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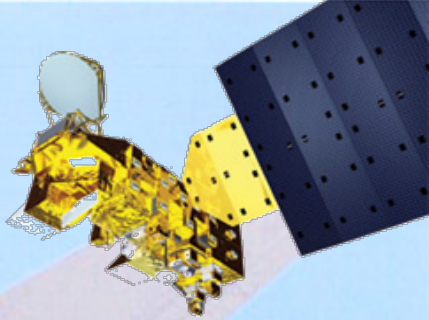
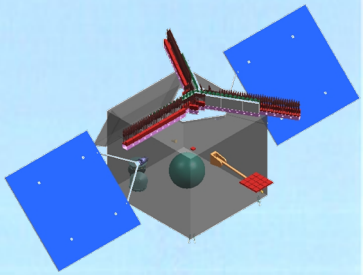


Hurricane Analysis with Microwave Sounder Observations

Bjorn Lambrigtsen, Shannon Brown

Jet Propulsion Laboratory
California Institute of Technology



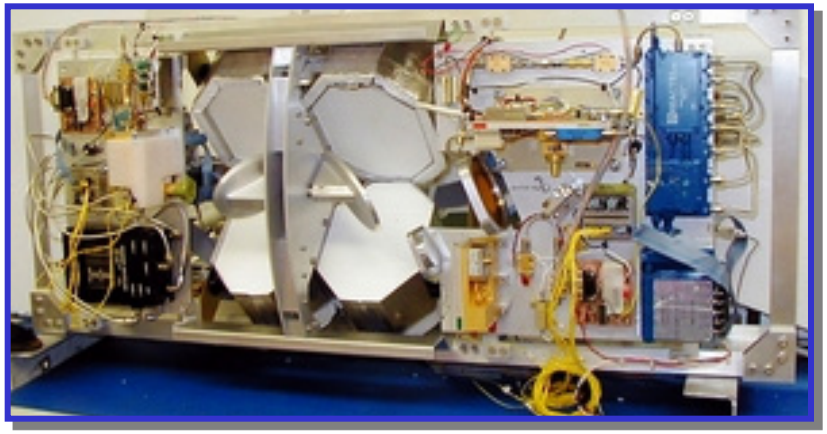
28th AMS Conference on Hurricanes and Tropical Meteorology

Orlando, FL; April 28 - May 2, 2008

The High Altitude MMIC Sounding Radiometer
HAMSR

Summary

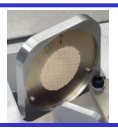
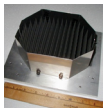
- Multi-function AMSU-A/B sounder in single package
  - Temperature, water vapor, cloud liq. water profile
  - Scattering & precipitation
- Multiple sounding bands, multiple channels
  - 8-channel T-sounding @ 50-60 GHz
  - 10-channel T-sounding @ 118 GHz
  - 7-channel H2O-sounding @ 183 GHz
- New technology
  - Small, low-power, low-mass
  - High performance



Development

- Developed under NASA Instrument Incubator Program, 1998-2001
- First MW sounder using MMIC receivers
  - New IC technology developed by NASA/JPL
- Other cutting-edge elements
  - Compact solid-state spectrometer/filter-bank
  - High-quality quasi-optics: dichroic diplexer
- Designed to operate from high-altitude aircraft
  - Initial plan: UAVs
  - First deployment: ER-2 (2001)
  - Also: DC-8 (2006)

Technology

MMIC receivers		InP MMIC chain: LNA + Filter + LO-multiplier + Mixer + IF-amp •Small, low power: 3”x2.5”x1”; 0.3 kg; 2 W (typical) •High performance: wide bandwidth, low noise
Filter banks		One module per band (3) •Allows single down conversion •Compact, low power, high performance (40 dB rejection)
Dichroic plate		Splits 183 GHz (passed) from 118 GHz (reflected) •High precision: 1.45 mm hole spacing, 0.2 mm wall thickness •High performance: < 2% transmission loss @ 183 GHz
Calibration targets		One pair (hot & cold) per scan reflector •Absorber-clad cones on metal core w/thermistors embedded •High performance: < -50 dB reflectivity (> 0.99999 emissivity)

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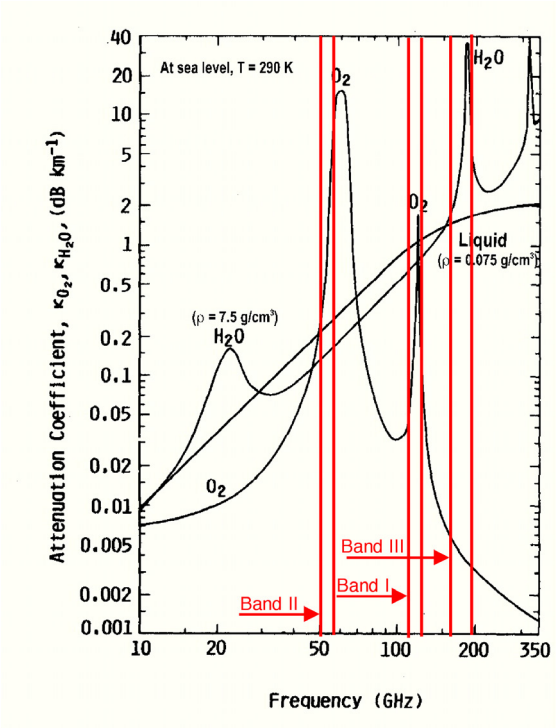
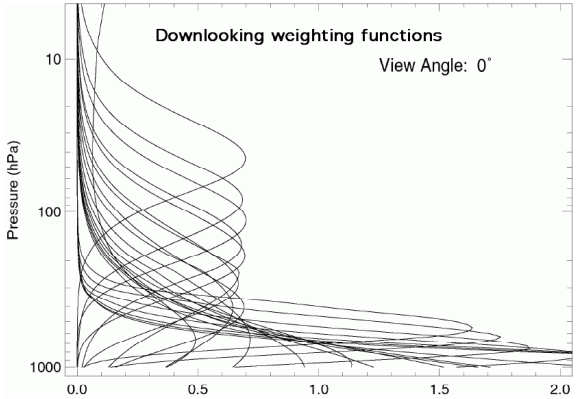
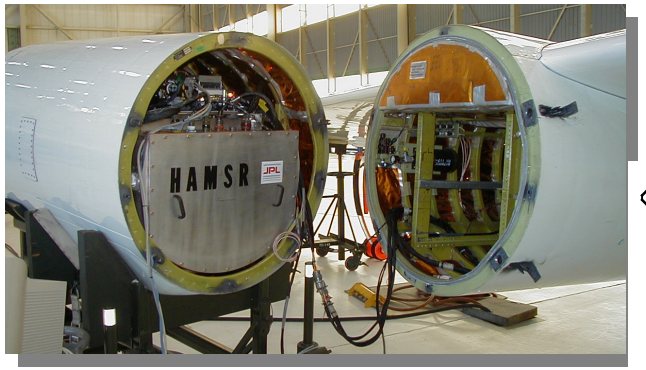
"HAMSR" Microwave Sounder

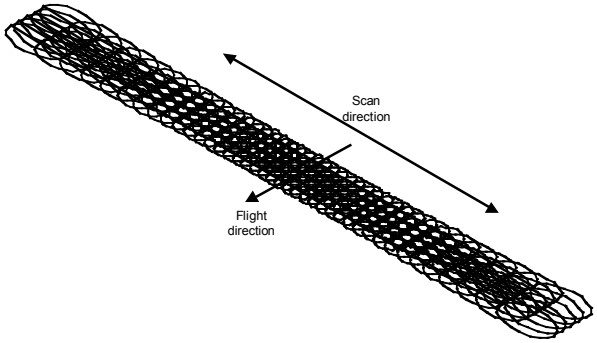
Deployed on NASA ER-2



Chan #	Center freq [GHz]	Offset [GHz]	Bandwidth [MHz]	Wt-func Peak [mb nom]
I-1	118.75	-5.50	0 160	Surface [300mb]
I-2	"	-3.50	0 100	Surface
I-3	"	-2.55	0 50	Surface
I-4	"	-2.05	0 50	100mb
I-5	"	-1.60	0 40	76mb
I-6	"	-1.20	0 40	40mb
I-7	"	±0.80	0 2x40	26mb
I-8	"	±0.45	0 2x30	16mb
I-9	"	±0.23	5 2x30	8mb
I-10	"	±0.12	0 2x30	4mb
I-11	50.3	0	0	180	Surface [10mm]
I-12	51.76	0	40	Surface
I-13	52.8	0	40	100mb
I-14	53.59	6	0.1	52x70	76mb
I-15	54.4	0	0	40	40mb
I-16	54.94	0	40	26mb
I-17	55.5	0	0	30	16mb
I-18	56.0 56.67	2	0	20 30	9mb
II-1	183.31	-7.0	400	[11mm]
II-2	"	±0.0	2x1000	[6.8mm]
II-3	"	±7.0	2x2000	[4.2mm]
II-4	"	±4.5	2x2000	[2.4mm]
II-5	"	±3.0	2x1000	[1.2mm]
II-6	"	±1.8	2x1000	[0.6mm]
II-7	"	±1.0	2x500	[0.3mm]



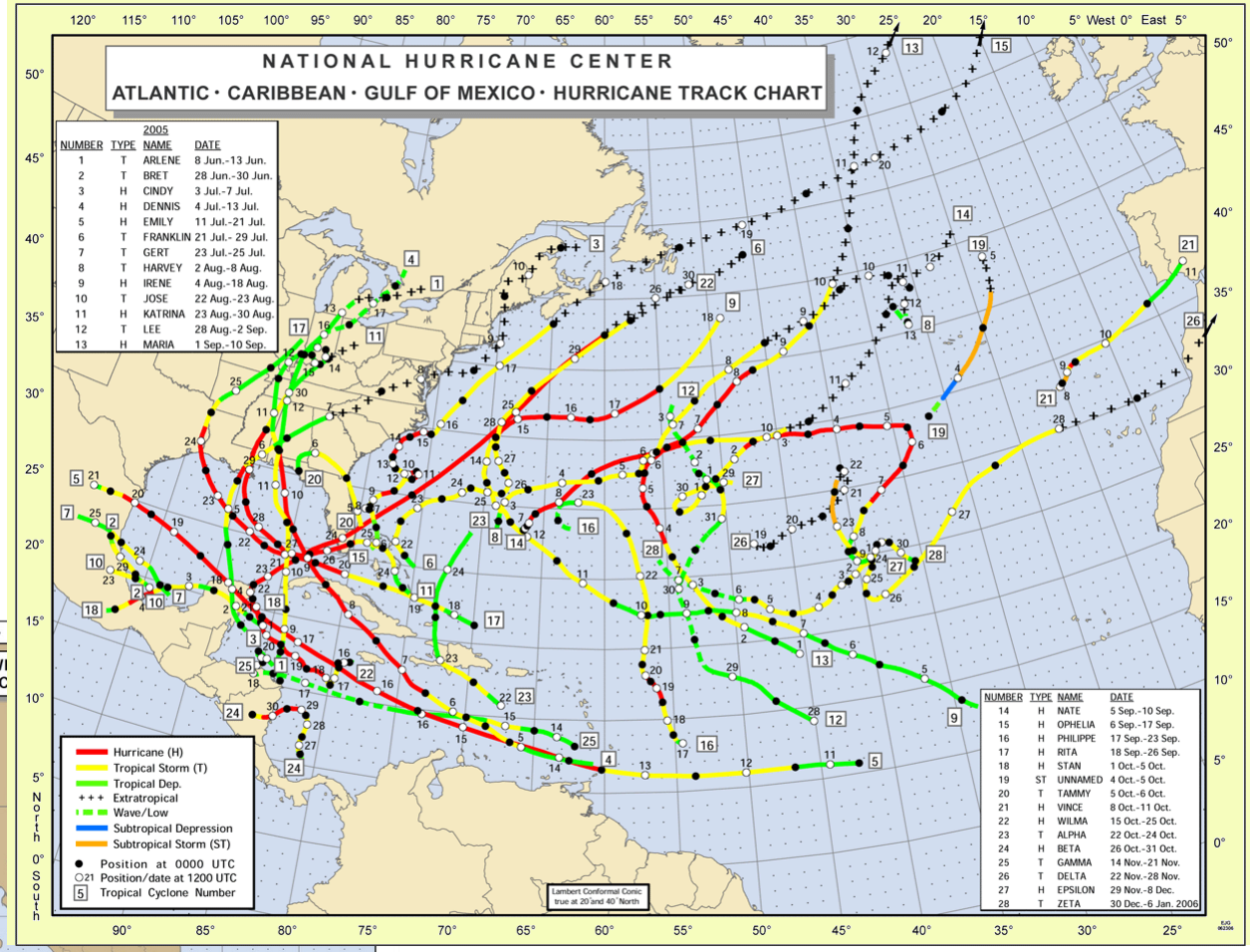


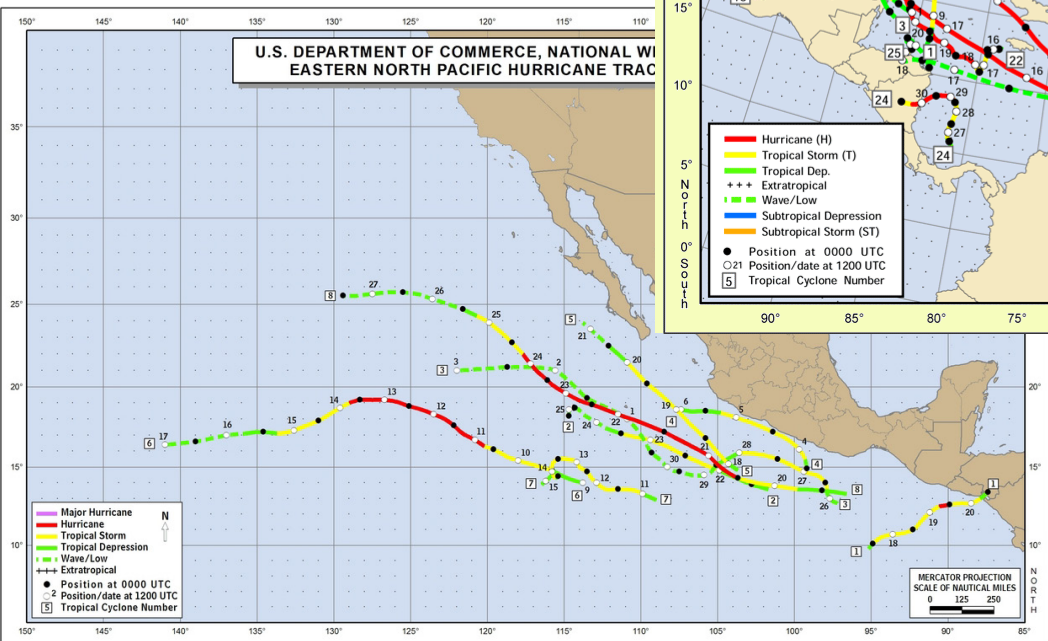


TCSP Hurricane Mission (2005)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

- **Objective: Hurricane processes, cyclogenesis**
- **HAMSR role: Provide core atmospheric measurements**
- **Deployment: Right-forward ER-2 superpod**
- **Field base: San Jose, Costa Rica**
- **Period: July 1-27, 2005**
- **Status: Successful flights**





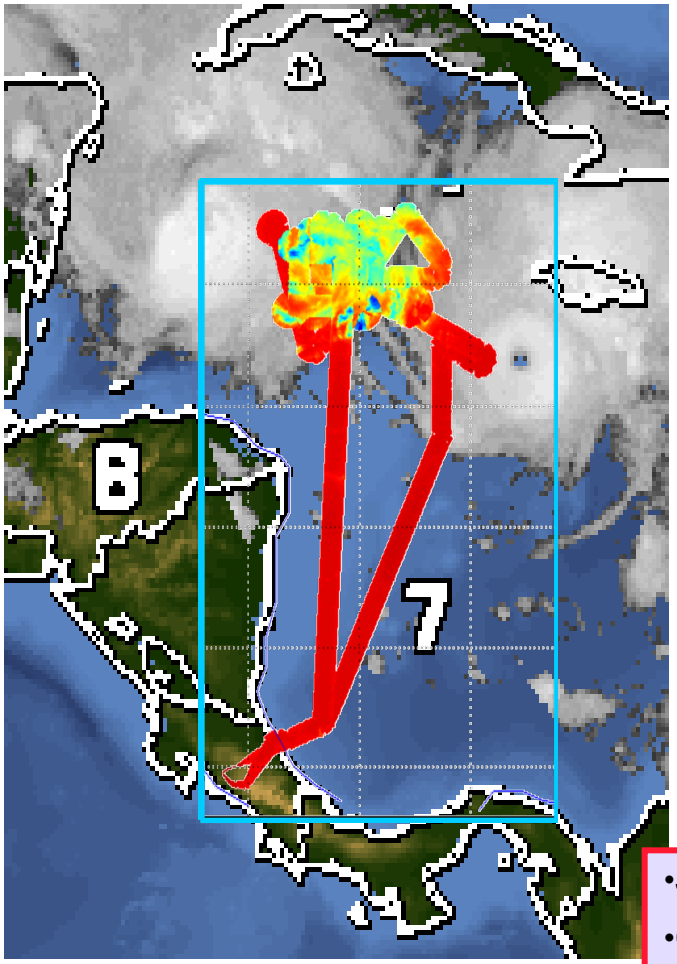
ER-2 payloads: Same as CAMEX, no dropsondes

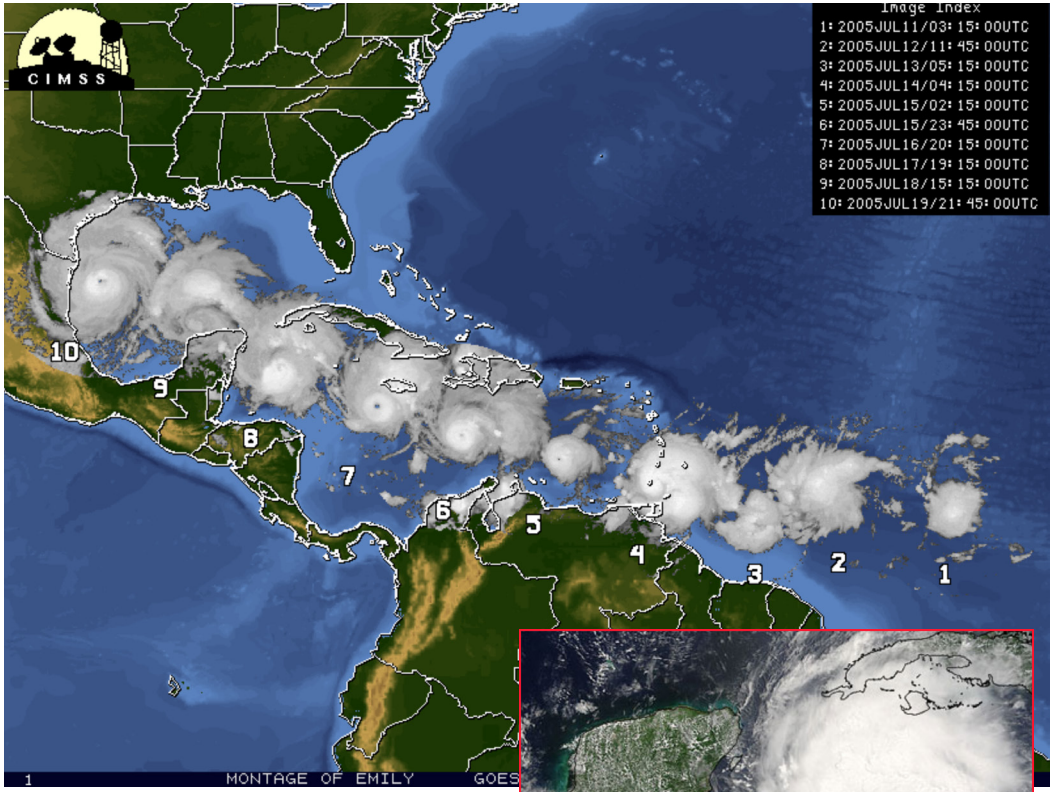
Formation flying with NOAA P-3's, no DC-8

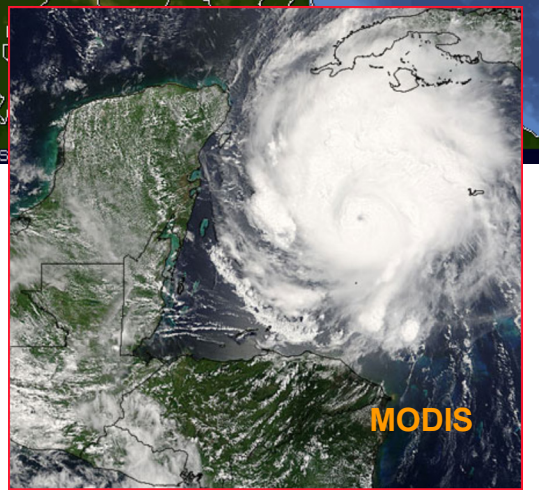
Data are publicly available

http://tcsp.nsstc.nasa.gov/

TCSP/HAMSR Example: Hurricane Emily

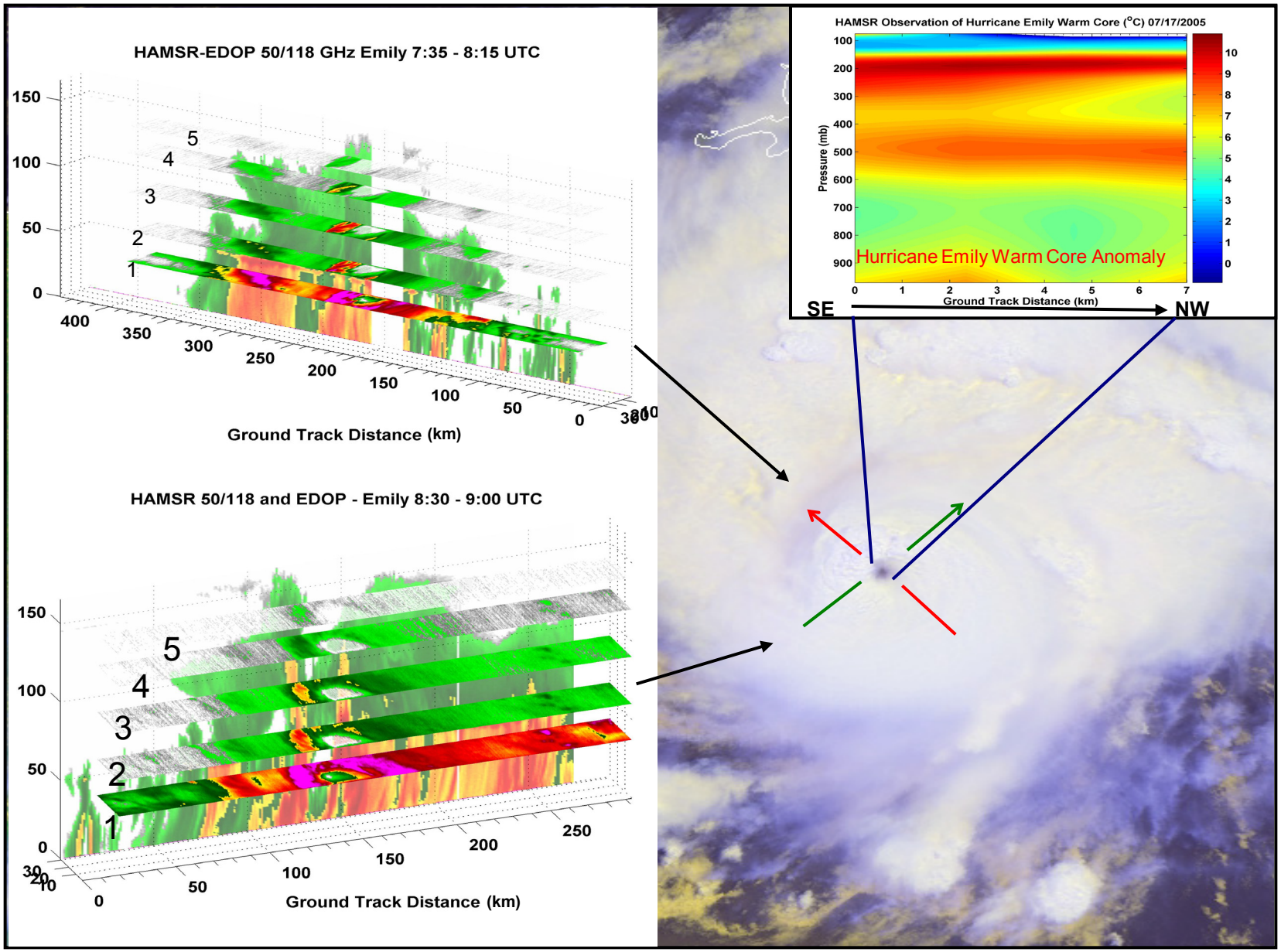






- July 17, 2005
- Overflights at 0730-1200 UT
- Strength @ 0900: 938 mb/130 kt, declining (strong Cat. 4)

Hurricane Emily: Core Observations



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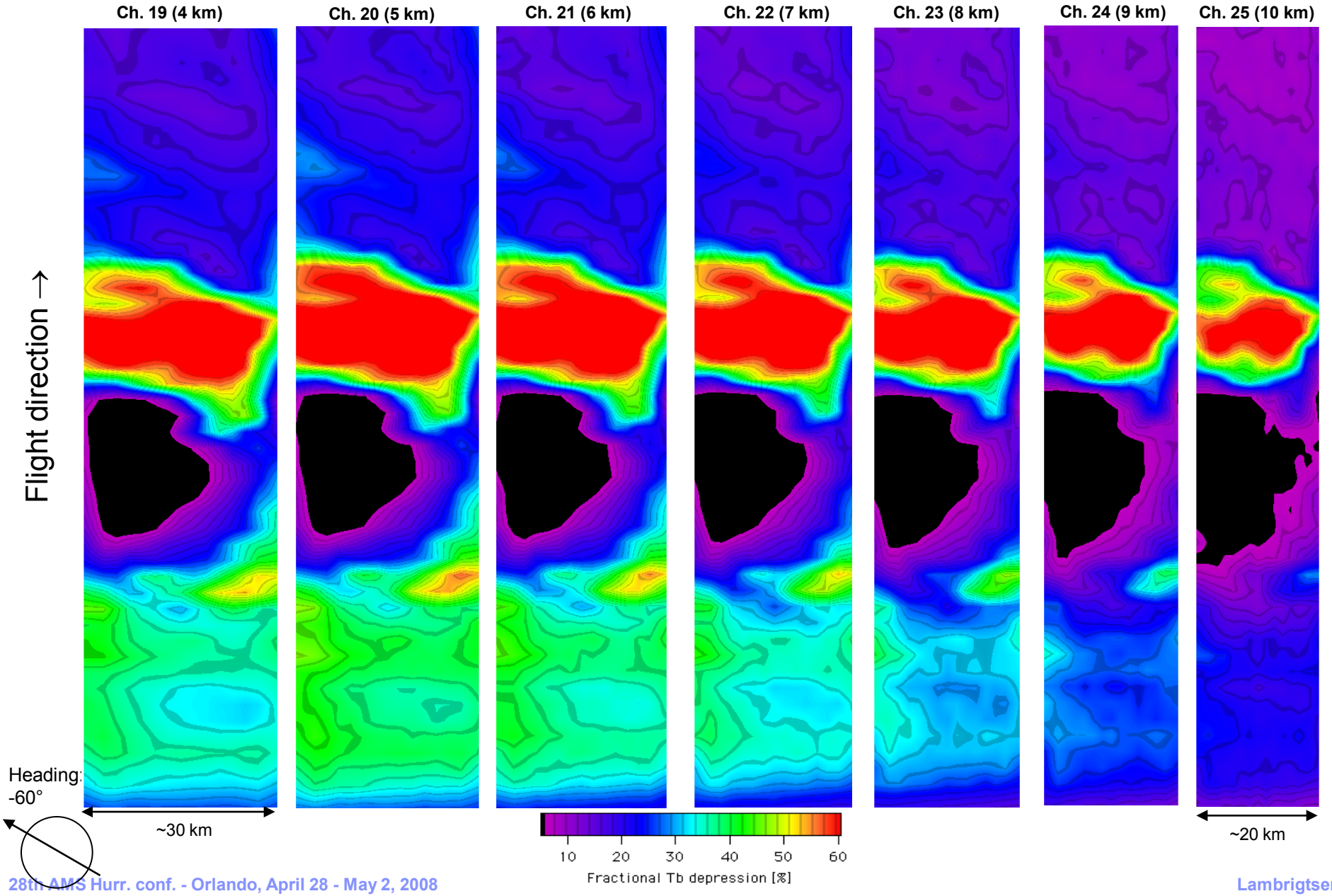
Hurricane Analysis with Microwave Sounder Observations

Hurricane Emily

July 17, 2005, 07:48-07:57 UTC



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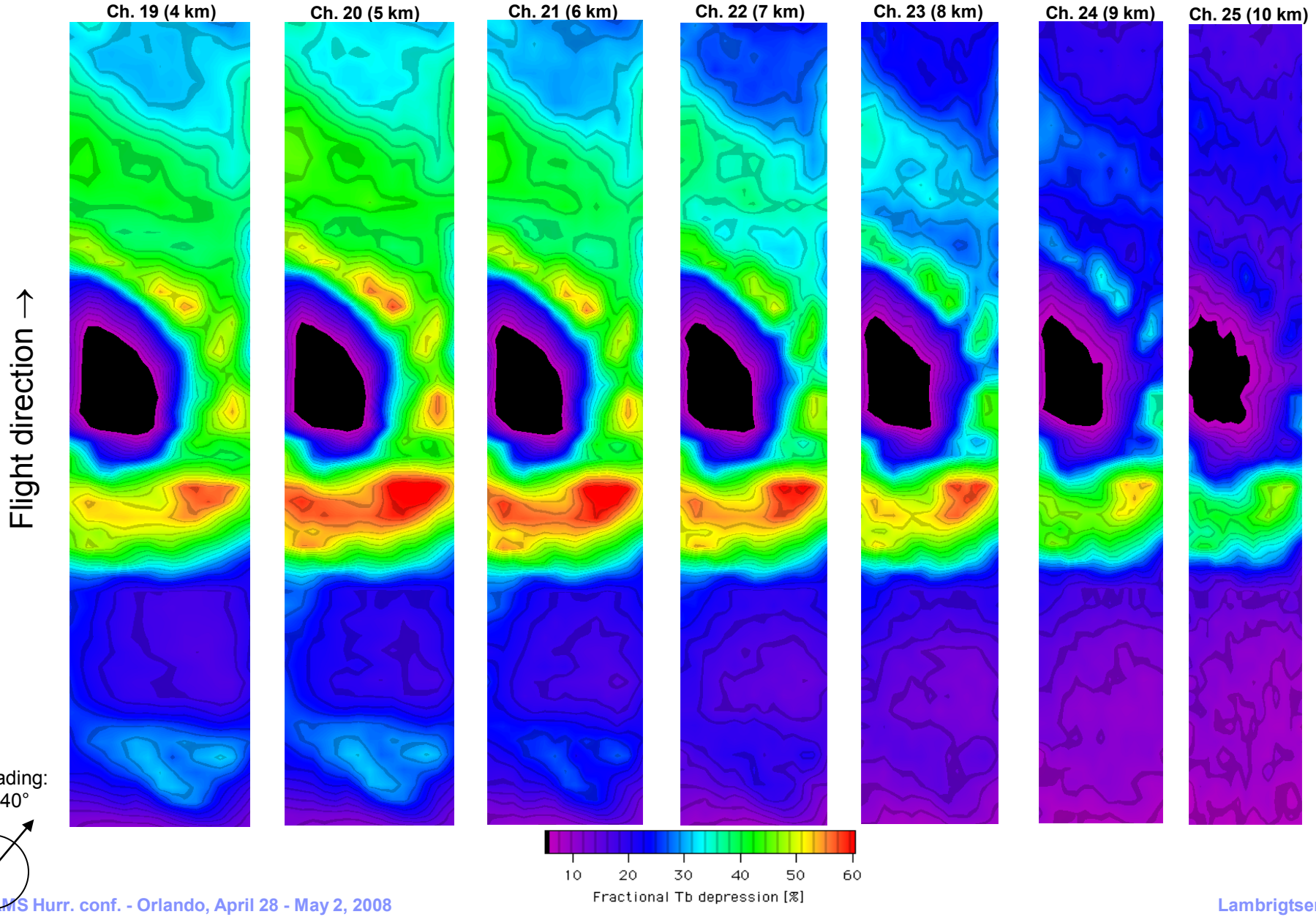
Hurricane Analysis with Microwave Sounder Observations

Hurricane Emily

July 17, 2005, 08:41-08:50 UTC



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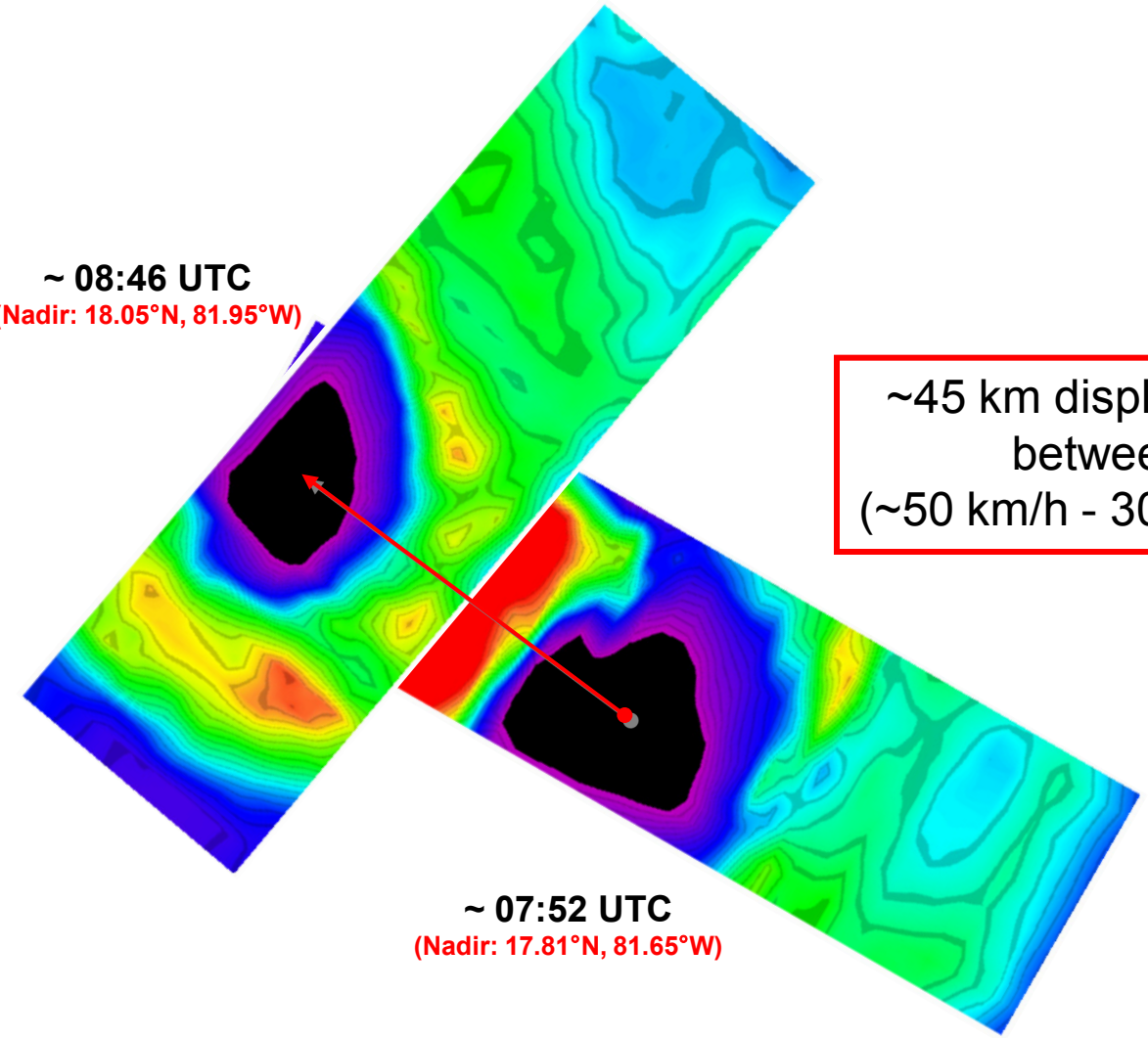
Repeat Views of Eye

Hurricane Emily — July 17, 2005, 07:52 & 08:46 UTC



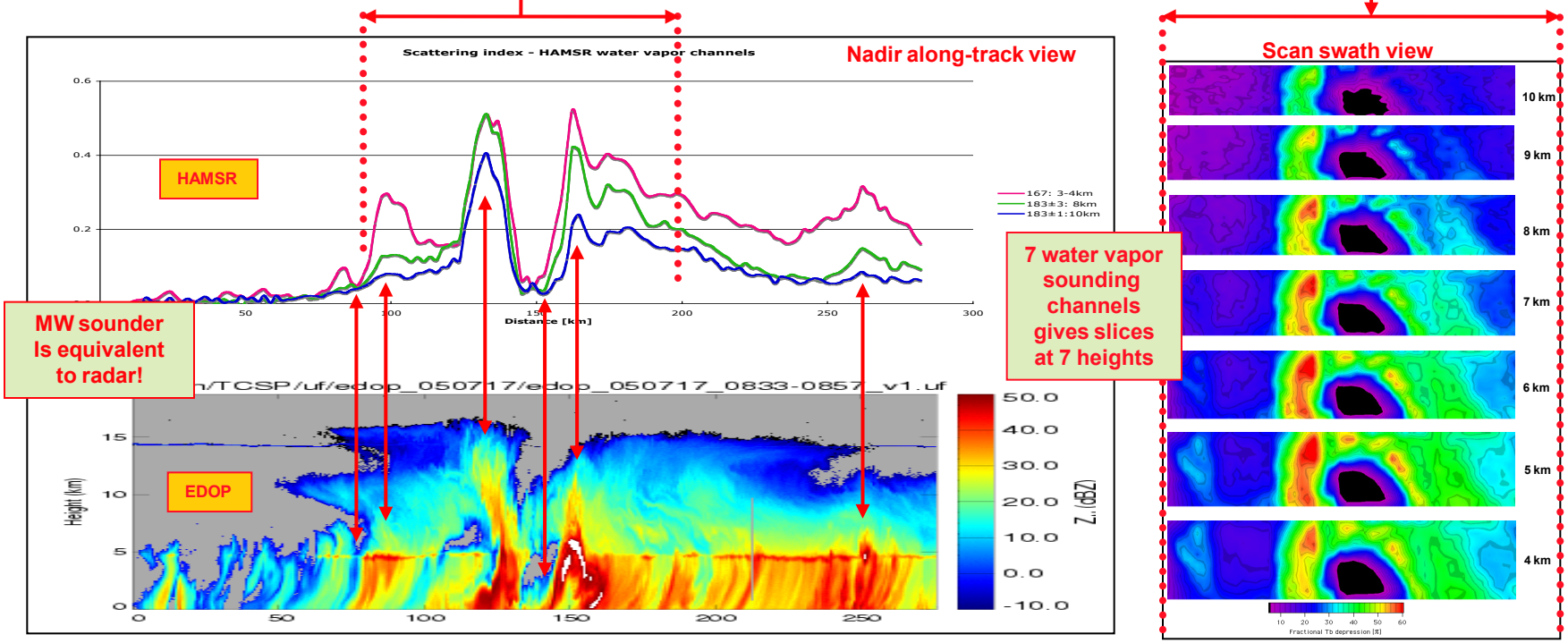
~45 km displacement to NW between passes
(~50 km/h - 30 mph - 13.5 m/s)

Scattering Observations

Comparison of microwave sounder (HAMSR) with doppler radar (EDOP)

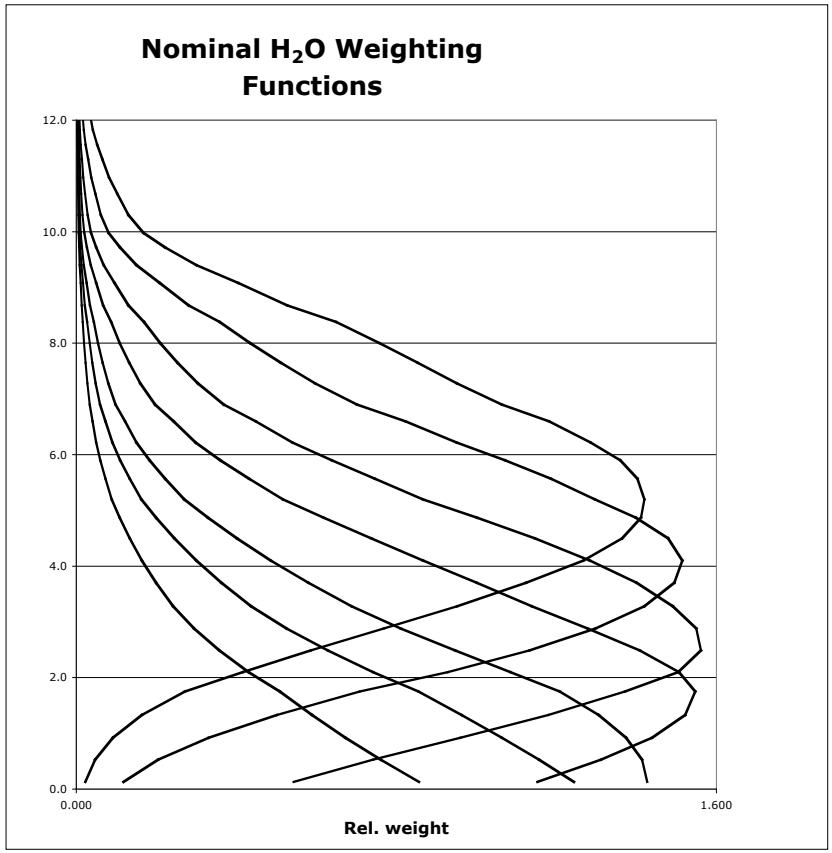
Hurricane Emily - July 17, 2005

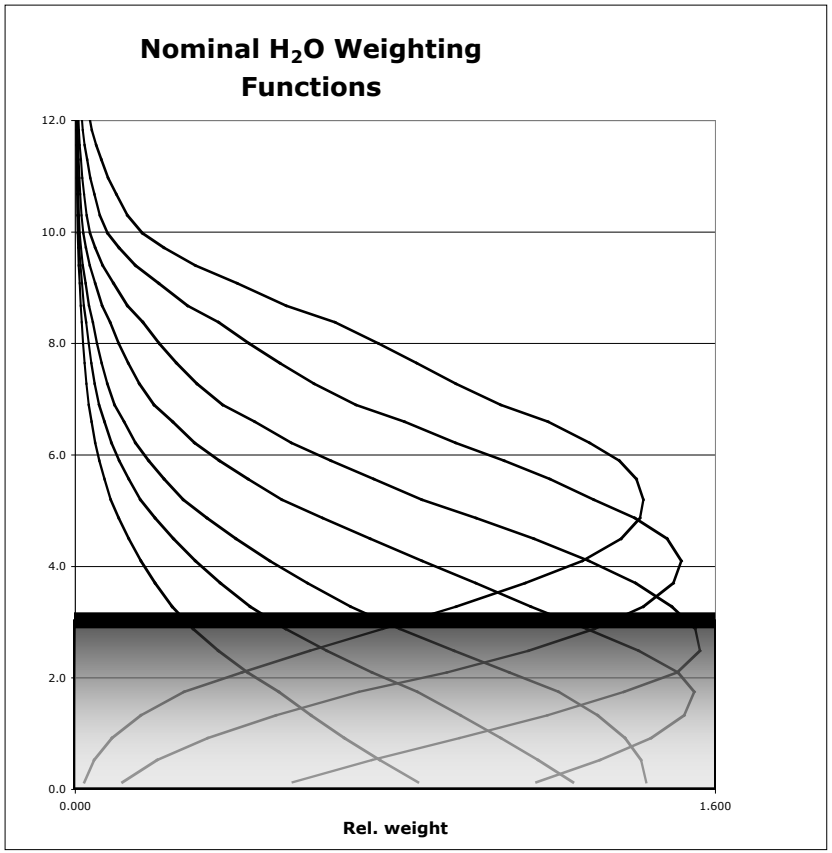
Vertical slicing through a hurricane



Strong correlations are apparent

Physical Basis for Scattering Profiling





RTE: $Tb = \varepsilon \cdot T_{sfc} \cdot \tau + \int T_{atm} d\tau$

Opaque channels ($\tau \approx 0$):
- $Tb \approx T_{atm}$ @ w.func peak

Transparent channels ($\tau \approx 1$) :
- $Tb \in [T_{atm}, \varepsilon \cdot T_{sfc}]$
- If ε is low, $Tb << T_{phys}$

Scattering layer acts like low-ε "surface"
- Cold "Tb_{sfc}" replaces lower range of integral
- Result is $Tb_{scatt} < Tb_{normal}$

ΔTb vs. channel => vertical distribution of scattering

ΔTb vs. band (wavelengths) => particle size info
- for d < 1 mm (otherwise in Mie regime)

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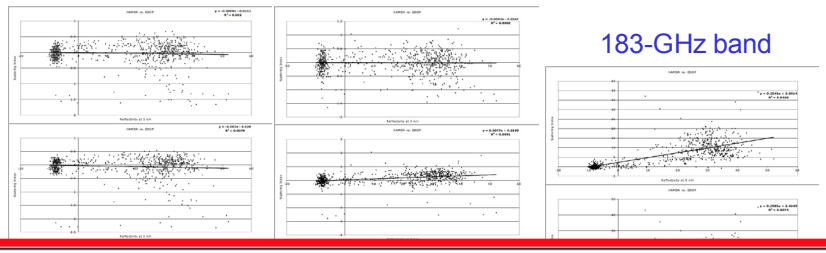
HAMSR-EDOP Correlations

Examples: 5 km & 10 km

5 km

50-GHz band | 118-GHz band | 183-GHz band

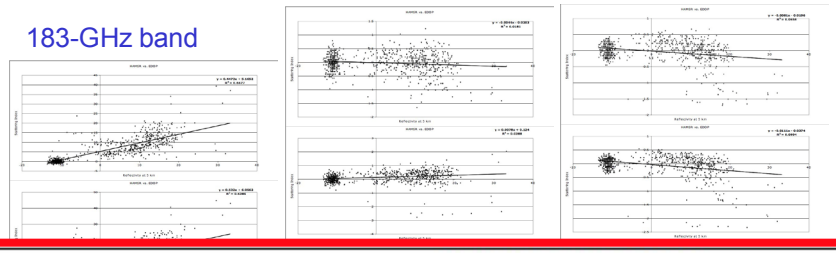


EDOP dBZ →

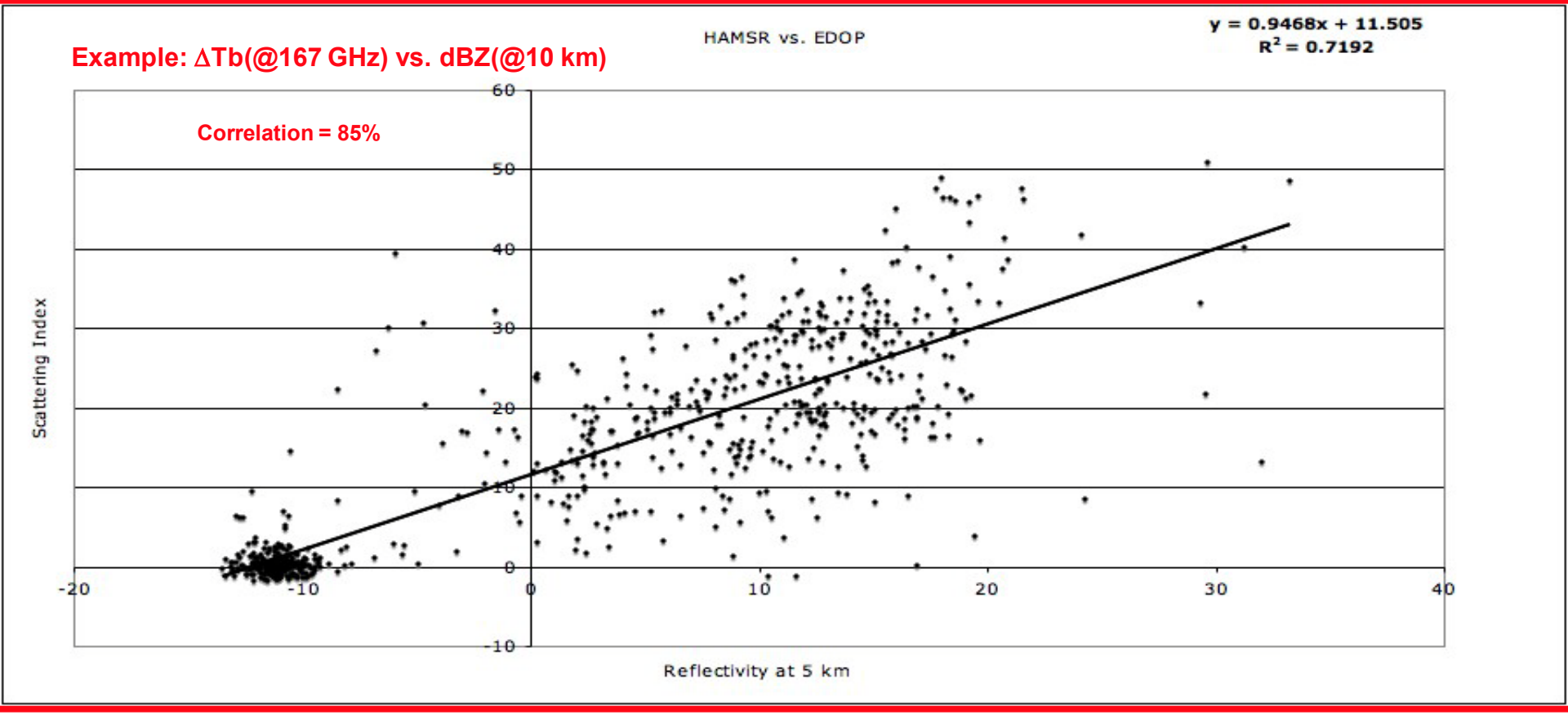
HAMSR Tb →

10 km

183-GHz band | 118-GHz band | 50-GHz band

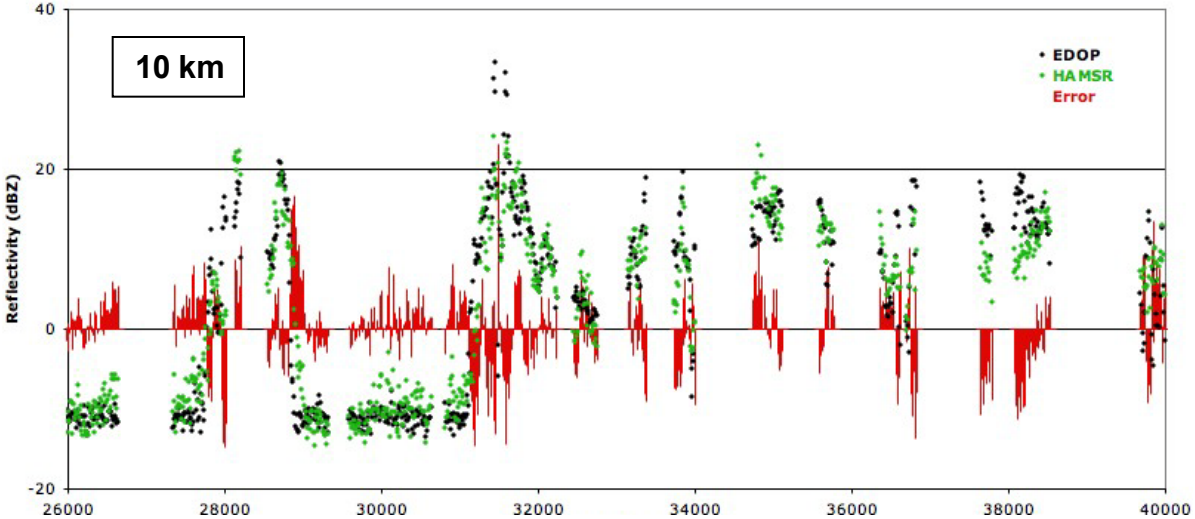


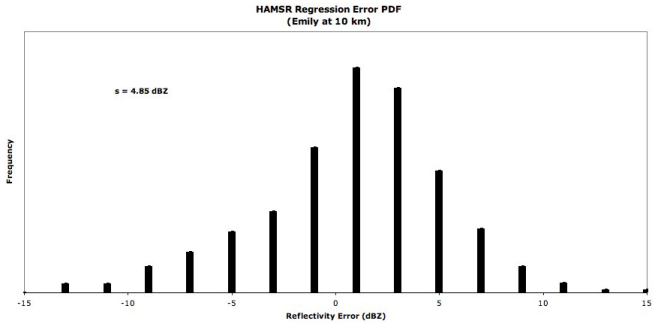
Example: ΔTb(@167 GHz) vs. dBZ(@10 km)

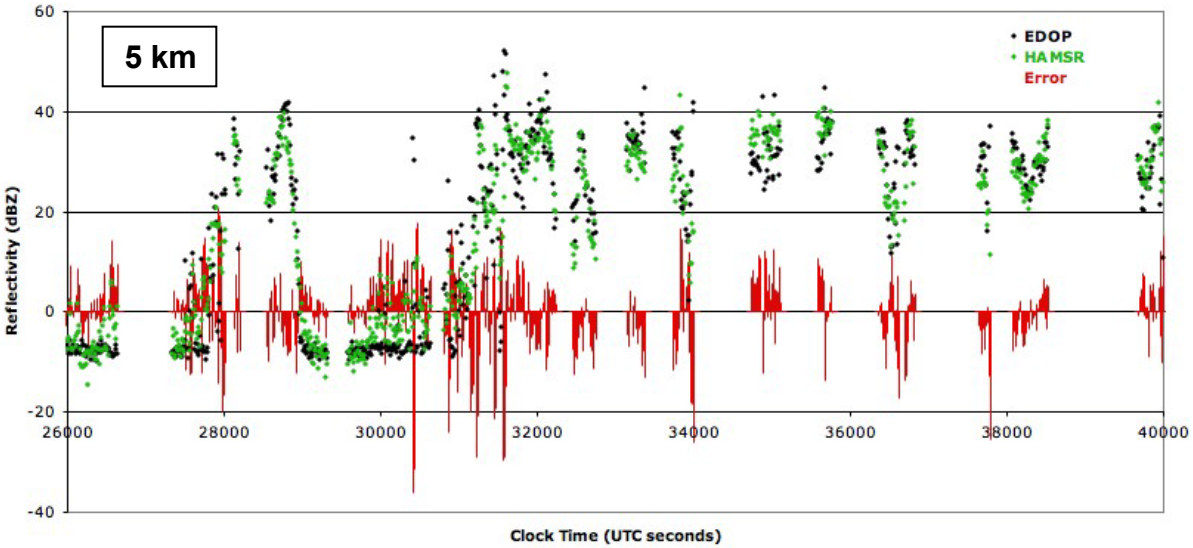


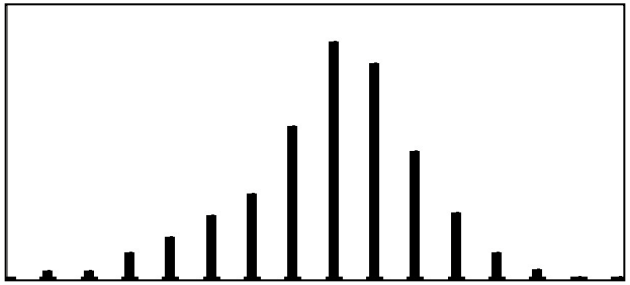
Regression Model Function

EDOP Reflectivity at 10 km vs. HAMSR Regression Prediction
Hurricane Emily, July 17, 2005 (TCSP)



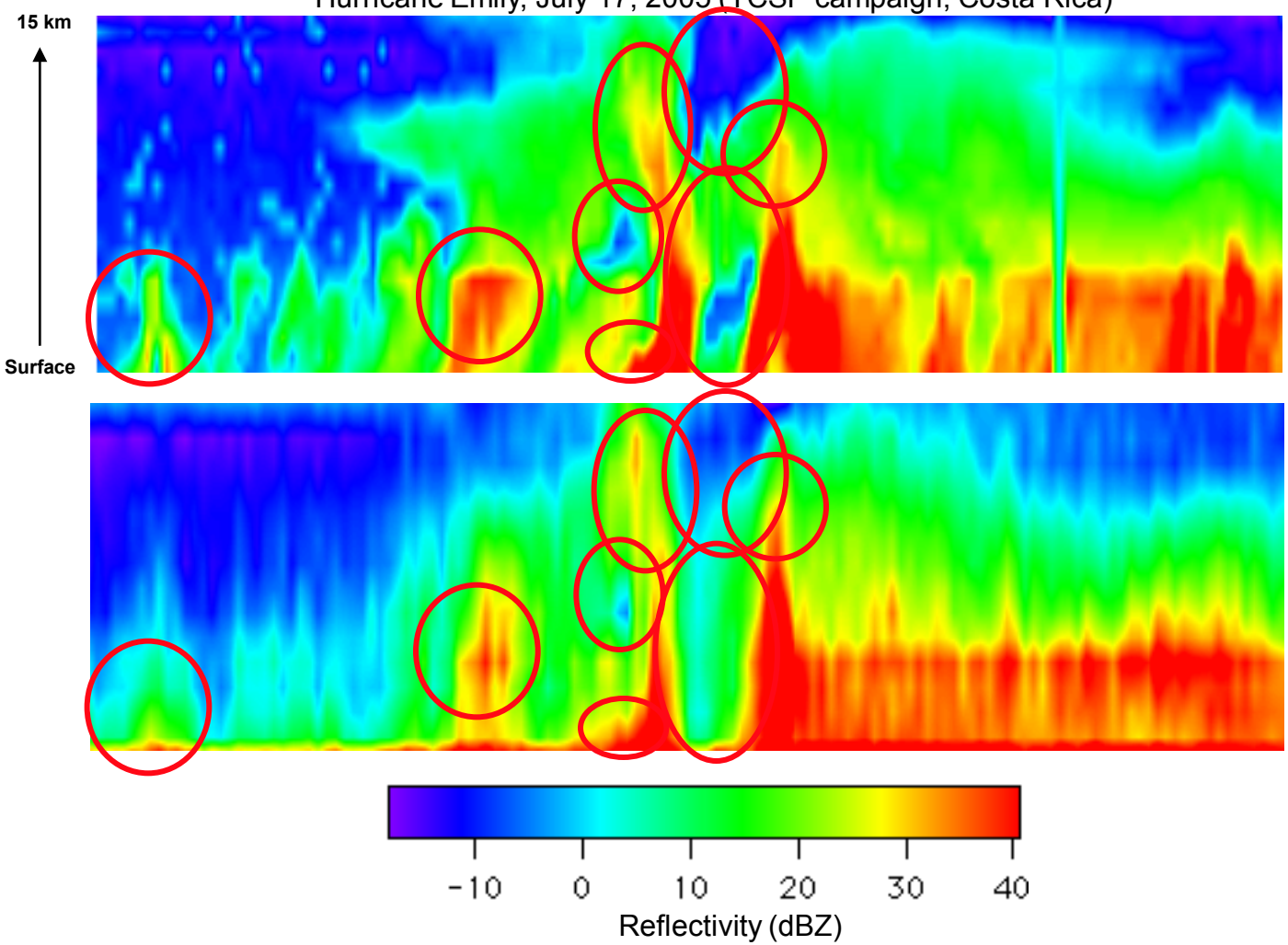






Results: Observed vs. Derived

Hurricane Emily, July 17, 2005 (TCSP campaign, Costa Rica)



Radar (EDOP)

Observed

Sounder (HAMSR)

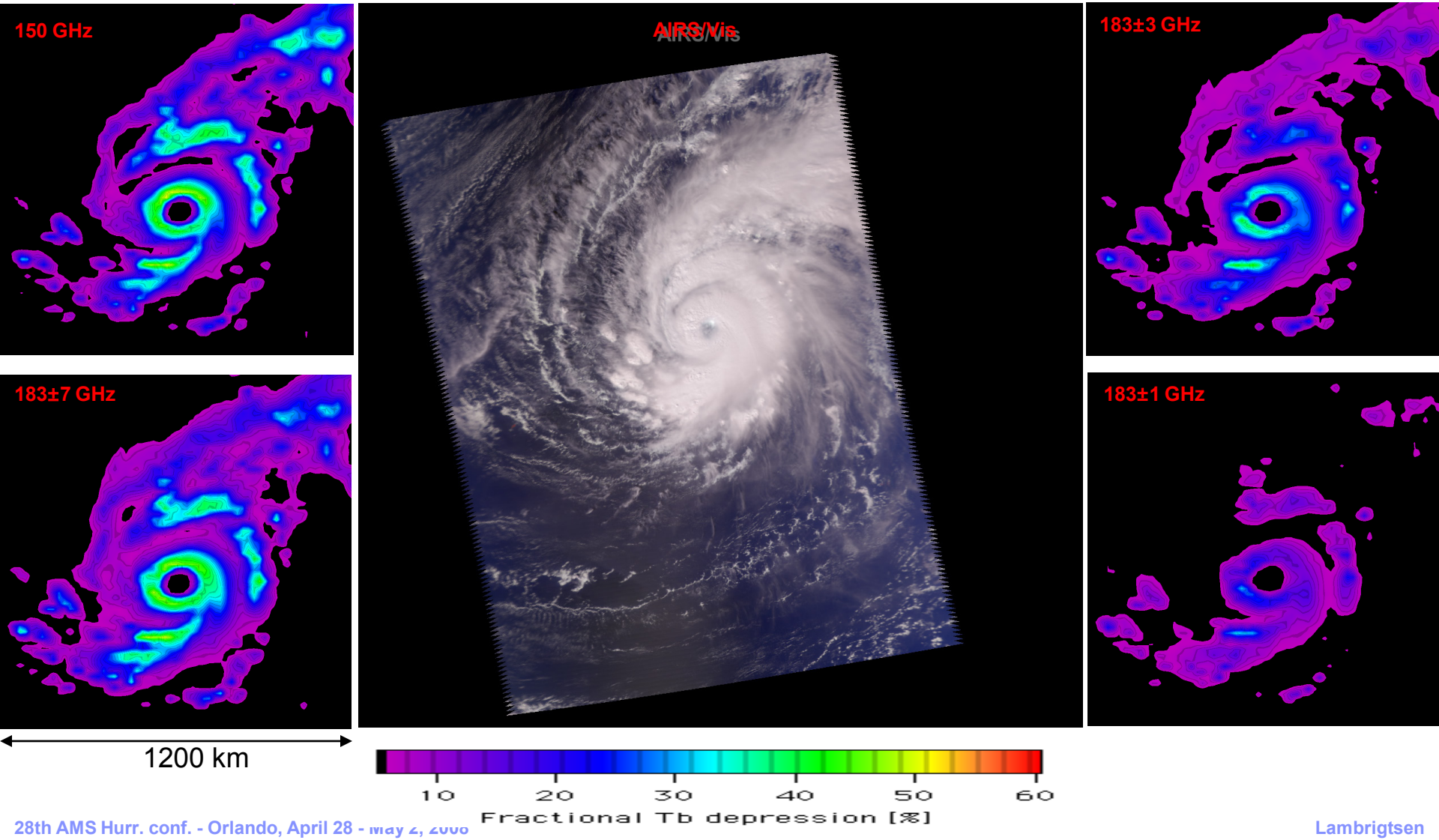
Derived

Soon to be published

Hurricane Emily: 3D View

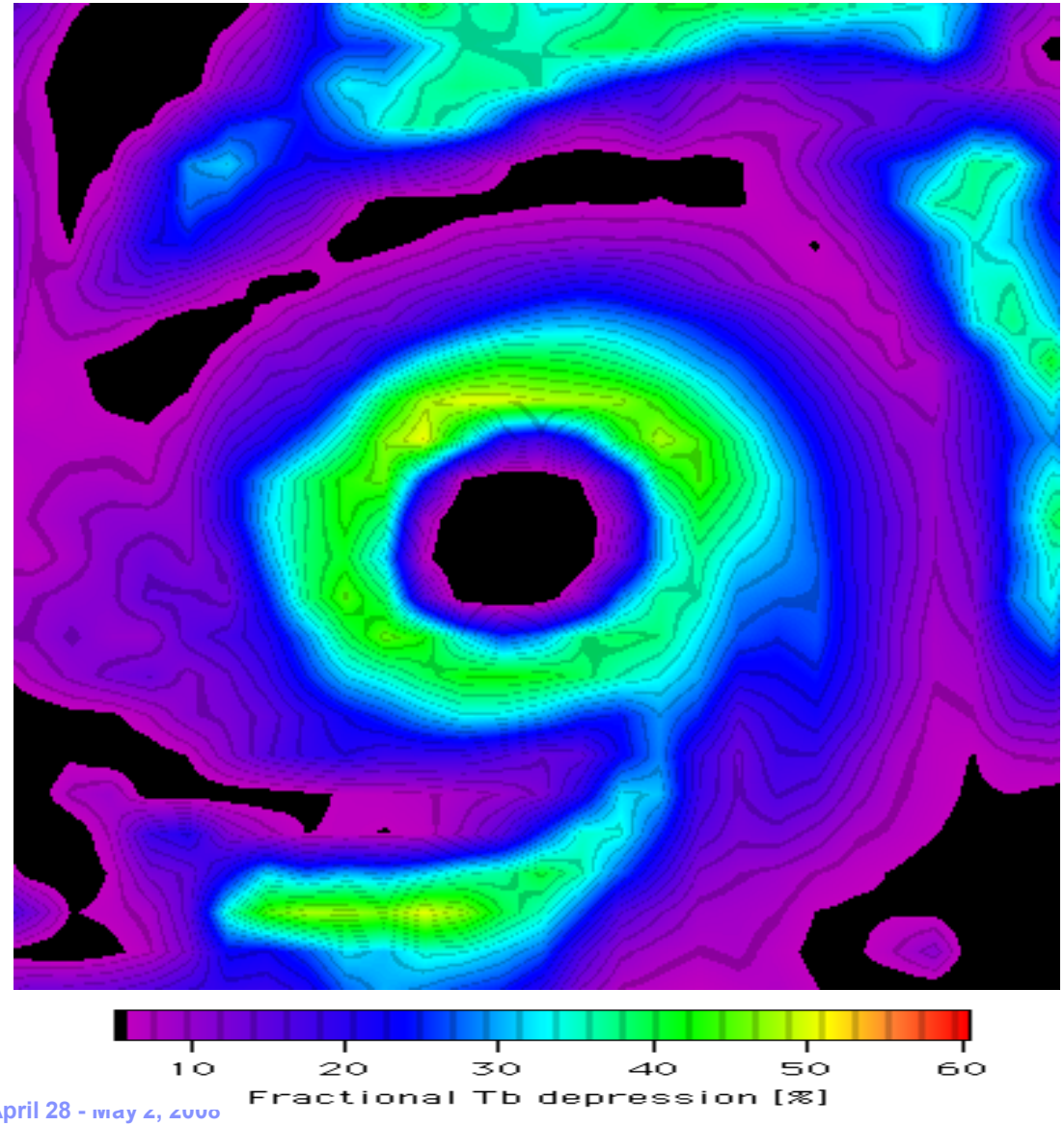
Next: The View From Space

Super Typhoon Pongsona at Guam — Aqua/HSB —December 8, 2002, 03:50 UTC



Closeup of Pongsona

Scattering-index/Convective-intensity per HSB 150-GHz channel



Large convective structures can be resolved with a 15-25 km spatial resolution

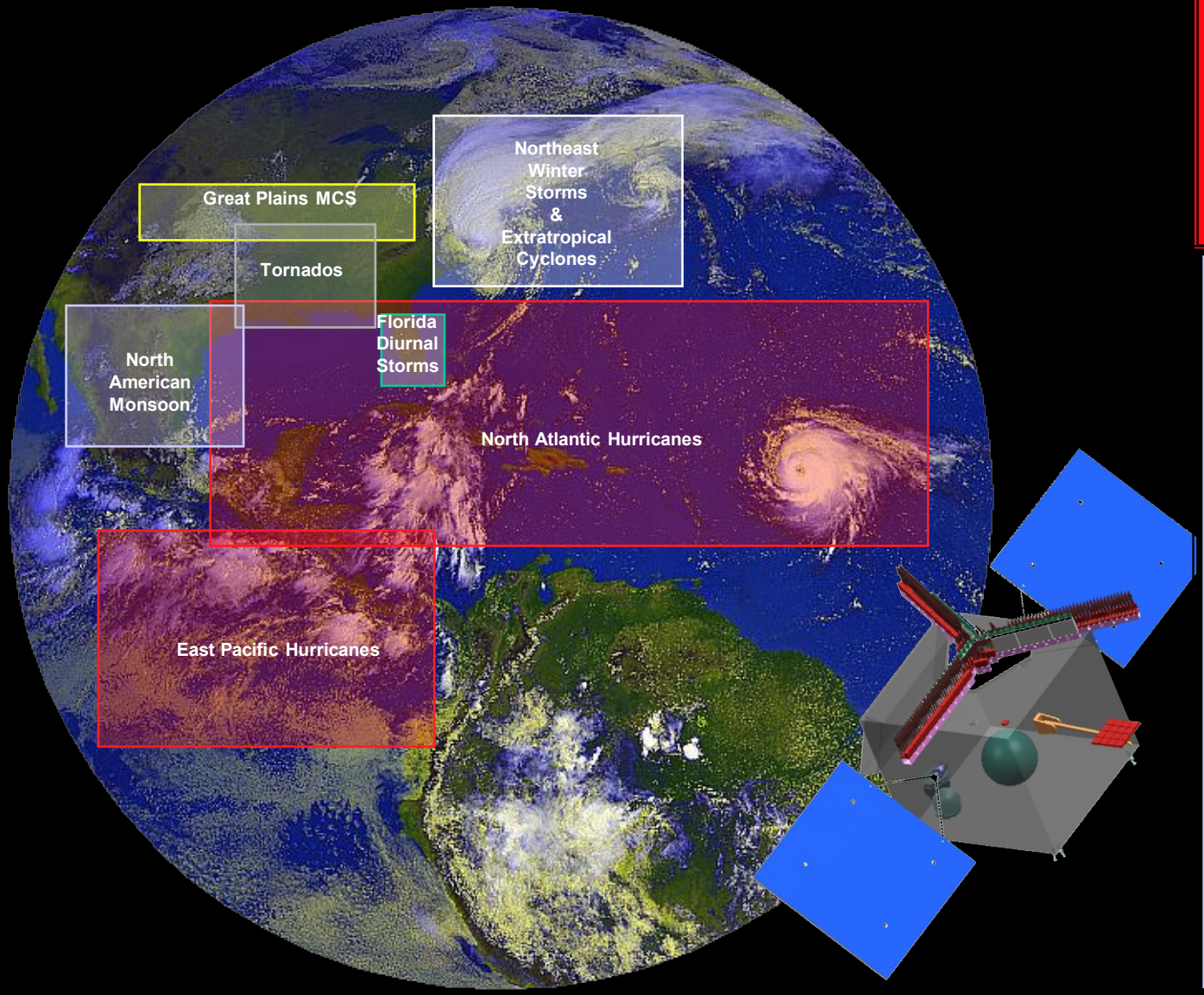
Vertical resolution is ~ 2 km

Spatial resolution:

15 km

And Finally, The View From GEO

GeoSTAR: HAMSR/AMSU functionality from GEO



Coming soon!

GeoSTAR to fly on "PATH", a Decadal-Survey mission

- Large aperture synthesized
- No mechanical scanning
- Continuous full-disk coverage
- Functionality similar to AMSU
  - T(p) @ 50 GHz/50 km every 20 min
  - q(p) @ 183 GHz/25 km every 15 min
  - precip, convective intensity, stability
- Low sidelobes; no scan bias
- Expandable to larger apertures
- Tunable to any channels

To Be Continued…

Working hypothesis:

- HAMSR scattering index is measure of convective intensity
- Differential scattering index is measure of vertical distribution of scatterers
- 118-183 GHz difference is measure of size distribution

Next steps:

- Use more accurate scattering-anomaly references
  - E.g., with nearby retrieved profiles
- Derive more accurate differential scattering index profiles
  - Using best estimates of actual weighting functions
- Solve scattering RTE
  - Will use both “macro” approach and “micro” approach
- Determine correlations between HAMSR scattering index & radar reflectivity
- Compare HAMSR scattering obs. with microphys. obs. during NAMMA
- Derive precipitation algorithms
  - Using radar algorithms
- Derive ice water path & microphysical properties of scatterers

And then:

- Apply to space observations
  - LEO: AMSU-A/B, SSM/IS, ATMS…
  - GEO: GeoSTAR