JPL High-Altitude MMIC Sounding Radiometer

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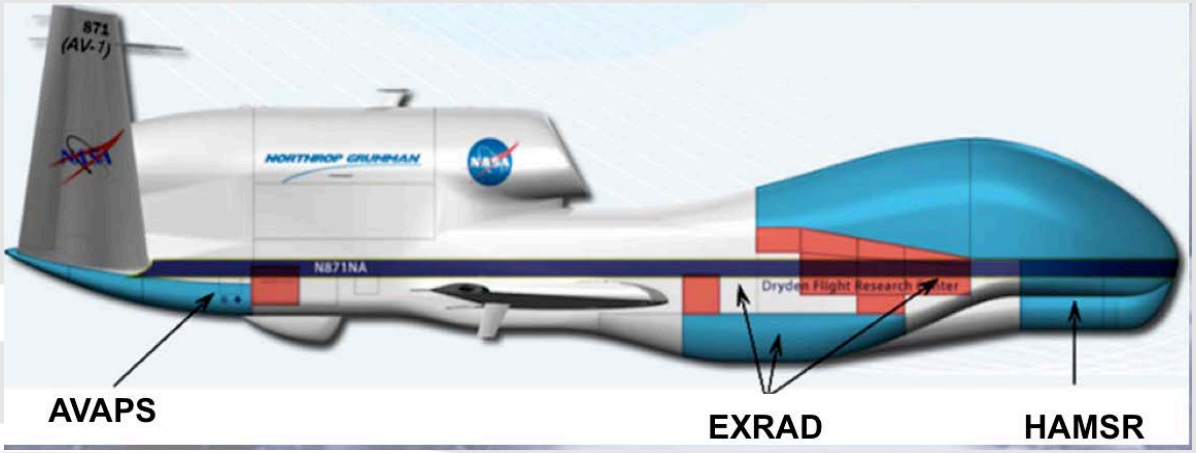
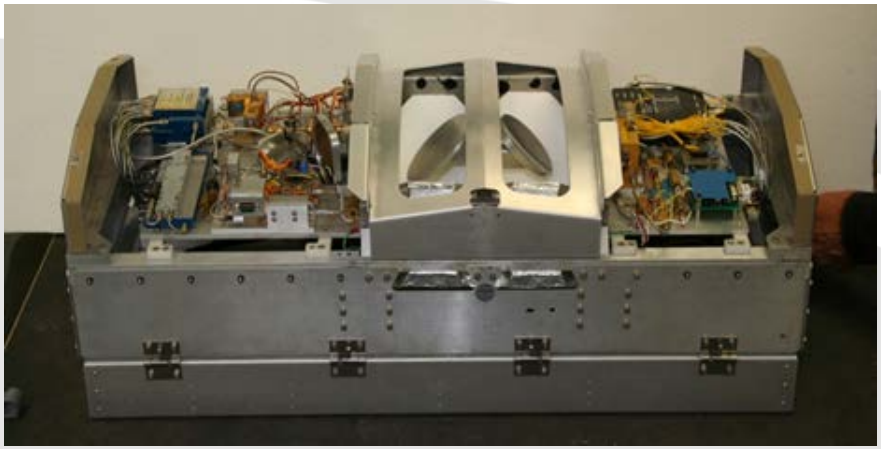
EPOCH Mission

Was already integrated on a Global Hawk during several flights and will be integrated for EPOCH on a science flight (~24 hours) during the 2017 hurricane season.



Instrument Overview



- Microwave radiometer for all-weather temperature and water vapor sounding (similar to AMSU)
- 25 sounding channels in three bands: 50-60 GHz, 118 GHz, 183 GHz
- Cross track scanning, $\pm$ 60^{o} off nadir (65km swath, 1.9km spatial resolution)
- View hot and ambient blackbody calibration loads each scan

- State of the art noise performance (sensitive to small scale variability)

Instrument Overview - Channels

HAMSR Channel Set

Channel	f_c – LSB [GHz]	BW – LSB [MHz]	W_1	f_c – USB [GHz]	BW – USB [MHz]	W_2
1	50.30	185.34	-	-	-	-
2	51.81	456.26	-	-	-	-
3	52.82	444.60	-	-	-	-
4	53.46	151.29	0.58	53.69	155.73	0.42
5	54.41	446.50	-	-	-	-
6	54.94	442.91	-	-	-	-
7	55.46	374.80	-	-	-	-
8	55.99	279.05	0.90	56.61	235.84	0.10
9	113.27	1062.11	-	-	-	-
10	115.19	1060.03	-	-	-	-
11	116.18	506.09	-	-	-	-
12	116.70	504.33	-	-	-	-
13	117.13	432.13	-	-	-	-
14	117.54	418.95	-	-	-	-
15	117.93	459.60	0.54	119.56	424.56	0.46
16	118.30	319.84	0.54	119.19	302.38	0.46
17	118.50	117.19	0.47	118.98	140.74	0.53
18	118.61	100.86	0.42	118.86	105.95	0.58
19	166.95	3812.82	-	-	-	-
20	173.22	3298.97	0.54	192.88	2926.96	0.46
21	176.26	2409.16	0.34	190.23	2472.45	0.66
22	178.74	2133.24	0.23	187.95	2162.90	0.77
23	180.39	1093.10	0.29	186.32	1119.17	0.71
24	181.44	1157.75	0.36	185.09	1109.80	0.64
25	182.30	536.28	0.27	184.31	539.22	0.73

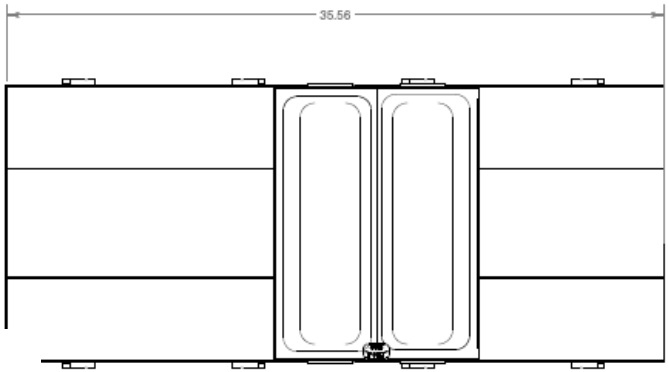
HAMSR 25 Channels: Centroid frequency, bandwidth and upper/ lower sideband weighting.

Instrument Overview - Noise

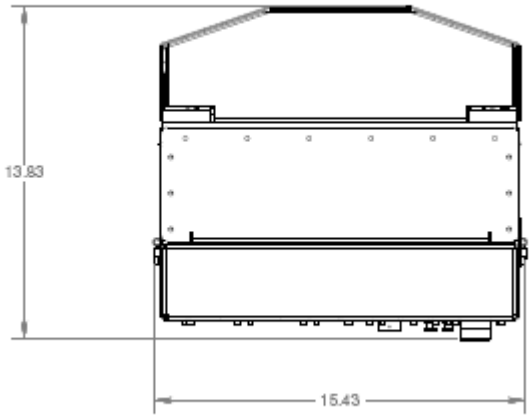
Channel	NEDT [K]	Channel	NEDT [K]	Channel	NEDT [K]
1	0.29	**10**	0.12	**19**	0.06
2	0.22	**11**	0.10	**20**	0.07
3	0.18	**12**	0.14	**21**	0.09
4	0.19	**13**	0.13	**22**	0.09
5	0.17	**14**	0.14	**23**	0.10
6	0.16	**15**	0.13	**24**	0.10
7	0.16	**16**	0.10	**25**	0.10
8	0.19	**17**	0.10		
		18	0.15		

Instrument Overview - Dimensions

- 35.56 inches fore to aft, 15.43 inches left to right, 13.83 inches top to bottom
- Power: 70W operating, 220W peak – 120V 60-400 Hz AC power
- Weight: 101 lbs
- Data rate: 75 kps



12x15.43” aperture



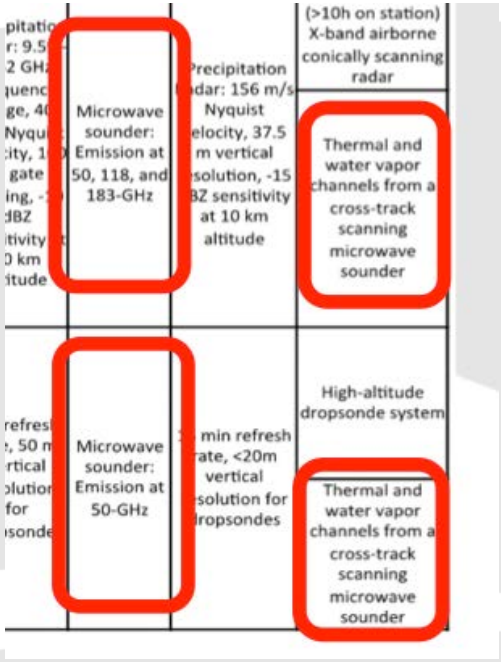
HAMSR Flight Missions

Campaign	*Timeframe*	*Main Airport*	*Main interest*
EPOCH	August 2017 (1-2 flights planned)	Armstrong Flight Research Center	Pacific Hurricanes
SHOUT	August 2016 (several flights planned)	Armstrong Flight Research Center	ENSO impact on West Coast
SHOUT	February 2016 (3 flights)	Armstrong Flight Research Center	ENSO impact on West Coast
SHOUT	August 2015 (7 flights)	Wallops Flight Facility	Hurricanes Atlantic
CalWater	Feb 2015	Armstrong Flight Research Center	Atmospheric Rivers
HS3	September 2013	Wallops Flight Facility	Hurricanes Atlantic
WISPAR	March 2011 (3 flights)	Dryden Center (now Armstrong)	Atmospheric Rivers
GRIP	Agust 2010	Wallops Flight Facility	Hurricanes Atlantic

Science Requirements

Science Goals	Science Objectives	Scientific Measurement Requirements		Instrument Requirements		Projected Performance	Mission Requirements (Top Level)
		Physical parameters	Observables				
Characteristics of rapidly evolving cloud and precipitation structures	Evolution of cloud and frozen/liqui precipitatio structure during hurricane intensificatio	Dual-Doppler radar 3-D wind and reflectivity	Precipitation and wind fields from cloud top to surface	Radar: dual-Doppler volume scans every 2 minutes, 75 m/s Nyquist velocity, <1km horizontal resolution	Dropsondes: Released into environment surrounding and into hurricane inner core every 20 minutes, <50m vertical resolution	Volume scans every 1 min, 156 m/s Nyquist velocity, 200-500 m horizontal resolution, Dropsonde releases every 15 min over hurricane with <20m vert. res.	Long duration (>10h on station) airborne conically scanning radar
		Atmospheric profiles of temperature, dewpoint, and winds	Temperature, dewpoint, wind speed and direction				High-altitude dropsonde system
Discovery of mechanisms upon which breakdown of ITCZ generates tropical disturbances	Identify occurrence of ITCZ breakdown north of the Equator in th East Pacific and classify triggering mechanism	Dual-Doppler radar 3-D wind and reflectivity	Reflectivity and Doppler winds	Precipitatio Radar: 9.5 9.62 GHz frequenc range, 4(m/s Nyqui velocity, 1 m gate spacing, - dBZ sensitivity 10 km altitude	Microwave sounder: Emission at 50, 118, and 183-GHz	Precipitation dar: 156 m/s Nyquist elocity, 37.5 m vertical solution, -15 BZ sensitivity at 10 km altitude	Long duration (>10h on station) X-band airborne conically scanning radar
		Temperature, water vapor, liquid water profiles, total precipitable	50, 118, and 183-GHz spectral band retrievals				Thermal and water vapor channels from a cross-track scanning microwave sounder
		rain rates, vert. precipitation profiles					
Role East Pacific environment plays in tropical cyclogenesis and intensification	Obtain critica measuremen s in hurrican environment to identify roles of large-scale synoptic factors such as troughs, jetstreams, and AEWs	Vert. profiles of temperature, relative humidity, and	Tropospheric profiles of temperature, dewpoint, wind speed and direction	1 h refres rate, 50 m vertical resolutio for dropsond	Microwave sounder: Emission at 50-GHz	min refresh ate, <20m vertical solution for ropsondes	High-altitude dropsonde system
		SSTs	SSTs				Thermal and water vapor channels from a cross-track scanning microwave sounder

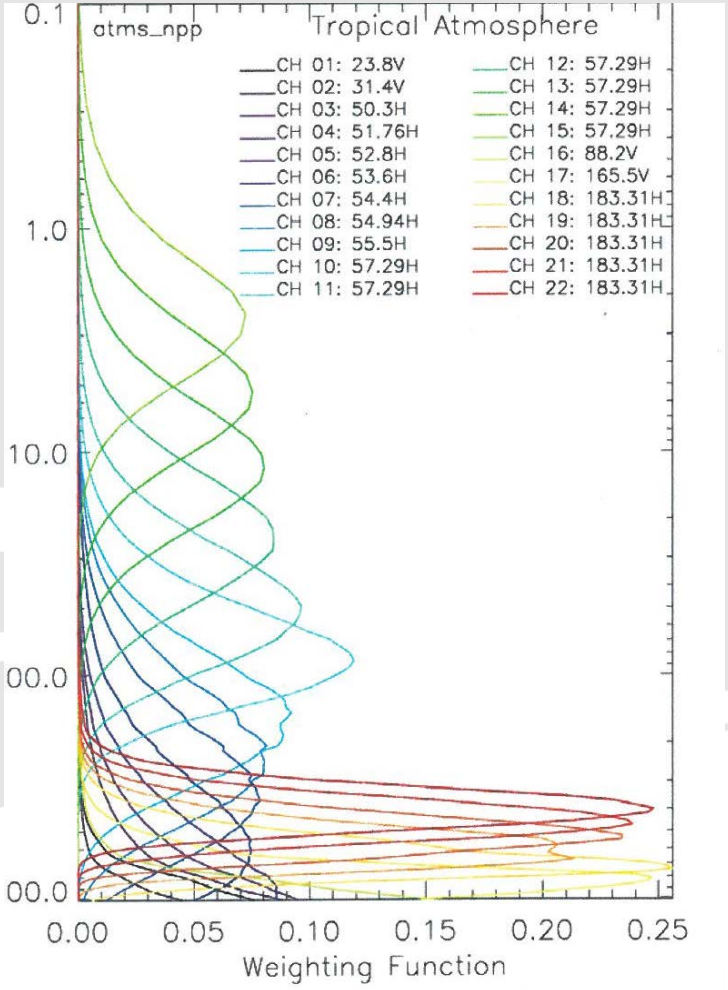
Science Requirements
Instrument



- 8 channels 50-56 GHz
  - ✓ surface and O_2 – emission line
  - ✓ Allows retrieval of Temperature profile [T(z)]
- 10 channels around 113 - 118 GHz
  - ✓ surface and O_2 – emission line
  - ✓ Allows retrieval of temperature profile [T(z)]
- 7 channels between 166 and 182 GHz
  - ✓ surface and H_2O – emission line
  - ✓ Allows retrieval of H_2O profile [q(z)]

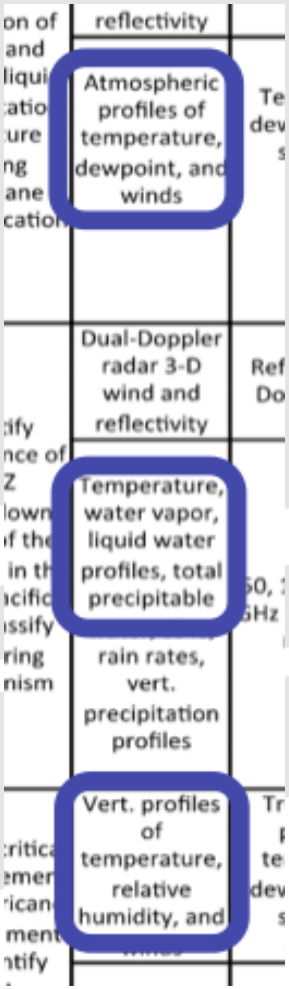
Science Requirements
Instrument

Weighting functions (taken from ATMS)



- ✓ Temperature sounding channels for mid and lower troposphere
- ✓ H2O channels for mid and lower troposphere

Science Requirements
Scientific Atmospheric Variables



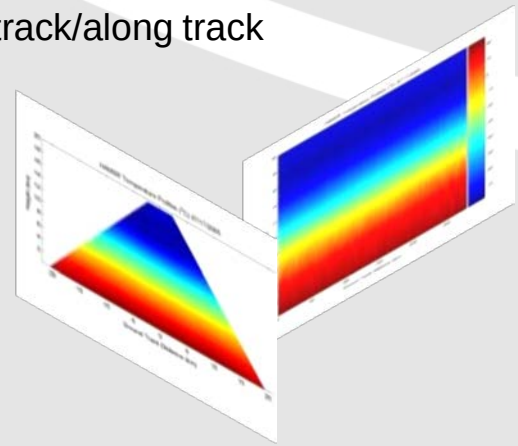
- Current retrieval : real time, neural network based optimal estimation based retrieval
  - ✓ Can provide good estimate of temperature, water vapor (or dew point) and liquid water
- Cloud structure via reflectivity (poor man's radar)
  - ✓ Can provide cloud vertical structure
- Post processing retrieval (work in progress)
  - o Will be able to provide better temperature, water vapor (or dew point) and liquid water
  - o Better handling of scattering (liquid/ice water content)
  - o Better rain rate estimate
  - o Traceable error covariance matrix
  - o Exchangeable first guess for better uncertainty analysis and higher accuracy

Science Requirements
Current HAMSR Real Time Retrieval

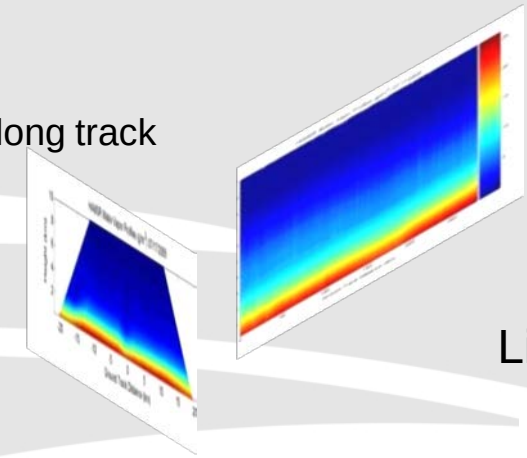
Current - near real time - retrieval :
Combination of neural network and optimal estimation inversion approach

- Atmospheric temperature
- water vapor
- cloud liquid water profiles

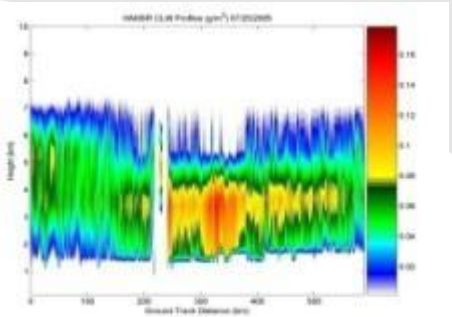
T(z): Cross-track/along track



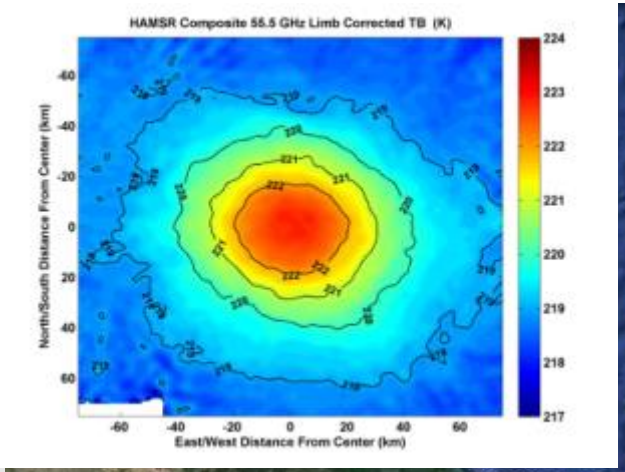
q(z): Cross-track/long track



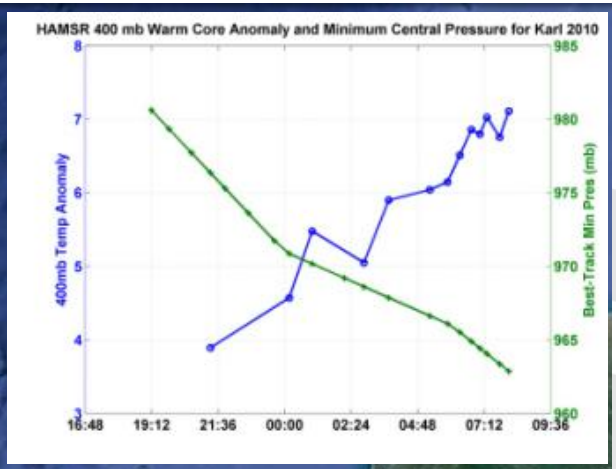
Liquid water (z): along track

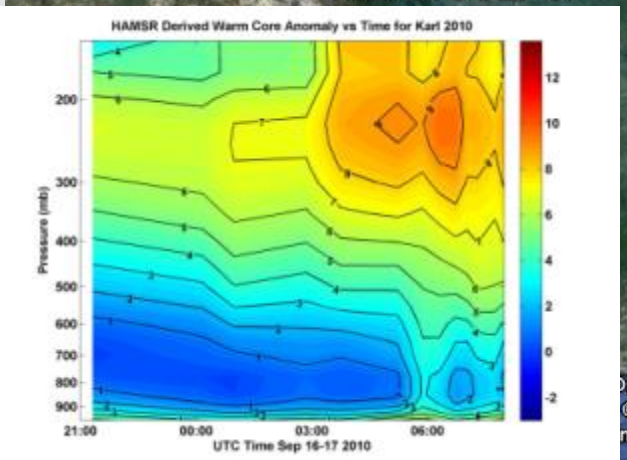


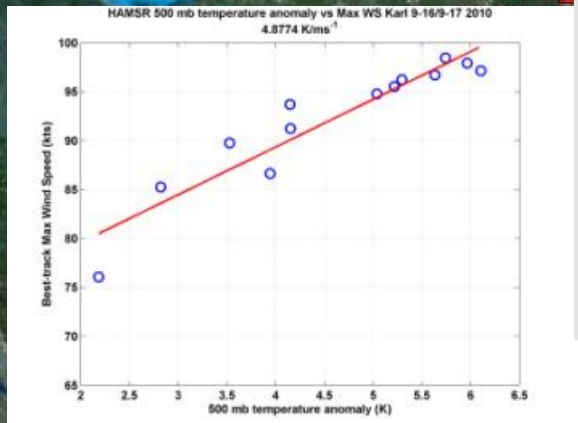
Current HAMSR Real Time Retrieval during Hurricane Karl



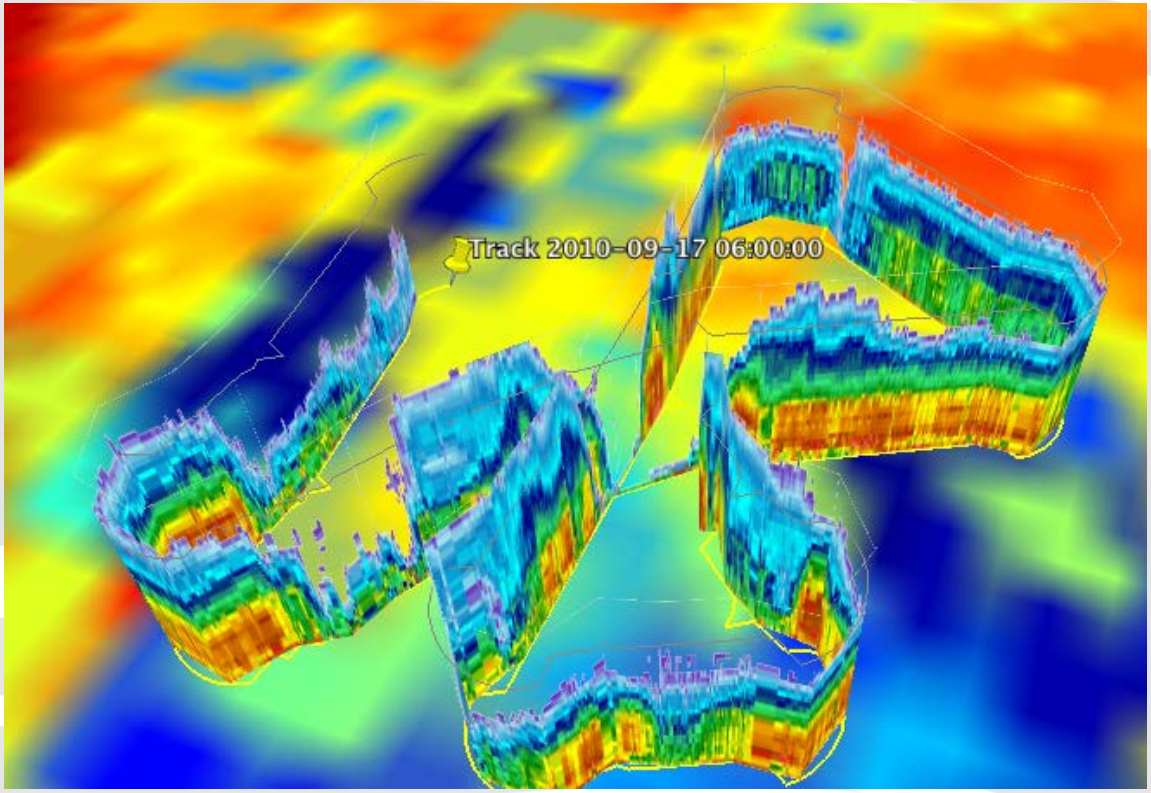
Karl observations during GRIP prove HAMSRs capability to monitor Hurricane intensity by tracking evolution of warm core anomaly







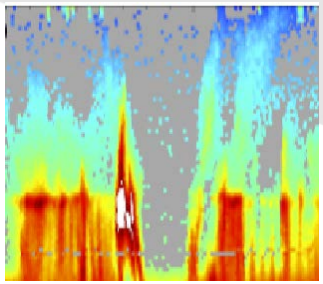
Reflectivity: Poor man's radar



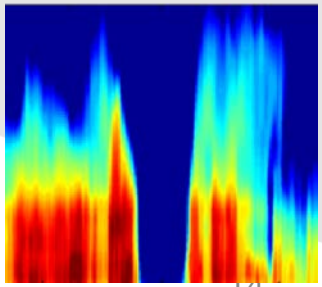
Vertical profiles of reflectivity across the full scan swath

- Resolution: 1-2 km;
  Precision: ~ 4 dBZ;
  Sensitivity: ~ 0 dBZ

HAMSR reproduces all major structures, but at lower spatial resolution
including cloud top structure
including eye/eyewall structure
HAMSR has reduced sensitivity near surface
HAMSR has reduced sensitivity through stratiform structures



HIWRAP



HAMSR

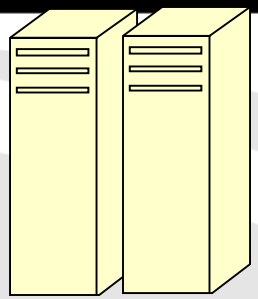
HAMSR Processing

Commanding

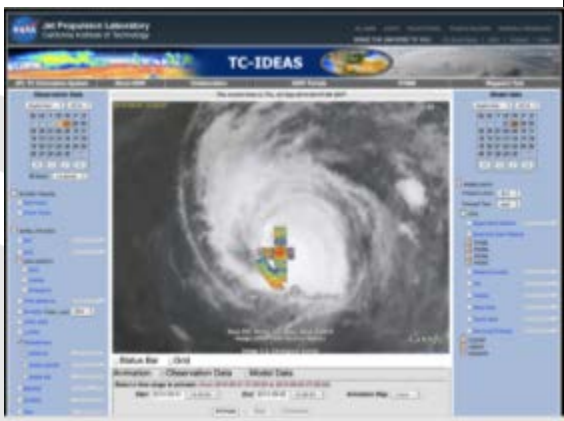
Data downlink

GHOC

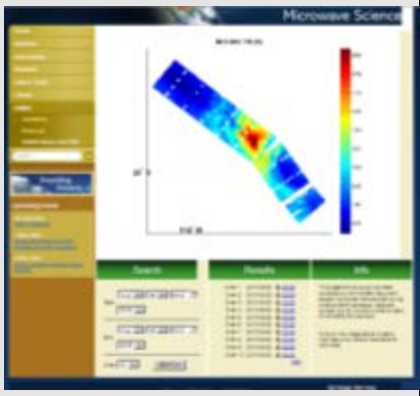
netCDF L1B files

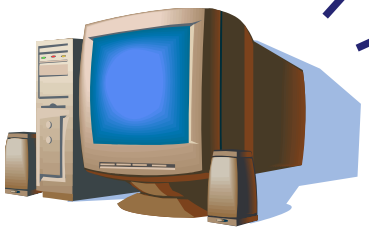


JPL Hurricane Portal



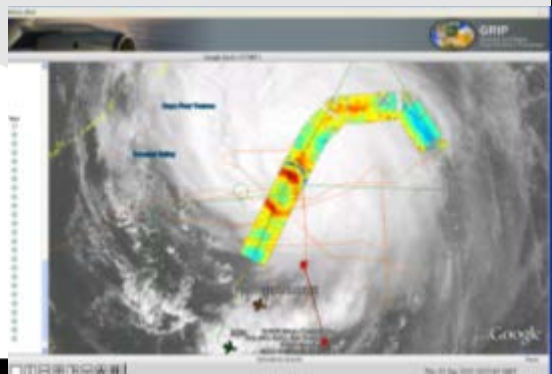
HAMSR website quick look images





HAMSR ground data processor

RTMM



Science Requirements
Planned HAMSR Post Processing Retrieval

Planned post-processing retrieval:

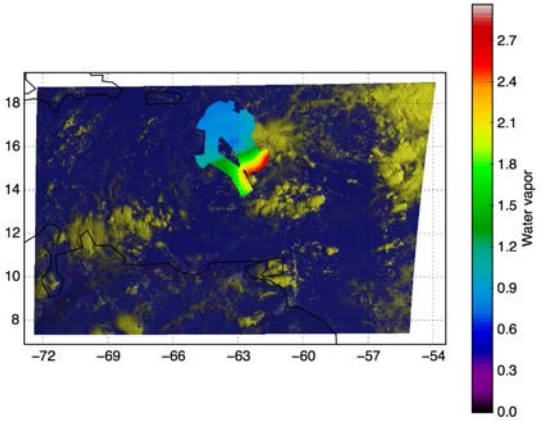
- ❑ Under development
- ❑ Optimal estimation, at the moment based on CRTM (exchangeable)

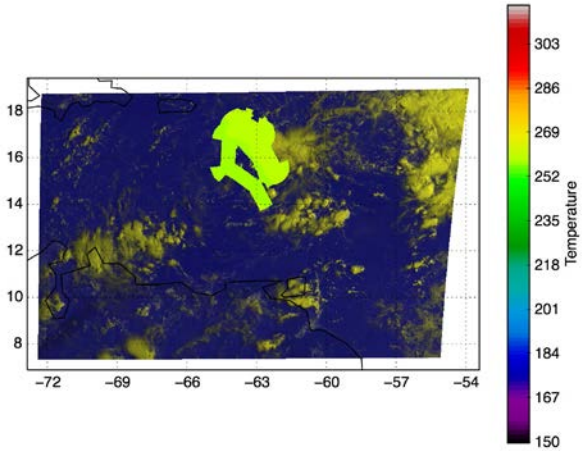
- ❑ Provides:
  - Atmospheric temperature
  - water vapor
  - cloud liquid water profiles
  - Error analysis

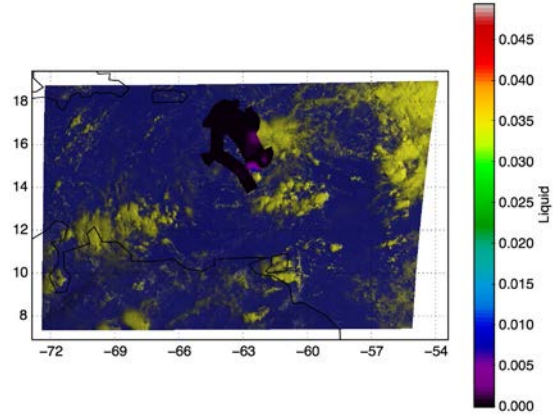
- ❑ Advantages:
  - Better handling of scattering (liquid/ice water content)
  - Better surface emissivity estimate (FASTEM)
  - Less scan angle dependence
  - Traceable error Covariance Matrix
  - Exchangeable first guess for better uncertainty analysis and higher accuracy

Post Processing Retrieval
Preliminary Results

Temperature, water vapor and liquid water at 600 hPa for flight over tropical storm Gabrielle (2013/09/03) (overlaid over GOES-image)







HAMSR Conclusion

- HAMSR has already shown to be compatible with Global Hawk
- Several successful missions
- Status at the moment : operational – no malfunction
- Has channels for temperature and water vapor sounding under tropical conditions
- Preliminary retrieval available
- Improved post-processing retrieval under development