Hurricane Imaging Radiometer (HIRAD) Wind Speed and Rain te Retrievals during the 2010 GRIP Flight Experiment

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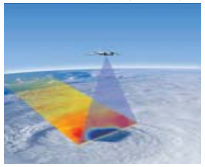
HIRAD Concept

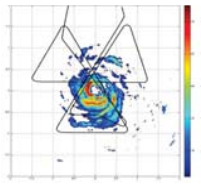
• HIRAD measures surface emissivity and path average rain intensity over a wide swath.
– Near-instantaneous mapping of entire inner-core hurricane surface wind field and rain structure.
–Measurement swath ~ 3 × Altitude
–IFOV ~ 2 Km @ nadir & 5 Km @ EOS
–Wind speed ~10 – 85 m/s
–Rain rate ~ 5 – 100 mm/hr
• 4-Freq C-band Radiometer
– 4, 5, 6 & 6.6 GHz @ H-pol

• One-dimensional Synthetic Thinned Aperture Array Radiometer
• 37 × 16 element stacked patch array antenna.

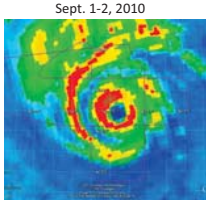


NASA GRIP Field Campaign 2010: Aircraft Flight Lines

Hurricane Karl
Sept. 16, 2010



Hurricane Earl
Sept. 1-2, 2010



Geophysical Retrieval Methods

- Near Real Time "Quick-look" Algo.
  – Single frequency empirical algorithm
    • 5 GHz linear for Wind Speed
    • 6.6 GHz second order for Rain Rate
- Multi-frequency MLE Algorithm
  – 4, 5 & 6.6 GHz for WS and RR
  – Radiative Transfer Theory based
  – Max. Likelihood Estimate of WS and RR
  – Comparing Observed Tb to Modeled Tb
  – Minimizing squared differences over all frequencies

Hurricane Earl Retrievals

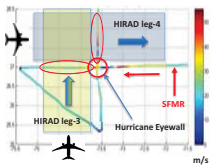
- Quick-look retrievals,
  – Good eyewall structure.
  – Good agreement with SFMR.
  – Rain band south of storm center agrees with WP3D.
  – Single frequency WS susceptible to rain.
- MLE retrievals,
  – Good eyewall structure.
  – Good Max. WS and RR agreement with SFMR.
  – Relatively noisy due to 6.6 GHz signal.

Hurricane Karl Retrievals

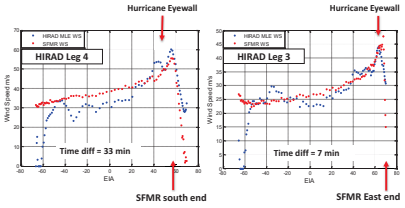
- Quick-look retrievals,
  – Same algorithm as with Earl.
  – Eyewall structure well defined.
  – Max. wind speed in agreement with SFMR.
- MLE Retrievals
  – Two HIRAD passes map entire inner-core hurricane surface wind and rain structure.
  – Good Max. WS and RR agreement with SFMR.
  – T_b calibrations need improvement.

Hurricane Earl

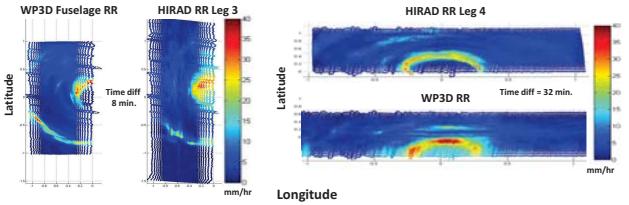
SFMR Simultaneous Crossing of HIRAD Swath (Leg-4: West to East 27.7° Latitude)



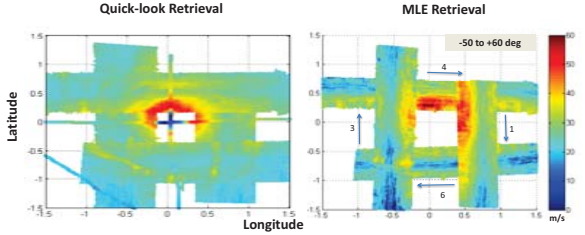
Comparison between HIRAD MLE and SFMR WS



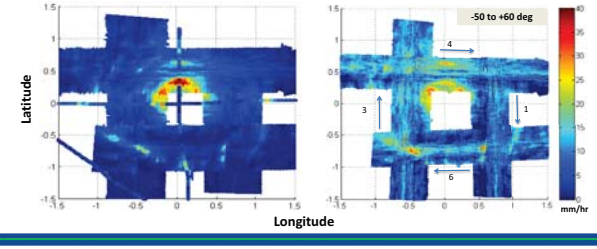
Comparison of HIRAD Quick-look to WP3D RR (HIRAD legs 3 & 4)



Wind Speed Composite Image (MLE 4,5 & 6.6 GHz freq., Legs 1,3,4 and 6)



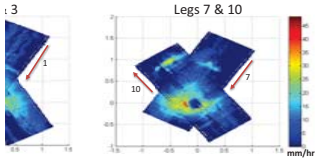
Rain Rate Composite Image(MLE 4,5 & 6.6 GHz freq., Legs 1,3,4 and 6)



Hurricane Karl

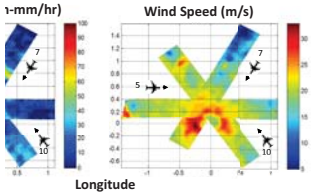
Rain Rate Composite

2 Frequency Retrievals(4 & 5 GHz)



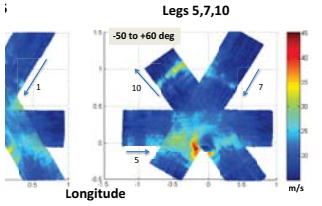
Speed and Integrated rain rate using cross track smoothing

Wind speed was adjusted to match H-winds



Speed Composite image (Quick-look)

5 GHz frequency

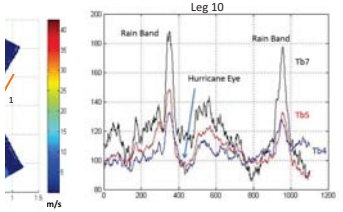


Composite

+60 deg.)

Current work

Time series of normalized TB @ EIA = 40



NASA Hurricane and Severe Storm Sentinel (HS3) Flight Program

Hurricane seasons 2012 – 2014

– Mission uses a two-Global Hawk UAV configuration:
Over the storm & Environment around the storm
– Over-storm vehicle includes HIRAD, HAMSR and HIWRAP
– Over-storm vehicle was not ready for 2012 season. One flight
– 2013 flights September 3,15 and 25 during slow hurricane season.

HIRAD installation on Global Hawk

- During HS3 mission, HIRAD was installed on one of NASA's Global Hawk unmanned aircraft (AV-1)
- Global Hawks have flight durations ~24 hours and fly over hurricanes at altitudes ~ 18 km
- Operated by pilots in ground control stations at Wallops Island, Va. And Dryden Flight Research Center at Edwards Air Force Base, Ca

Conclusion

- The HIRAD concept, with its broad swath measurement capability, offers the potential for significant improvement over the current SFMR
  • Using high-flying, long duration, unmanned aircraft such as the Global Hawk, real-time tropical cyclone surveillance can be possible
- HIRAD has demonstrated the ability to produce a 2D Wind Speed and Rain Rate image in a single pass
  • Swath width is 2x to 3x the aircraft altitude
- Under the HS3 program, hardware improvements have been implemented that improve the radiometric calibration accuracy and stability
  • Future HIRAD retrievals will improve with better calibrated Tb's
  • Anticipate HS3 2014 Hurricane flights
- The HIRAD has the potential for space borne application