Hurricane observations with HAMSR in the GRIP and HS3 field campaigns

An RI Case Study: Hurricane Karl (2010)

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Thermodynamics: HAMSR is an accurate sounder

Sounders are normally used to determine thermodynamic structure:

- Retrieval of 3-D atmospheric temperature, water vapor and cloud liquid water profiles using optimal estimation inversion approach
- Good agreement with dropsonde observations
- Vertical resolution (averaging kernels) is 2-3 km

- 50 dropsonde comparisons during HS3 over a wide variety of atmospheric conditions
- Dropsonde profiles smoothed vertically to match HAMSR vertical resolution
- HAMSR website contains validation reports for each flight
- Reports include comparison to MERRA and dropsondes T,q,RH
NEW: Scattering profiling $\Rightarrow$ Reflectivity algorithm

Based on comparison of microwave sounder (HAMSIR) with doppler radar (EDOP) during TCSP/2005

Hurricane observations with MW sounder (HAMSIR) compared with doppler radar (EDOP)
Observations from NASA TCSP campaign, Costa Rica, 2005

Vertical slicing through hurricane Emily - July 17, 2005

MW sounder is equivalent to radar!

Height resolved “Radar reflectivity”
$\Rightarrow$ Use radar algorithms to derive
- Precipitation rate
- Ice water path
- Convective intensity
- Vertical structure

Correlation between MW-sounder $\Delta T_b$ and radar reflectivity exceeds 90% at all levels except near surface
Reflectivity retrieval accuracy: 2-5 dBZ

Black curve represents overall accuracy: 2-5 dBZ

Colored curves represent category clusters and reflect clustering uncertainty and not retrieval uncertainty.
Averaging kernels and vertical resolution

Averaging kernels:

Vertical resolution:

2-3 km true vertical resolution
Comparison with radar (HIWRAP)

H. Karl, 0644 UTC 9/17/2010

Note: Perfect space-time match since both sensors are on same aircraft

HIWRAP

HAMSAR reproduces all major structures, but at lower spatial resolution
including cloud top structure
including eye/eyewall structure
HAMSAR has reduced sensitivity near surface
HAMSAR has reduced sensitivity through stratiform structures
Not much happening in the 2013 HS3 campaign

**TD 25L (9/4/2013)**
Not yet organized; 2 centers of convection

**Gabrielle (9/10/2013)**
Flight aborted due to problems with the aircraft

**Ingrid (9/16/2013)**
Flight cut short due to low T @ flight altitude (~195 K)

Height of convection from HAMSR reflectivity (real-time display)
Back to GRIP: Hurricane Karl flight (9/16-17, 2010)

Data viewable at the JPL Hurricane Portal (http://grip.jpl.nasa.gov):
Rapid Intensification period

13-hour Global Hawk flight
20 passes over the eye in 13 hours

Max. Z at h ≥ 8 km

Mexico
Warm core anomaly

Tb-anomaly at 54.94 GHz (HAMSР ch. 6 = AMSU ch. 7)  
~ 250 mb

Tb-anomaly at 55.5 GHz (HAMSР ch. 7 = AMSU ch. 8)  
~ 150 mb
Closeup views of the inner core

Warm core anomaly
HAMS R ch. 6 = AMSU ch. 7

10 minutes
Warm core temperature anomaly correlations

\[ \Delta T \] @ 11 km vs. \( P_{\text{eye}} \)

\[ \Delta T \] @ 7 km vs. \( P_{\text{eye}} \)

\[ \Delta T \] @ 5 km vs. \( P_{\text{eye}} \)

Strongest correlation at 7 km
-0.3 K/mb
Closeup view of warm anomaly & reflectivity

Nadir reflectivity and 250-mb Tb anomaly during two eye passes (06-07Z, 9/17/10)
Thermodynamic structure of the warm core

Warm anomaly propagates to lower levels as the storm intensifies with the peak warm anomaly increasing by ~2-3°C

Decreasing RH in upper troposphere while air below the inversion layer remained near saturation

Evolution near the end of the flight may be influenced by proximity of land
Evolution of thermodynamics & convective structure
Average CFAD
Hurricane Karl (2010)

**Inner core structure change in 12 hours of RI**

9/16/1949Z (75 kt)

9/17/0745Z (88 kt)

Reflectivity (surface to 15 km)

50.3 GHz brightness temperature

**Eye is cloudy**
Deep convective structures
Large asymmetric nonuniform inner 50-GHz ring

**Eye is clear and smaller**
Deep convection has weakened
Ring is uniform, symmetric, lower & smaller

*Is this related to the 37-GHz ring hypothesis?*
Kieper, M. E., H. Jiang, and J. P. Zagrodnik, 2012: Using the 37 Color Composite PMW for Rapid Intensification Forecasts of Tropical Cyclones, 2012 Fall AGU

From simultaneous radar vertical cross sections, the inner edge portion of the ring is nearly 100% closed surrounding the TC center and mainly consists of shallow precipitation from near or below the freezing level to the surface (Kieper and Jiang, 2012). The outer edge portion of the ring could have asymmetric intense convection (i.e., hot towers) embedded within the ring. This outer edge portion of intense convection (the pink color) is highly asymmetric.

“A cyan ring feature on the 37 color composite image has been observed to forecast rapid intensification of tropical cyclones under favorable environmental conditions.”
HAMSAR 50 GHz view similar to 37 GHz view

September 17th, 2013: 04Z
HAMSAR – channel 1 TB (50 GHz) and vertical cross-section of derived reflectivity

Warm 50 GHz Tb where precipitation is from the freezing level to the surface

Cold 50 GHz Tb where precipitation extents up above the freezing level
Evolution of the 50 GHZ HAMSR ring

Sept. 16, 2010 – 20Z
Ring is not well organized

Sept. 16, 2010 – 21Z

Sept. 16, 2010 – 22Z

Sept. 17, 2010 – 01Z
Ring becomes well organized

Sept. 17, 2010 – 04Z

Sept. 17, 2010 – 07Z
Trends in convective structure during RI

Inner core (eye wall) reflectivity

Eye wall convection is becoming more uniform
Other trends

Eye clears

Legend:
- Zmax@9km
- Tb-anomaly_width
- \( \times \) Vmax/2
- Clear-diameter
- Wall-diameter
Some preliminary observations from 13 hours of RI:

- Warm core develops at 200 mb and spreads down to surface
- Inner core drying starts at 300 mb and spreads to top of BL
- There is a slow compression of the BL (from 3 km to 2 km)
- Warm core extends well beyond the inner eye wall
- Warm core contracts when the eye becomes cloud free
- Eye wall convective structure changes significantly
  - Deep convective cells disappear
  - Inner-core convection becomes symmetric, uniform, shallower
  - Eye clears and changes in diameter:
    - Clear and low-reflectivity area expands
    - Eye walls contract and narrow
- Convective structure may be exhibiting oscillatory behavior (TBD)

HAMSR is a valuable tool for hurricane research
- Brightness temperatures → Warm core anomaly
- Sounding products → Thermodynamics
- Reflectivity products → Convective structure

The analysis will continue