (by variance or background temperature)
  - It may be useful to define the eye size by the inflection point.
  - Core size and strength can be represented by the azimuthal average global minimum(or, maximum in second derivative).

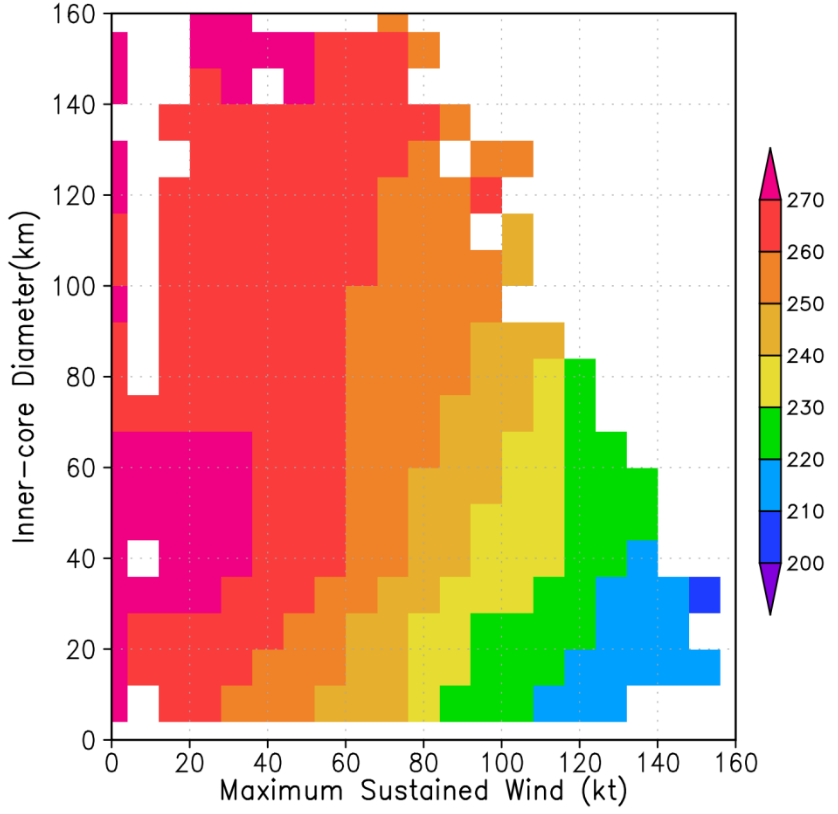
Analyzing the Azimuthal Minimum

- Most observed TCs: weaker, small inner-core radius
- Lower brightness temperatures (more ice, water scattering) seen in stronger storms, smaller radii.

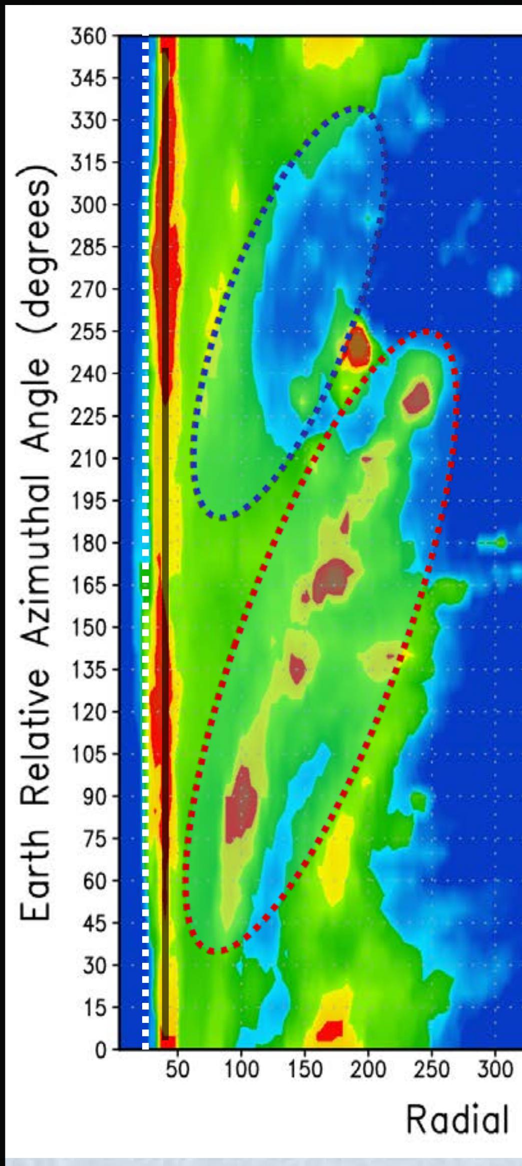
Observed Frequency



Azimuthal Mean B_T (K)



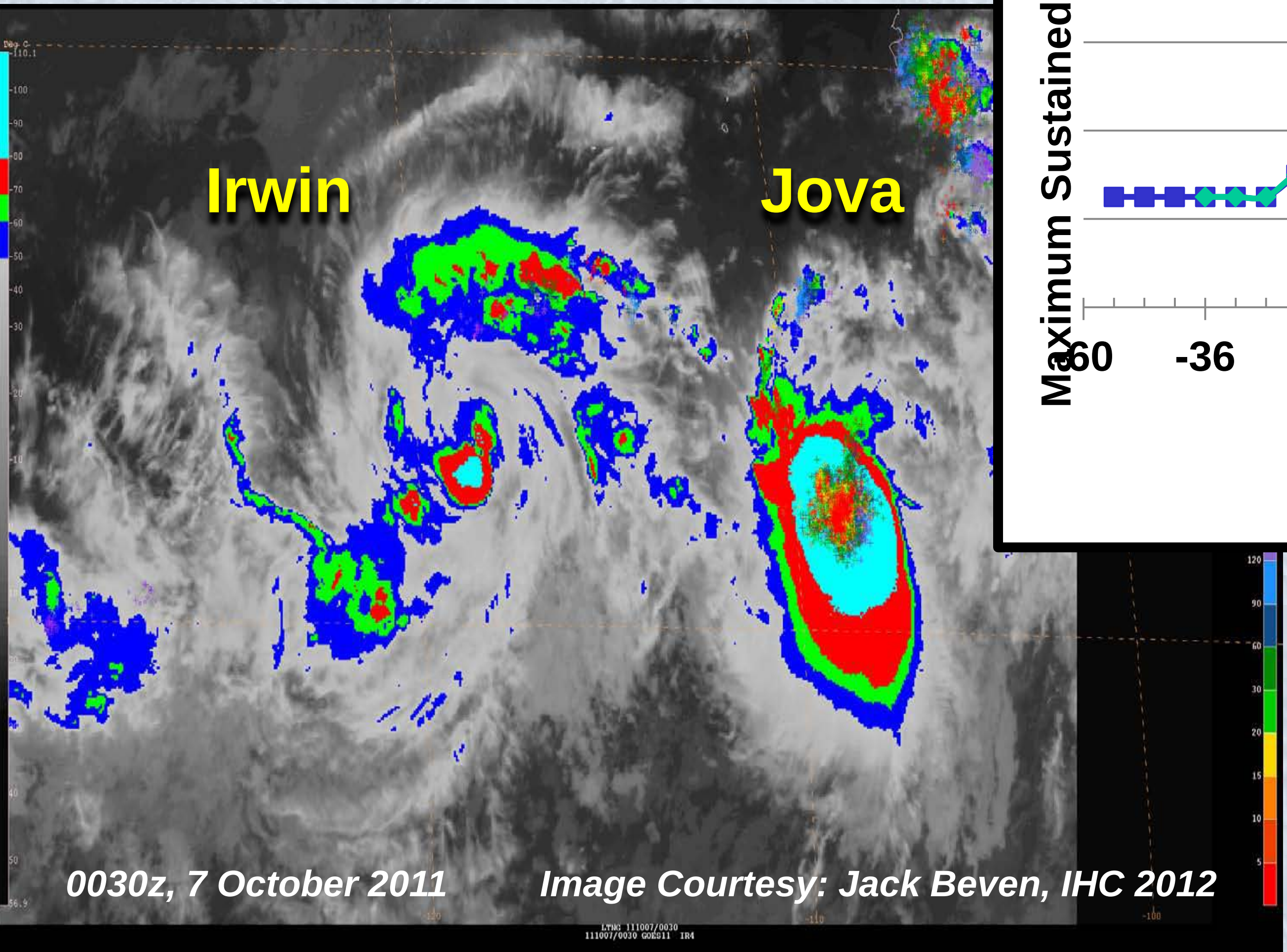
Summary

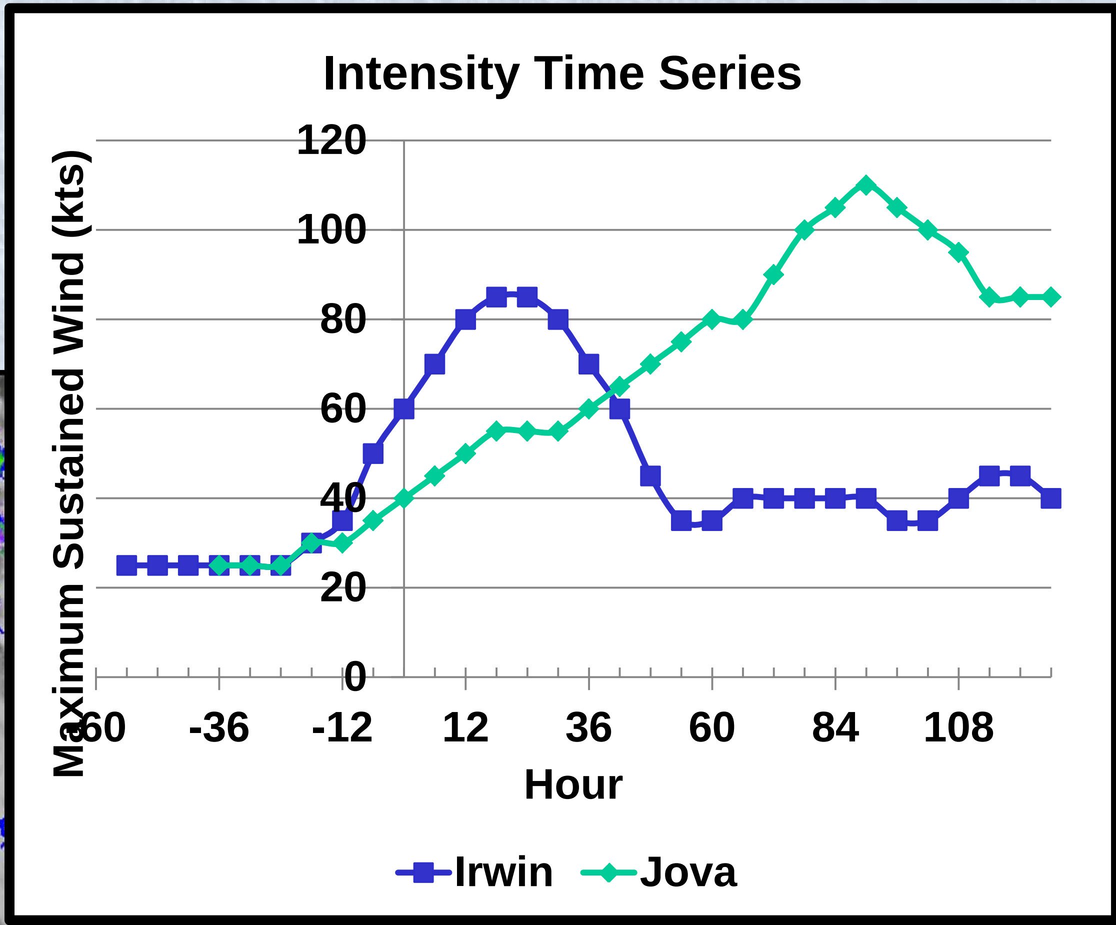


- **Creation of a standardized global satellite microwave archive of TCs underway, in collaboration with NRL.**
- **Objective, non-sensor centric methods of define structure can be used to compare TCs.**
- **Future work to expand analysis to all parts of the TC, including moats and banding.**

Coda

Can structural cues help inform short to medium term prediction of TC intensity changes?





Acknowledgments

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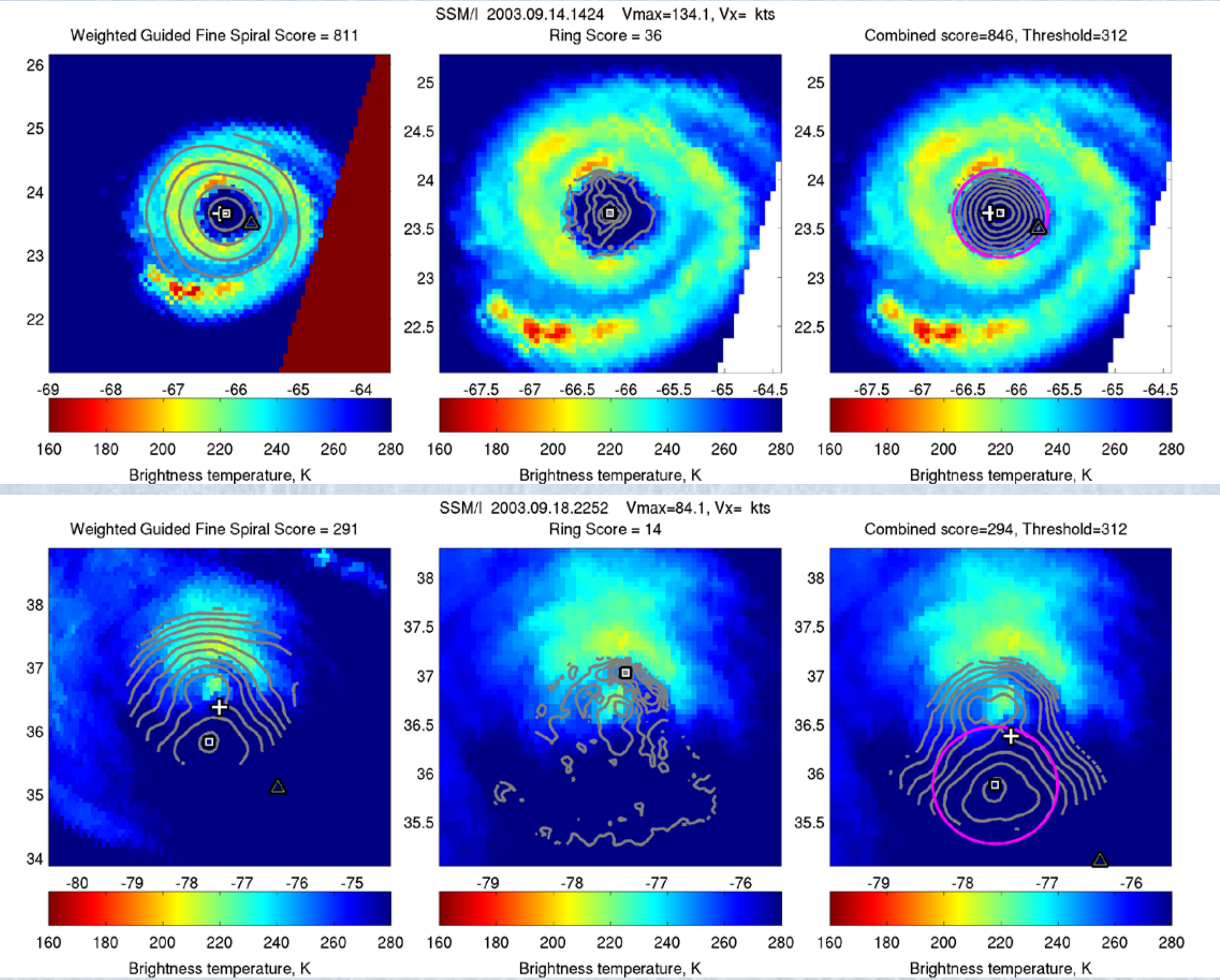
- Funding (supported in part by):
  - ONR National Defense Science and Engineering Graduate Fellowship
  - AMS Graduate Fellowship (sponsored by SAIC/Advanced Science and Engineering Operation)
  - FSU Presidential Fellowship

Additional ARCHER

Wimmers and Velden 2010

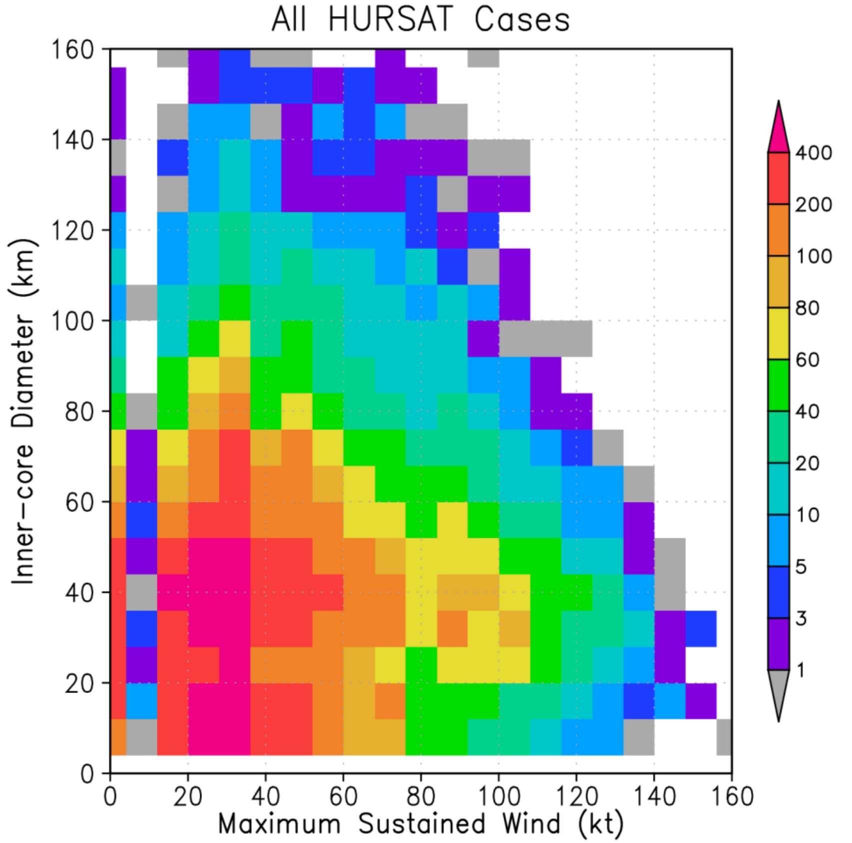


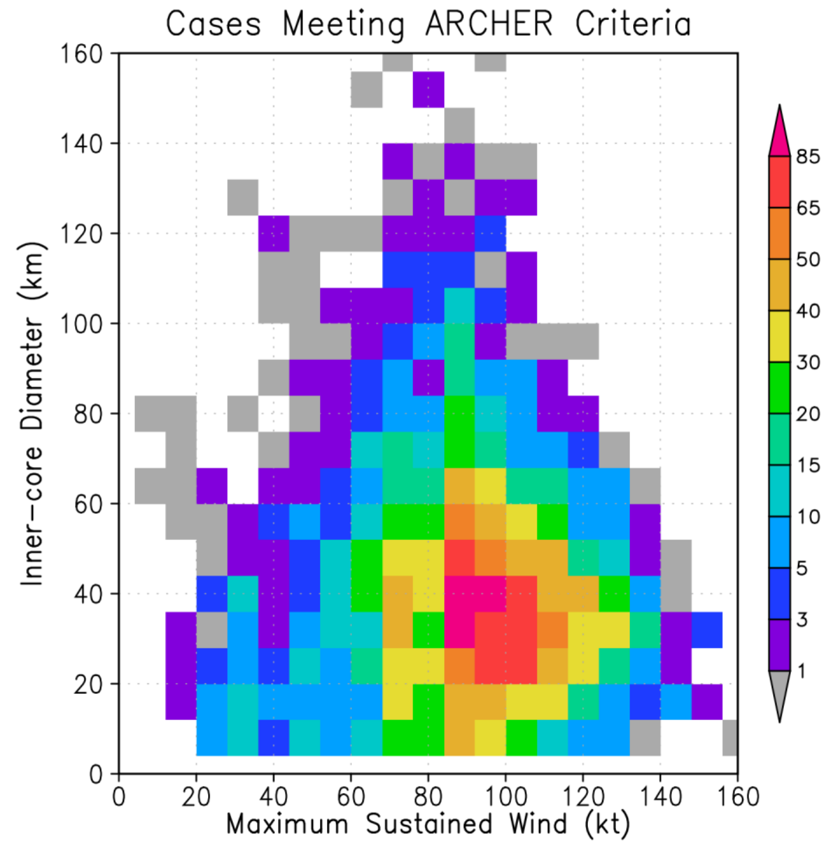
- Versions of ARCHER are used in real-time TC products (e.g. ADT, MIMIC)
- Uses information in satellite image to determine TC center.
  - Spiral banding (left)
  - Eye scene (middle)
  - Final center (right)
- Case used: Isabel 2003

Analyzing the Azimuthal Minimum

- TCs with clearer spiral and eye patterns are more easily analyzed by ARCHER
  - Weaker systems also have stricter thresholds in ARCHER

Frequency of Occurrence

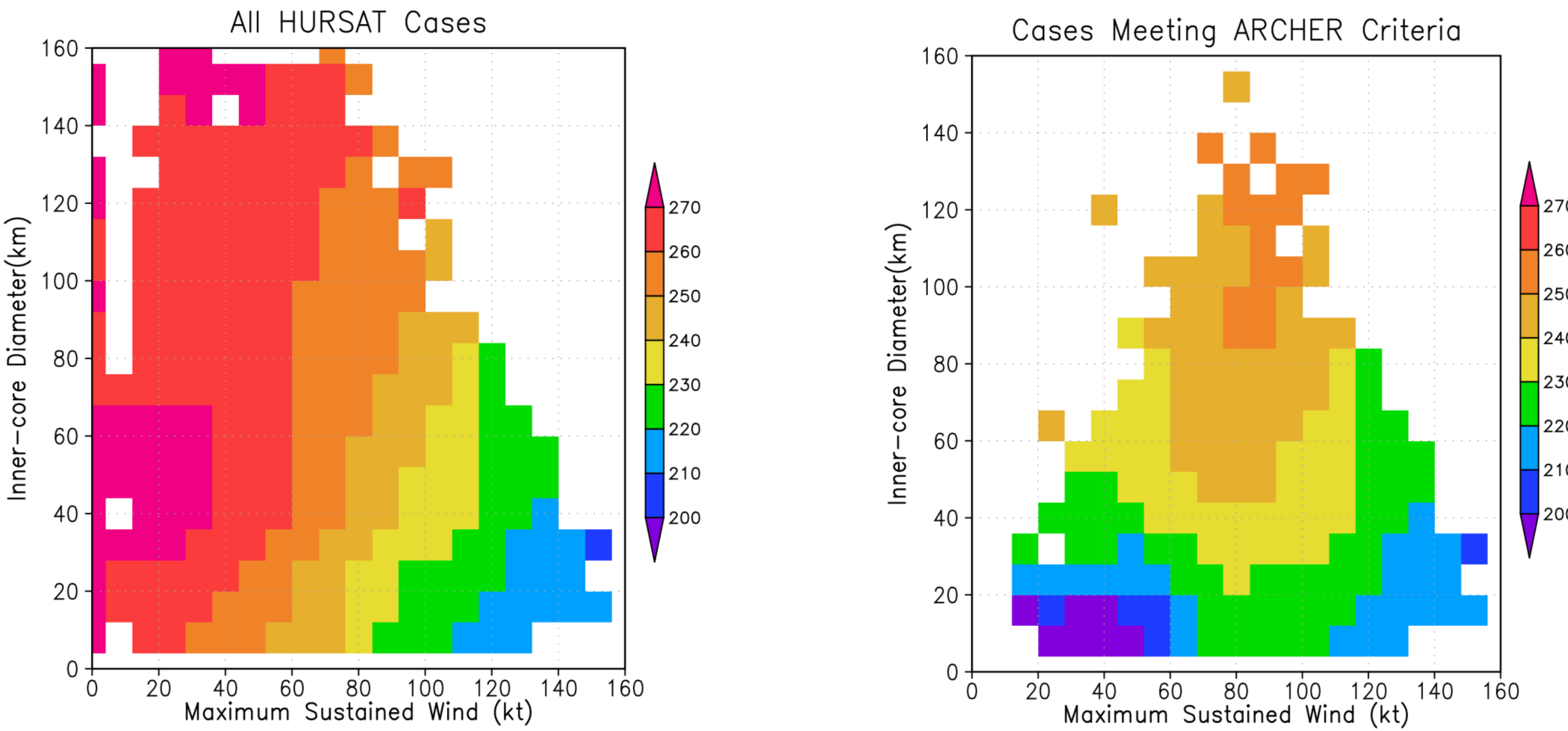




Analyzing the Azimuthal Minimum

- Lower brightness temperatures (more ice, water scattering) seen in stronger storms, smaller radii.
  - ARCHER picks up weaker storms with strong convective signal

Azimuthal Mean Brightness Temperature (K)



Analyzing the Azimuthal Minimum

- There may be preferred convective signatures at various radii to signify points along the TC lifecycle.
  - Again, smallest radii (< ~20km) have data resolution issues

Mean Intensity (kts)