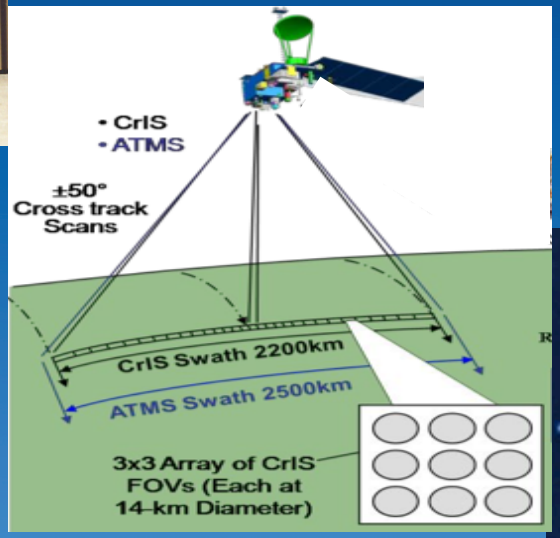
CrIS - Evolution of the Operational Advanced Sounder

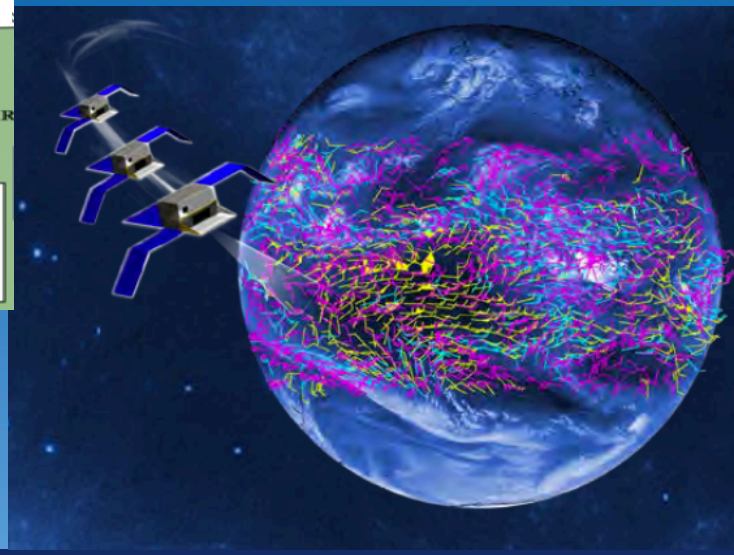
W.L. Smith Sr., H.E. Revercomb, F. Best, R. Glumb, D. Klaes, R. Knuteson, A. Larar, S. Mango, D. Santek, D. Tobin

UW – ER2 HIS (1985)

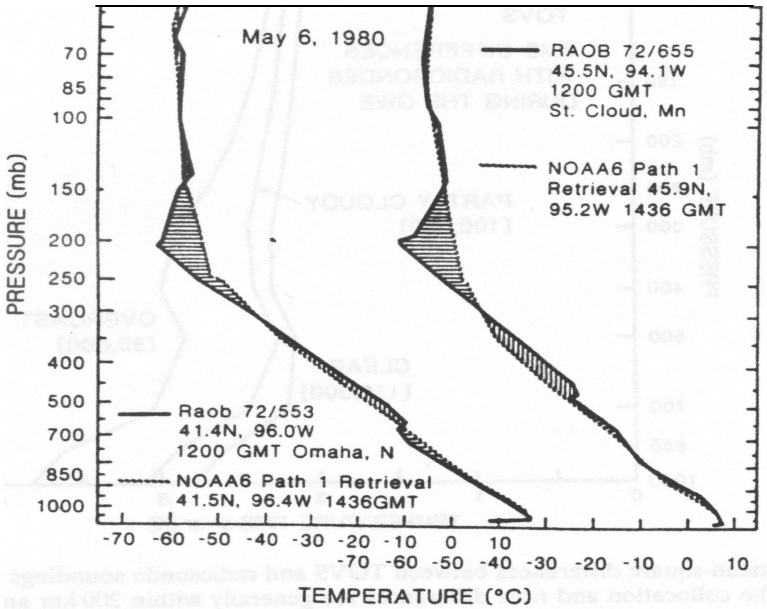
SNPP CrIS (2011)



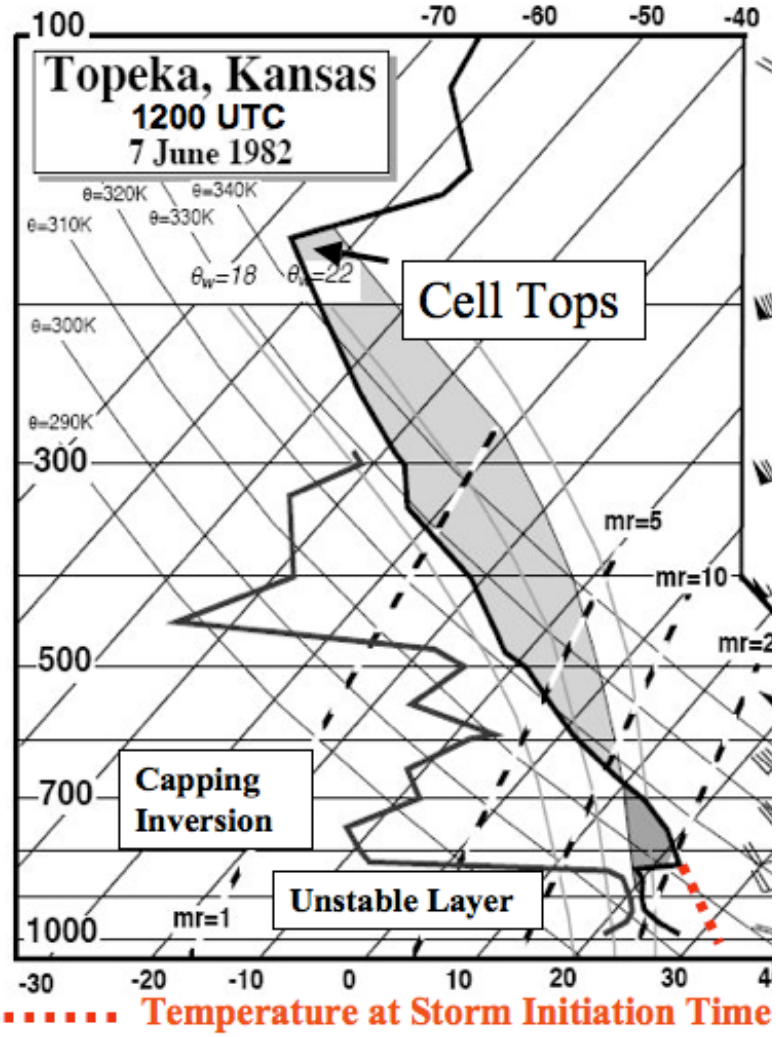
WHISPER HyFI (2021)



Why Hyperspectral Resolution for Sounding?



Significant temperature vertical structure could not be resolved from low spectral resolution radiances

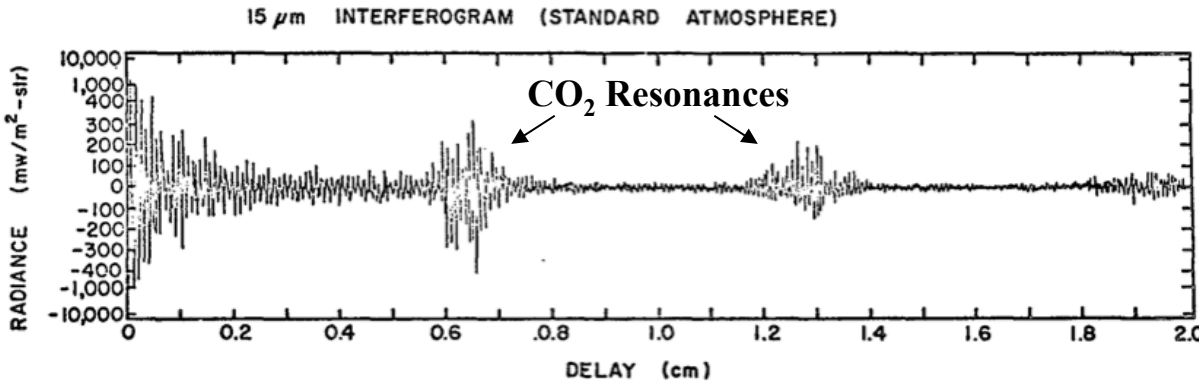


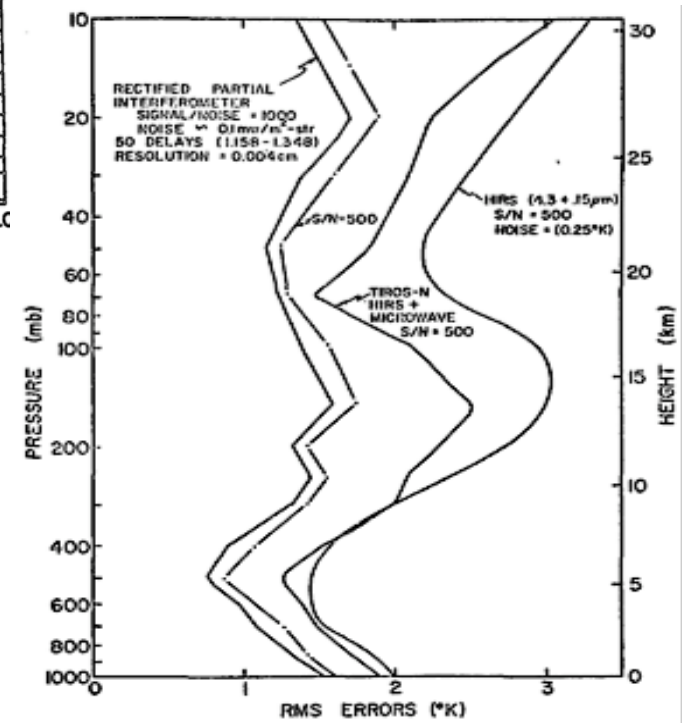
In the Beginning

- Interferometer Sounding Concept (1977)
  - Partial Interferometry - Tom G. Kyle (Temperature Sounding with a Partially Scanned Interferogram, Applied Optics 326-333)

Journal of the Atmospheric Sciences
Vol. 36, No. 4 April 1979

The Use of Interferometric Radiance Measurements for Sounding the Atmosphere
W. L. Smith, H.B. Howell, and H. M. Woolf





Whereas spectral radiance is emission from a deep layer of the atmosphere, the CO_2 interferogram resonance signal results from the vertical temperature structure within an atmospheric layer. The improvement in temperature sounding accuracy using an interferometer Vs. a filter radiometer is ~ 1 K

High-resolution Interferometer Sounder (HIS) - 1980-1998

Experimental Validation of the High Vertical Resolution Sounding Concept

A DESIGN FEASIBILITY STUDY

FOR A

HIGH RESOLUTION INTERFEROMETER SOUNDER (HIS)

FROM

THE UNIVERSITY OF WISCONSIN
SPACE SCIENCE AND ENGINEERING CENTER
1225 WEST DAYTON STREET
MADISON, WI 53706

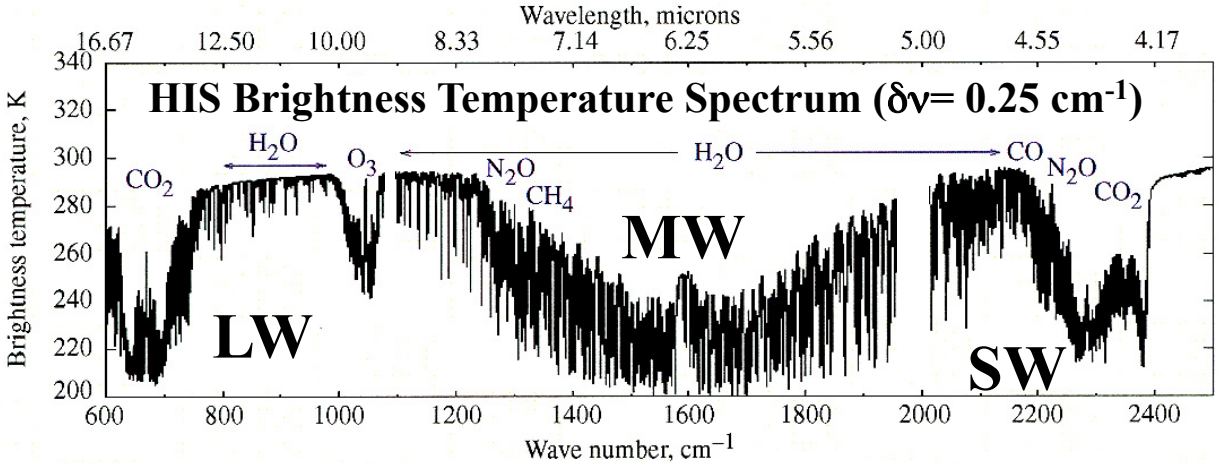
22 APRIL 1980

HIS Aircraft Instrument: U2 Shadowed in background, 1985

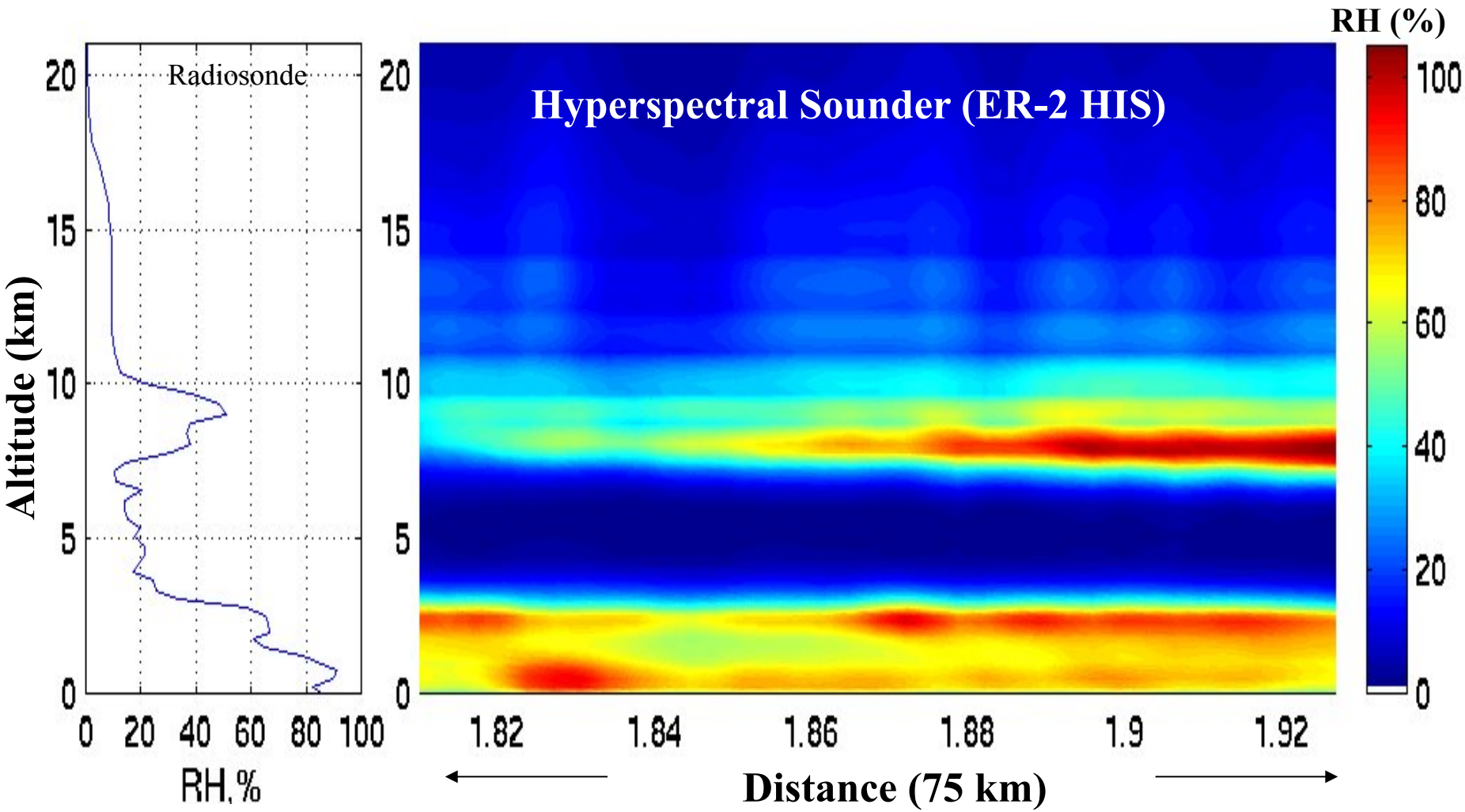
Three spectral bands, covering most of the region from 3.8 to 16 microns, with a spectral resolution ~ 0.25cm^{-1}

H. Revercomb et. al.,, "Radiometric calibration of IR Fourier transform spectrometers: solution to a problem with the High-Resolution Interferometer Sounder (HIS)," Appl. Opt. 27, 3210-3218 (1988).

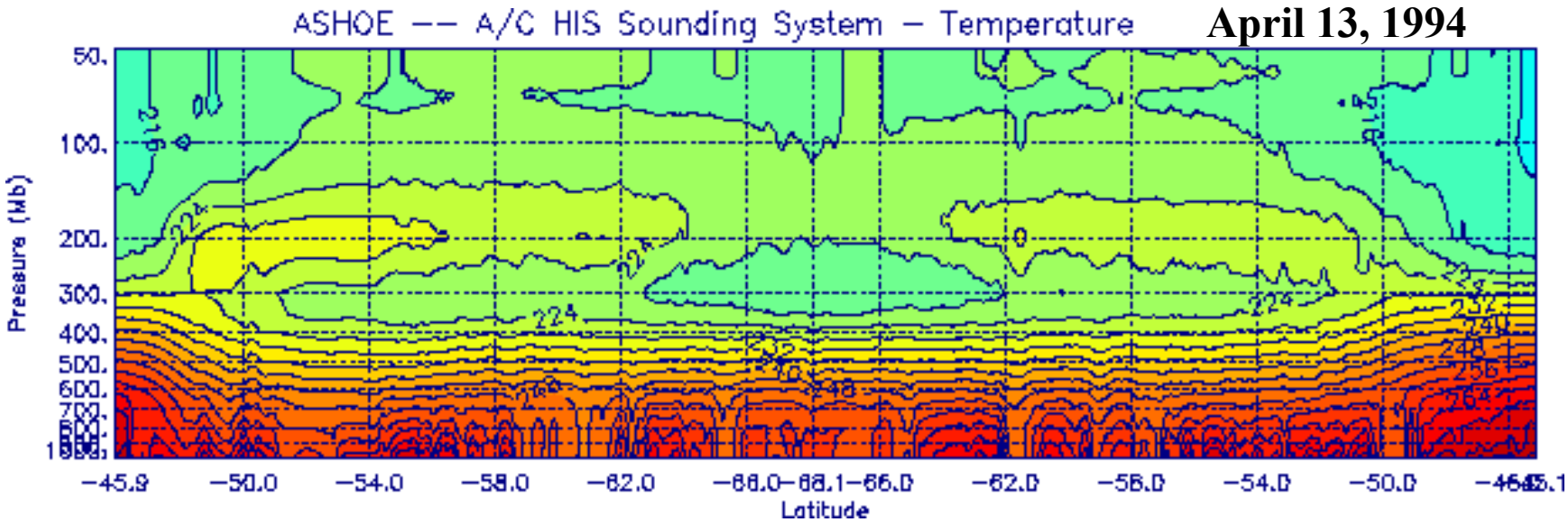
HIS Mounted in ER-2 Pod



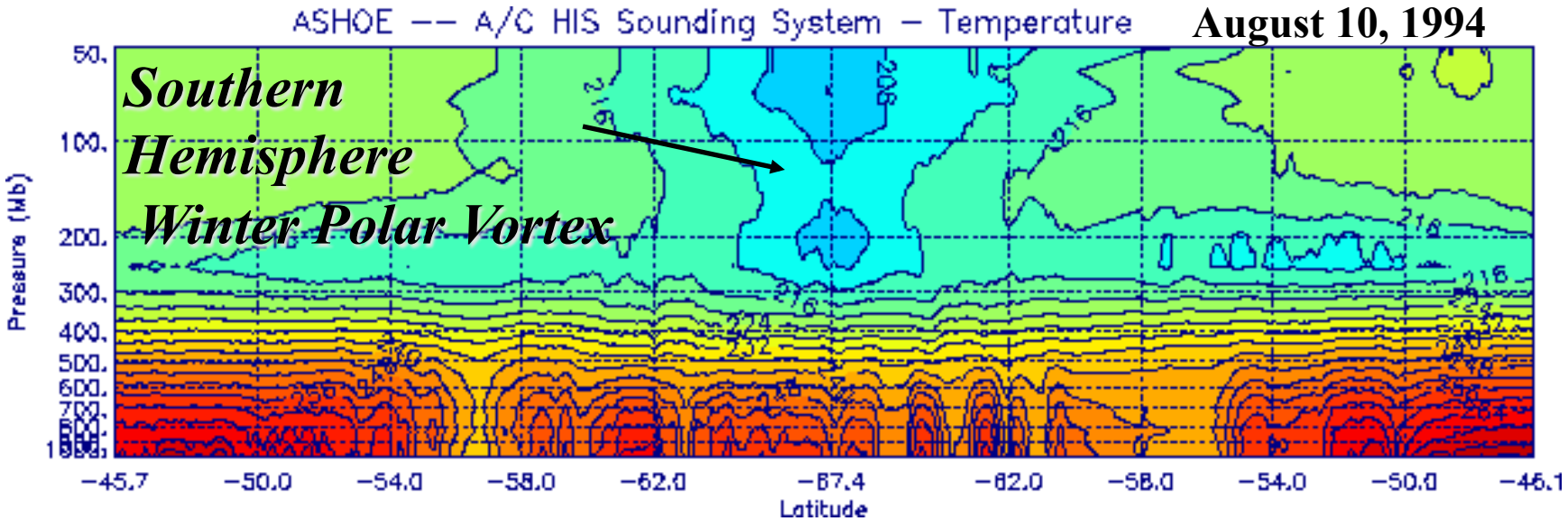
Hyperspectral Resolution High Vertical Resolution Sounding Information Demonstrated in 1986



ER-2 Airborne Southern Hemisphere Ozone Experiment



HIS High Vertical Resolution Soundings Over the SH Oceans



INTERFEROMETER THERMAL SOUNDER (ITS)

Study Lead:
H. E. Revercomb (UW-Madison)

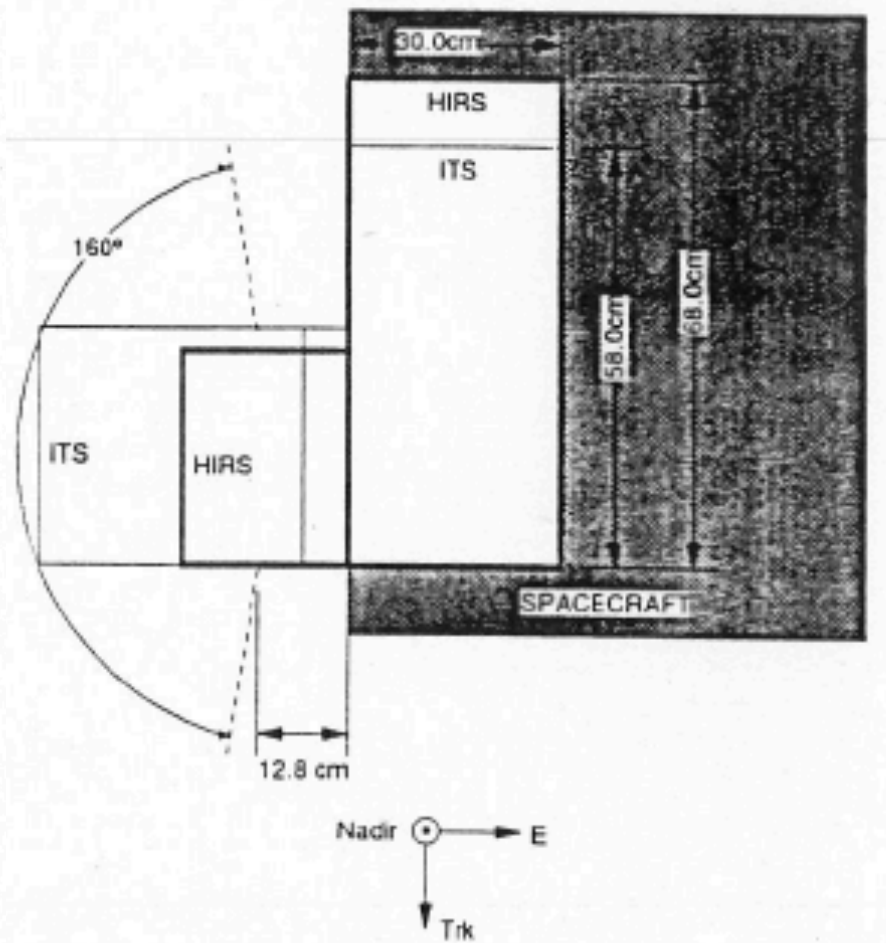
FEASIBILITY STUDY
FINAL REPORT

PREPARED FOR
EUMETSAT

PREPARED BY
UNIVERSITY OF WISCONSIN
SPACE SCIENCE AND ENGINEERING CENTER
AND
HUGHES SANTA BARBARA RESEARCH CENTER

DECEMBER 20 1991

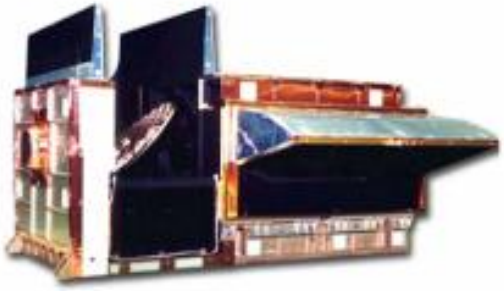
ITS Designed to Replace HIRS on the NOAA Satellites



ITS Objective: Much Higher Spectral Resolution for Improved Soundings

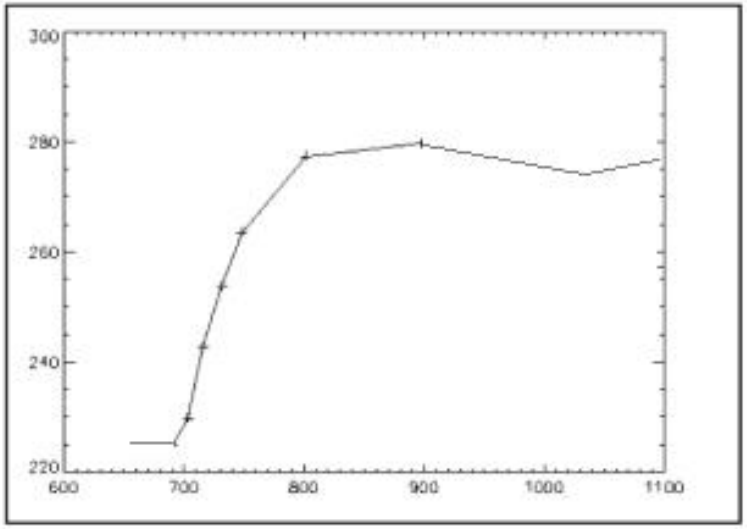
Current Generation

HIRS

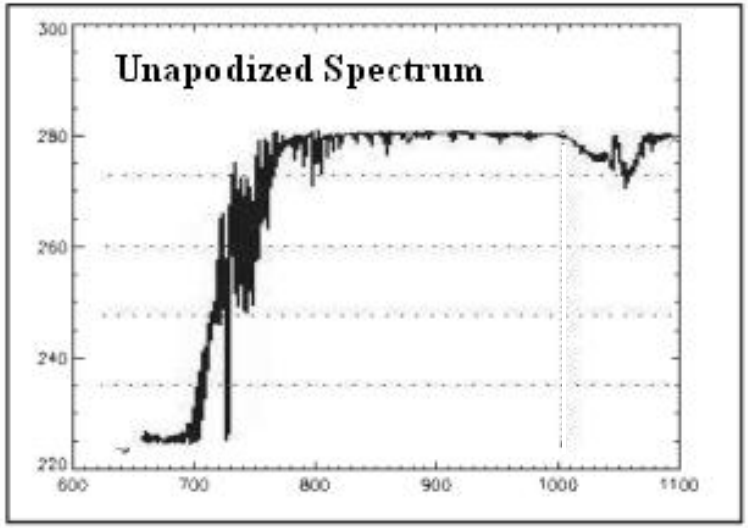


Next Generation

ITS/CrIS



HIRS LW Spectrum (12 Channels)

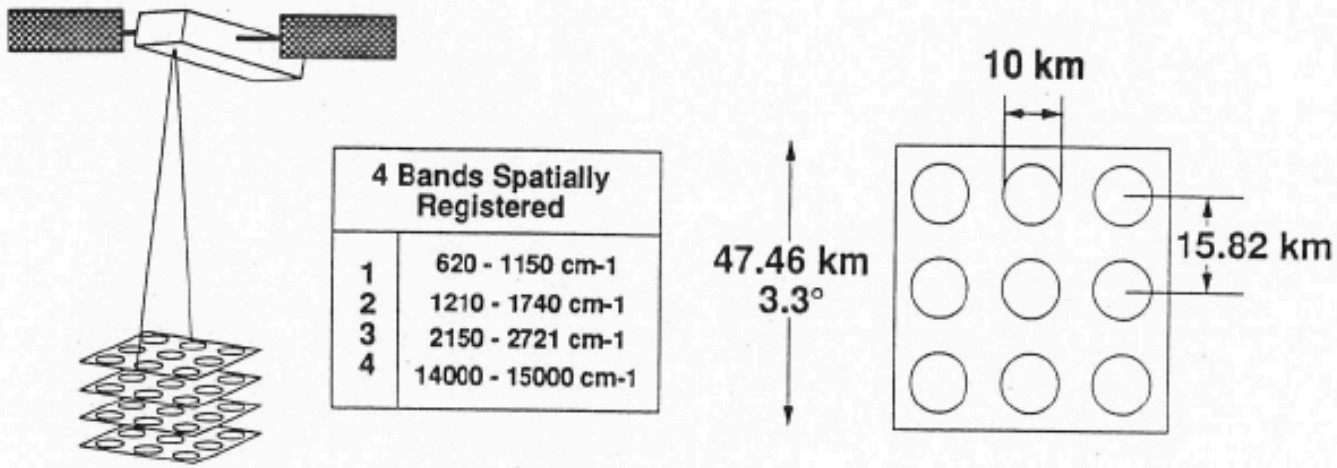


ITS/CrIS LW Spectrum (712 Channels)

More Spectral Channels Improves Sounding Accuracy and Vertical Resolution

1.3 ITS Design and Performance

The spatial resolution and coverage of the ITS are illustrated in Figure 1.2, which also gives the spectral coverage. A 3x3 array of 10 km fields of view sample a 50x50 km region during each of 30 cross-track dwell periods. The 10 km spot size offers good cloud clearing opportunities, and the array size and cross-track scan timing are chosen to facilitate common processing with data from the advanced microwave instruments.

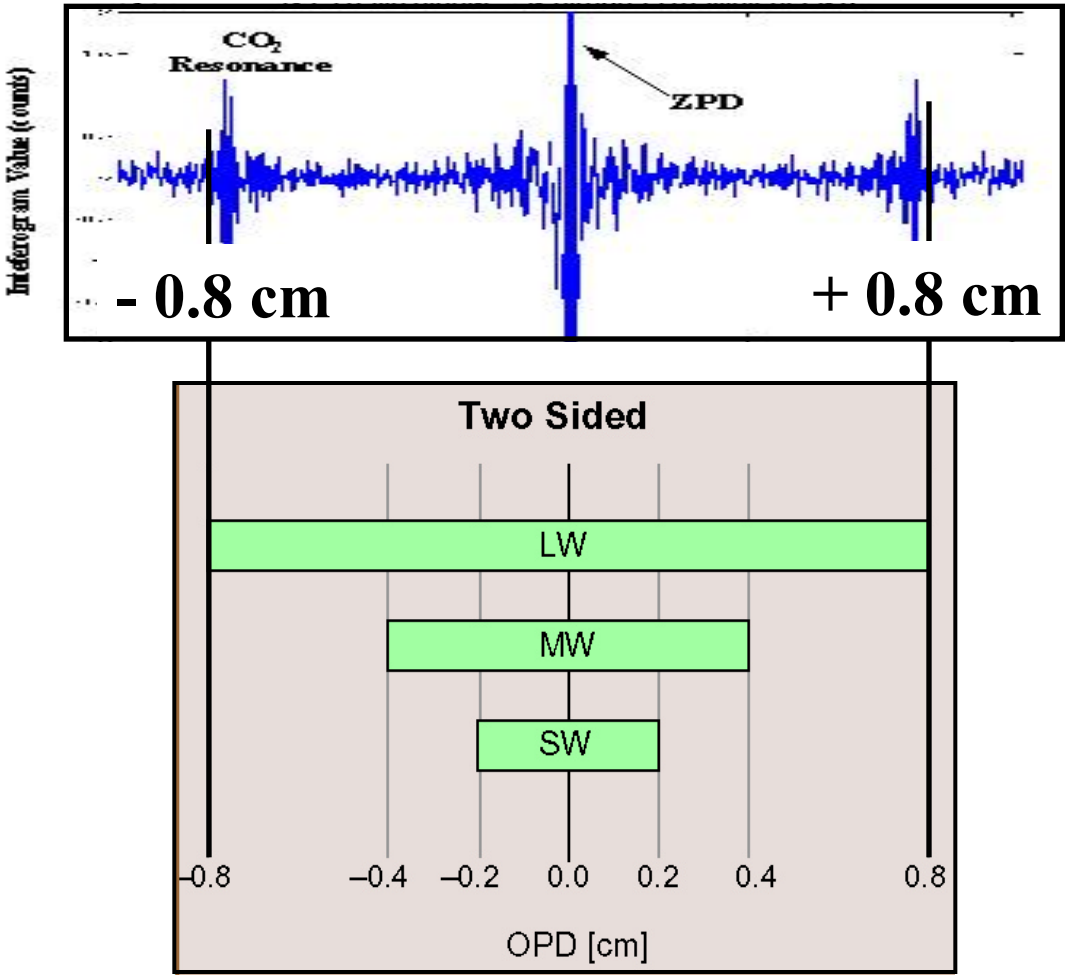


- Pixels Sized for Improved Sounding
- Sample Spacing Designed to Match AMSU-B
- 5.24 km Gap Along Track: (Spacecraft Moves 52.7 km in 8s at 824 km Orbit)
- Visible Channel (14000-15000 cm-1) Does Not Generate Interferogram

Taken from 1991 UW ITS Design Feasibility Report

Figure 1.2 ITS spatial resolution and coverage.

ITS (CrIS) Measurement Capabilities



Interferogram

ITS (CrIS) Interferogram Sampling

ITS Sampling Optimized to Meet Data Rate Limitations of NOAA Spacecraft

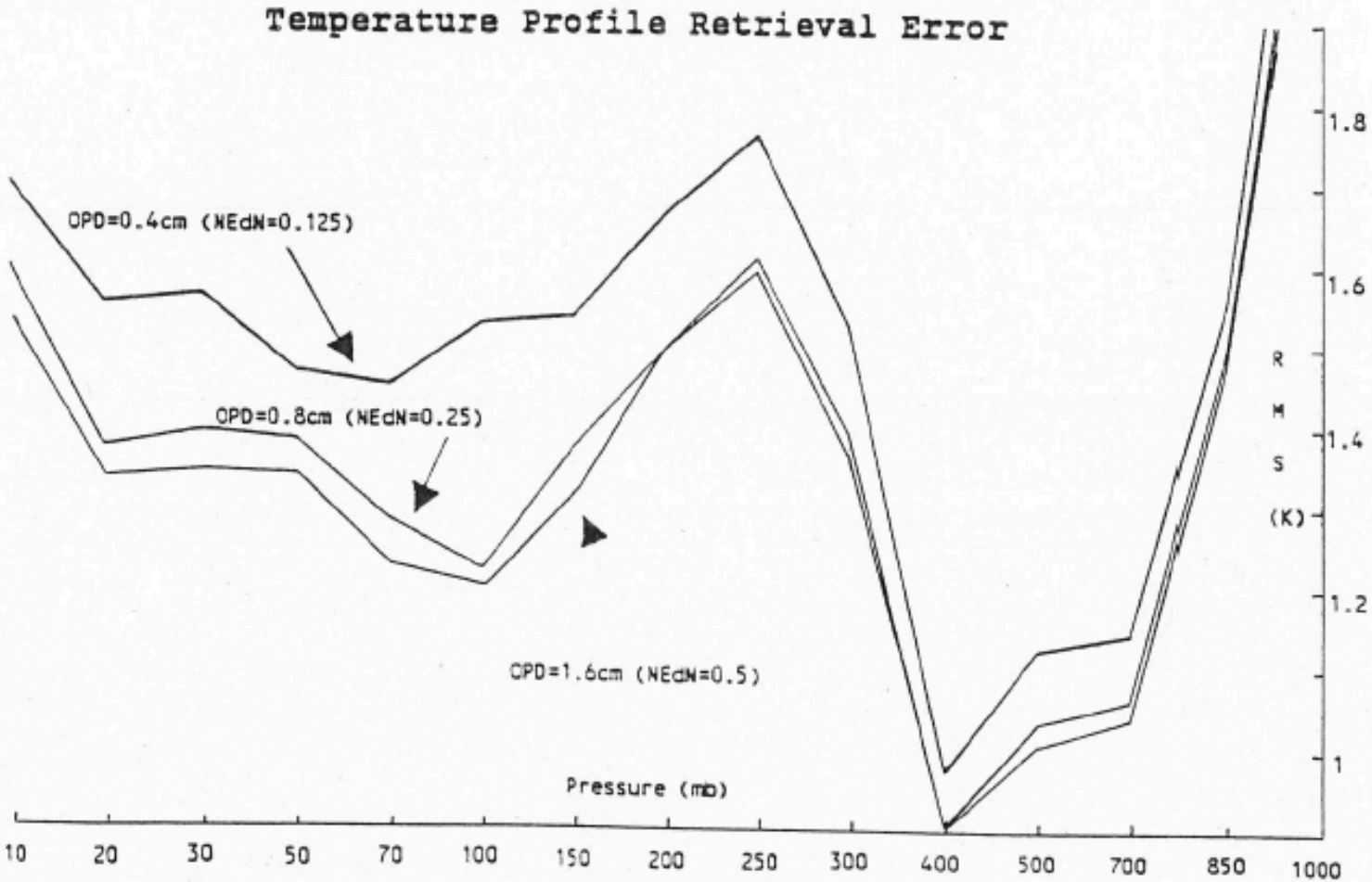
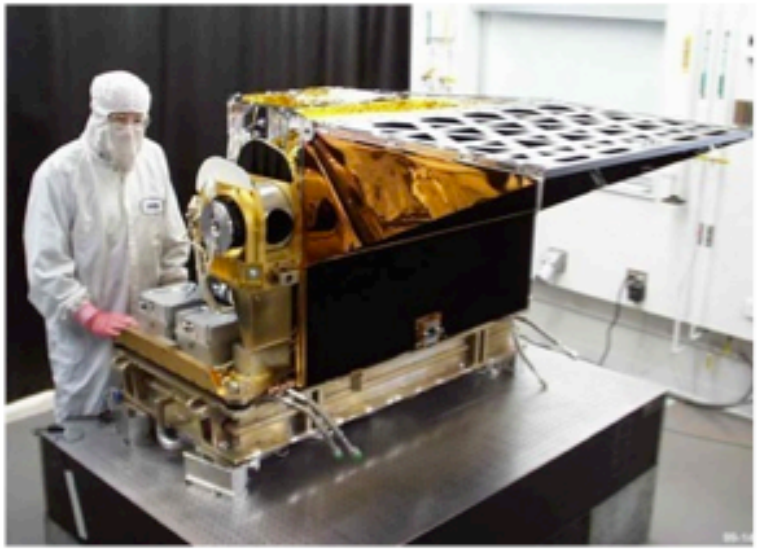


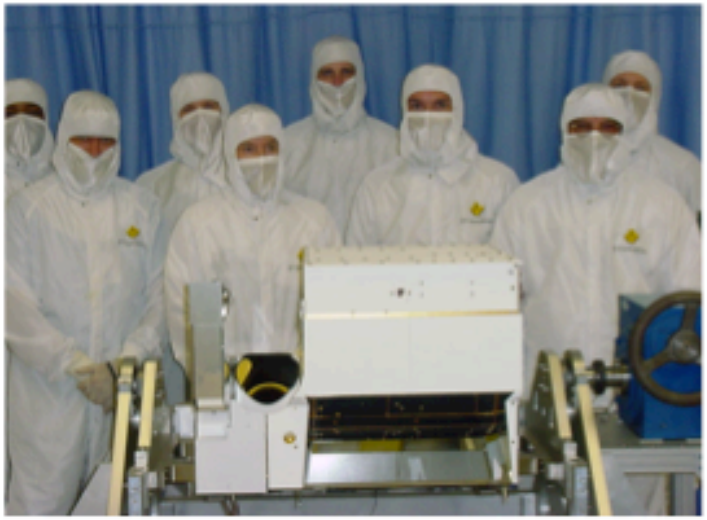
Figure 4.6 Root Mean Square (RMS) temperature error associated with profile retrievals for three different maximum Optical Path Difference (OPD) conditions: 0.4 cm, 0.8 cm, and 1.6 cm. The noise equivalent radiance (NEN) values are given in mW/m^2-str-cm^{-1}.

It was shown in the ITS design study that observing the first CO2 resonance enabled high vertical resolution temperature profiles



AIRS
Atmospheric InfraRed Sounder
Grating spectrometer
166 kg, 256 W
13.5 km FOV at nadir, contiguous
Launched on Aqua in 2002

IASI
Infrared Atmospheric Sounding Interferometer
Michelson interferometer
236 kg, 210 W
2x2 12 km FOVs at nadir, non-contiguous
Launched on MetOp-A in 2006 and MetOp-B in 2012

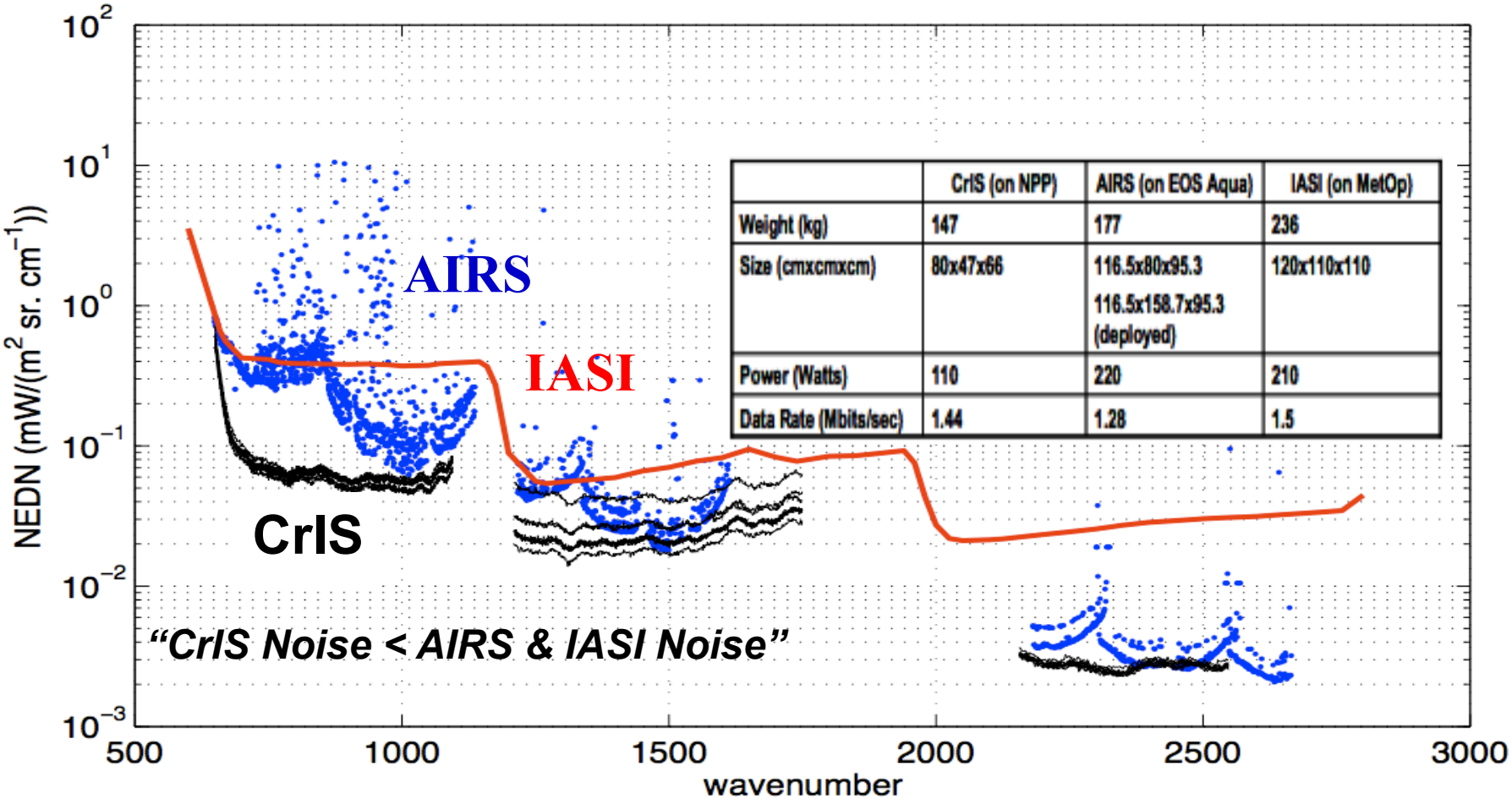


CrIS
Cross-track Infrared Sounder
Michelson interferometer
85 kg, 110 W
3 x 3 14 km FOVs at nadir, contiguous
Launched on S-NPP in 2011

CrIS is small and light

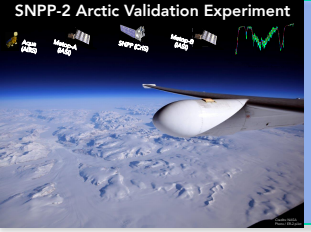
Cross-Track Infrared Sounder (CrIS)

Suomi-NPP – Launched: October 28, 2011

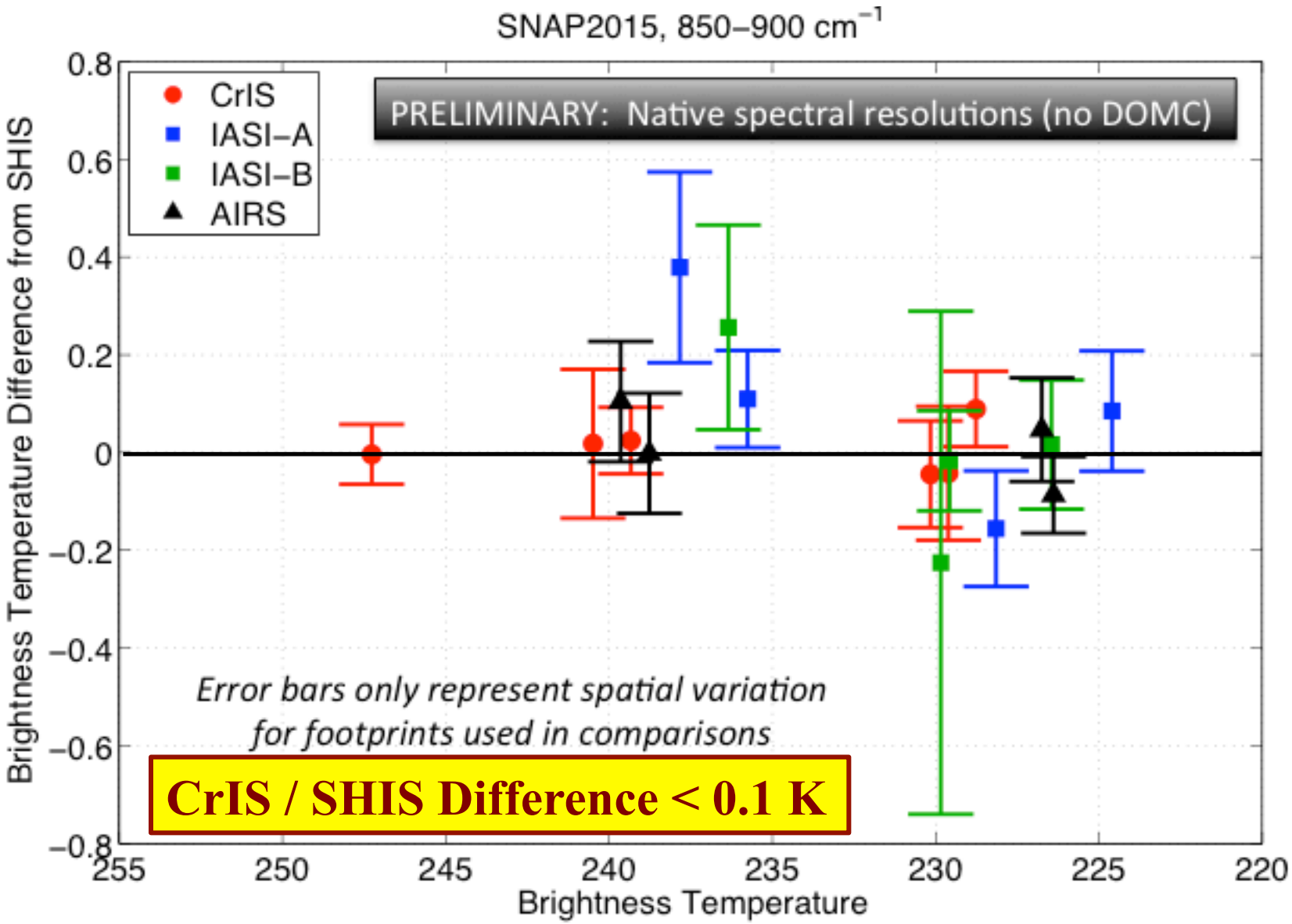


	CrIS (on NPP)	AIRS (on EOS Aqua)	IASI (on MetOp)
Weight (kg)	147	177	236
Size (cmxcmxcm)	80x47x66	116.5x80x95.3 116.5x158.7x95.3 (deployed)	120x110x110
Power (Watts)	110	220	210
Data Rate (Mbits/sec)	1.44	1.28	1.5

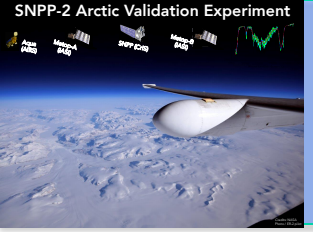
CrIS Single Sample Radiance Noise is Excellent



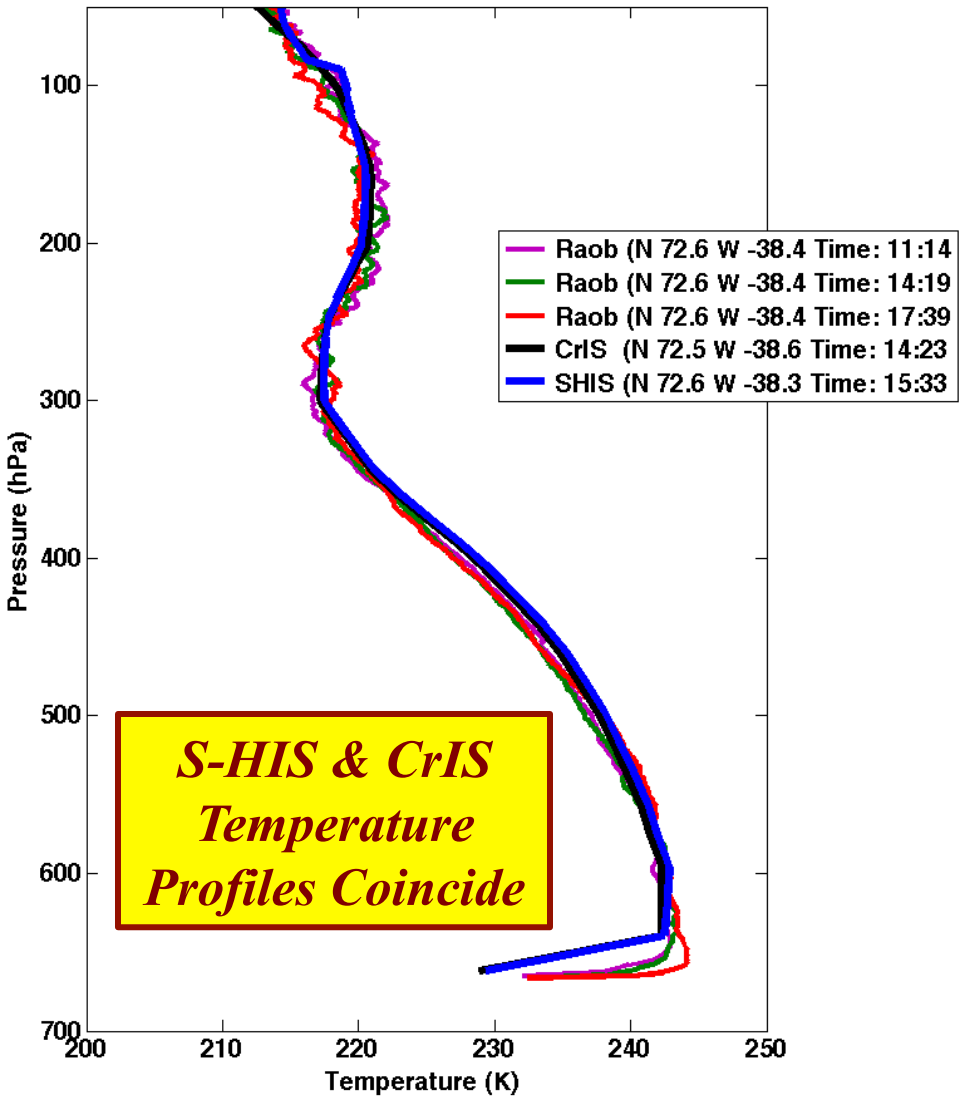
S-NPP Arctic Calibration Validation Campaign (March 2015)

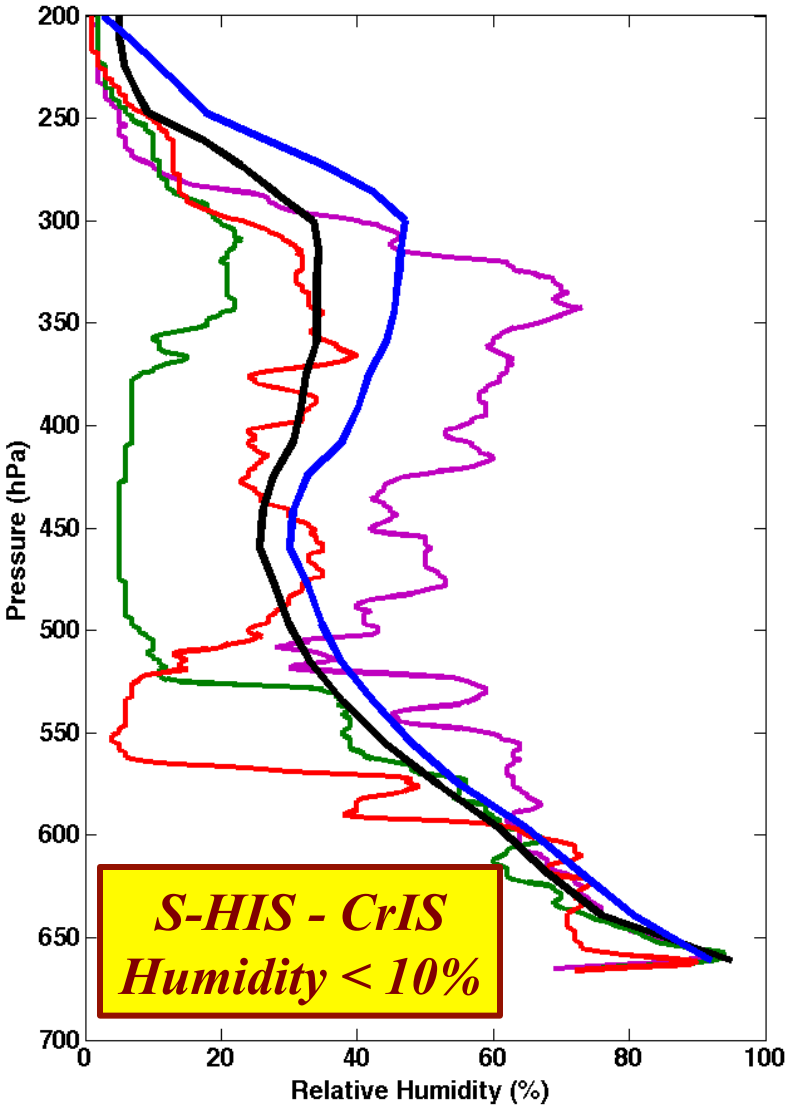


CrIS / SHIS Difference < 0.1 K

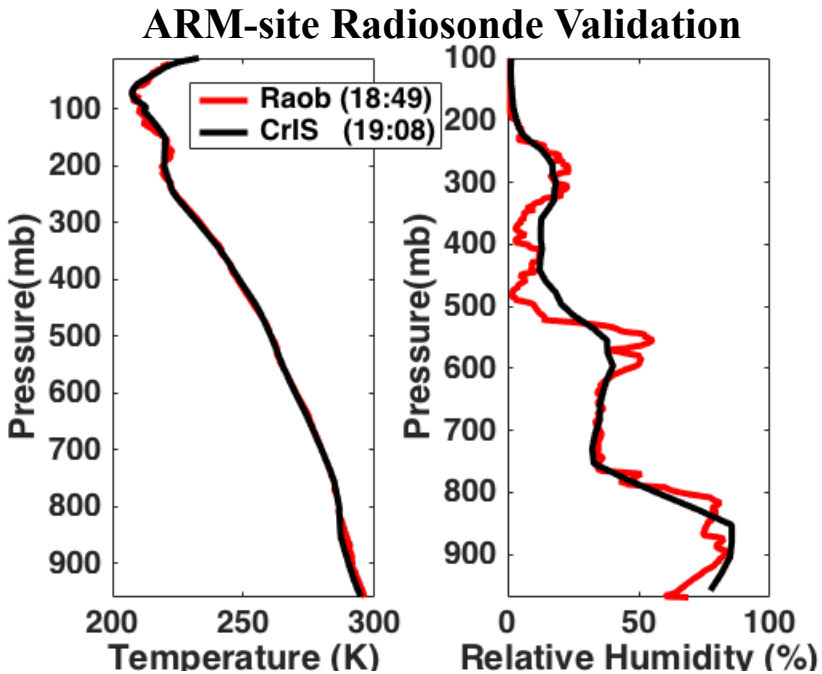


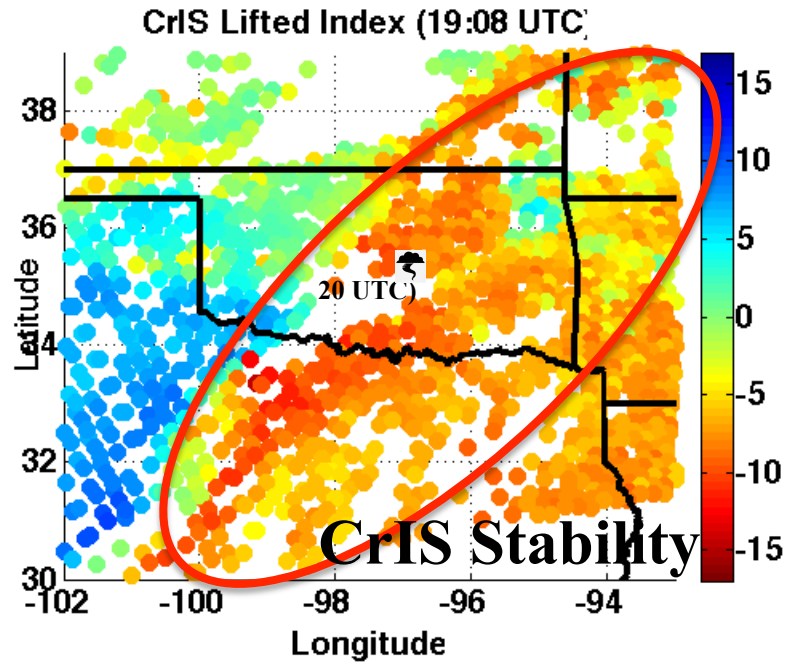
S-HIS & Radiosonde Validation of CrIS Sounding at Summit Greenland (March 23, 2015)

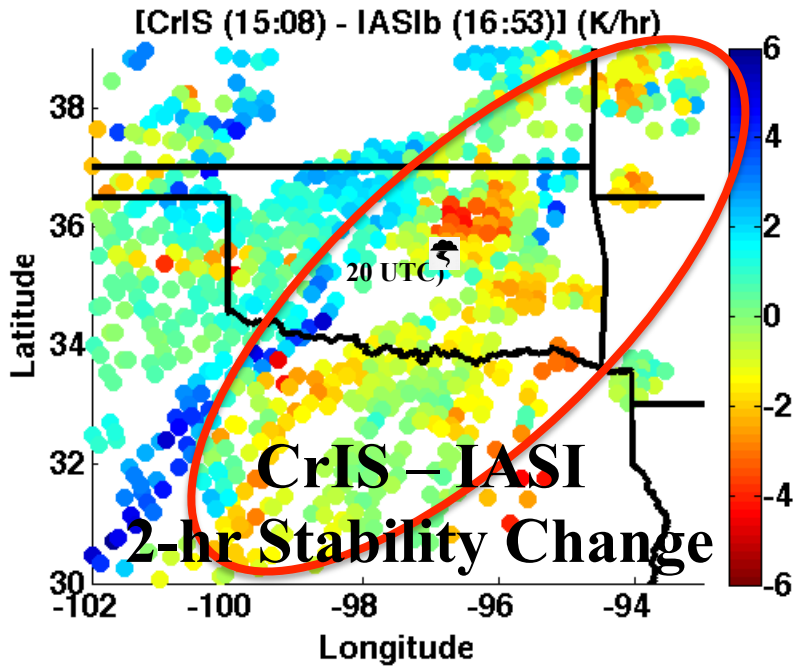


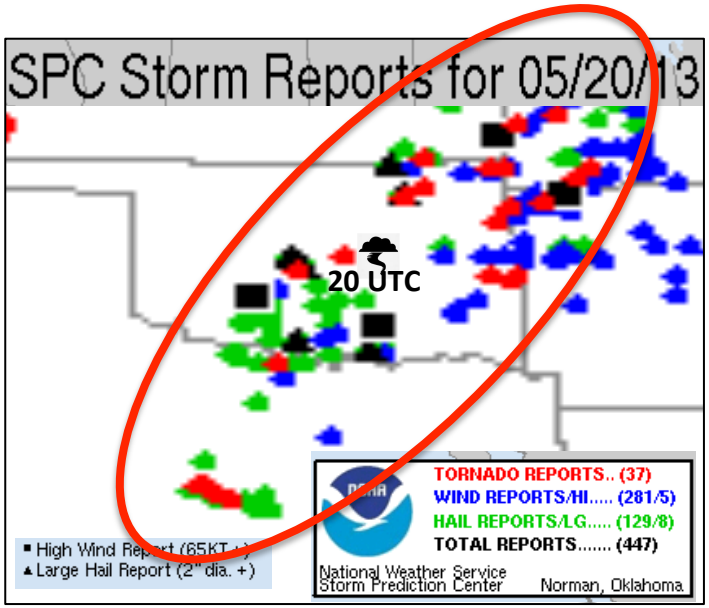


CrIS/IASI Stability Observations (May 20, 2013)









Wind Profiles, Moisture Fluxes, and Stability Tendencies

Winds from Hyperspectral Infrared Sounding Passive Environmental Radiometer (WHISPER)

Proposed for the second NASA Earth Venture Mission (EVM-2) – D. Santek (PI)

CrIS Upgrades

Current Generation

- **Full spectral band resolution data without spectral gaps**
  - **Mid-Wave: improved water vapor profile accuracy**
  - **Short Wave: tropospheric carbon monoxide**
- **Change field stop to reduce IFOV**
  - **Increase scene uniformity**
  - **Increase clear air sampling & cloud clearing accuracy**

Next Generation

- **Larger detector arrays**
  - **Higher spatial resolution and denser coverage**
    - **improved cloud clearing**
    - **mesoscale feature detection**
- **Microsat Fleet Implementation of mini-CrIS instruments**
  - **Water vapor/cloud tracer wind velocity profiles**
  - **Stability tendencies for severe weather prediction**