Hurricane Imaging Radiometer (HIRAD) 2014 and 2015 Observations

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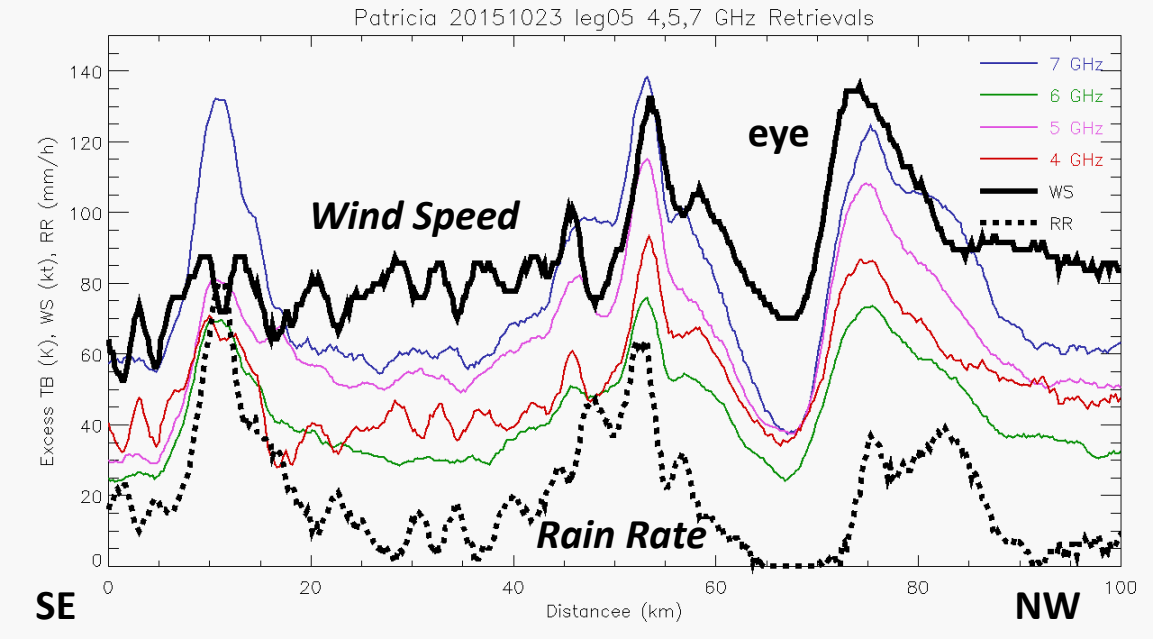
HIRAD Background

C-band (4, 5, 6, 6.6 GHz) radiometer

Retrieval concept similar to the operational Stepped Frequency Microwave Radiometer (SFMR)

Retrieve Wind Speed and Rain Rate over ocean, *but over a wide swath*



Rain especially affects higher freq channels

Wind causes an increase in all channels

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

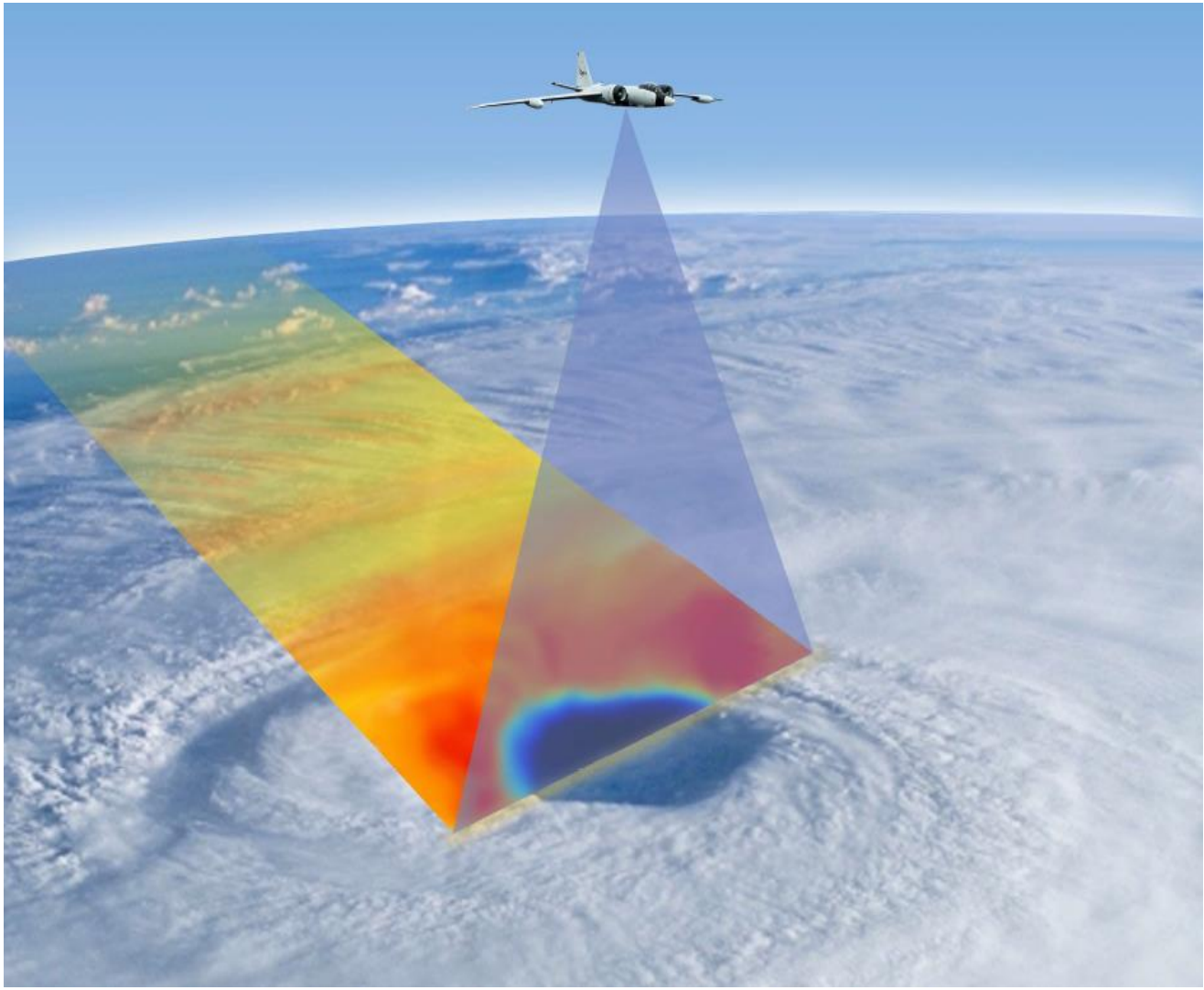
HIRAD on NASA WB-57

HIRAD flew on WB-57 for NASA HS3 in 2014 and ONR TCI in 2015.

~20 km altitude, looking down on storm

~50-70 km swath width

WB57 also had High Density Dropsonde System (HDSS) in 2015, typically dropping ~70-80 sondes in a flight.



Tropical Cyclone Intensity Experiment (TCI 2015)

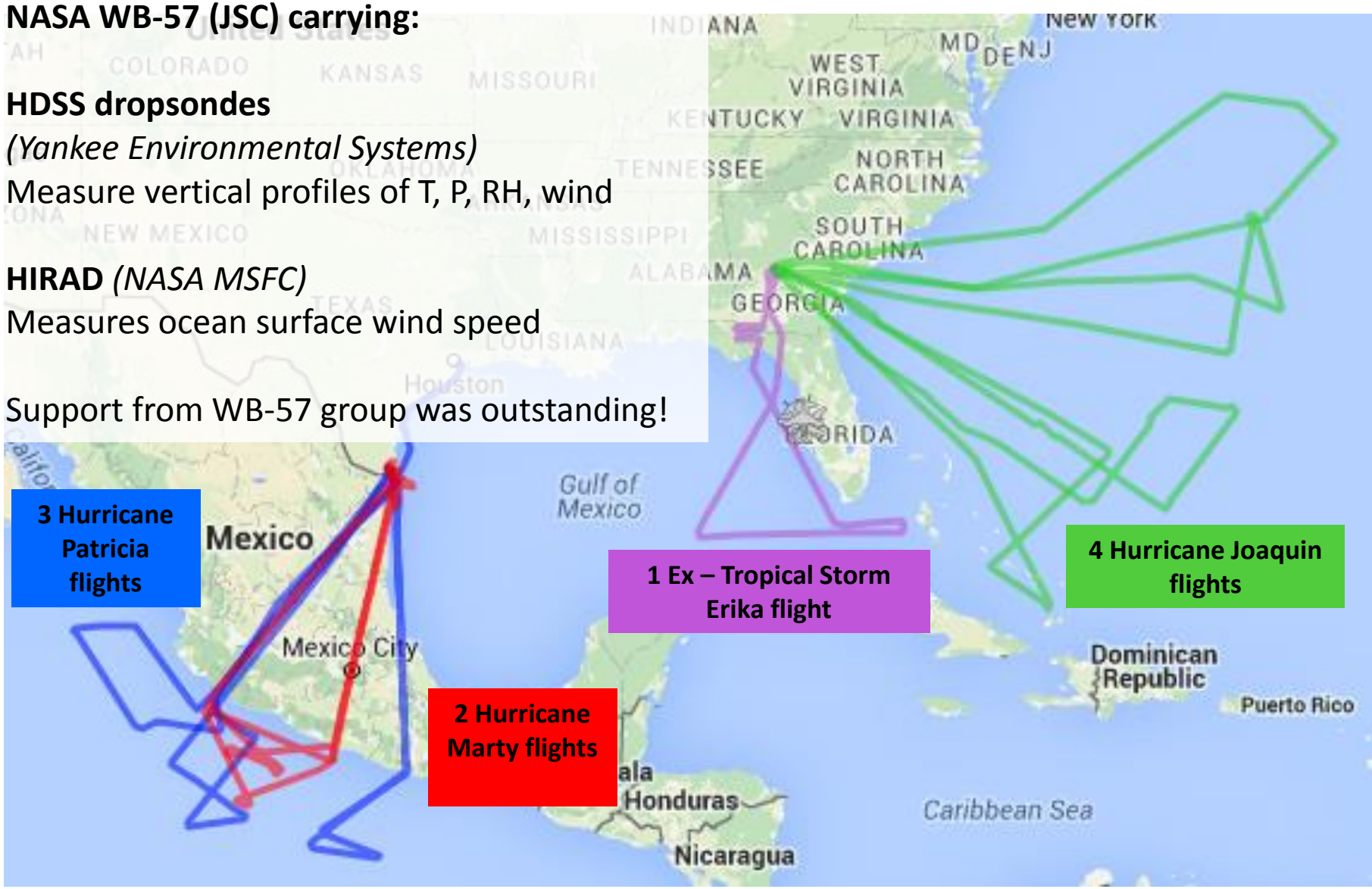
funded by Office of Naval Research

NASA WB-57 (JSC) carrying:

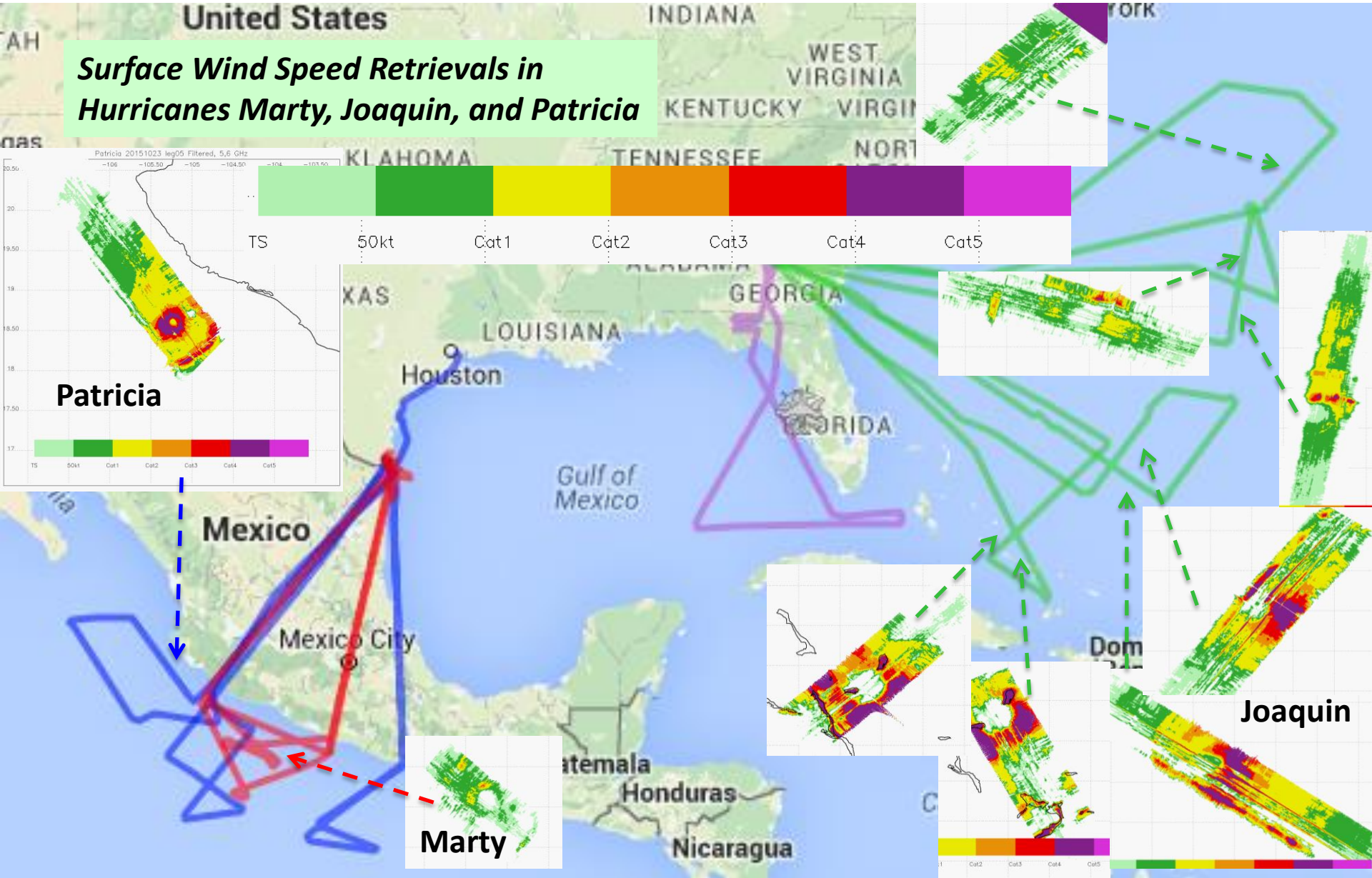
HDSS dropsondes
(Yankee Environmental Systems)
Measure vertical profiles of T, P, RH, wind

HIRAD *(NASA MSFC)*
Measures ocean surface wind speed

Support from WB-57 group was outstanding!



2015 Tropical Cyclone Intensity (TCI) Science Flights



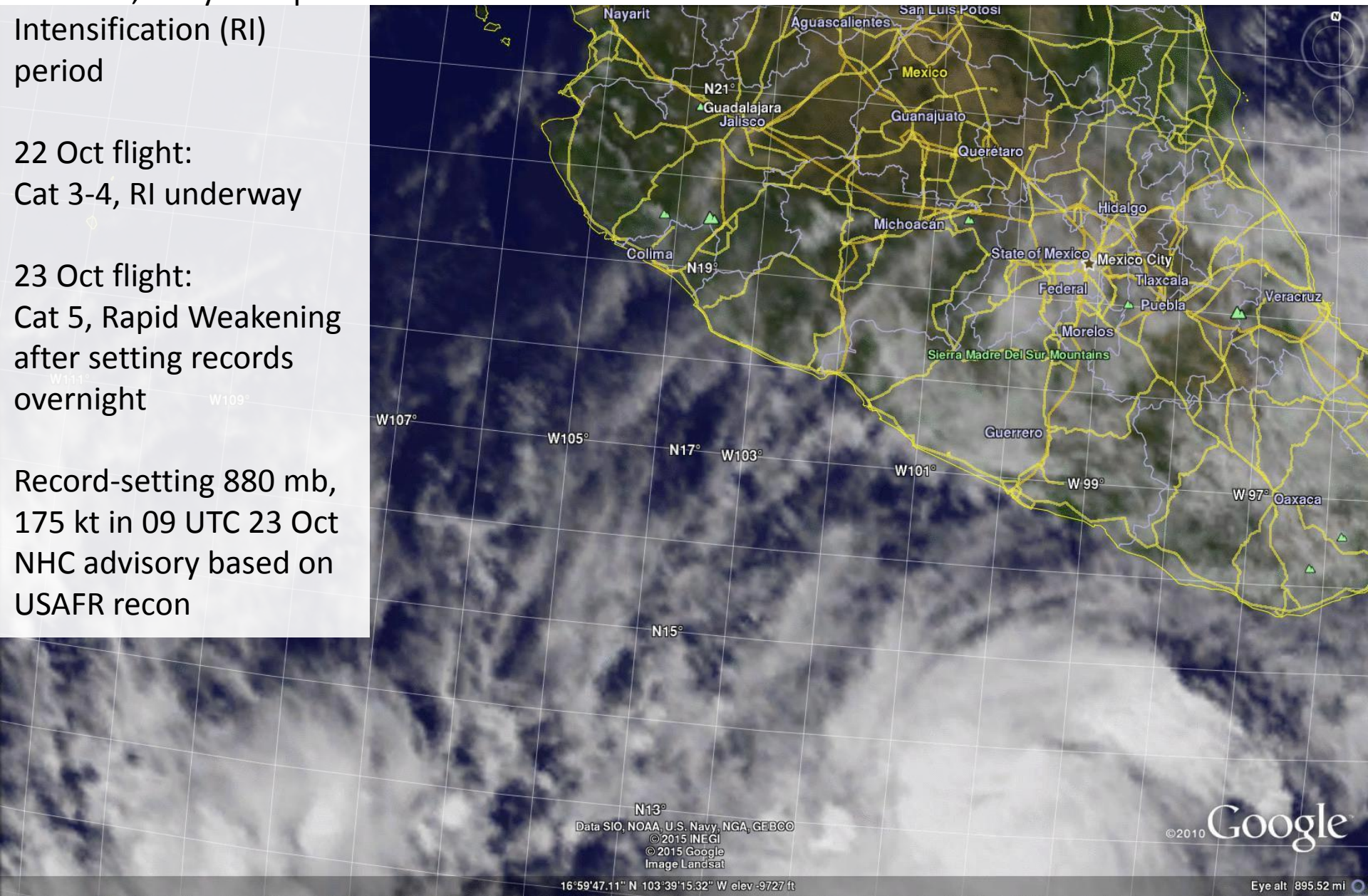
Hurricane Patricia (2015)

21 Oct flight:
Weak TS, early in Rapid Intensification (RI) period

22 Oct flight:
Cat 3-4, RI underway

23 Oct flight:
Cat 5, Rapid Weakening after setting records overnight

Record-setting 880 mb, 175 kt in 09 UTC 23 Oct NHC advisory based on USAFR recon

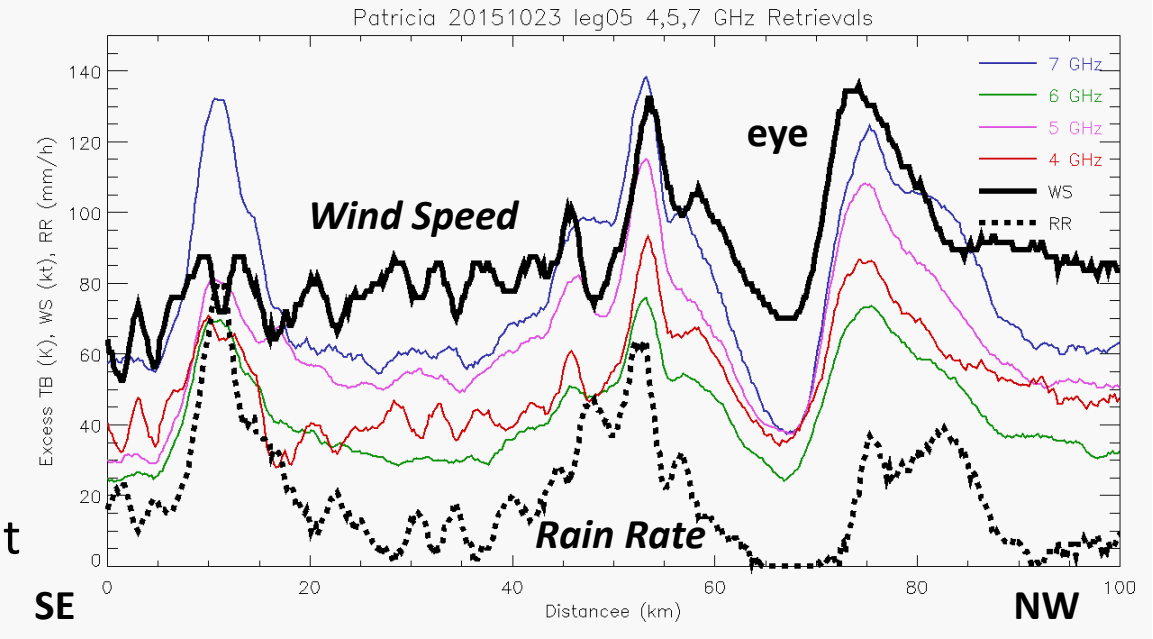


HIRAD Calibration & Retrievals

Retrievals are sensitive to overall calibration, and relative calibration between channels

Bias in one channel can push retrievals toward unrealistic combinations of wind and rain

Biases are not constant from flight to flight, and also vary with scan position (striping)



Rain especially affects higher freq channels

Wind causes an increase in all channels

6 GHz channel is biased low in this Hurricane Patricia example. Retrieval excludes 6 GHz channel

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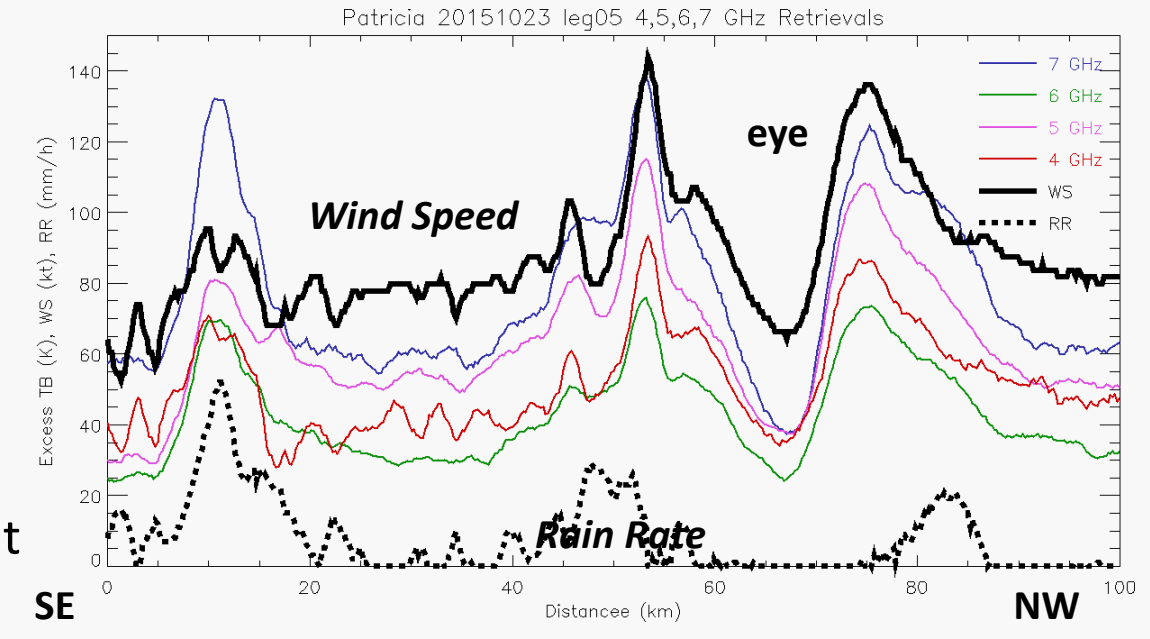

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6 GHz channel is biased low in this Hurricane Patricia example. 4-channel retrieval increases peak wind, decreases rain rate

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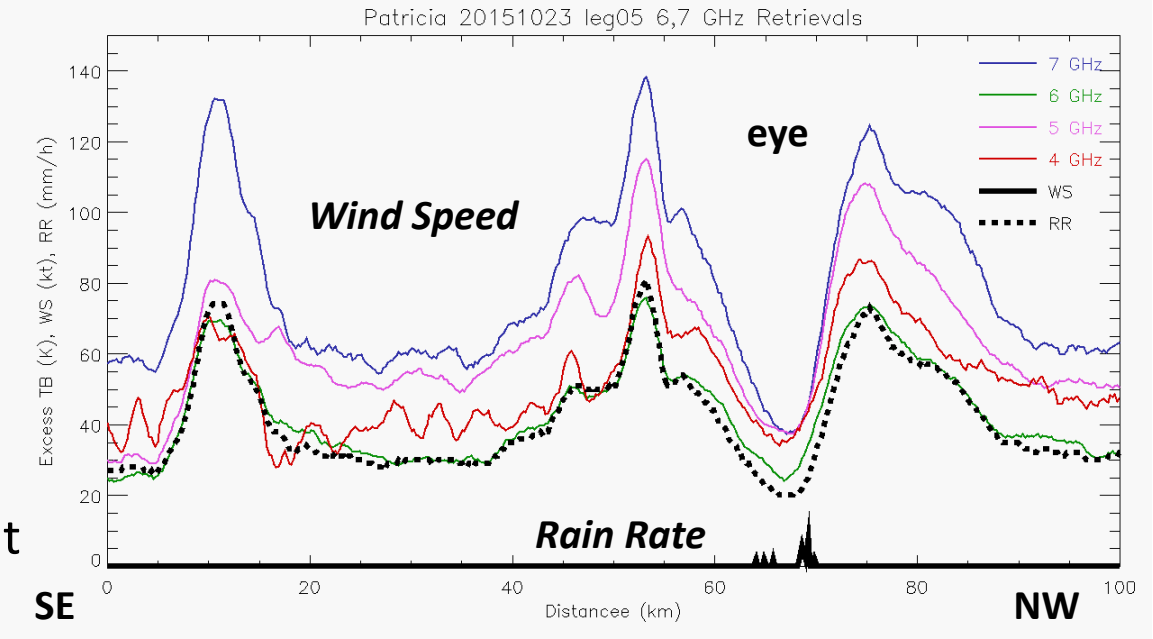

Rain especially affects higher freq channels

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6 GHz channel is biased low in this Hurricane Patricia example. 2-channel retrieval using 6 & 7 GHz interprets everything as rain, almost no wind, because 6 GHz is too low

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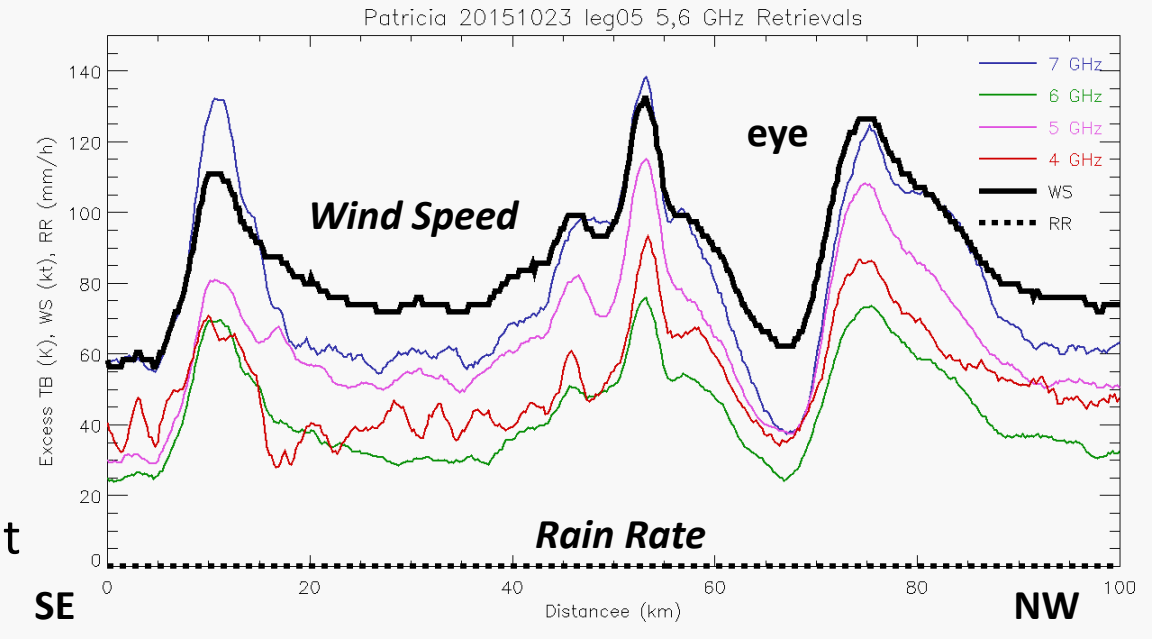

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6 GHz channel is biased low in this Hurricane Patricia example. 2-channel retrieval using 5 & 6 GHz interprets everything as wind, with no rain, because 6 GHz is too low

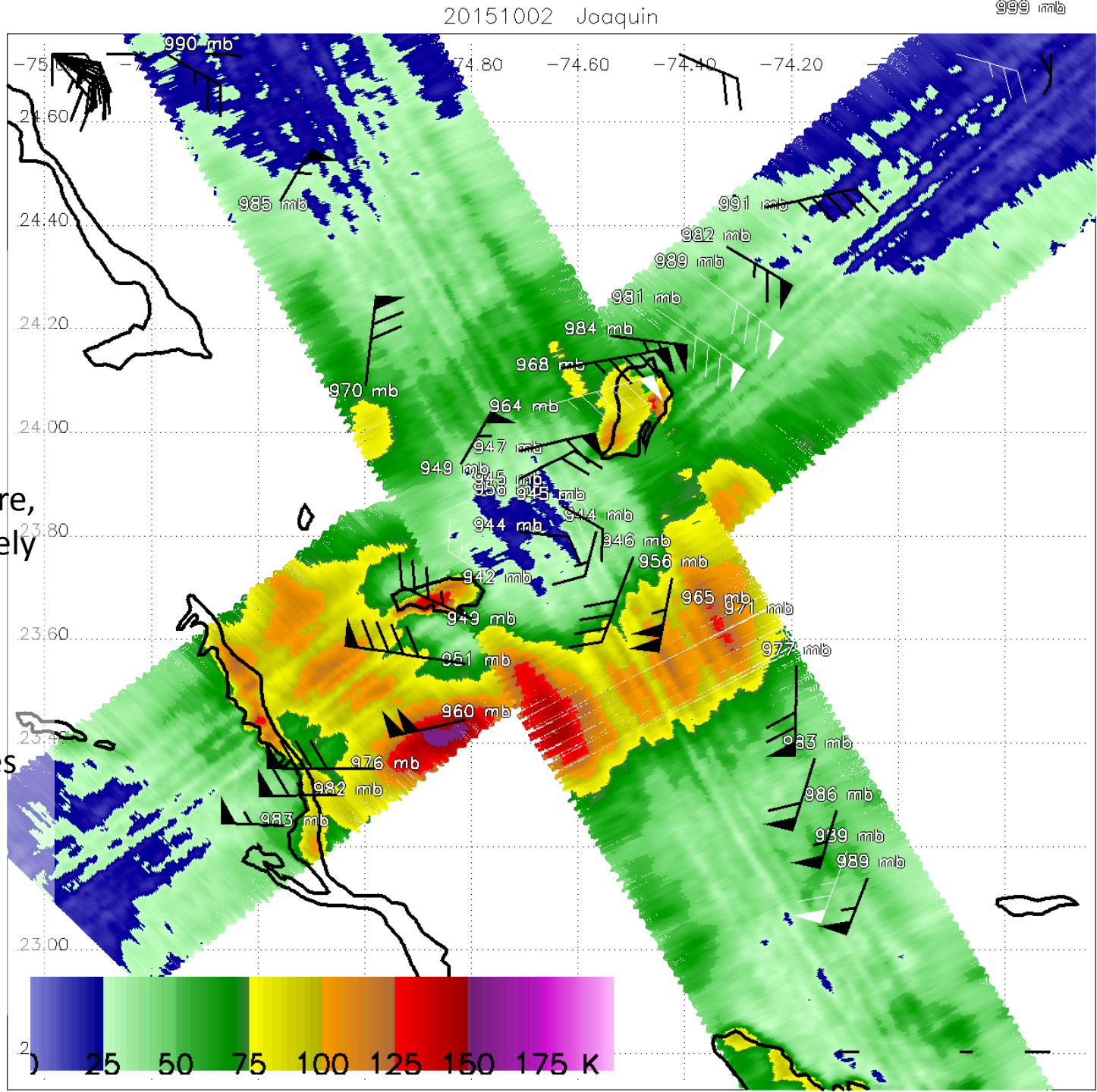
Hurricane Joaquin 02 Oct 2015

Preliminary HIRAD 6.6 GHz Excess TB, rough calibration.

WB-57 dropsondes support 942 mb pressure, 105 kt surface wind, likely missed max wind

Wind Barbs are surface wind speed estimates from WB-57 dropsondes

White barbs are estimates from sondes that failed higher than 150 m above surface



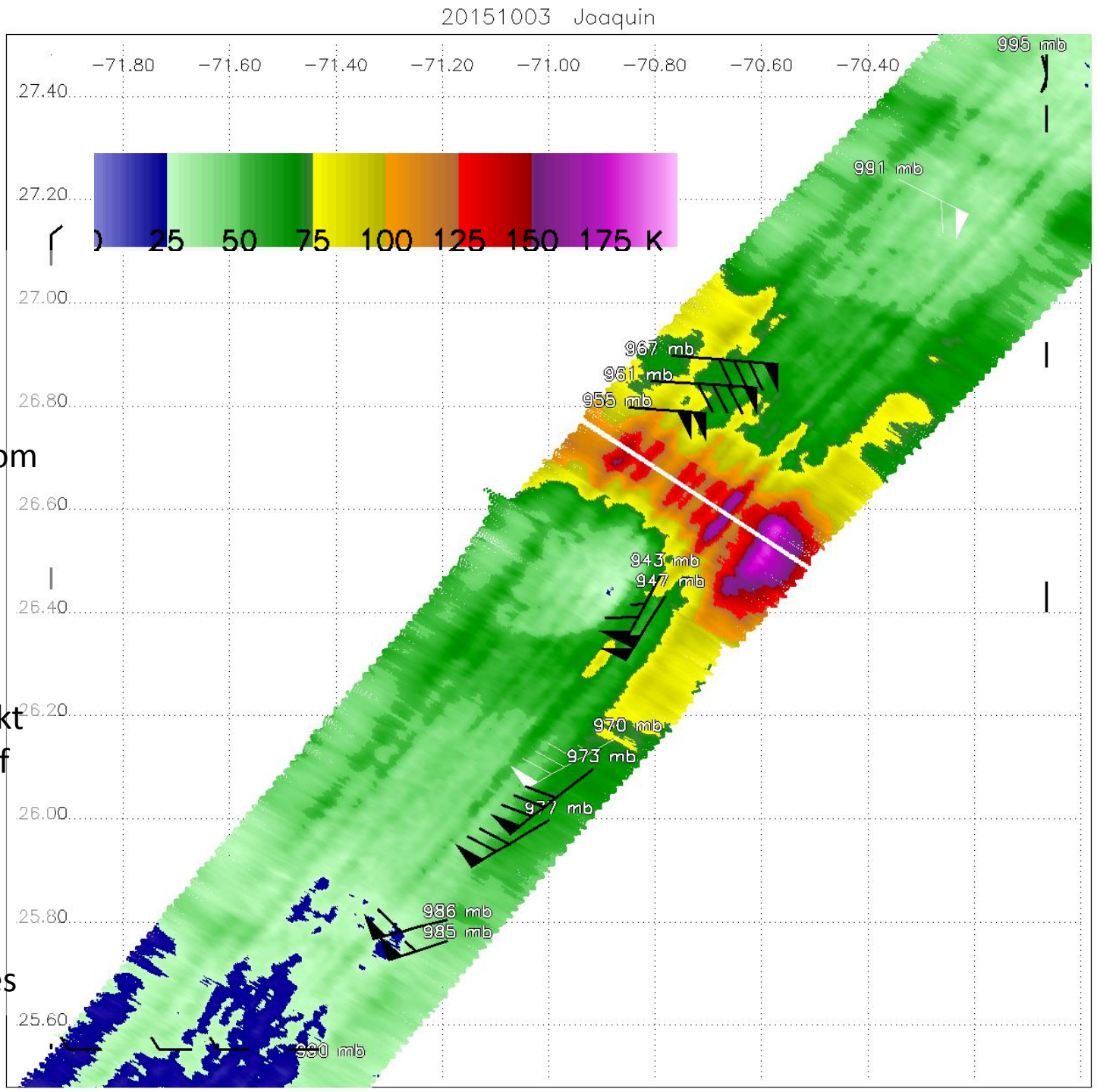
Hurricane Joaquin 03 Oct 2015

Preliminary HIRAD 6.6 GHz Excess TB, rough calibration.

100 kt surface winds from dropsondes, but *HIRAD shows those sondes missed the region of strongest winds*

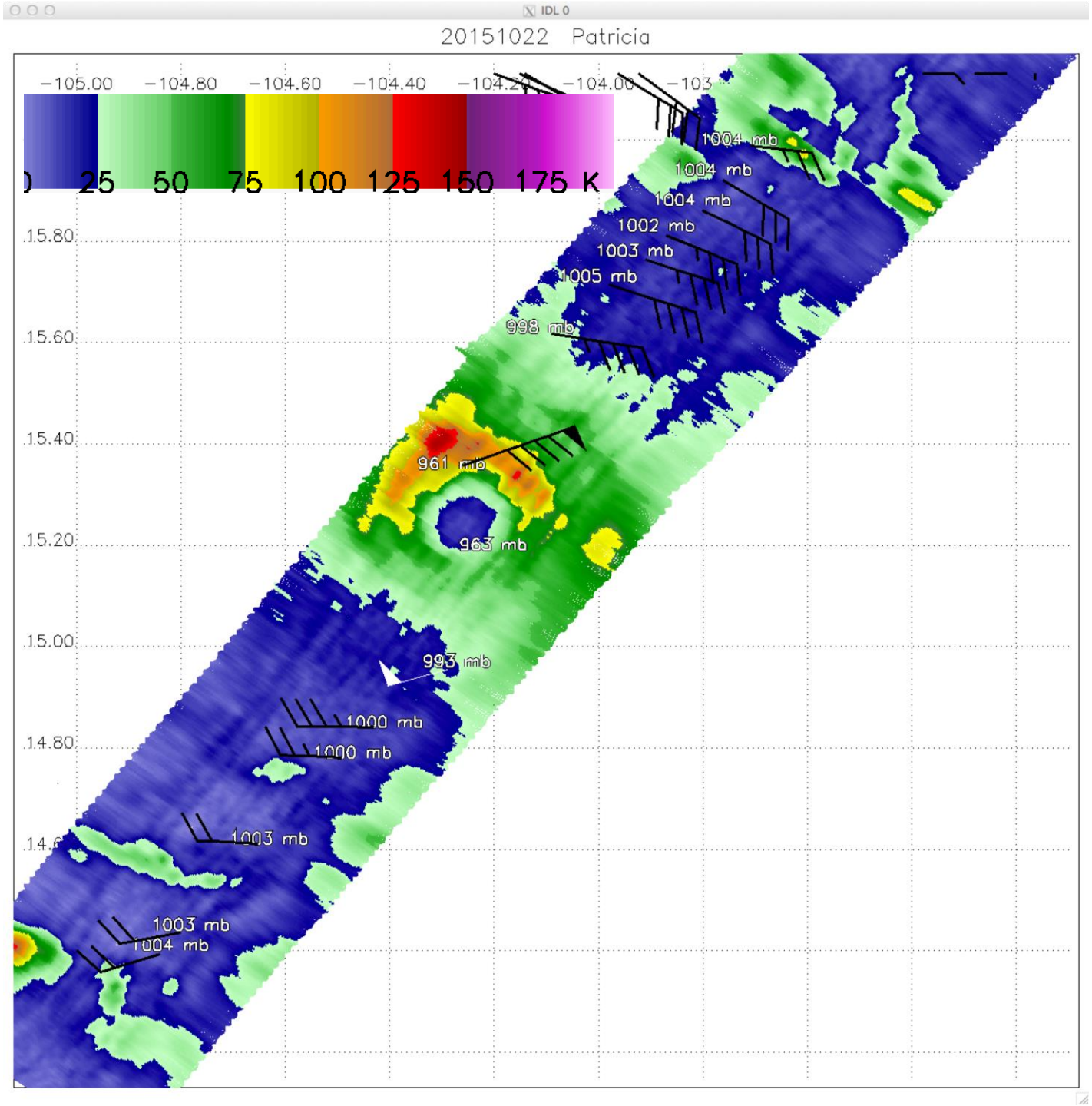
NHC estimate was 130 kt during this flight, end of RI period

Wind Barbs are surface wind speed estimates from WB-57 dropsondes



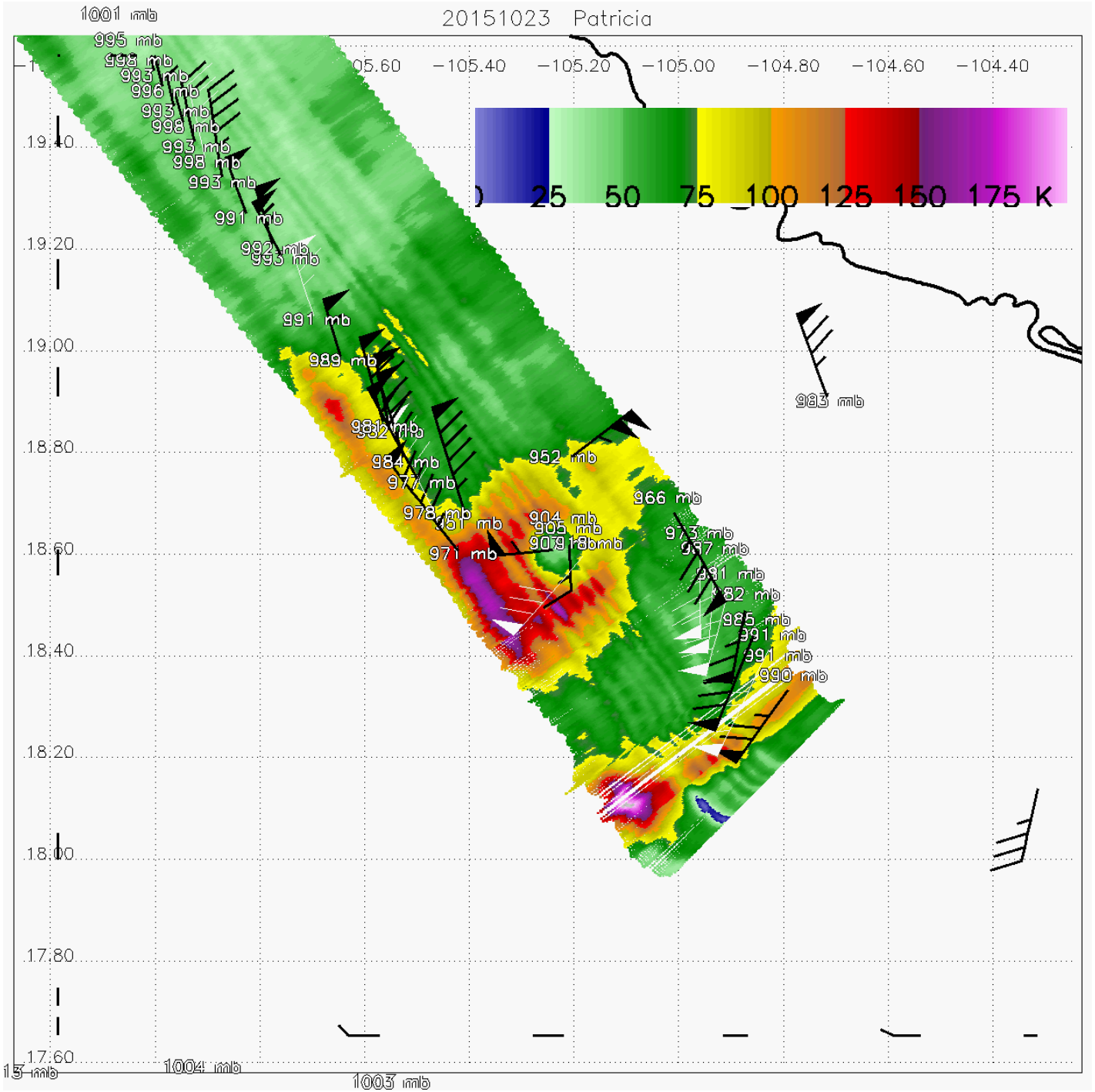
Hurricane Patricia 22 Oct 2015

6.6 GHz Excess TB and near-surface dropsonde winds



Hurricane Patricia 23 Oct 2015

6.6 GHz Excess TB and near-surface dropsonde winds

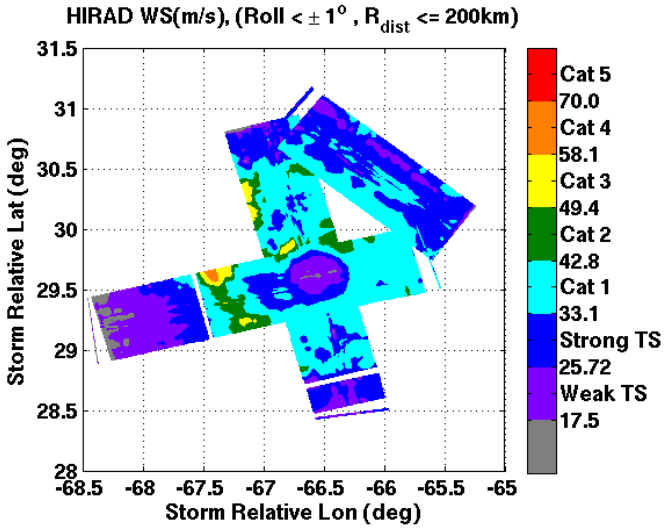


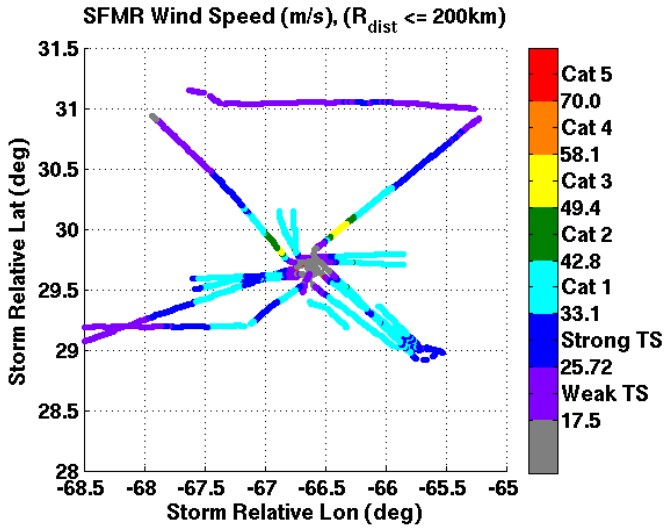
Hurricane Gonzalo (2014) Wind Speed

Wind Speed Retrievals from Hurricane Gonzalo (2014) flights appear successful

Left: HIRAD Wind Speed

Right: SFMR (operational instrument) Wind Speed from separate aircraft





HIRAD paints more complete picture of the storm with only two passes from WB-57, compared to nadir-viewing SFMR with several passes on low-altitude recon aircraft

Status

- Initial retrievals realistically depict the *horizontal structure* of the hurricanes (Gonzalo 14, Marty 15, Joaquin 15, Patricia 15)
- But quantitative aspects of the calibration and retrievals need more work
- Instrument subject to along-track biases that depend on scan position and are not constant throughout / between flights
- 4.0 GHz channel very noisy, other channels are especially noisy on some flights
- Initial retrievals have some obvious large errors, where inadequate brightness temperature calibrations lead to the signal being interpreted as all-wind or all-rain, instead of a mixture of both

Future / Ongoing Work

- Filtering the scan-position-dependent biases (promising, but imperfect)
- Improve relative calibrations between the channels, in order to improve the retrievals
- New antenna + beamformer is being designed and built, to improve sensitivity (reduce signal loss) and stability of calibration. Current design is not sensitive below about 35 kt (17 m/s) surface wind speed.
- Possible integration on NOAA P3, NASA Global Hawk, and/or more WB-57 flights
- Long term, hope to add wind *direction*