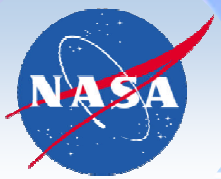
Observations during GRIP from HIRAD: Ocean surface wind speed and rain rate

Timothy L. Miller, NASA/MSFC, Huntsville, AL; and M. W. James, W. L. Jones, C. S. Ruf, E. W. Uhlhorn, M. C. Bailey, C. D. Buckley, D. E. Simmons, S. Johnstone, A. Peterson, L. A. Schultz, S. Biswas, J. W. Johnson, G. Shah, D. Fenigstein, W. H. Cleveland, and R. E. Hood

HIRAD (Hurricane Imaging Radiometer) flew on the WB-57 during NASA's GRIP (Genesis and Rapid Intensification Processes) campaign in August – September of 2010. HIRAD is a new C-band radiometer using a synthetic thinned array radiometer (STAR) technology to obtain cross-track resolution of approximately 3 degrees, out to approximately 60 degrees to each side of nadir. By obtaining measurements of emissions at 4, 5, 6, and 6.6 GHz, observations of ocean surface wind speed and rain rate can be inferred. This technique has been used for many years by precursor instruments, including the Stepped Frequency Microwave Radiometer (SFMR), which has been flying on the NOAA and USAF hurricane reconnaissance aircraft for several years. The advantage of HIRAD over SFMR is that HIRAD can observe a +/- 60-degree swath, rather than a single footprint at nadir angle.

Results from the flights during the GRIP campaign will be shown, including images of brightness temperatures, wind speed, and rain rate. To the extent possible, comparisons will be made with observations from other instruments on the GRIP campaign, for which HIRAD observations are either directly comparable or are complementary. Potential impacts on operational ocean surface wind analyses and on numerical weather forecasts will also be discussed.



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Genesis and Rapid Intensification Processes (GRIP) experiment

GRIP Science Objectives:

- Genesis: Distinguish the role of the larger-scale environment vs. mesoscale-convective processes near the putative developing center.
- Rapid Intensification (RI): Relative role of environmental vs. inner core processes? Is RI predictable?
- Test-bed: Evaluate candidate technologies for remote sensing from aircraft and from satellites. Wind lidar, passive microwave, dual-frequency radars, lightning, the Global Hawk itself.

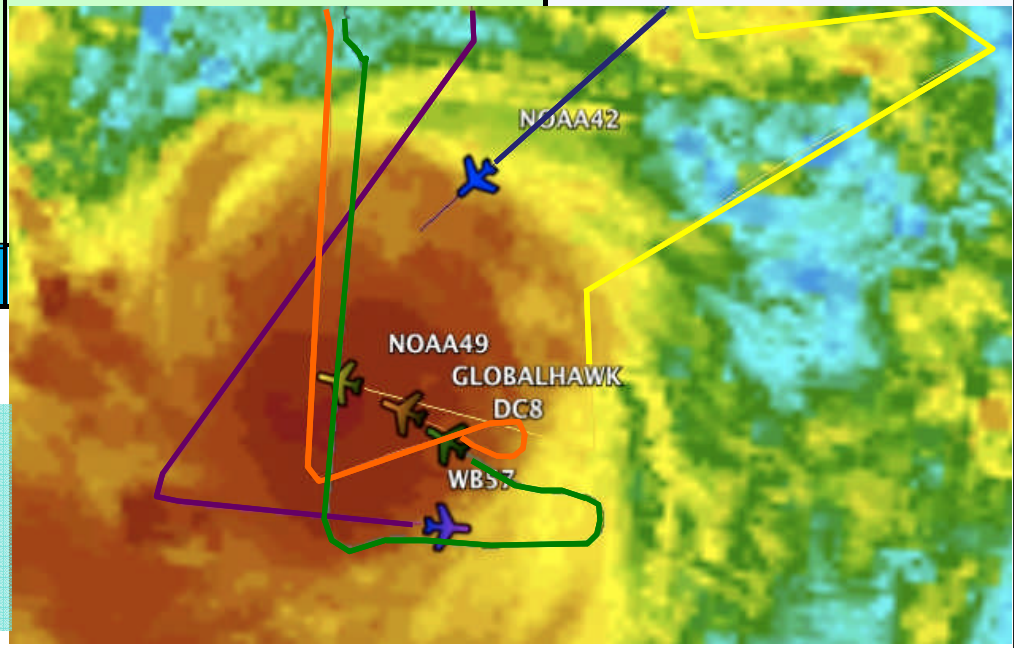
GRIP Operations

NASA Aircraft:

- Global Hawk – Unmanned Aerial System based at Dryden Flight Facility, California
  - Instruments: Lightning Instrument Package (LIP), High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), and High Altitude MMIC Sounding Radiometer (HAMSR)
- DC-8 – Based in Fort Lauderdale
  - Dropsondes, LASE, DAWN, APR-2, MMS, CAPS, CSI, PIP
- WB-57 – Based in Houston, Tampa
  - Hurricane Imaging Radiometer (HIRAD)

GRIP Aircraft Coordination

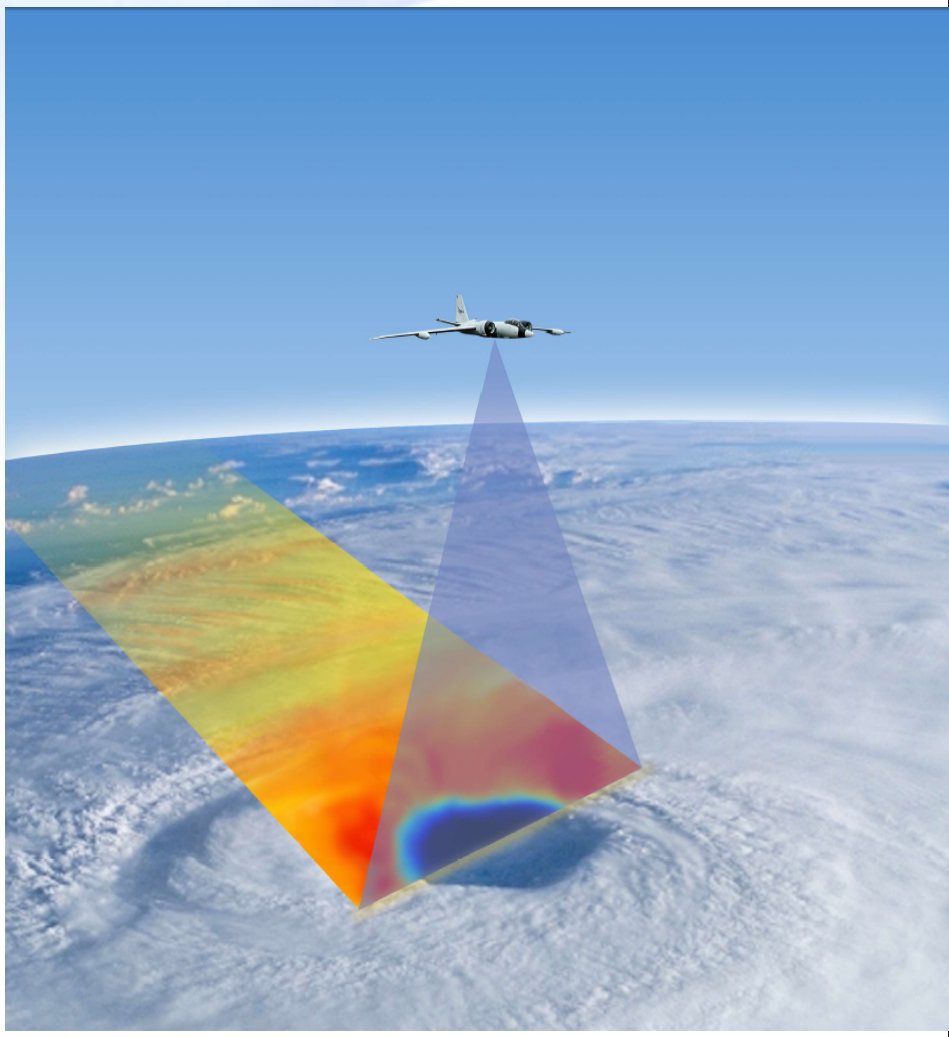
	NASA Aircraft Hours in GRIP			Partner Agency Participation		
Storm	Global Hawk	DC-8	WB-57	NOAA	NCAR	Air Force
Frank	15.3	0.0	0.0	No	No	No
Earl	24.2	39.3	5.5	Yes	Yes	Yes
Gaston	0.0	14.5	0.0	No	Yes	No
Karl	48.5	41.0	17.5	Yes	Yes	Yes
Other Science	0.0	12.2	0.0			
Transit and Test Flights	8.6	15.3	5.4			
Total	**96.6**	**122.3**	**28.4**			



Coordination of a combined 7 NASA, NOAA, AF aircraft in Hurricane Karl on 16 September 2010 at ~1955 UTC

Hurricane Imaging Radiometer (HIRAD)

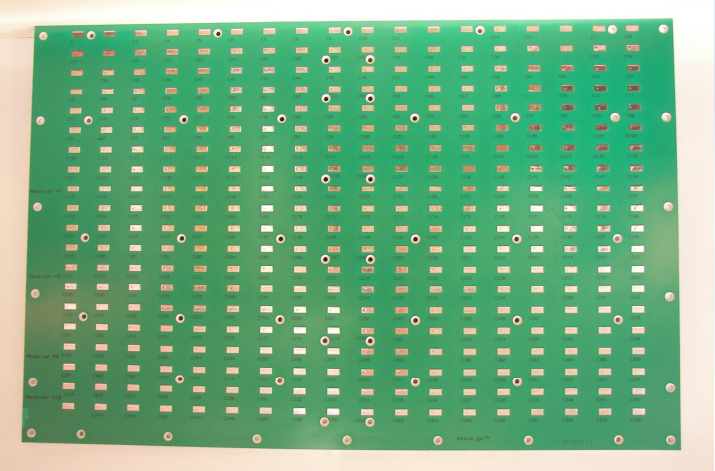
- Passive microwave (C-band, or 4 – 7 GHz) radiometer to infer wind speed over ocean surface
- HIRAD's unique contribution: Measurement of rain rate and hurricane-strength winds, even through heavy rain
  - Wind speed ~10 – 85 m/s
  - Rain rate ~ 5 – 100 mm/hr
- Operations: Better definition of max wind speed and location
- Science Hypothesis: Short-term forecasts of intensity and structure will be improved by assimilation of HIRAD data

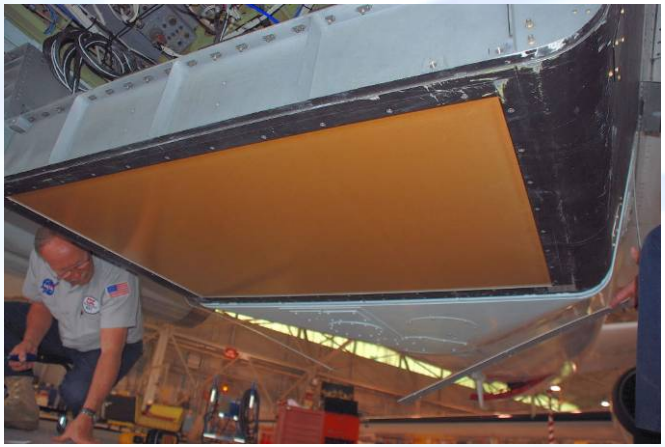


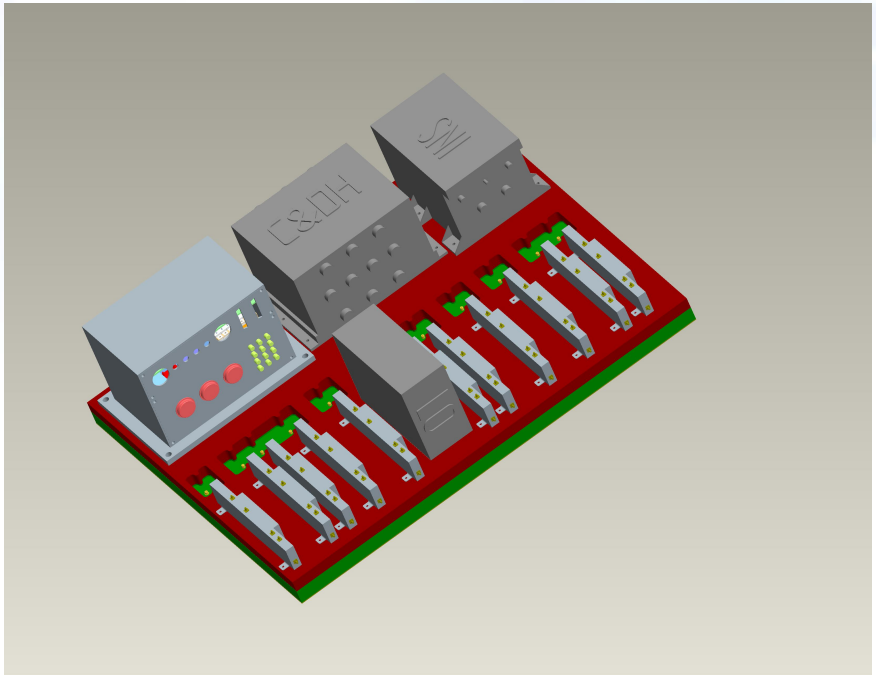
HIRAD physical principles

- Emissivity of ocean surface is increased by the presence of sea foam generated by wind
- Brightness temperature (Tb) measured by radiometer affected by:
  - Wind speed over the ocean surface
  - Rainwater column
  - Sea surface temperature and salinity
  - Earth incidence angle (EIA) – for H-pol, Tb drops off away from nadir
  - Other, weaker effects: Water vapor, atmosphere temperature
- Note: SFMR (Stepped Frequency Microwave Radiometer) uses similar frequencies, makes same measurement, but only at nadir
  - Flies operationally on NOAA and USAF aircraft
  - Wind speed relationship to Tb has been well validated
- HIRAD makes cross-track scan using no moving parts
  - Synthetic thinned array radiometer (STAR) technology
  - Cross-track resolution ~2 km at nadir, ~6 km at 60º

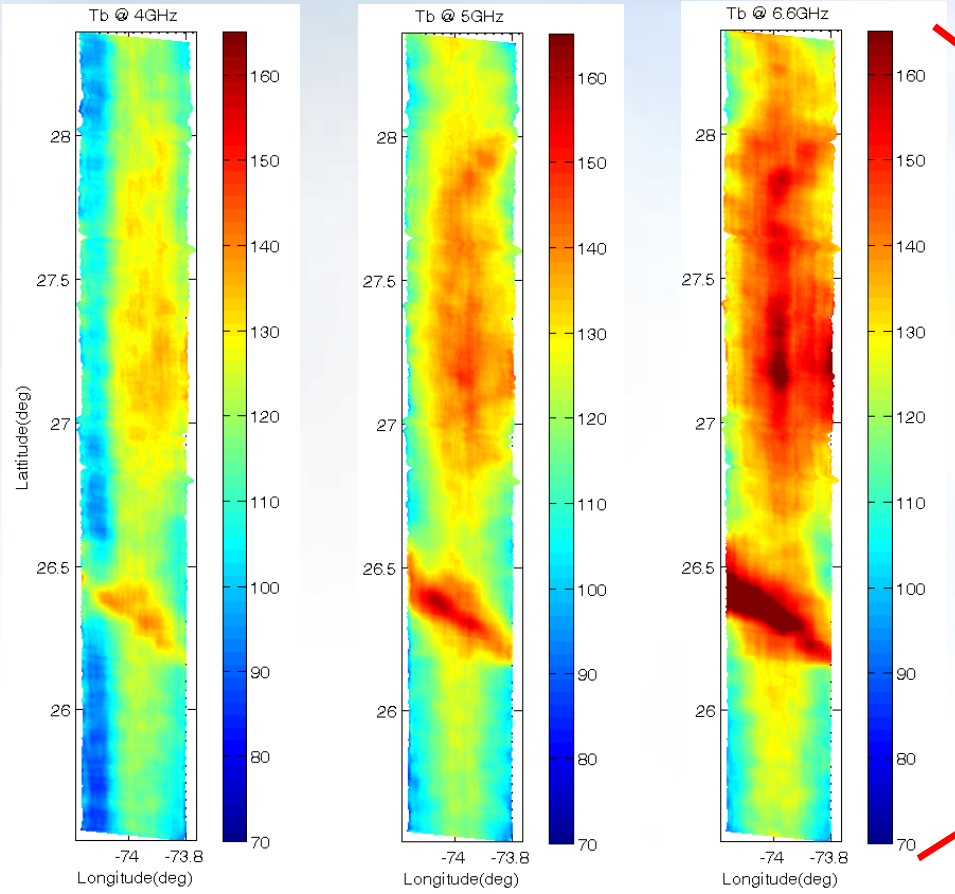
HIRAD Hardware

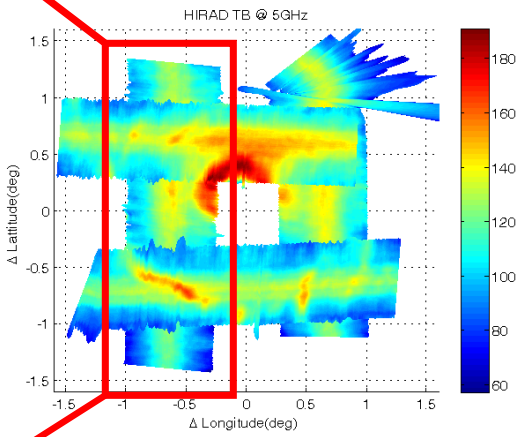






HIRAD TB Images at 4.0, 5.0 and 6.6 GHz along Northbound Earl Overpass

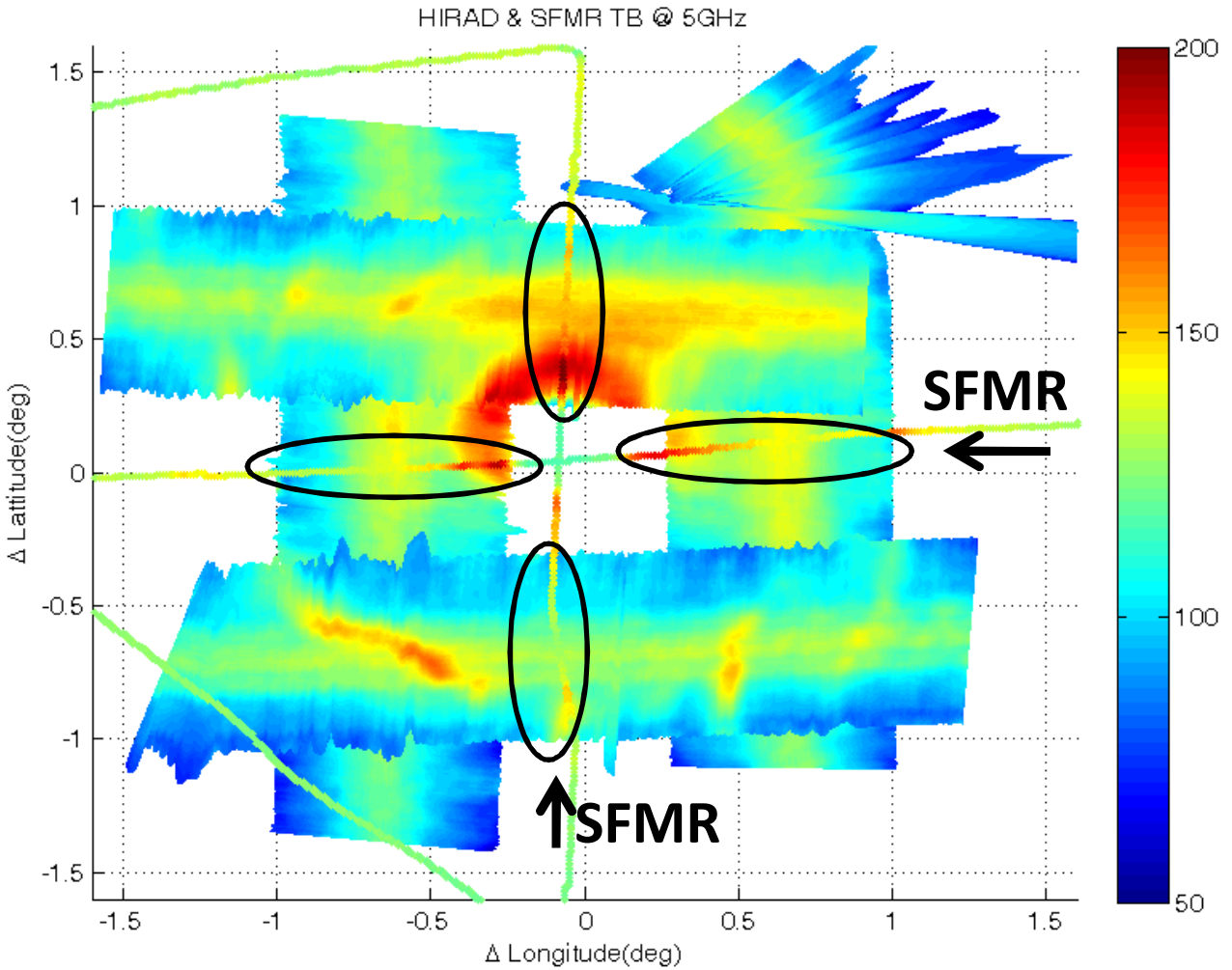




4.0 GHz 5.0 GHz 6.6 GHz

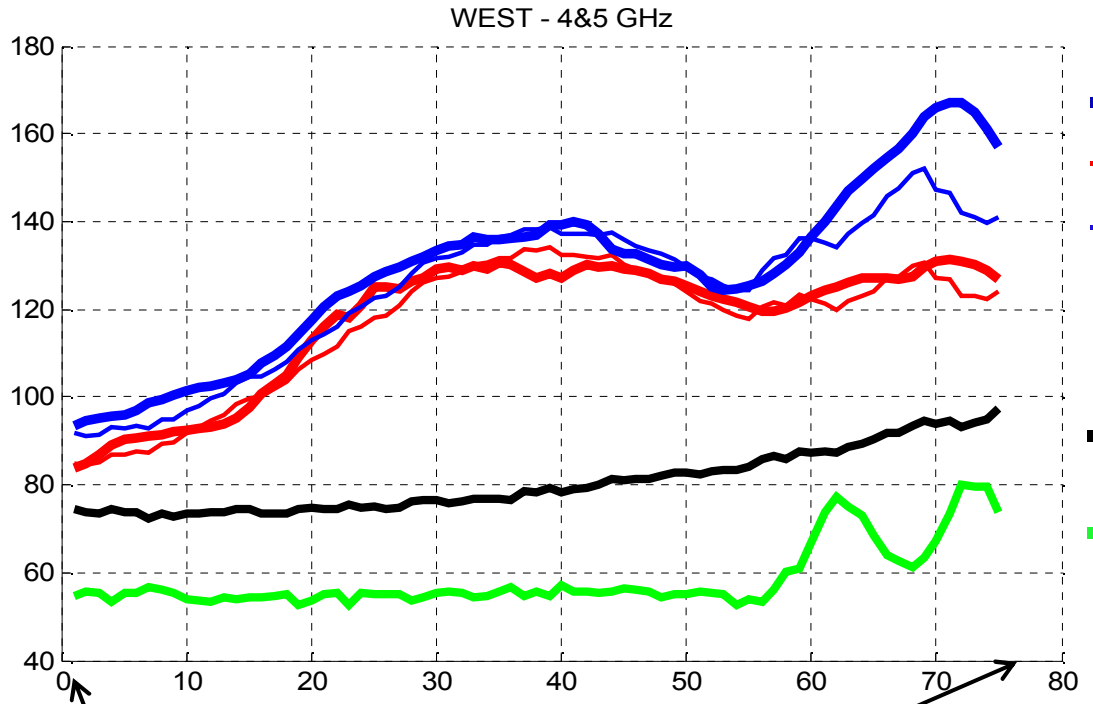
SFMR passes over HIRAD swath

Storm-centric coordinate system



HIRAD and SFMR should match at HIRAD's nadir point

HIRAD/SFMR West Leg Overpass



HIRAD Tb@ 4GHz

HIRAD Tb@ 5GHz

Model Tb@ 4GHz

Model Tb@ 5GHz

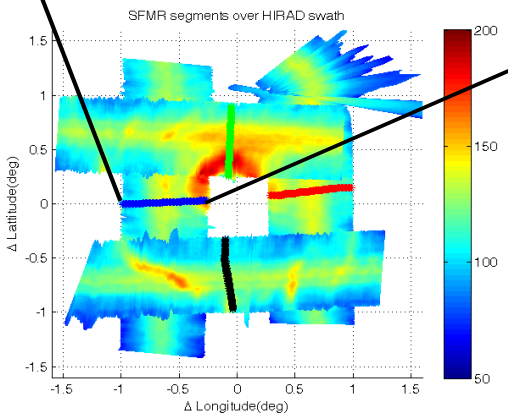
SFMR Wind +50 (m/s)

SFMR Rain +50 (mm/hr)

stop

start

SFMR Flt Dir



"Model" data are Tb's computed from SFMR wind & rain fields

UCF

Summary

- The WB-57, with HIRAD aboard, flew once over Earl, 3 times over Karl during GRIP
- Preliminary data analysis of the Earl case indicates excellent performance and comparison with SFMR
- Currently developing data processing methodology to eliminate radio frequency interference (RFI) and to maintain calibration in all channels and sub-bands
- Targeting release of Tb and wind/rain data in 3 months
- We have proposed to develop HIRAD II, a full polarization system that will detect wind direction
- This technology has potential for space flight as a complement to scatterometers and higher-frequency radiometers