Hurricane Imaging Radiometer (HIRAD)

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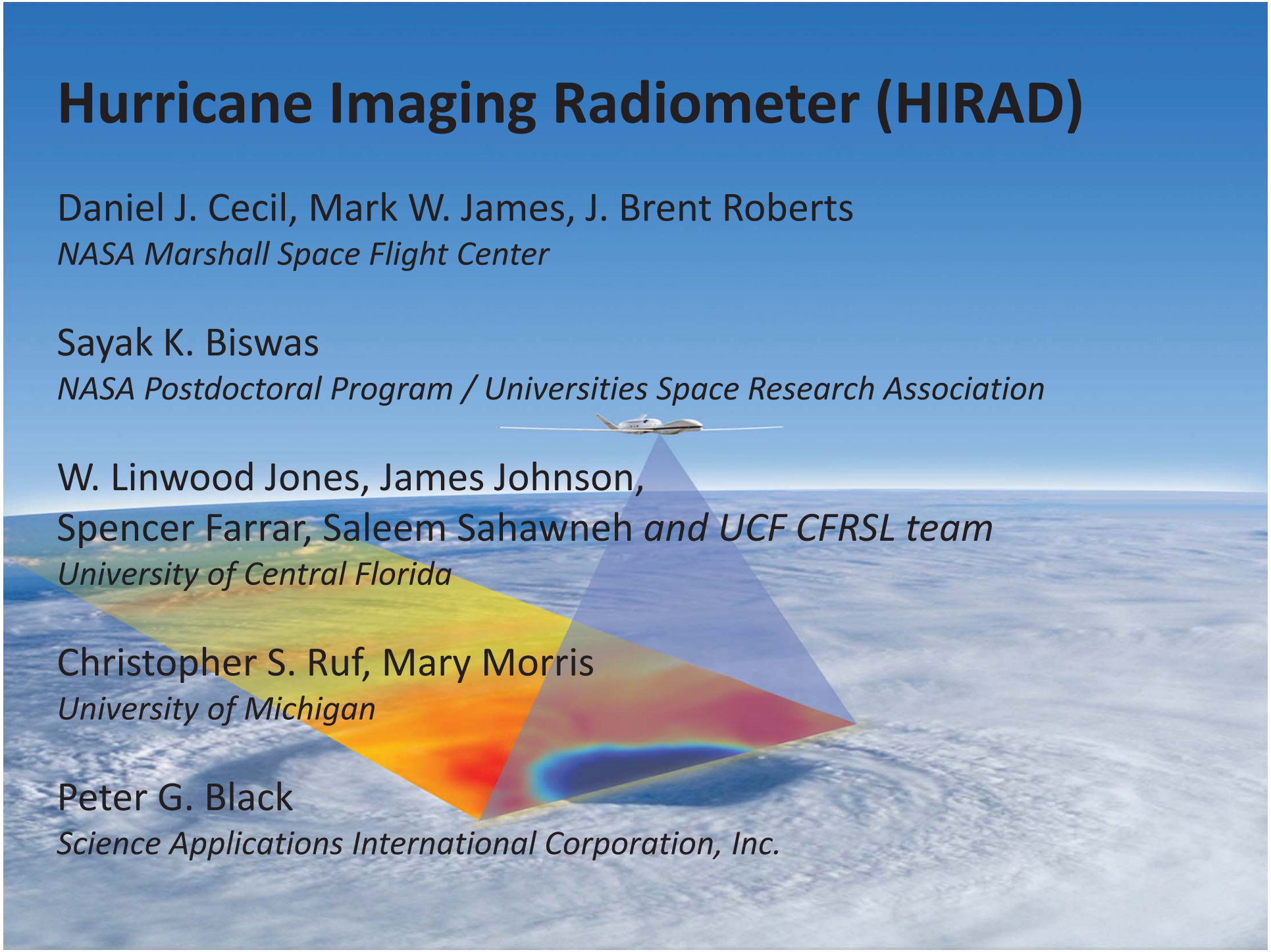
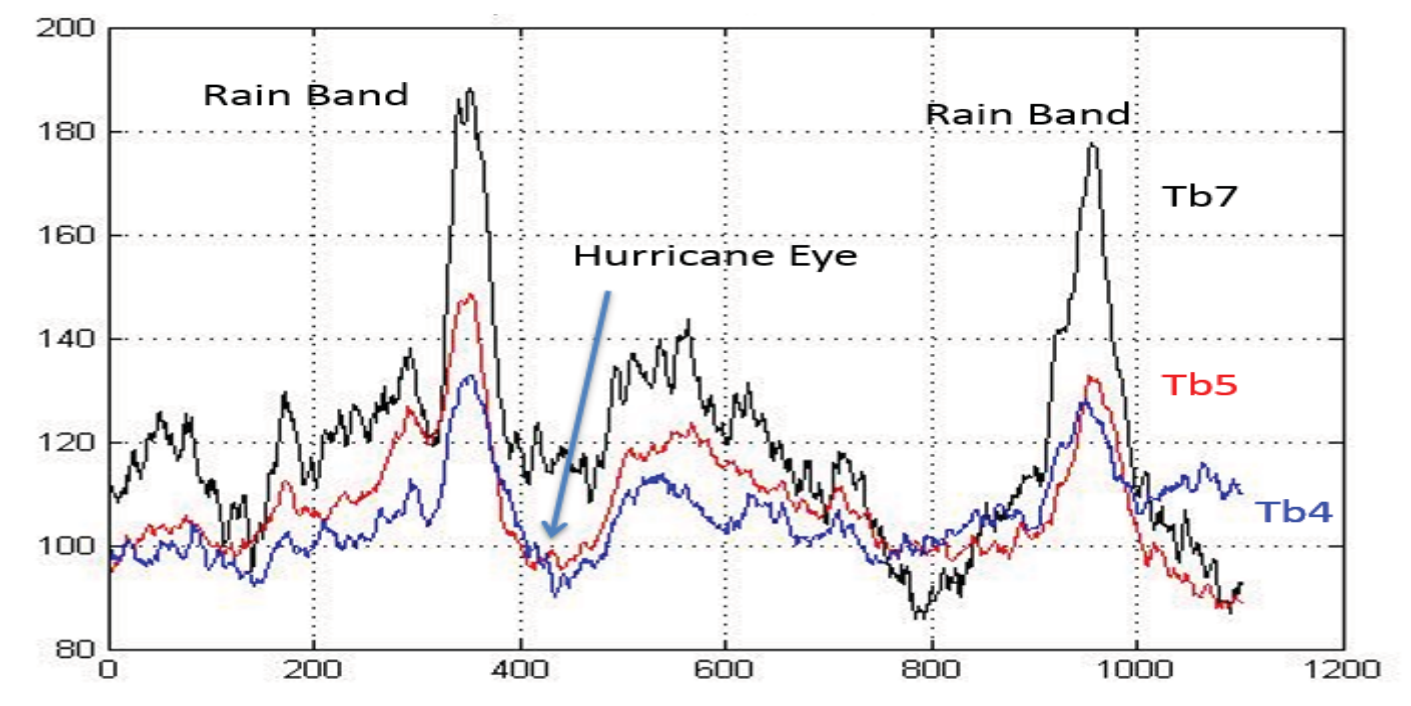


HIRAD Background

C-band (4, 5, 6, 6.6 GHz) radiometer with retrieval concept similar to SFMR

Retrieve Wind Speed and Rain Rate over ocean

C-band frequencies have varying sensitivity to rain but ~equal sensitivity to wind speed (emission from foam on wind-roughened ocean surface)



From Hurricane Karl (2010), at 40° incidence angle, multiple passes across storm

HIRAD Background

Combination of frequencies (4, 5, 6, 6.6 GHz) allows simultaneous retrieval of wind and rain

STAR antenna technology allows observation of wide swath below aircraft – ***swath width about 2.5 x aircraft altitude***

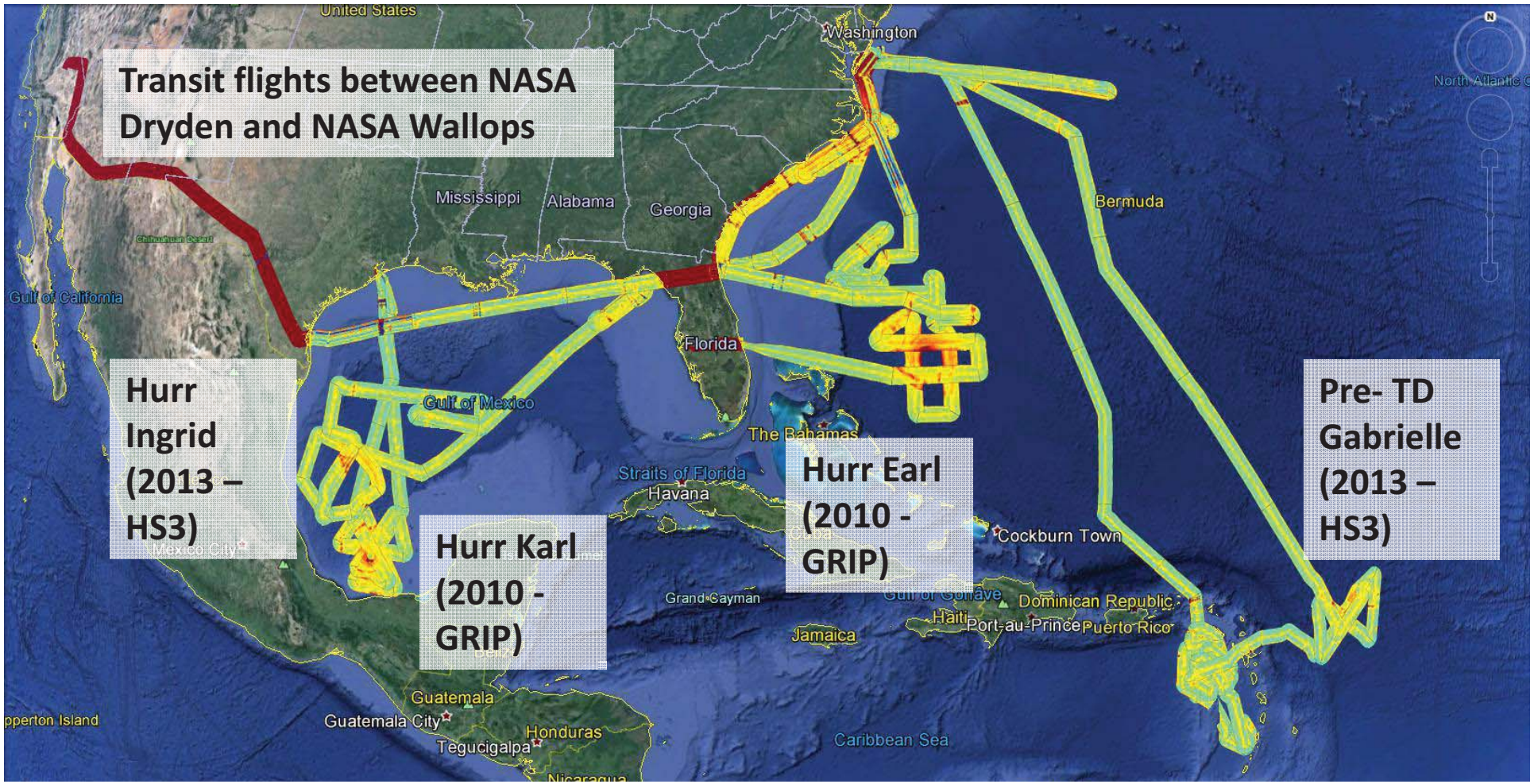
~50 km swath from NASA Global Hawk and WB-57

Partnership between NASA, NOAA, UMich, UCF, SAIC

Flights from Global Hawk in HS3 (2012-14) and WB-57 in GRIP (2010)

Re-calibration of previous data is underway. Plots here use old data that will be corrected this spring.

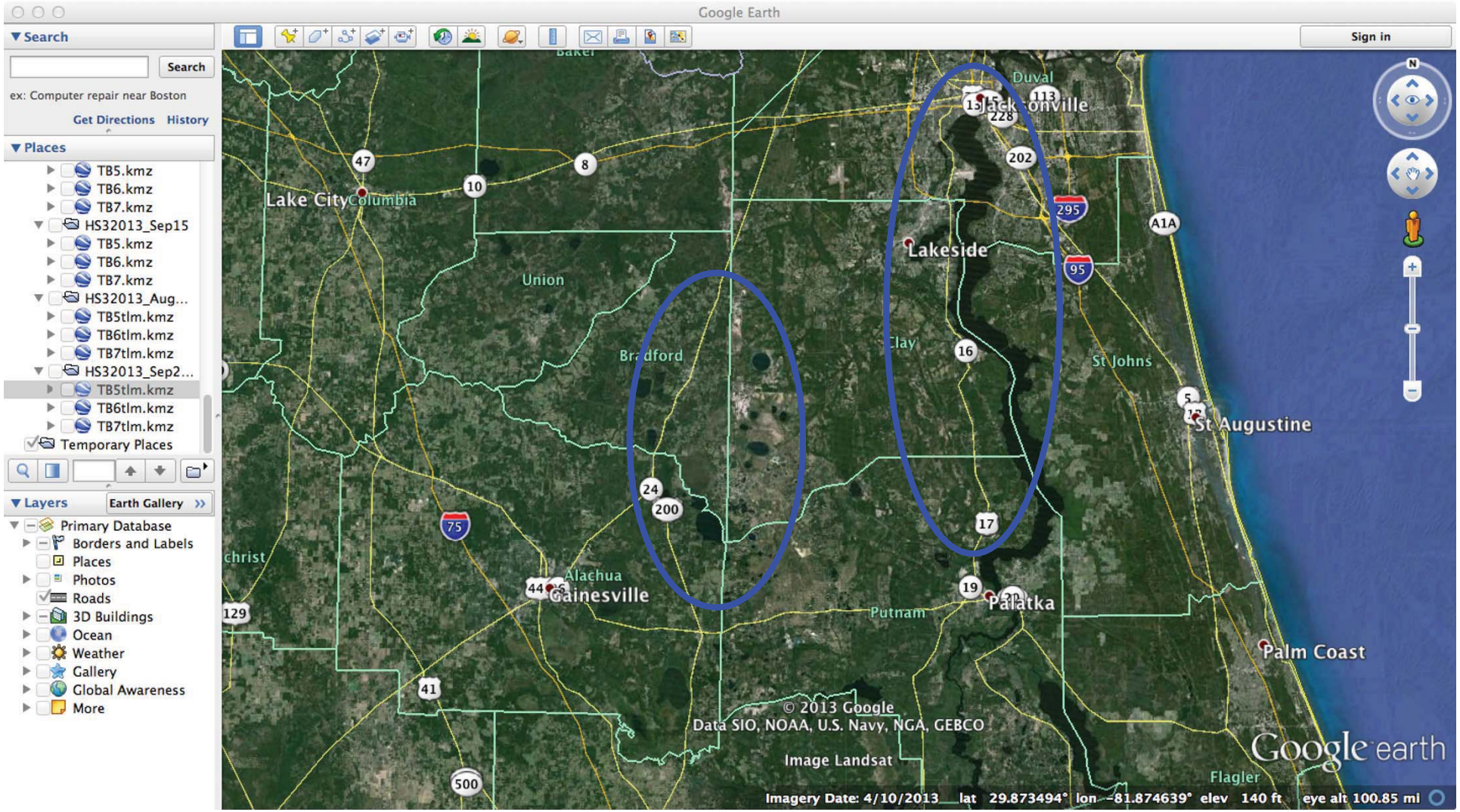
Flights in 2010 & 2013 - HIRAD 6.6 GHz TB



Earl and Karl (2010) flights from WB-57; Global Hawk allows longer duration, greater sampling
Note size difference between Hurricane Earl and Hurricane Karl

Cross-Scan structure

- Synthetic Thinned Array Radiometer (STAR) antenna technology
- The antenna is not mechanically scanning across discrete scenes
- Instead the swath is derived based on combination of signals from many antenna patches
- Want to confirm that real spatial structures are represented in the swath



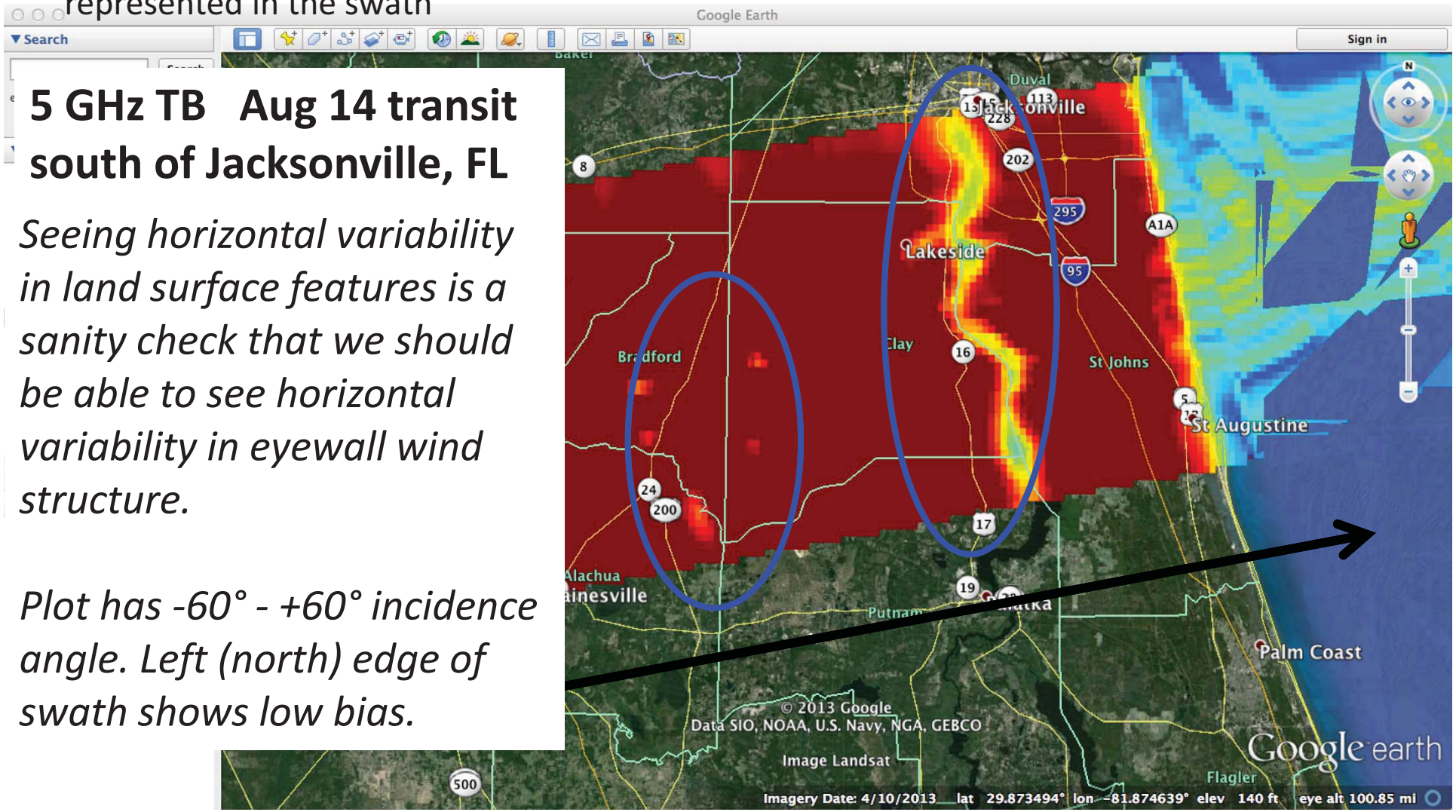
Cross-Scan structure

- Synthetic Thinned Array Radiometer (STAR) antenna technology
- The antenna is *not* mechanically scanning across discrete scenes
- Instead the swath is derived based on combination of signals from many antenna patches
- Comparisons with rivers, lakes, barrier islands confirms that real spatial structures are represented in the swath

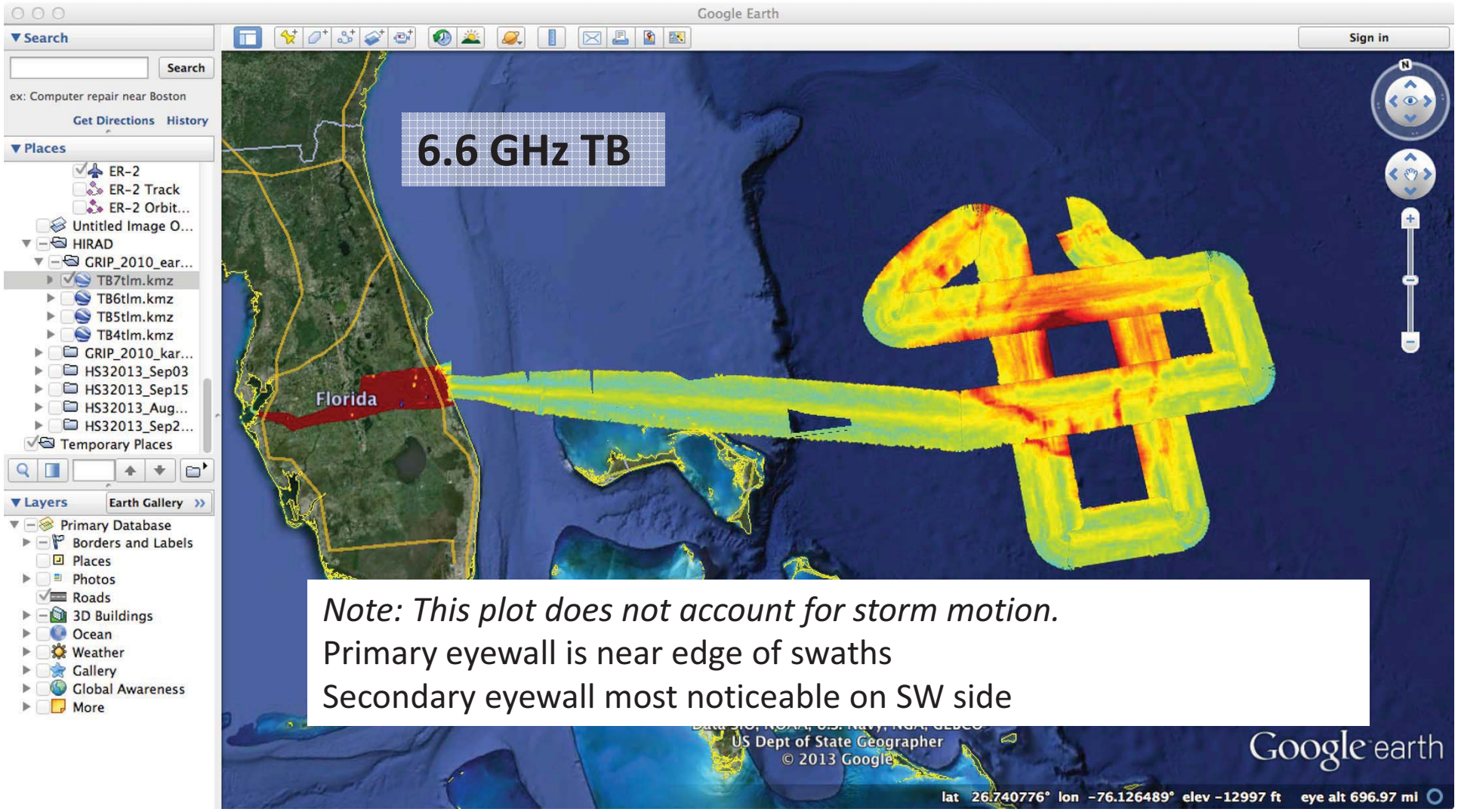
5 GHz TB Aug 14 transit south of Jacksonville, FL

Seeing horizontal variability in land surface features is a sanity check that we should be able to see horizontal variability in eyewall wind structure.

Plot has -60° - +60° incidence angle. Left (north) edge of swath shows low bias.



Hurricane Earl (2010) Brightness Temp

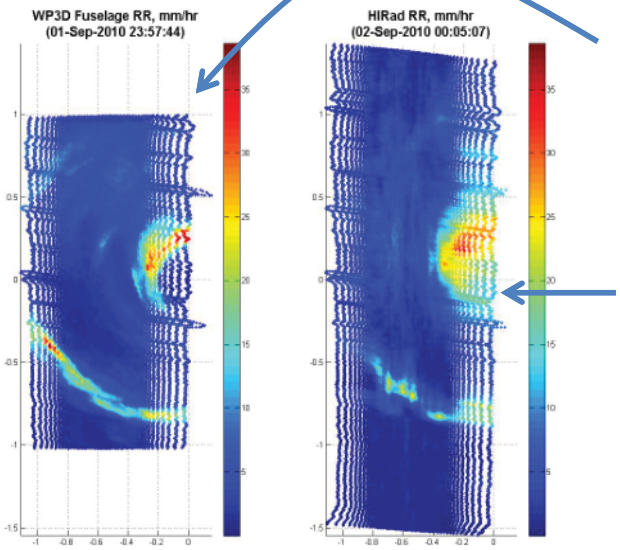


Note: This plot does not account for storm motion.

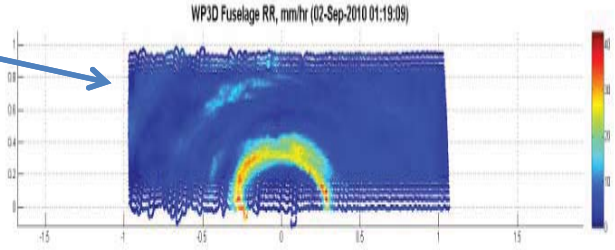
Primary eyewall is near edge of swaths

Secondary eyewall most noticeable on SW side

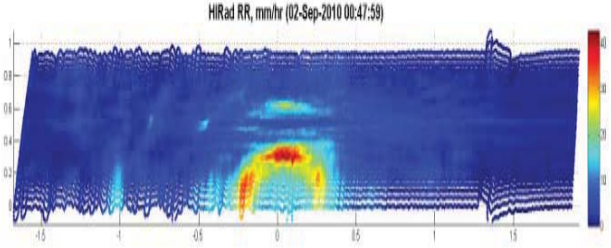
HIRAD rain rates vs re-mapped radar rain rates



P-3 LF radar-derived rain rates



HIRAD retrieved rain rates

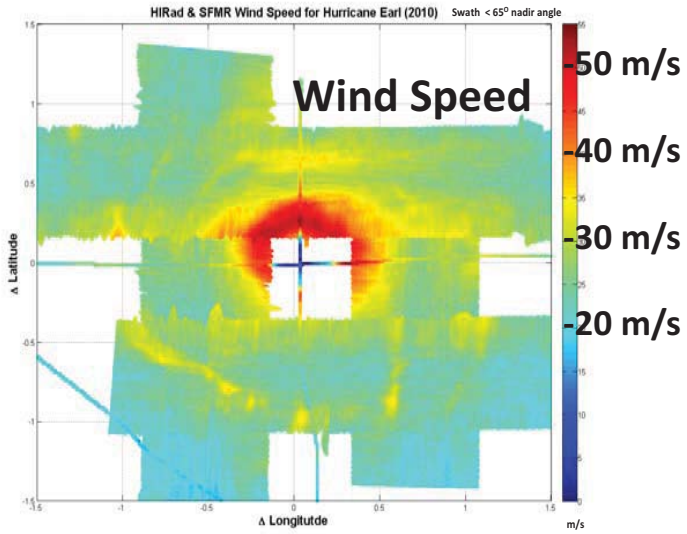


With eye near the edge of the swath (as in Hurricane Earl flight), simplest HIRAD algorithms will mis-assign some eyewall rain from the slant path to the surface in the eye.

Mary Morris and Chris Ruf (UMich) working on Coupled Retrieval Algorithm to account for this. (not shown in this presentation)

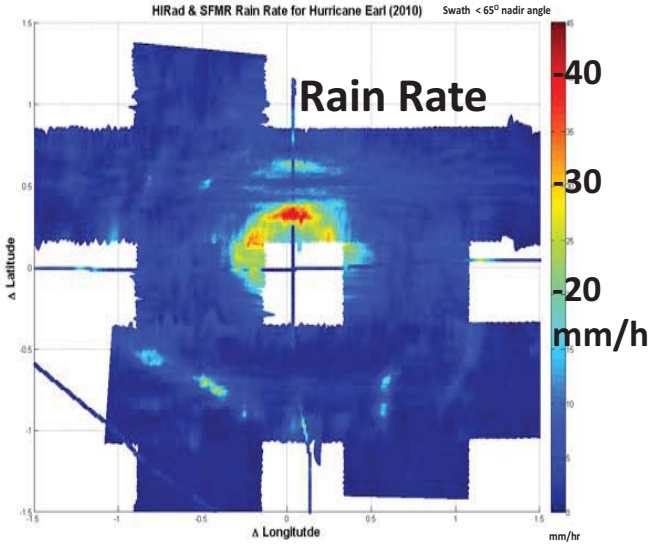
Retrievals in this presentation use uncoupled algorithms from UCF group (Linwood Jones et al.)

Hurricane Earl (2010) retrievals



Aircraft track was outside the eyewall, but eyewall was mostly mapped within the swath

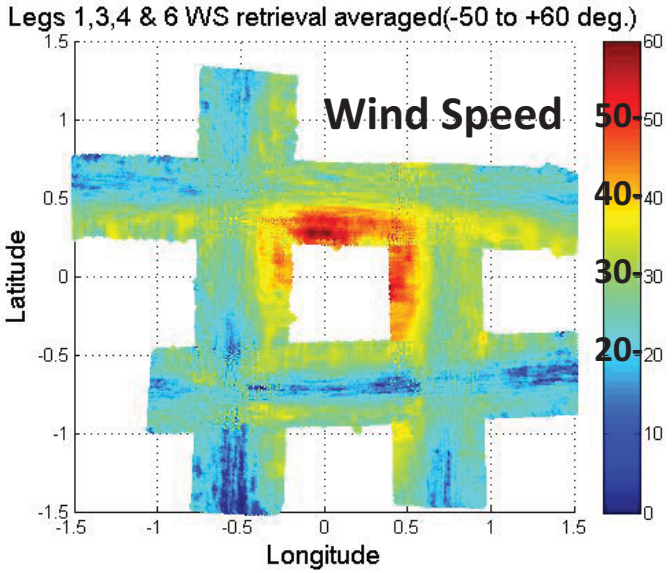
There are across-track biases to clean up



"Quick-look Retrieval": Empirical algorithm, based on SFMR colocations

- 5 GHz linear relationship with Wind Speed
- 6.6 GHz second-order relationship with Rain Rate

Hurricane Earl (2010) retrievals



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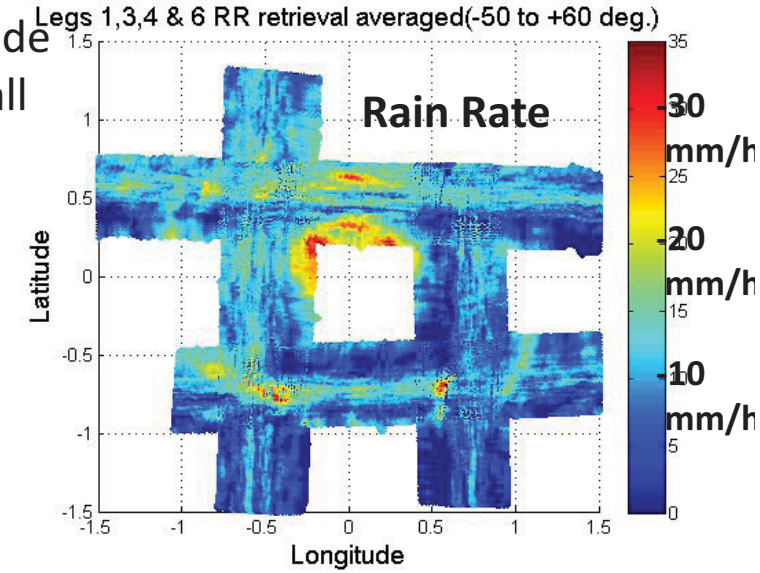
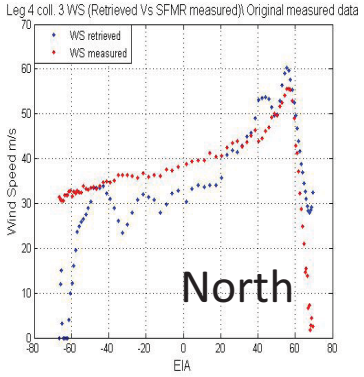


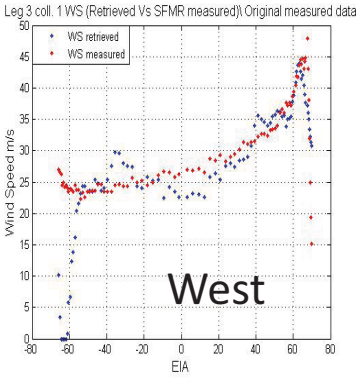
"Maximum Likelihood Estimate (MLE)": Physical algorithm, based on radiative transfer model

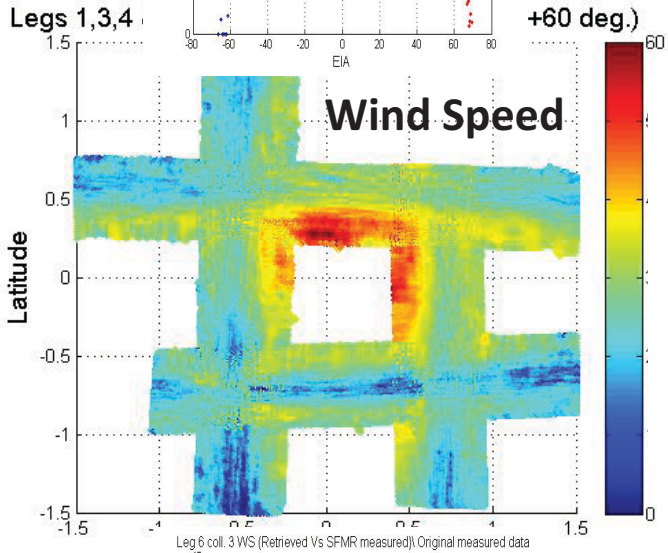
- 4.0, 5.0, and 6.6 GHz channels used
- 6.0 GHz channel was noisy in GRIP

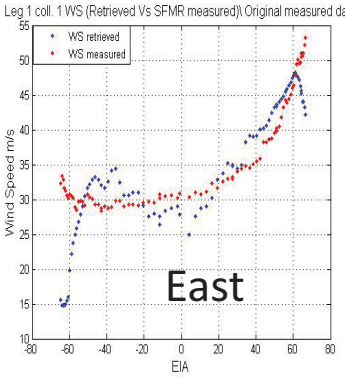
Hurricane Earl (2010) HIRAD vs SFMR

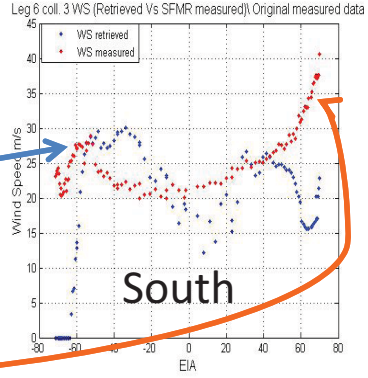
X-axis Earth Incidence Angle (EIA) corresponds to about 300 m per degree of EIA











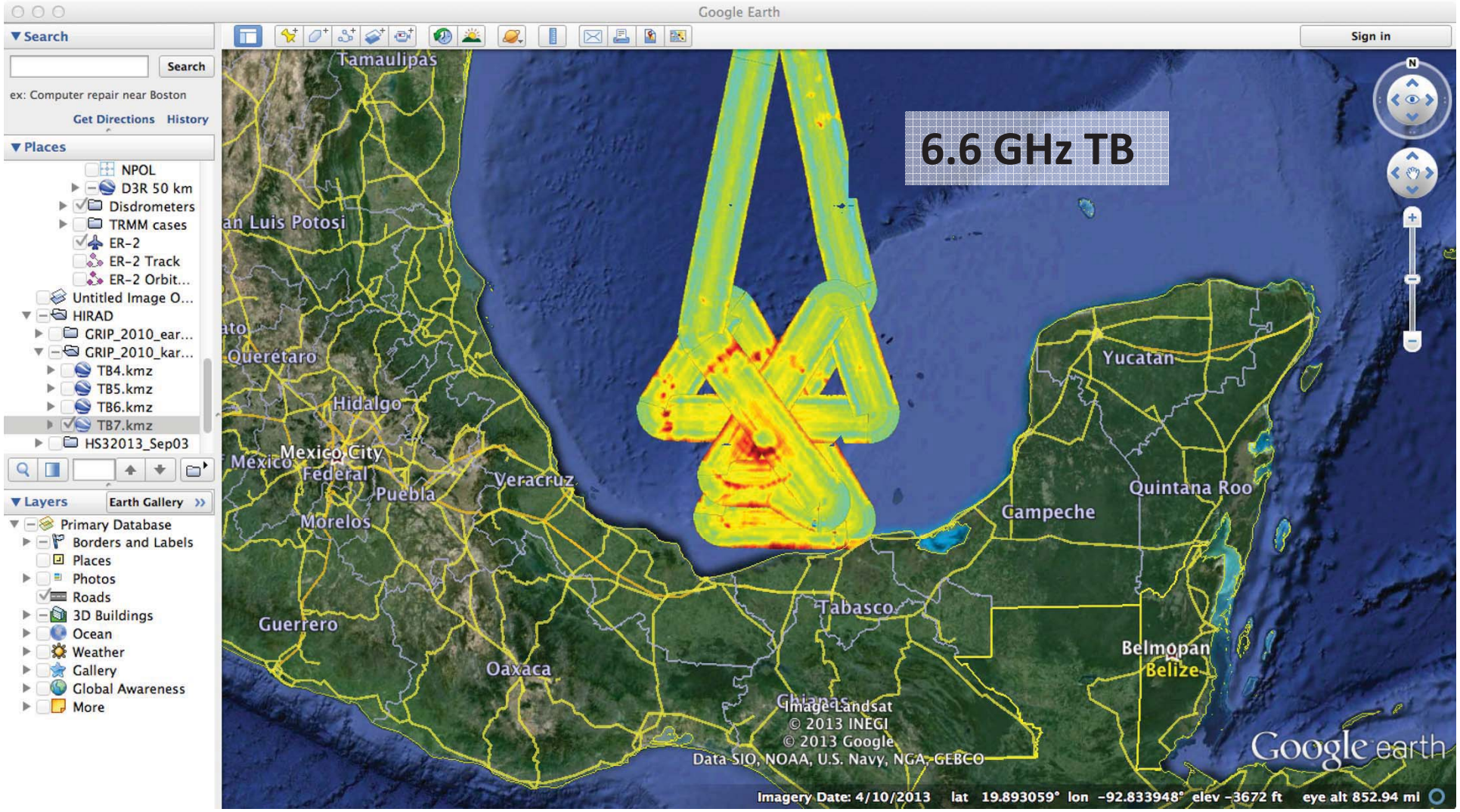
Large differences on south side: HIRAD sees secondary eyewall further north than SFMR, does not see peak eyewall winds near edge of swath

HIRAD retrievals (blue) mostly match up well with SFMR retrievals (red) in places where SFMR flew through the HIRAD swath.

HIRAD data appears good between -50° - +60° azimuths. Large biases on left edge of swaths.

Some differences due to tens of minutes offset between observations.

Hurricane Karl (2010) Brightness Temp

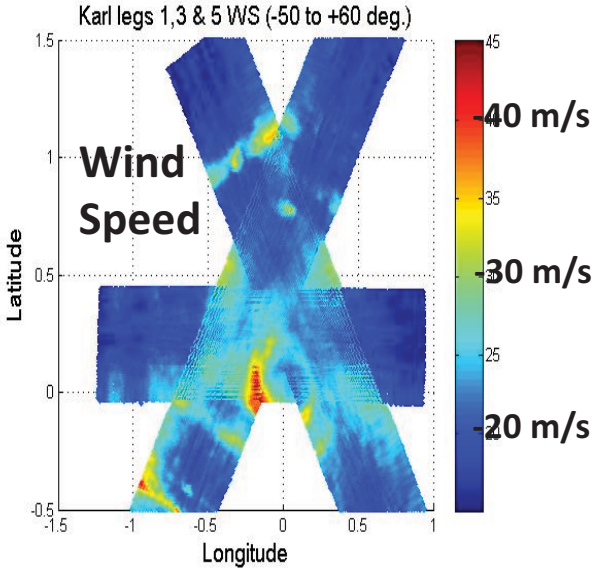


Hurricane Karl (2010) wind speed

"Quick-look Retrieval": Empirical algorithm, based on SFMR colocations

trained with Hurricane Earl (no re-tuning)

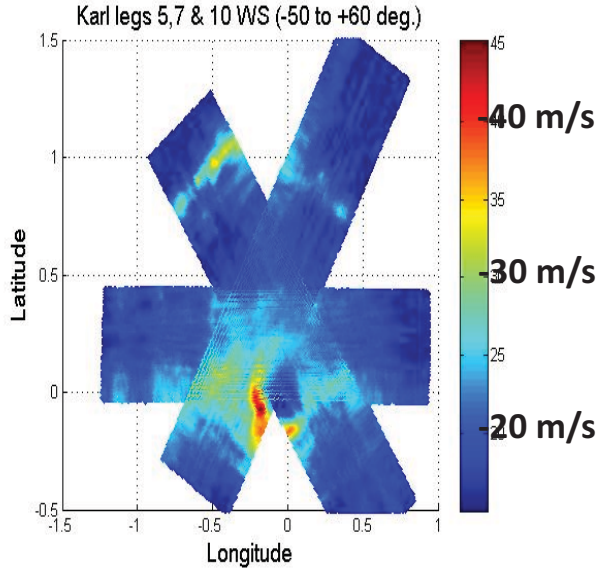
- 5 GHz linear relationship with Wind Speed



Repeated patterns near the center, mapping storm structure

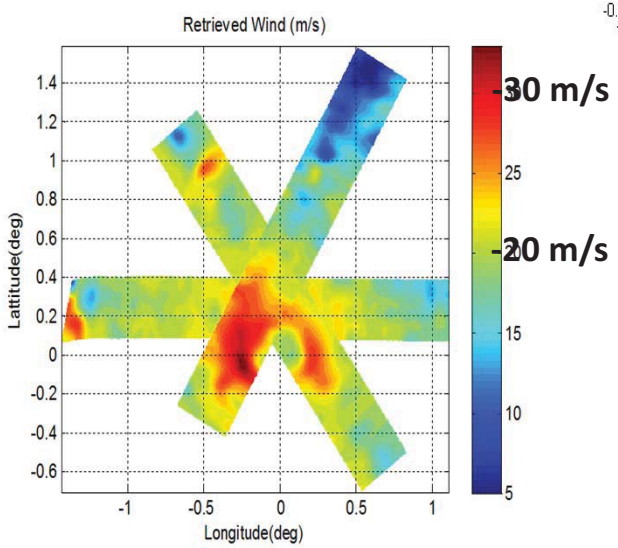
Legs 1, 3, 5 on left

Legs 5, 7, 10 on right

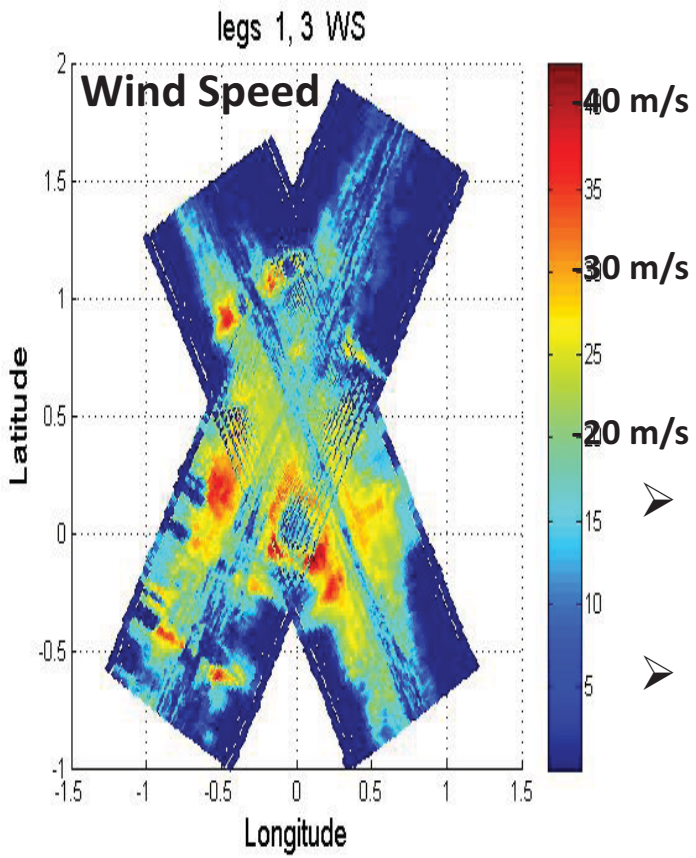


Bottom : Additional smoothing of TBs for legs 5, 7, 10.

Removes some noise, but decreases wind speed too much.



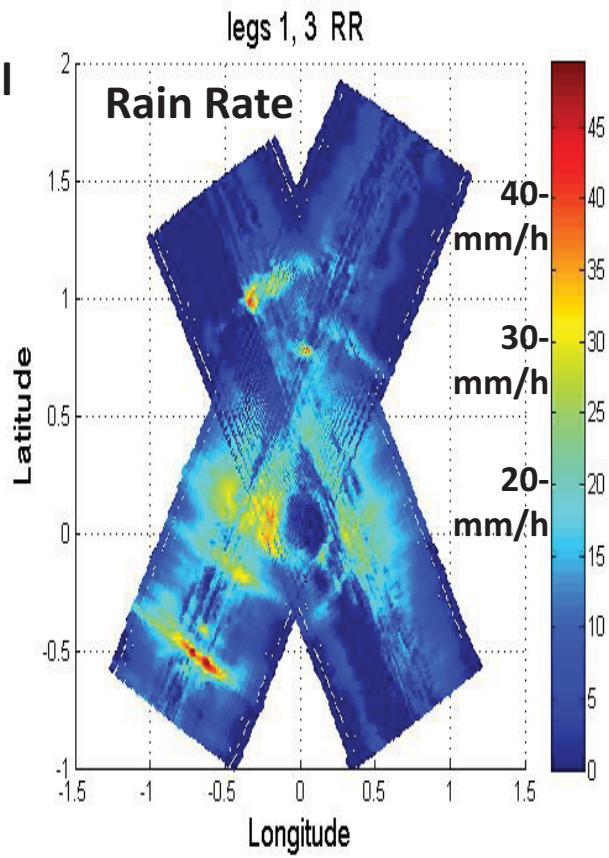
Hurricane Karl (2010) retrievals



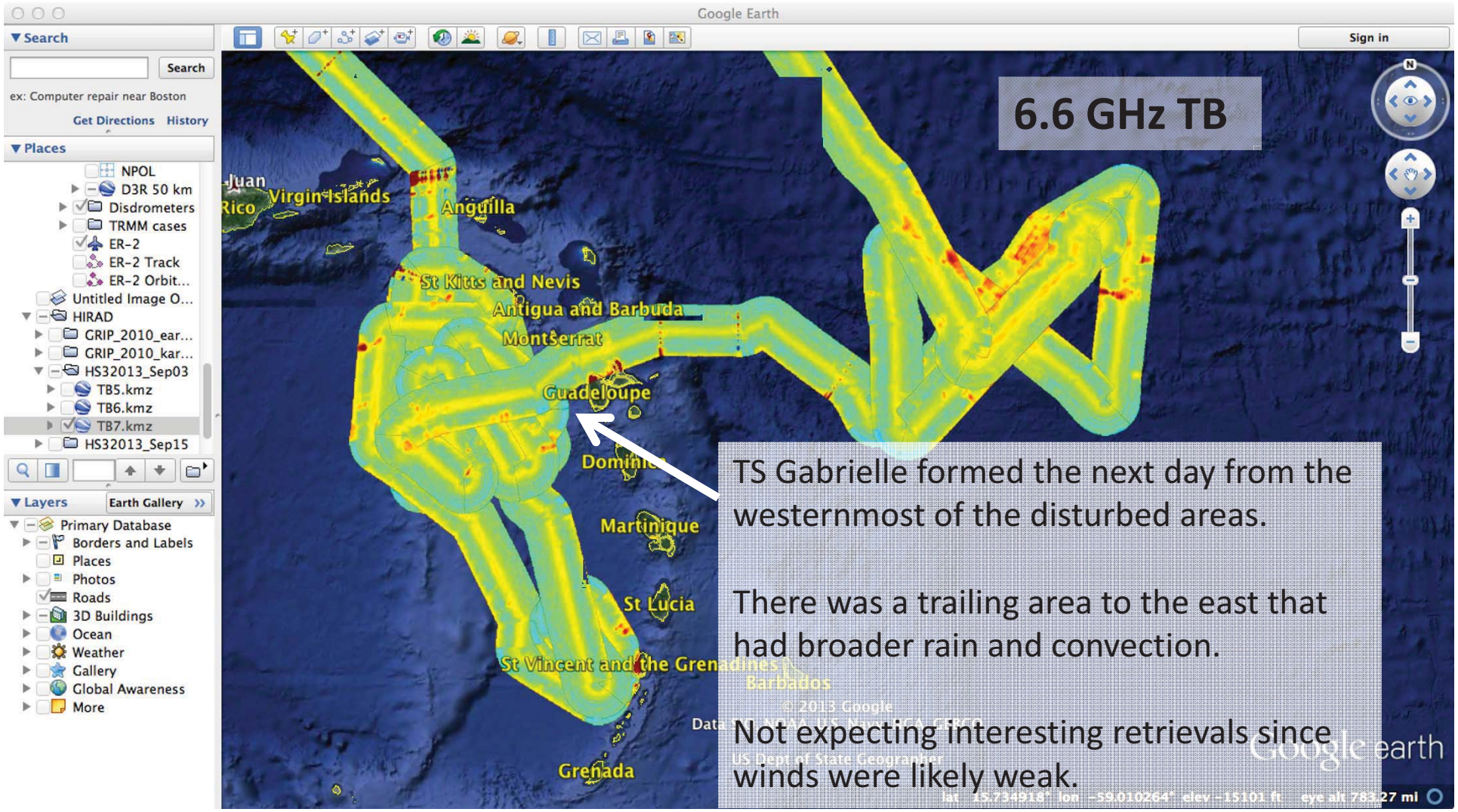
"Maximum Likelihood Estimate (MLE)": Physical algorithm, based on radiative transfer model

- 4.0, 5.0, and 6.6 GHz channels used
- 6.0 GHz channel was noisy in GRIP

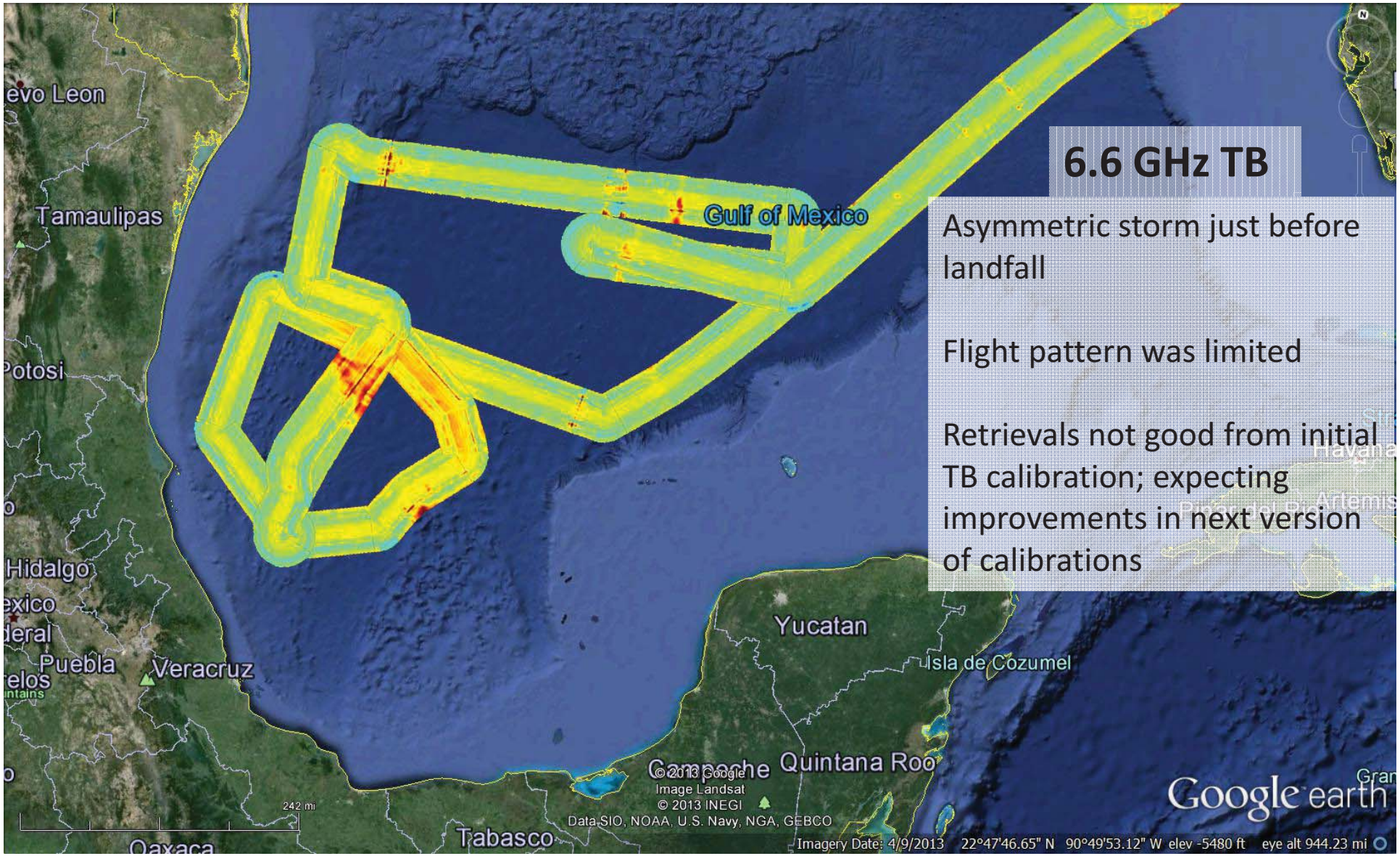
- Clearly more noise in this retrieval than in the quicklook
- MLE is more sensitive to relative calibrations of each channel; ***improvements to calibrations are in progress***
- These plots include large incidence angles, where performance is worst (edge of swath)



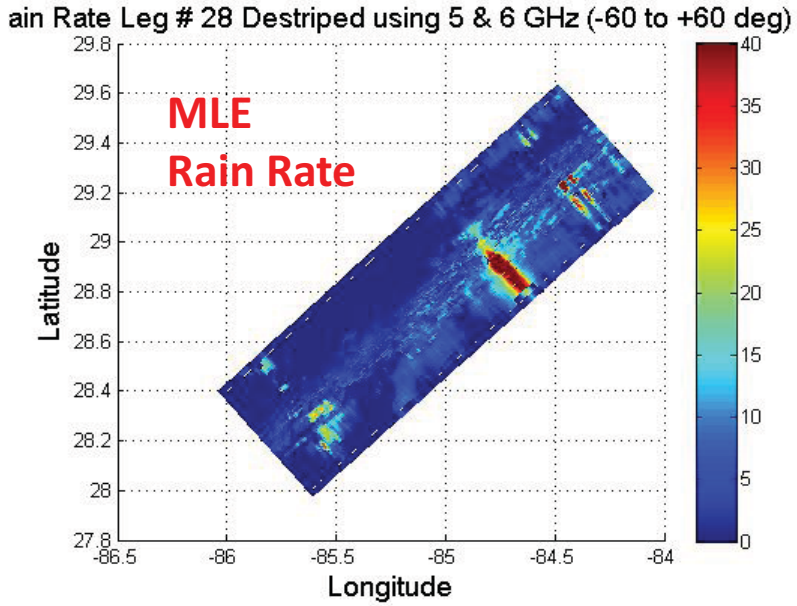
Pre-TD Gabrielle (2013) Brightness Temp

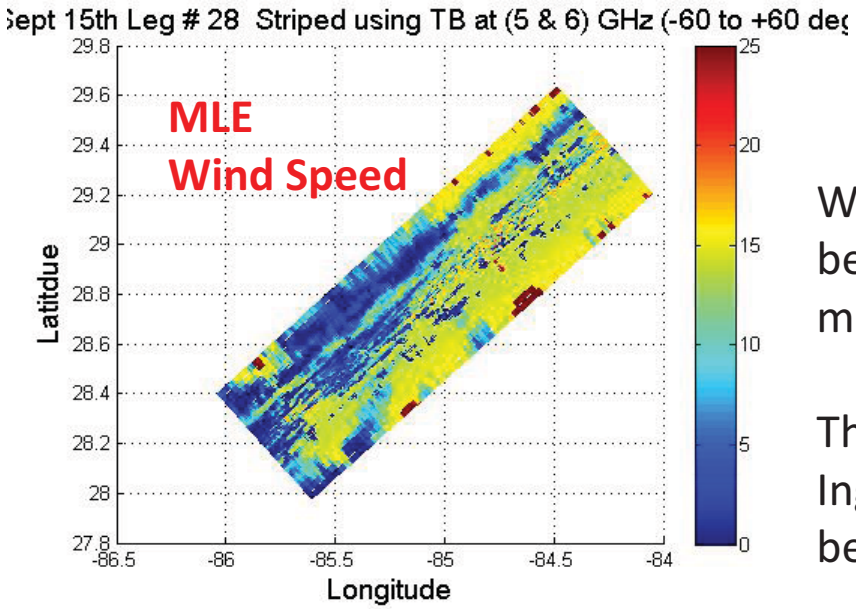


Hurr Ingrid (2013) Brightness Temp

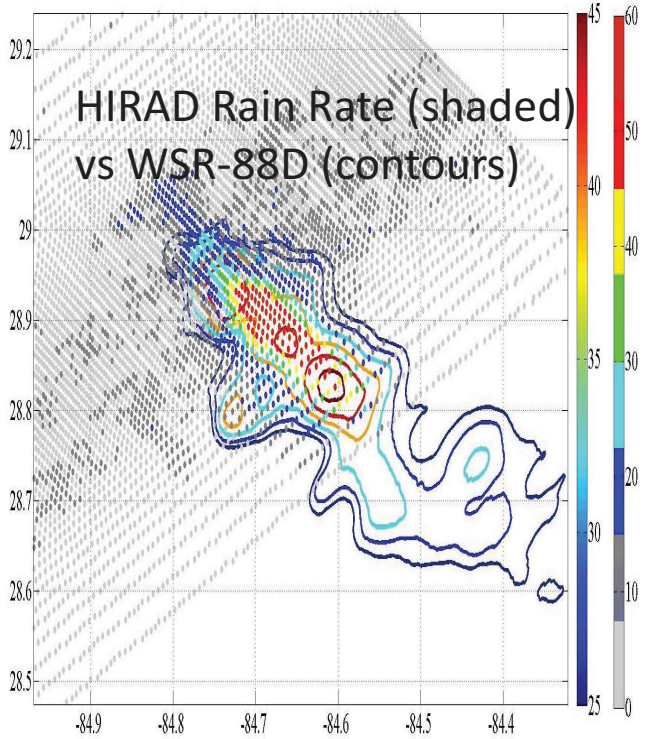


Rain case near Tampa 88D





On the return from H. Ingrid, we sampled rain bands near the Tampa WSR-88D. Retrievals of heavy rain match up well with 88D reflectivity contours.



Wind retrievals (bottom) are below 15 m/s – below HIRAD's ability to detect anything meaningful.

That is good – this is far from Hurricane Ingrid, and we expected wind speeds to be below our detectability here.

Summary

- HIRAD is designed to make SFMR-like retrievals of surface wind speed over a wide swath from high-altitude aircraft
- Hurricane flights so far:
  - Earl (2010) from WB-57 (GRIP)
  - Karl (2010) from WB-57 (GRIP)
  - Ingrid (2013) from Global Hawk (HS3)
- Improved calibration procedures currently being implemented. Plots shown here are all from old calibration.
- Robust spatial structure is seen across the swath
- Signal degrades at incidence angles > ~50°
- Empirical (quicklook) and physical (MLE) retrieval algorithms both show promise, but depend on accurate TB calibration
- Biases as a function of incidence angle require further smoothing / filtering

Upcoming work

- Improved calibration procedures for brightness temperatures currently being implemented; will be applied to the data that has already been collected
- New wind and rain retrievals late this spring
- Better thermal control of instrument in future flights
- HS3 flights Aug-Sep 2014