New Results from CrIS

the Cross-track Infrared Sounder on Suomi NPP, Part 1

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University of Wisconsin - Madison
Space Science and Engineering Center (SSEC)

International TOVS Study Conference
ITSC-18, Toulouse, France
21-27 March 2012

NPP Satellite renamed Suomi NPP

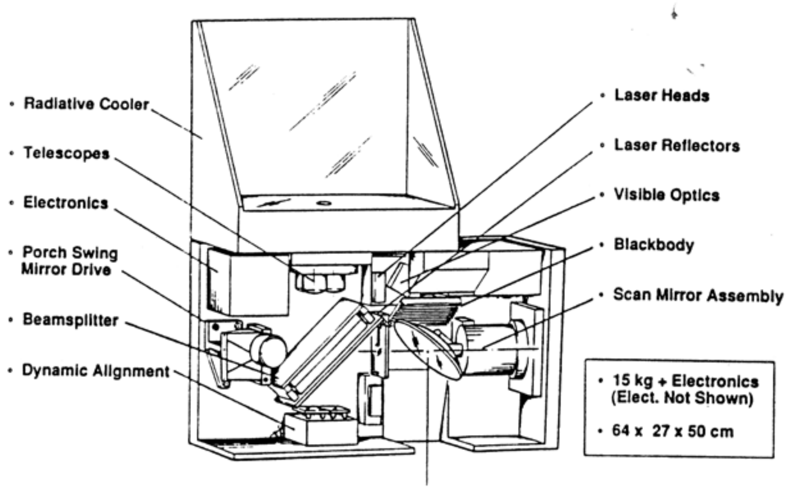
After UW-Madison Pioneer

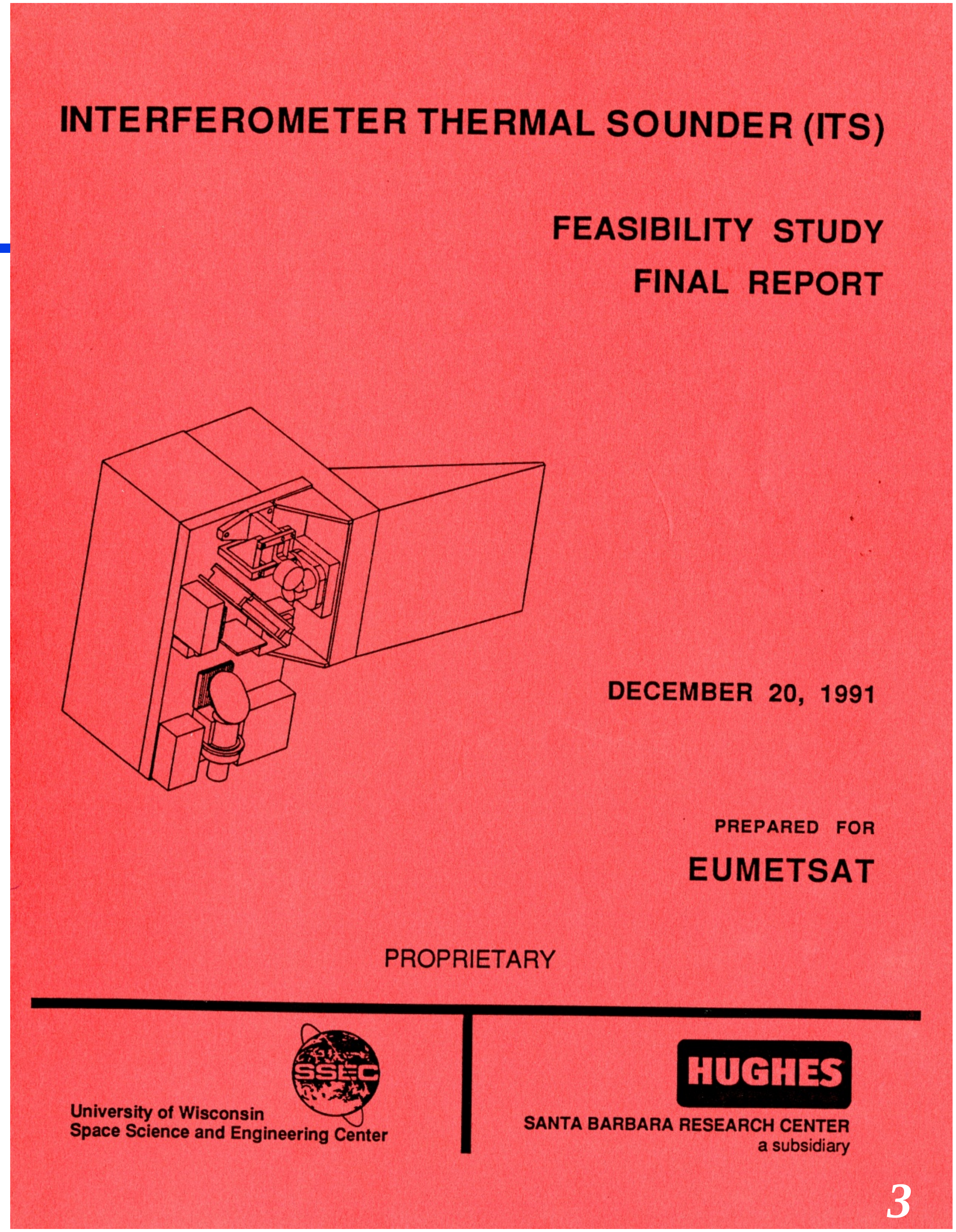
Verner E. Suomi
1915-1995

NPP VIIRS Image, GSFC

CrIS: 1990/91 Historical Roots

- ***EUMETSAT (John Morgan)*** *sponsorship*
- ***Originated by Bill Smith,*** *in residence at EUMETSAT*
- ***UW-Madison/SSEC prime,*** *Hank Revercomb, PI*
- ***Detailed design by SBRC, Bomem DA interferometer*** *Still Chase, Henry Buijs*





INTERFEROMETER THERMAL SOUNDER (ITS)

FEASIBILITY STUDY

FINAL REPORT

DECEMBER 20, 1991

PREPARED FOR

EUMETSAT

PROPRIETARY

SSEC

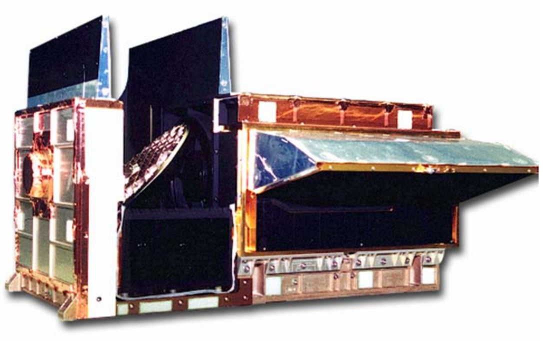
University of Wisconsin
Space Science and Engineering Center

HUGHES

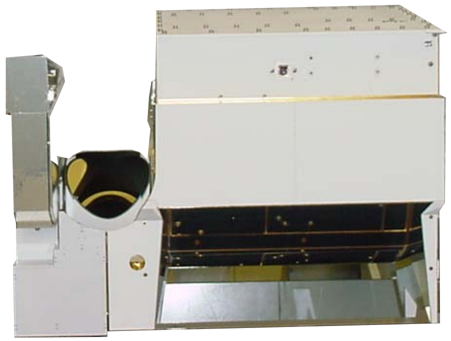
SANTA BARBARA RESEARCH CENTER
a subsidiary

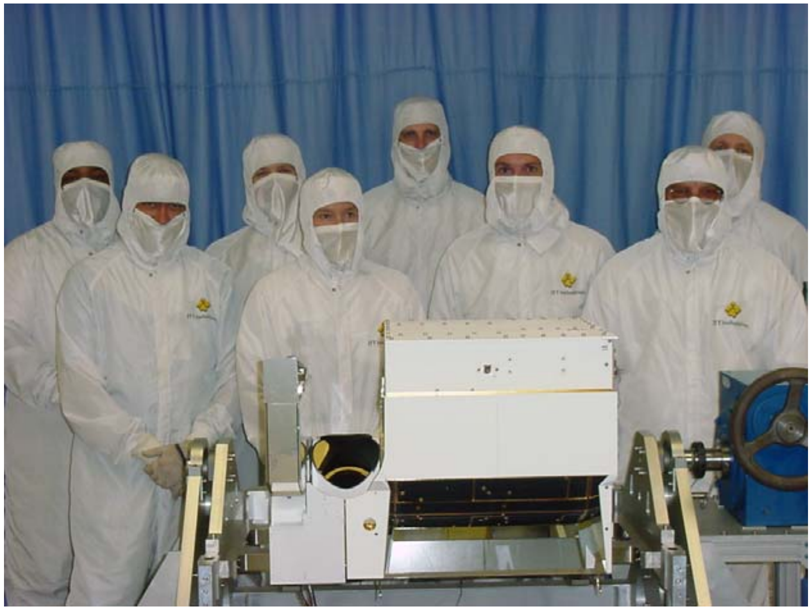
CrIS—about the size of HIRS

HIRS
(20 ch):
30⁺ year history



CrIS
(1307 ch):
NPP/JPSS





Volume: < 71 x 80 x 95 cm
Mass: 146 kg
Power: 110 W

from Williams, Glumb and Predina, ITT, August 2005 SPIE

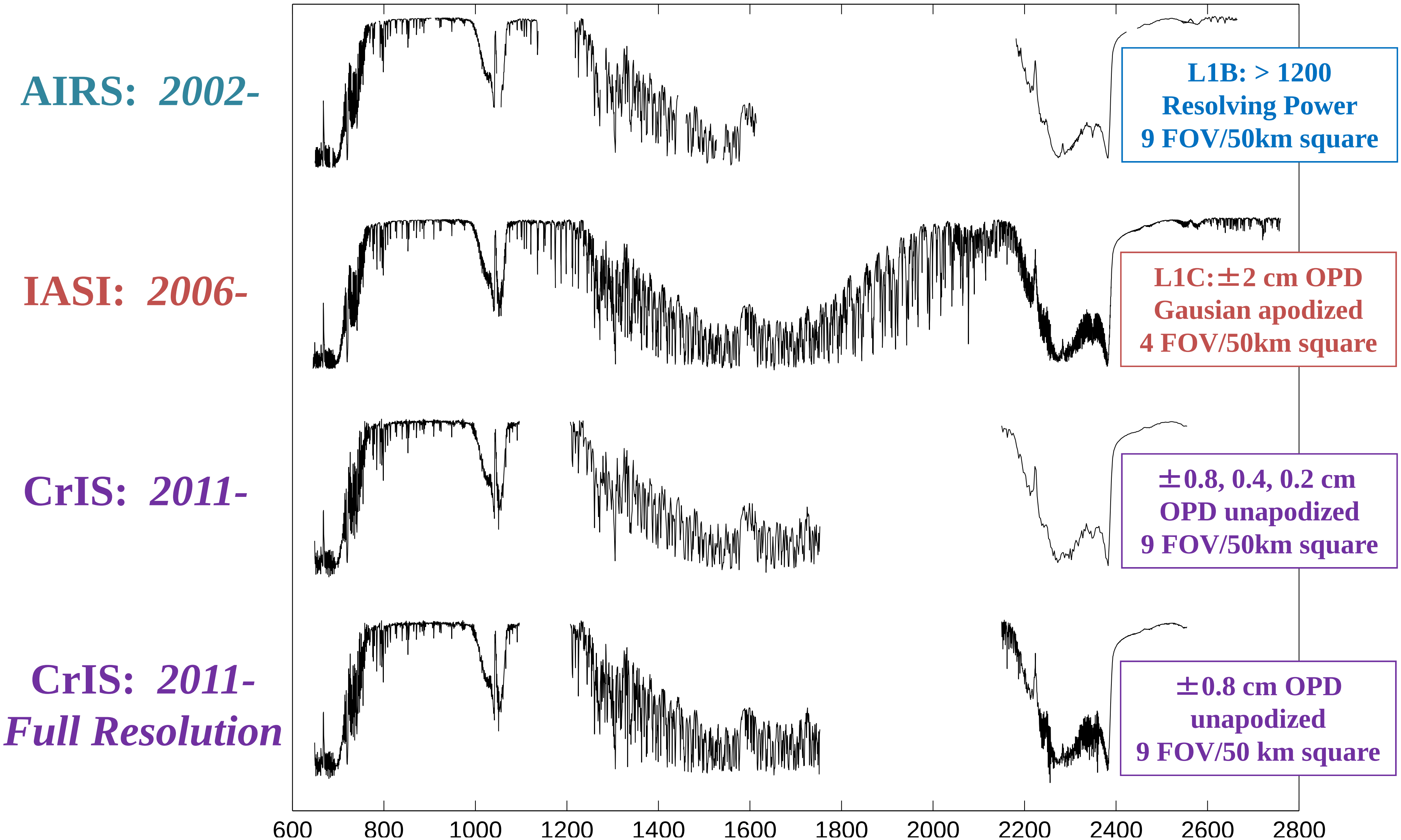
AIRS
Atmospheric InfraRed Sounder
Grating spectrometer
166 kg, 256 W
13.5 km FOV at nadir, contiguous
Launched on NASA Aqua in 2002

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

Full scale model at 2010 IASI meeting

CrIS
Cross-track Infrared Sounder
Michelson interferometer
146 kg, 110 W
3x3 14 km FOVs at nadir, contiguous
Launched on Suomi NPP, 28 Oct 2011

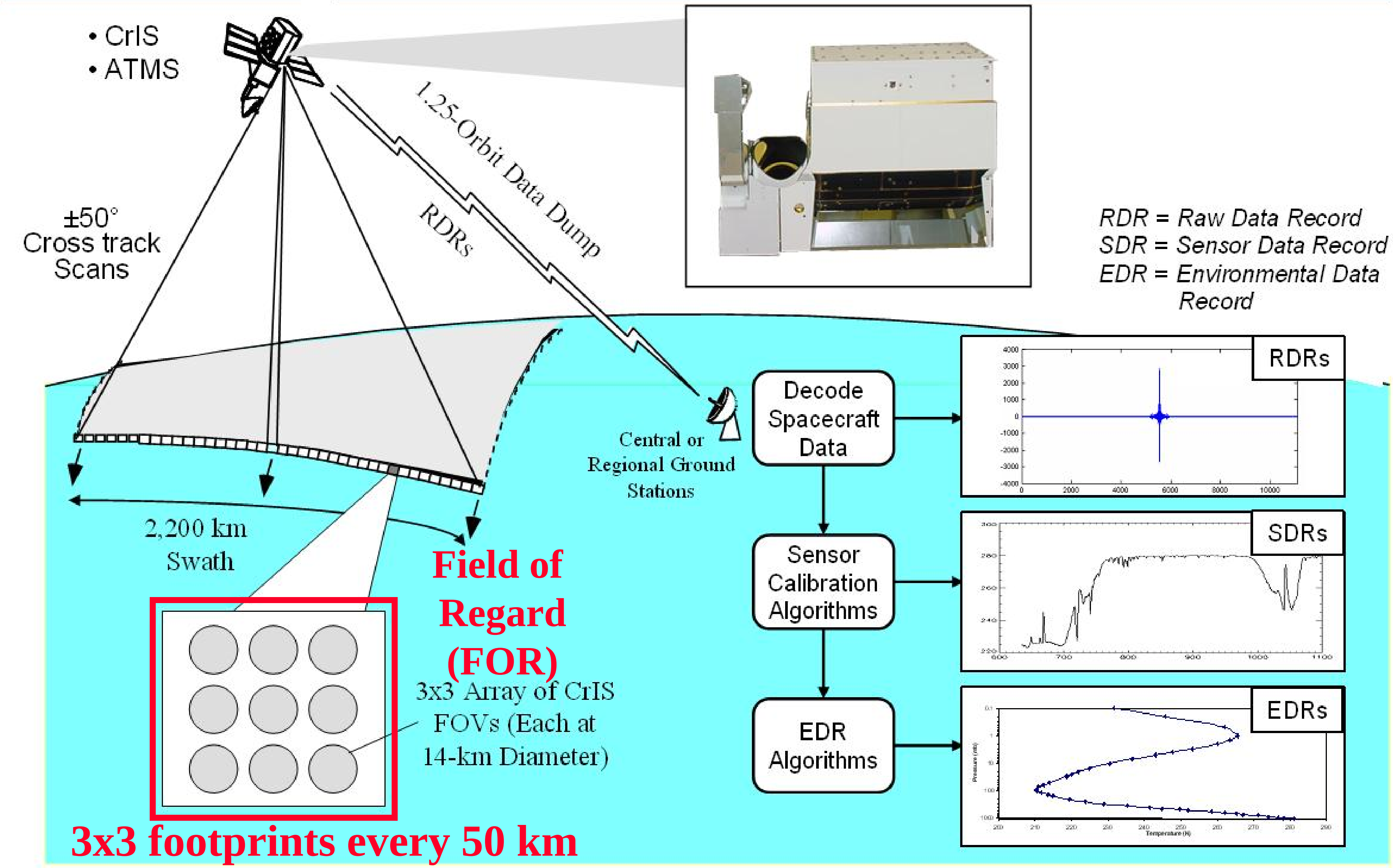
Spectral Coverage and Resolution Comparison



from LBLRTM for US Standard Atmosphere

Mission Overview

CrIS Mission: Construct Vertical Profiles of Temperature, Moisture, and Pressure (EDRs)



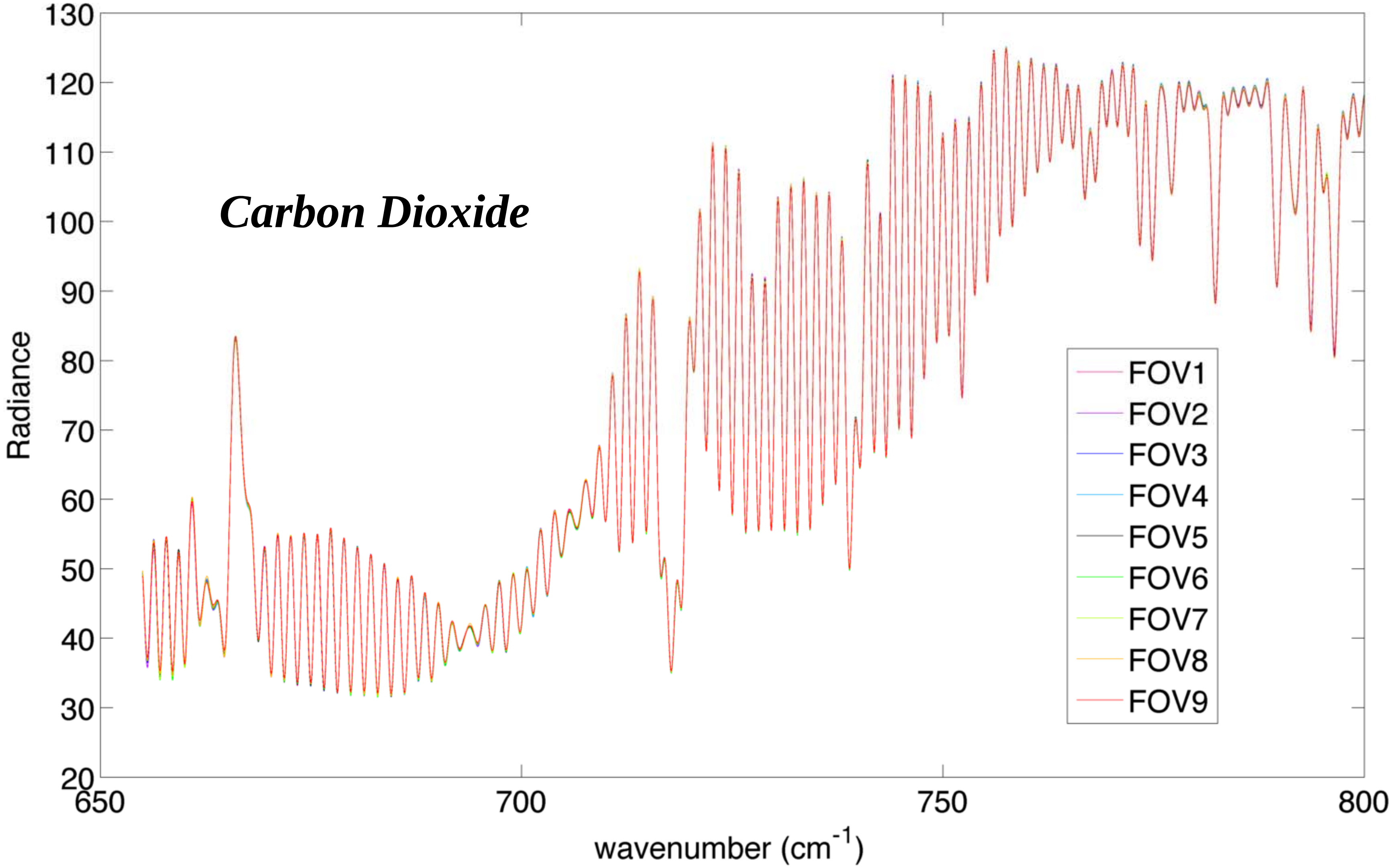
Processing from raw data (RDRs) to calibrated spectra (SDRs)

- **IDPS/ADA: Operational Code & test version**
  - **Not yet up**
- **ADL: Raytheon Unix version of Ops Code**
  - **Output currently represents planned Ops results**
- **ITT/Exelis science code: precursor to ADL/ADA**
  - **ABB/Bomem heritage--Supports Exelis and SDL analyses**
- **UW CSPP (Community Science Processing Package built on ADL for Direct Broadcast)**
  - **Successfully running at UW-Madison SSEC**
- **UW/UMBC CCAST (CrIS Calibration Algorithm & Sensor Testbed)**
  - **Developed as Cal/Val tool to explore processing differences & new approaches**
  - **Provided:**
    - » **Day 1 CrIS processing & early results for AMS…**
    - » **Early proof of proper instrument performance**

Results shown here are from CSPP and CCAST

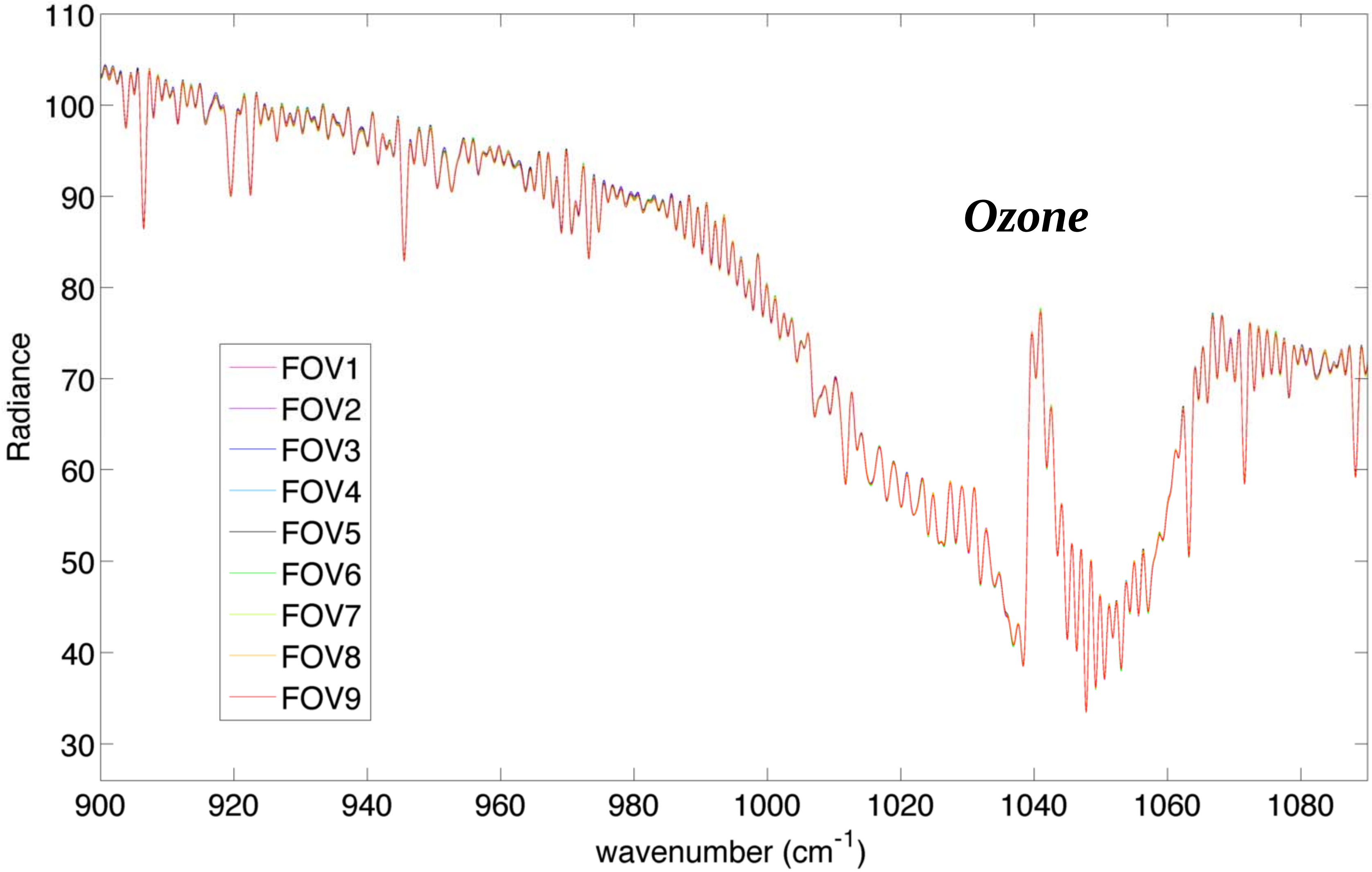
Sample "1st Light" spectra (20 January)

Overlays for a uniform 3x3 FOR



Sample "1st Light" spectra (20 January)

Overlays for a uniform 3x3 FOR



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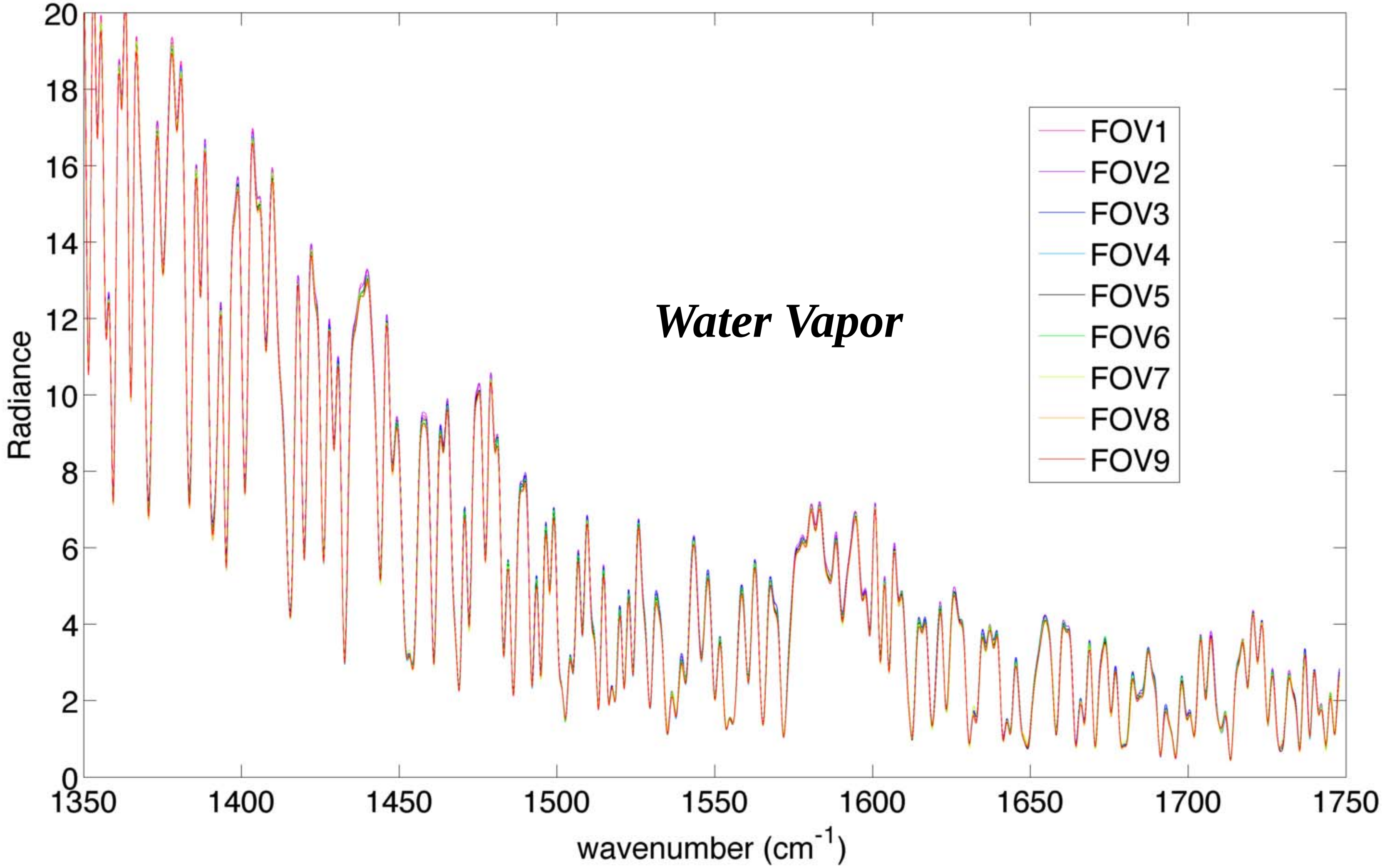
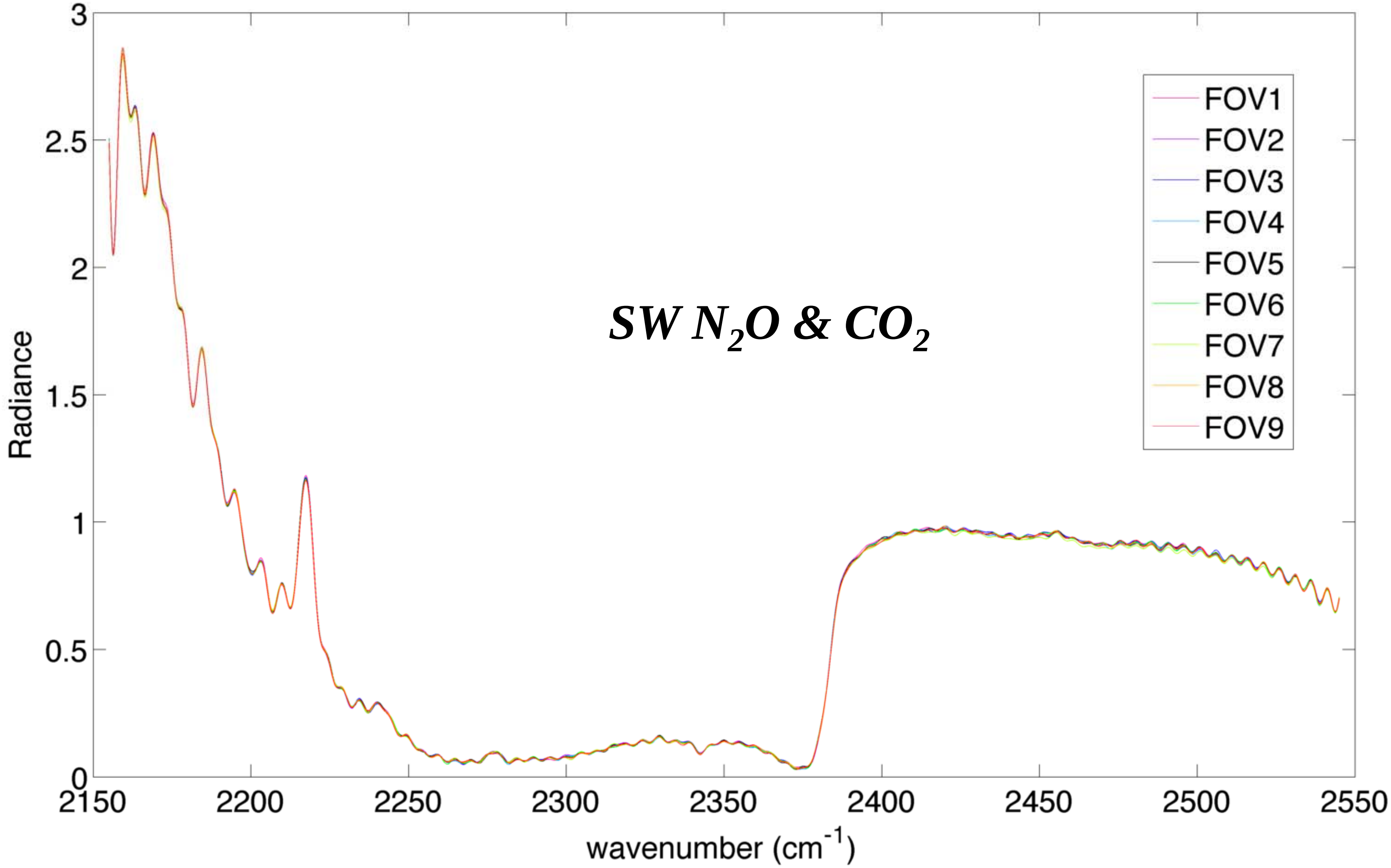


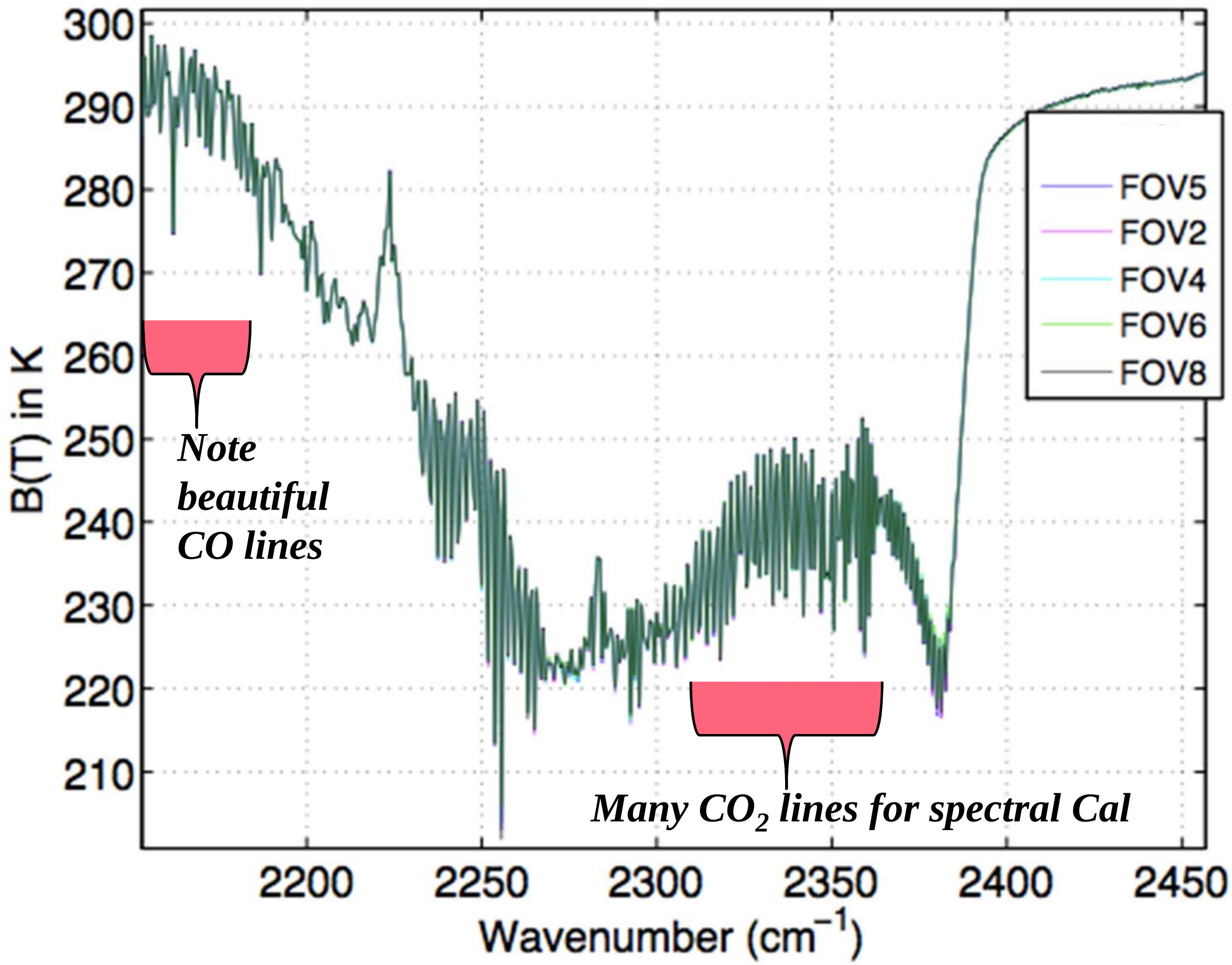
Sample "1st Light" spectra (20 January)

Overlays for a uniform 3x3 FOR



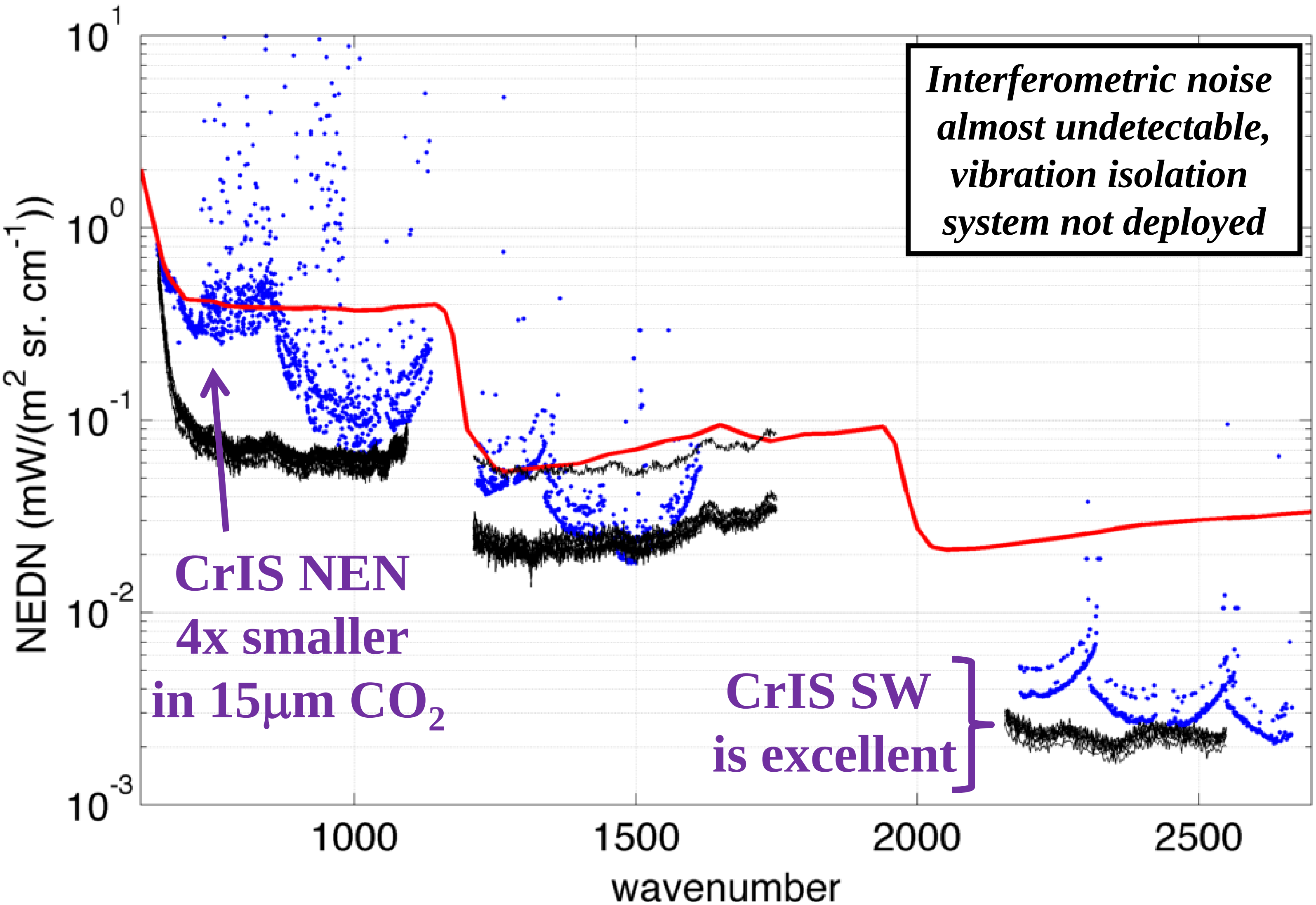
Full Resolution SW band from CrIS

We need to lobby for running this resolution routinely



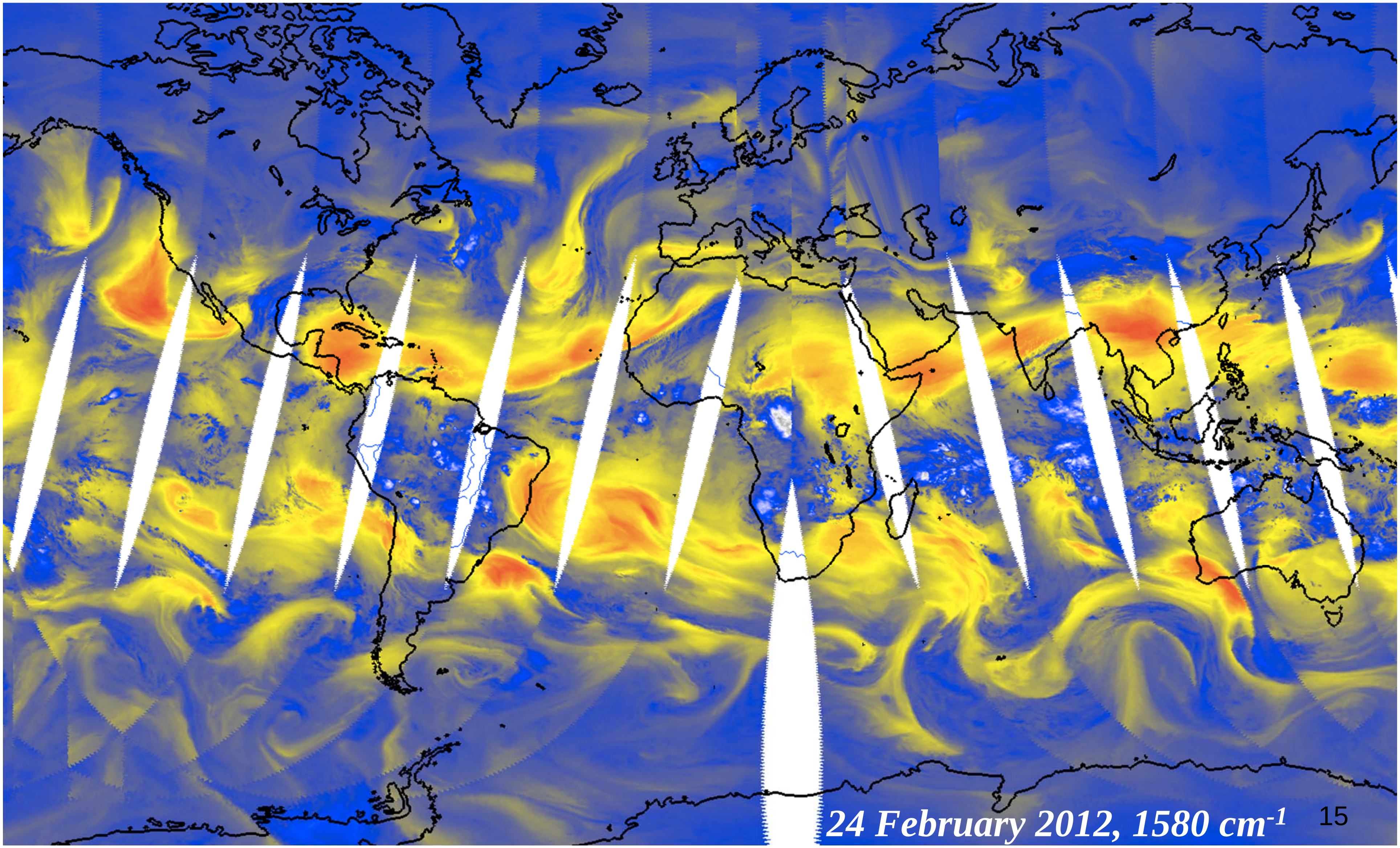
Calibrated with UW/UMBC CCAST—thanks to Larrabee Strow

Noise Comparison:
CrIS, AIRS L1B, IASI L1C



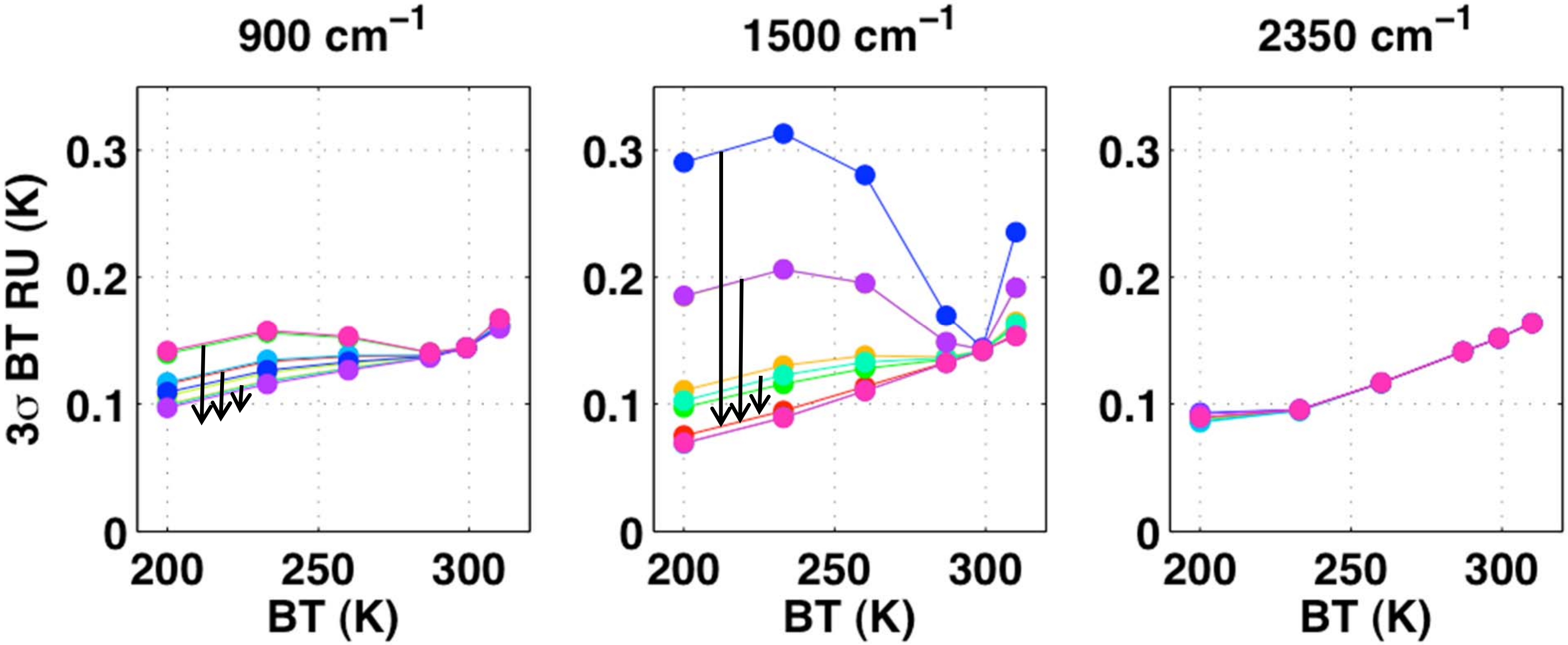
Water Vapor Map from CrIS

Especially important given lack of WV channels on VIIRS



Expected Radiometric Uncertainty

Shown versus scene temperature for all FOVs for ~mid-band spectral channels



FOV to FOV spread in LW and especially MW is due to non-linearity

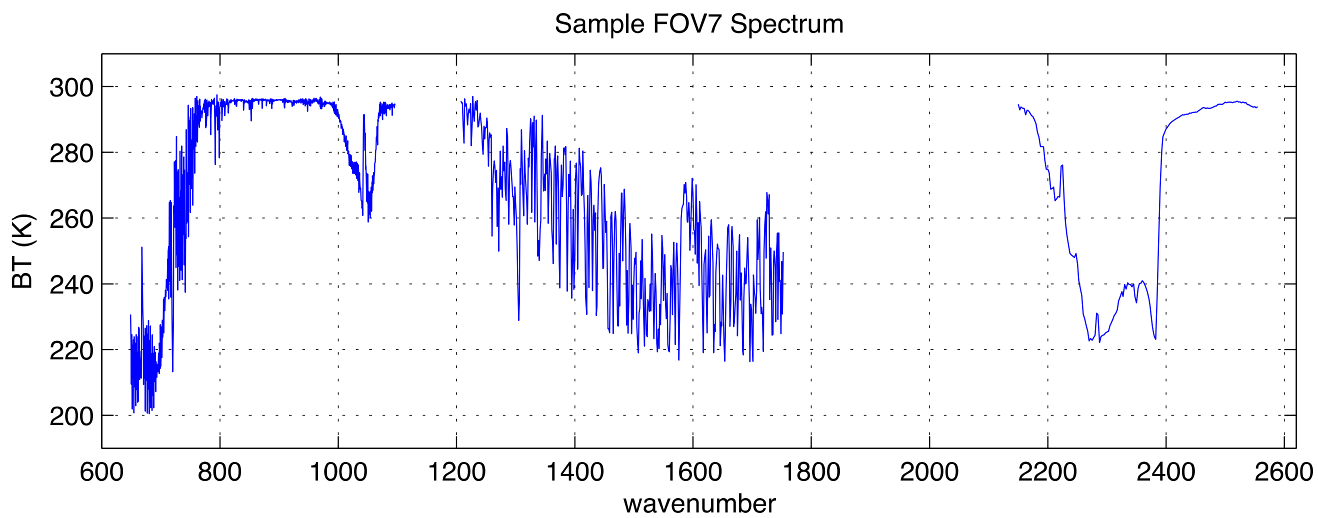
Final inflight uncertainty far better than spec!

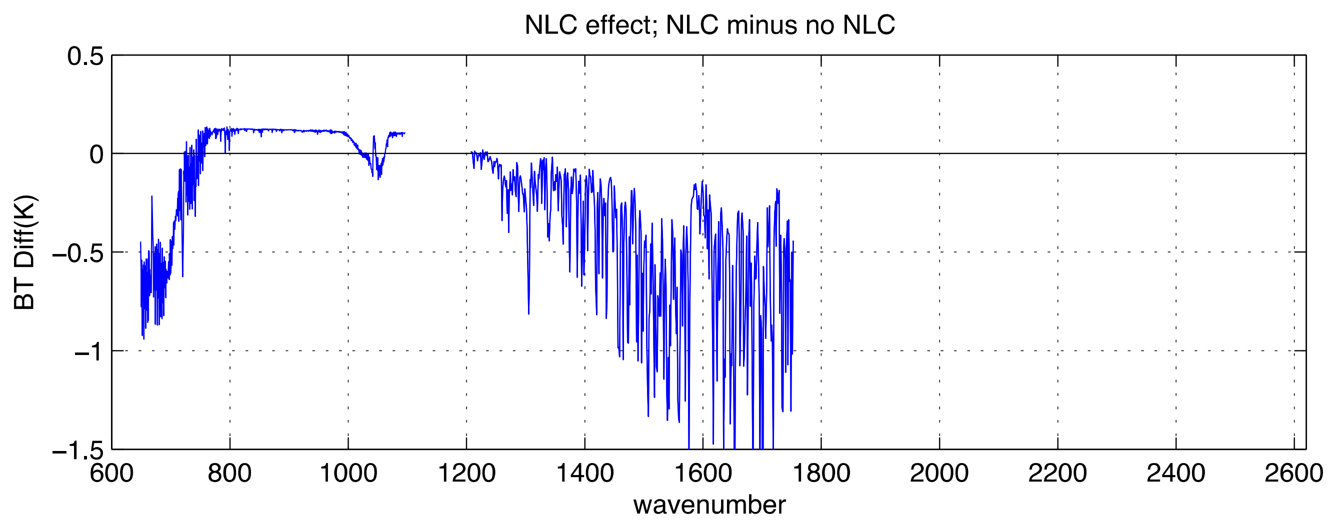
(< 0.2K 3-sigma, after inflight non-linearity refinement)

Non-linearity Correction

- **Out-of-Band Harmonics**
  - **Shape fits squared non-linearity**
  - **Low wavenumber signal fit to a_2, coefficient of squared term**
- **Relative FOV to FOV adjustments with Earth data**
  - **Samples weighted by uniformity**
  - **As reference, MW uses its one very linear detector (FOV9)**
  - **As reference, LW uses a_2 for FOV5 from Out-of-Band Harmonic analysis**

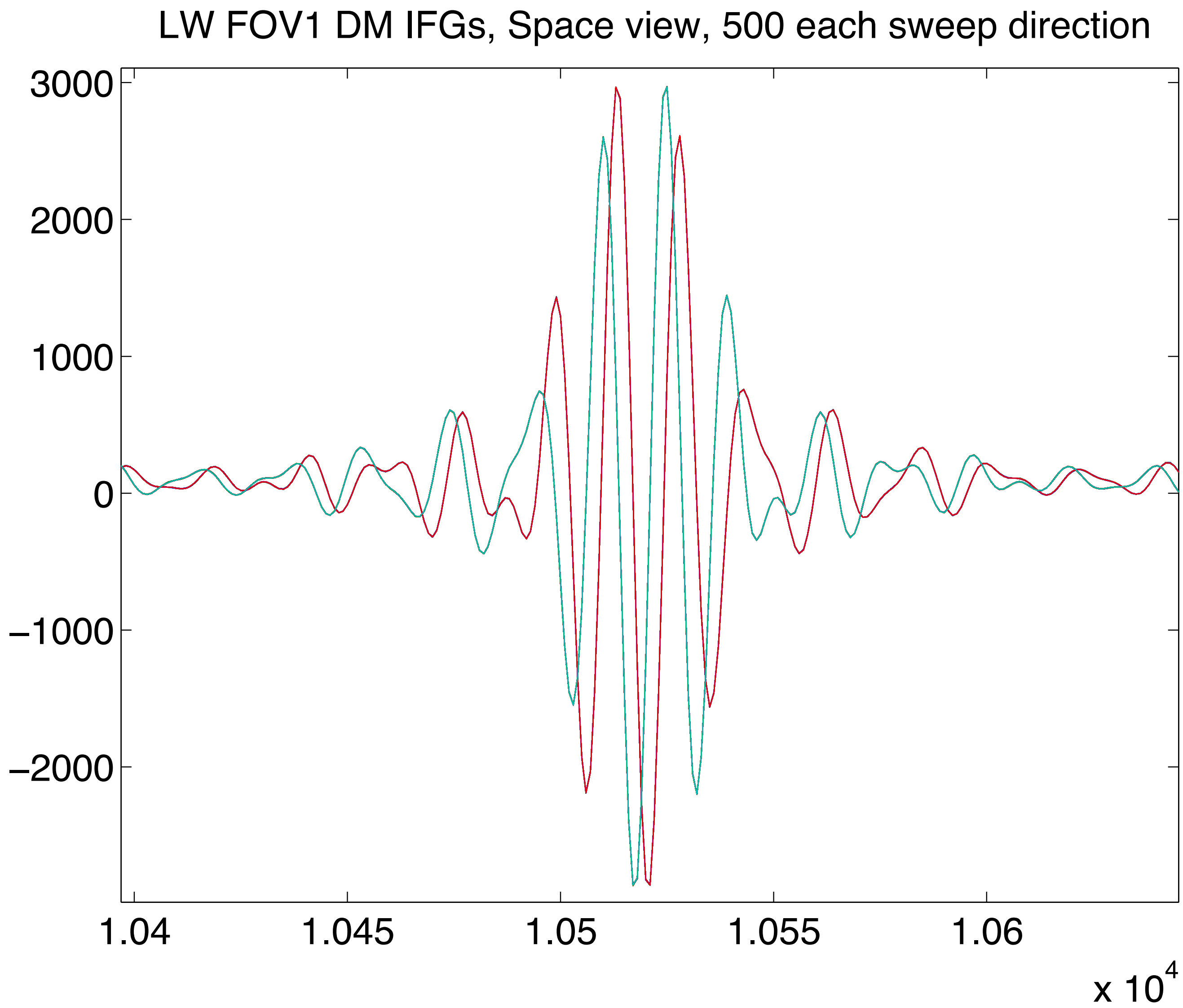
Example Non-linearity
(~Largest)



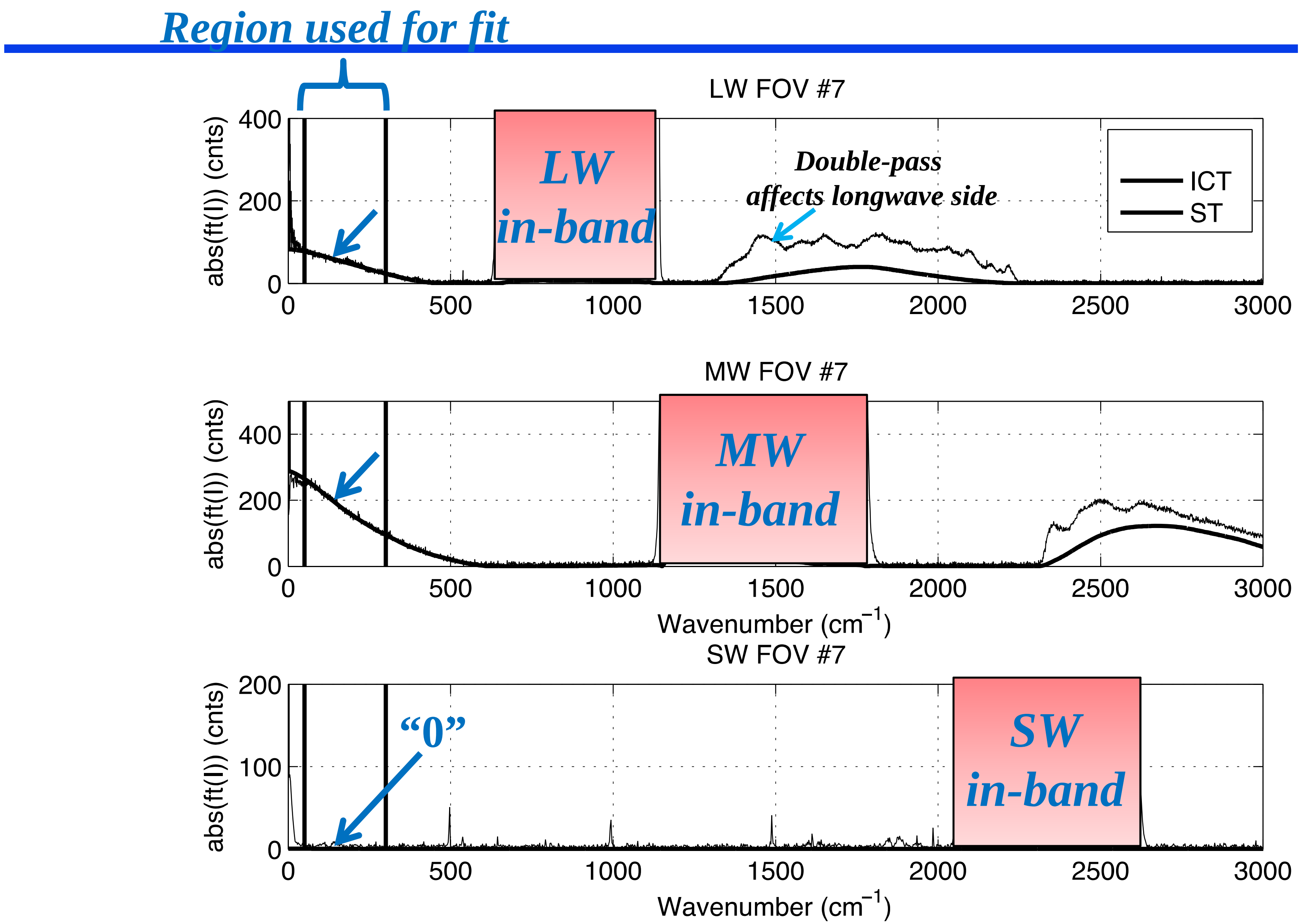


Example Interferograms

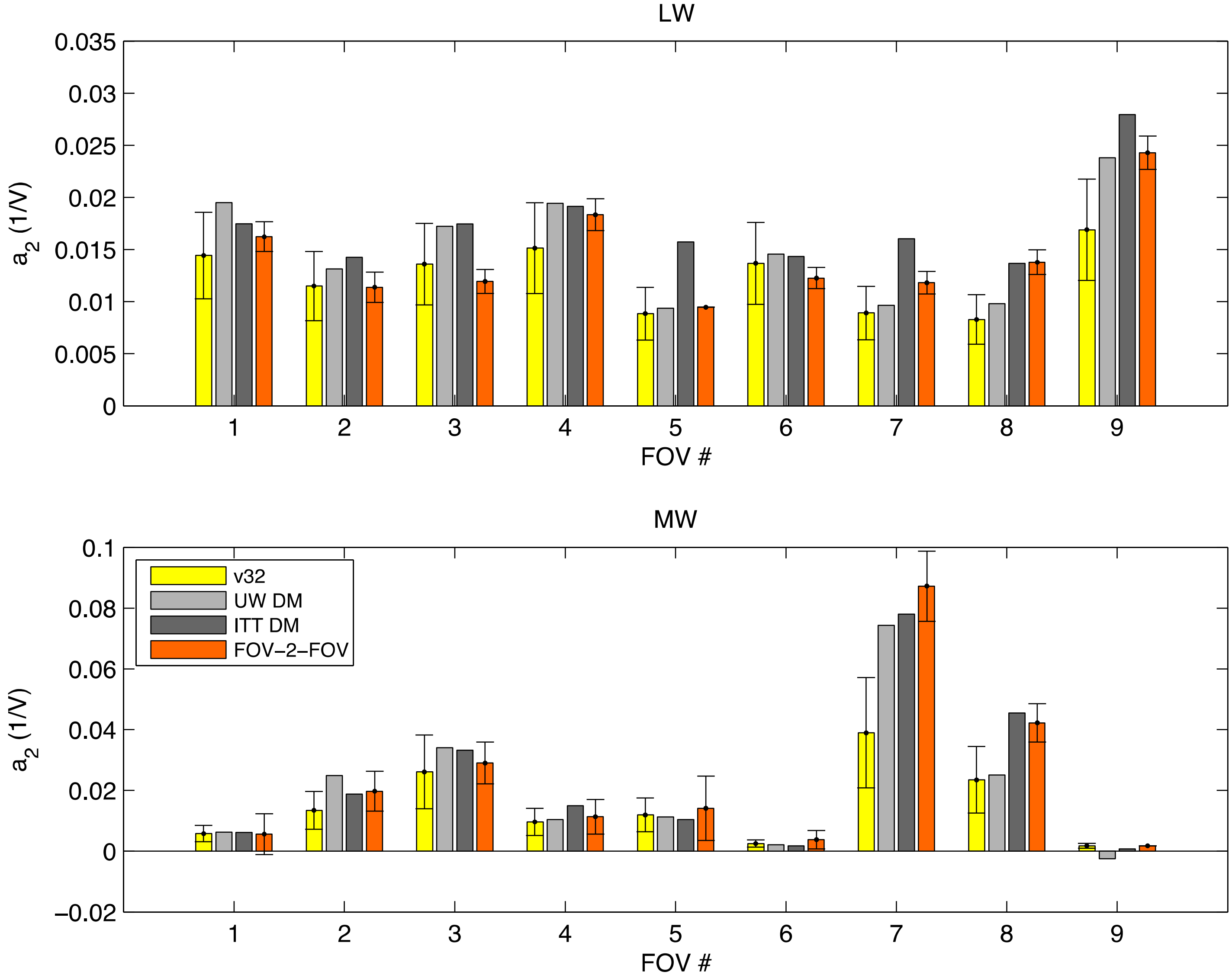
Over-sampled to preserve Non-linearity Harmonics



Fit for squared non-linearity coefficient a_2



Non-Linearity Correction Coefficient, a_2



v32 based on TVAC3; "02" based on Earth view FOV-to-FOV analysis; Gray from Out-of-Band analyses

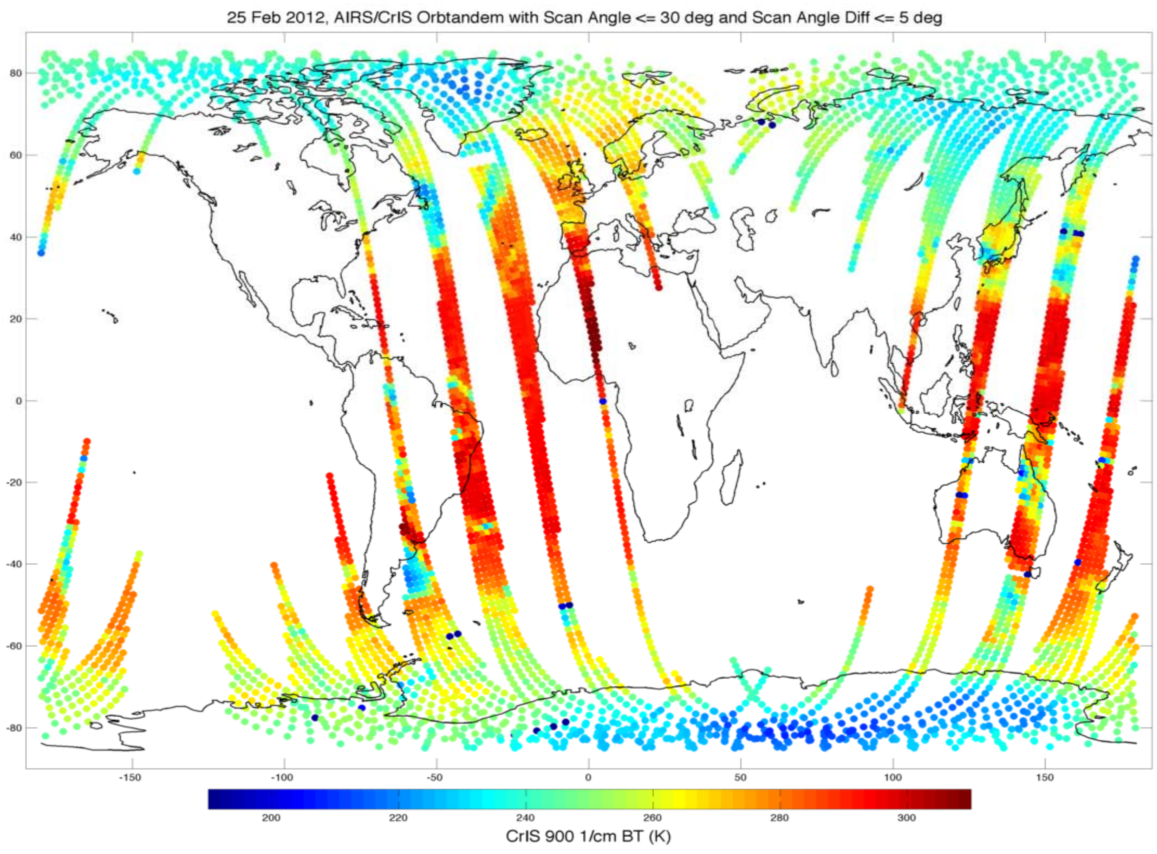
Corrected Raw Complex Spectrum = Raw Complex Spectrum $\times$ ***(1+ 2*** a_2 ***V)***

where V is DC level voltage at 1st stage of preamplifier

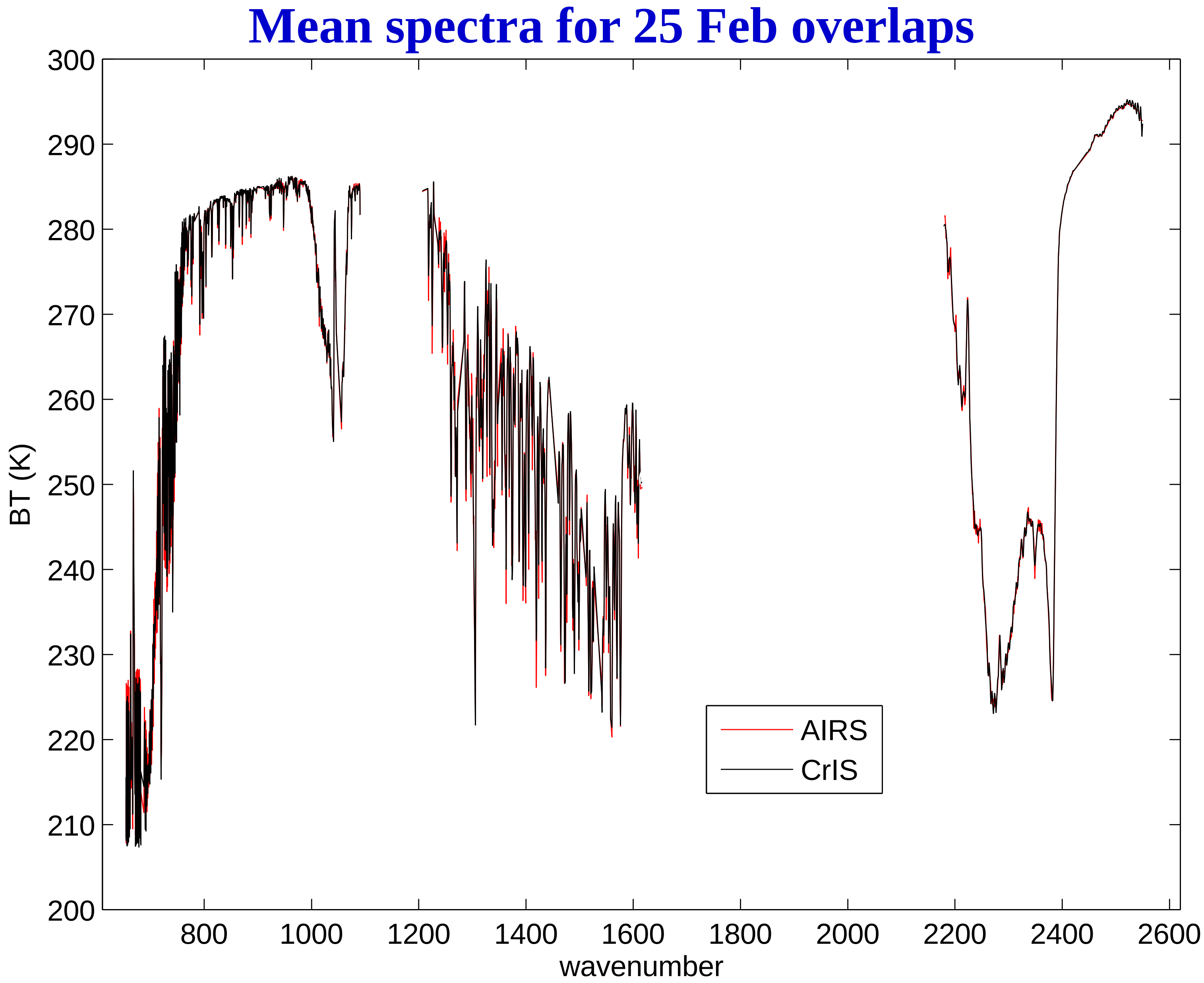
Preliminary Comparisons with AIRS

- Analogous to other prior SNO type comparisons
- AIRS and CrIS data within large ellipsoids gathered (~100 km dia at nadir)
- Mean spectra and StdDev of spectra recorded
- Data screened by time matchup, view angle, etc and weighted by scene variability to examine biases
- Spectral manipulations performed to view channel-by-channel differences

25 Feb overlaps,
Scan angles ≤30°
&
Scan angle dif ≤5°



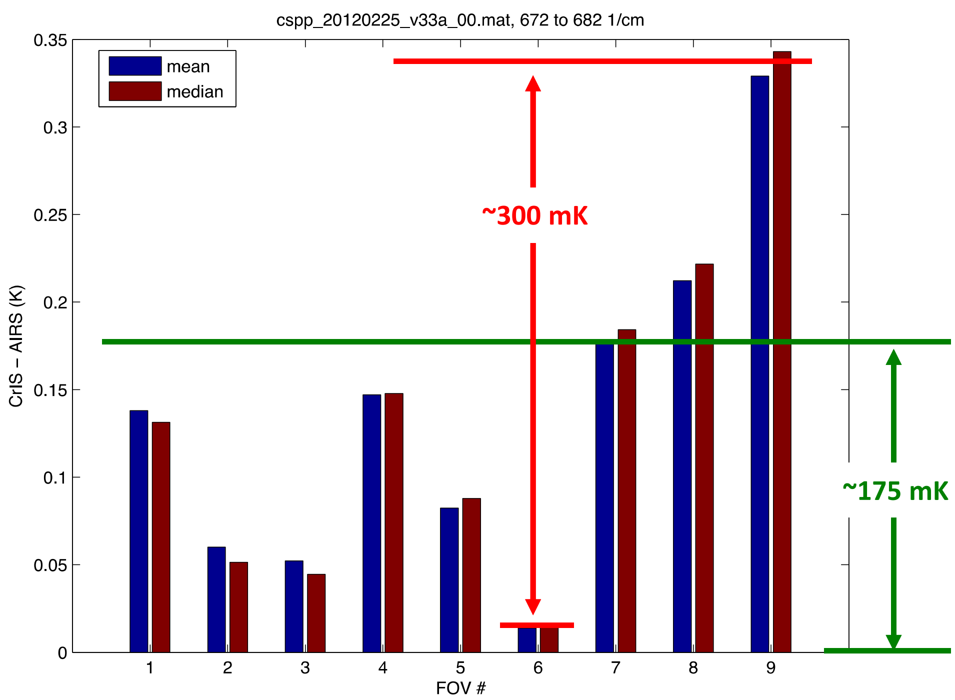
Preliminary Comparison to AIRS



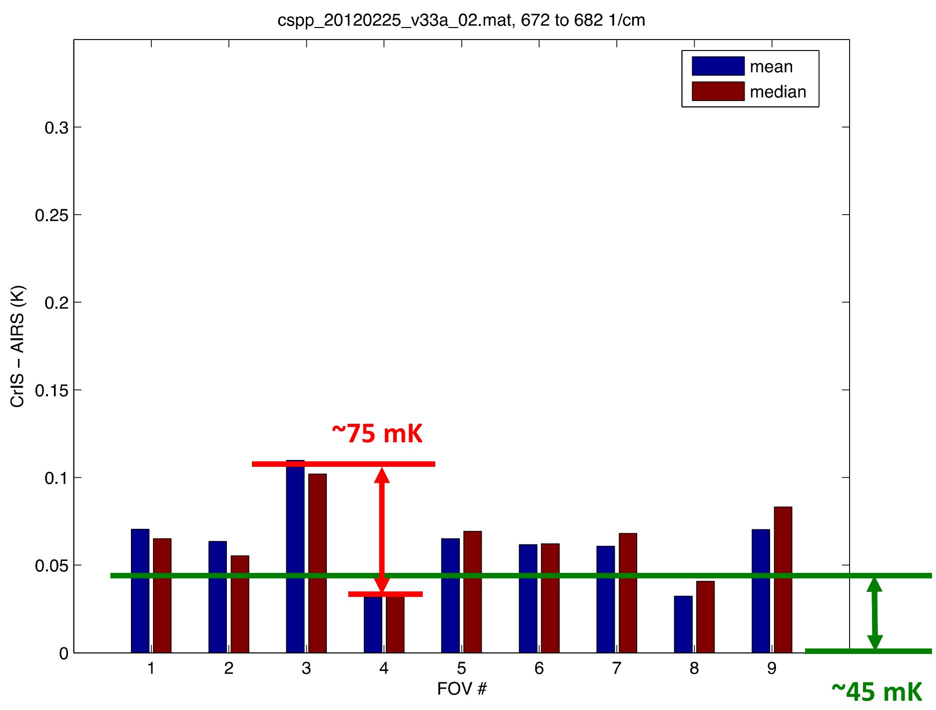
Improved LW a_2 from On-orbit Analyses:

FOV-to-FOV Consistency also reduces difference from AIRS

TVAC a_2 values



On-orbit a_2 values

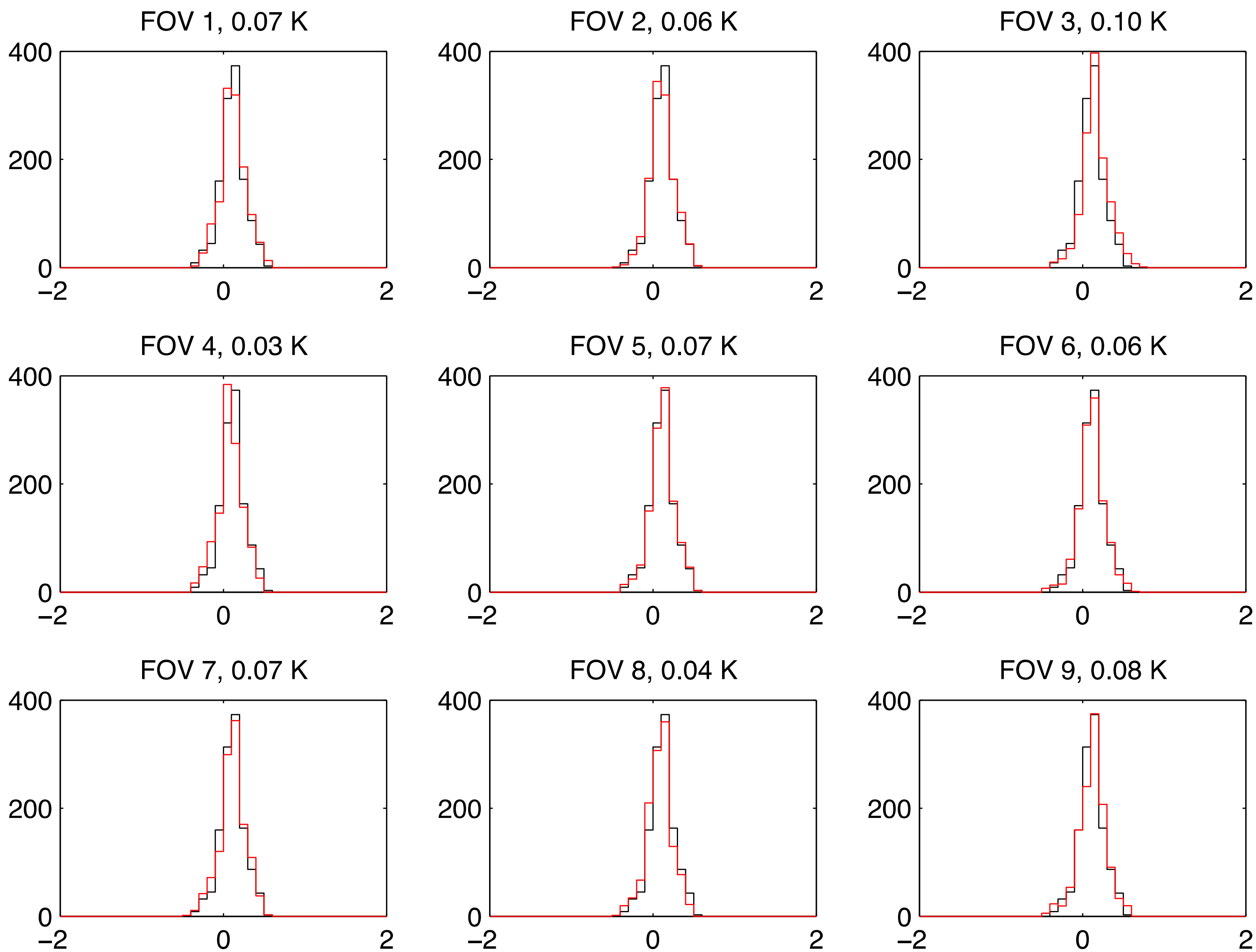


LW CO2: FOV-2-FOV range and median difference from AIRS

Resulting Differences from AIRS are quite small

CrIS minus AIRS BT(K) Differences Well Behaved

LW @ 672-682 cm^{-1}

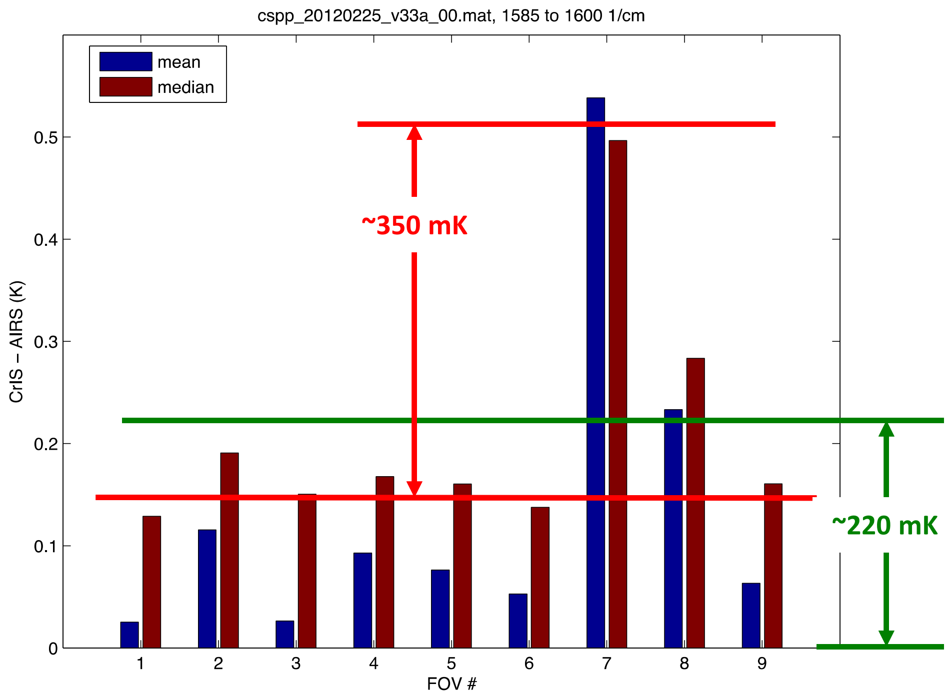


Black = All FOVs (same in all panels)

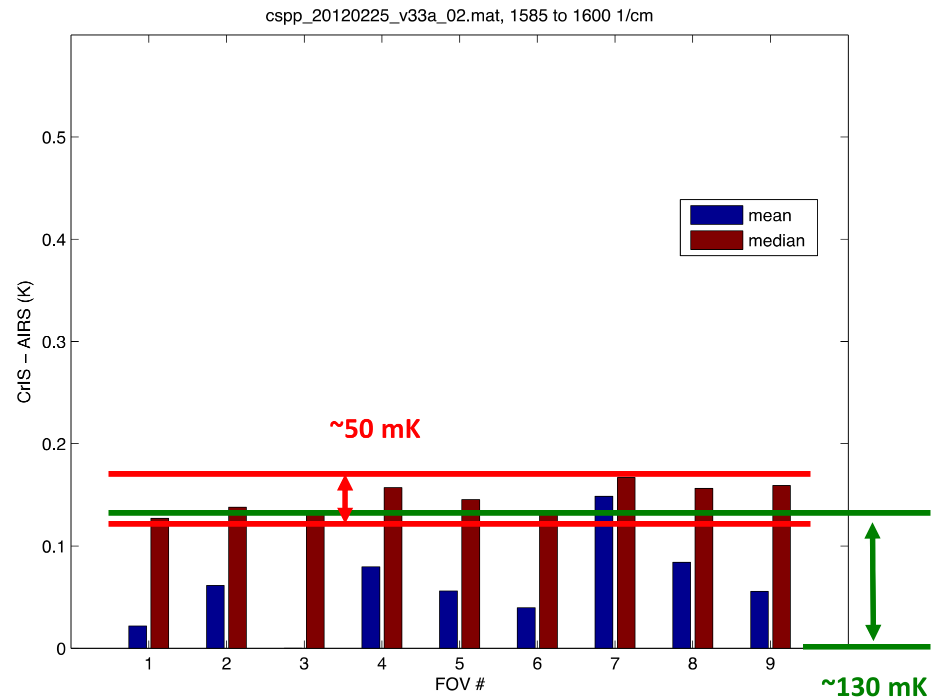
Improved MW a_2 from On-orbit Analyses:

FOV-to-FOV Consistency also reduces difference from AIRS

TVAC a_2 values



On-orbit a_2 values



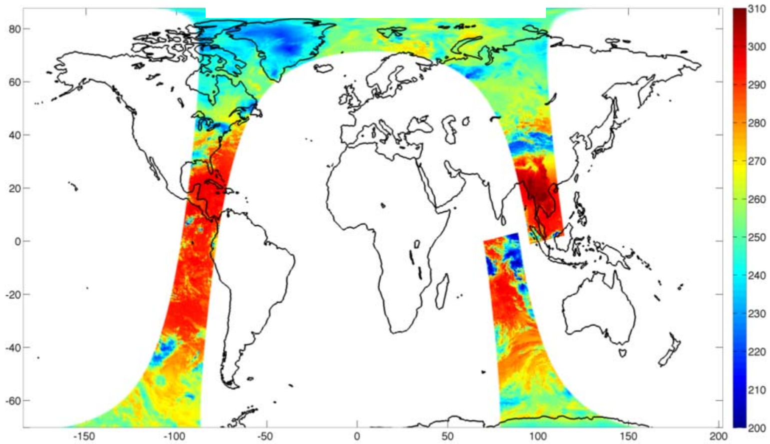
MW WV: FOV-2-FOV range and median difference from AIRS

Spectral Calibration

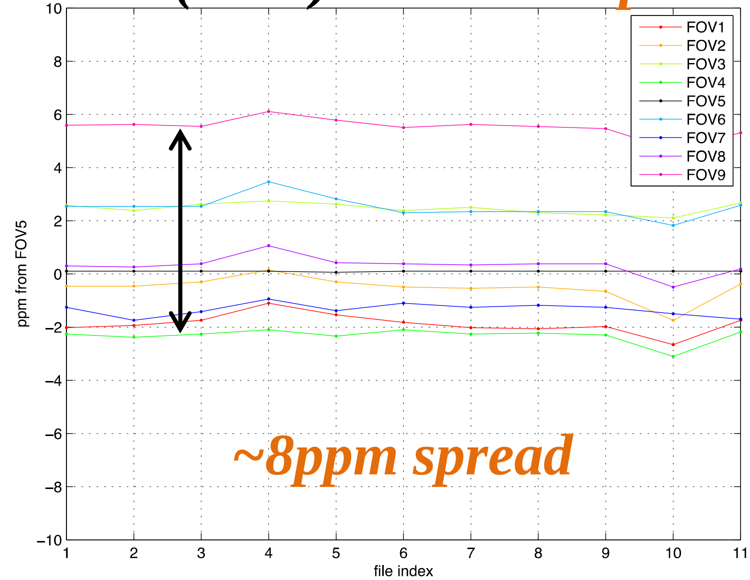
- Relative FOV to FOV
  - **No calculations needed**
  - **Highly accurate**
- Absolute performed by Larrabee Strow's group at UMBC
  - **Based on calculations**
  - **Good agreement with onboard Neon source**

LW FOV-to-FOV Spectral Cal Analysis

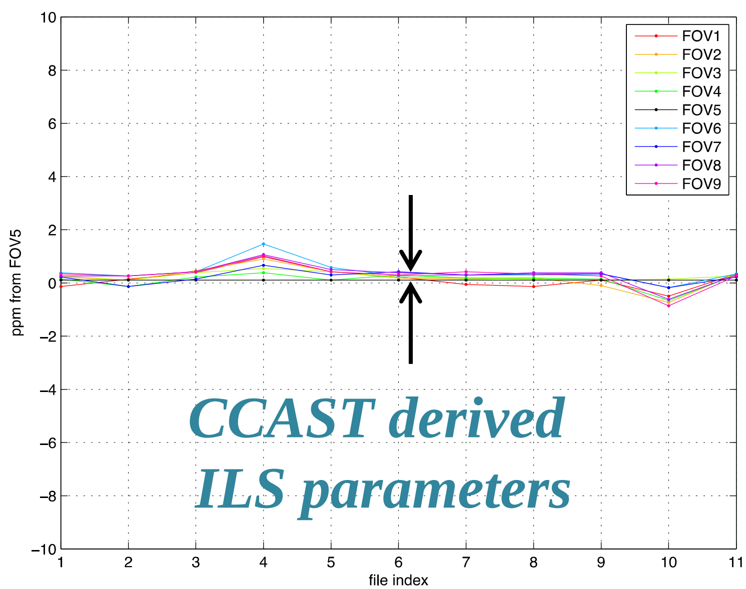
Orbit 01687



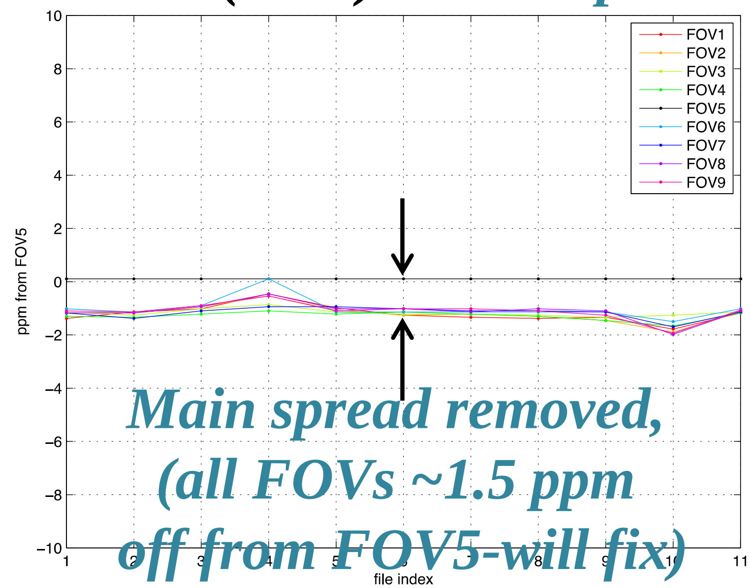
CSPP (ADL)-TVAC ILS params



UW/UMBC CCAST

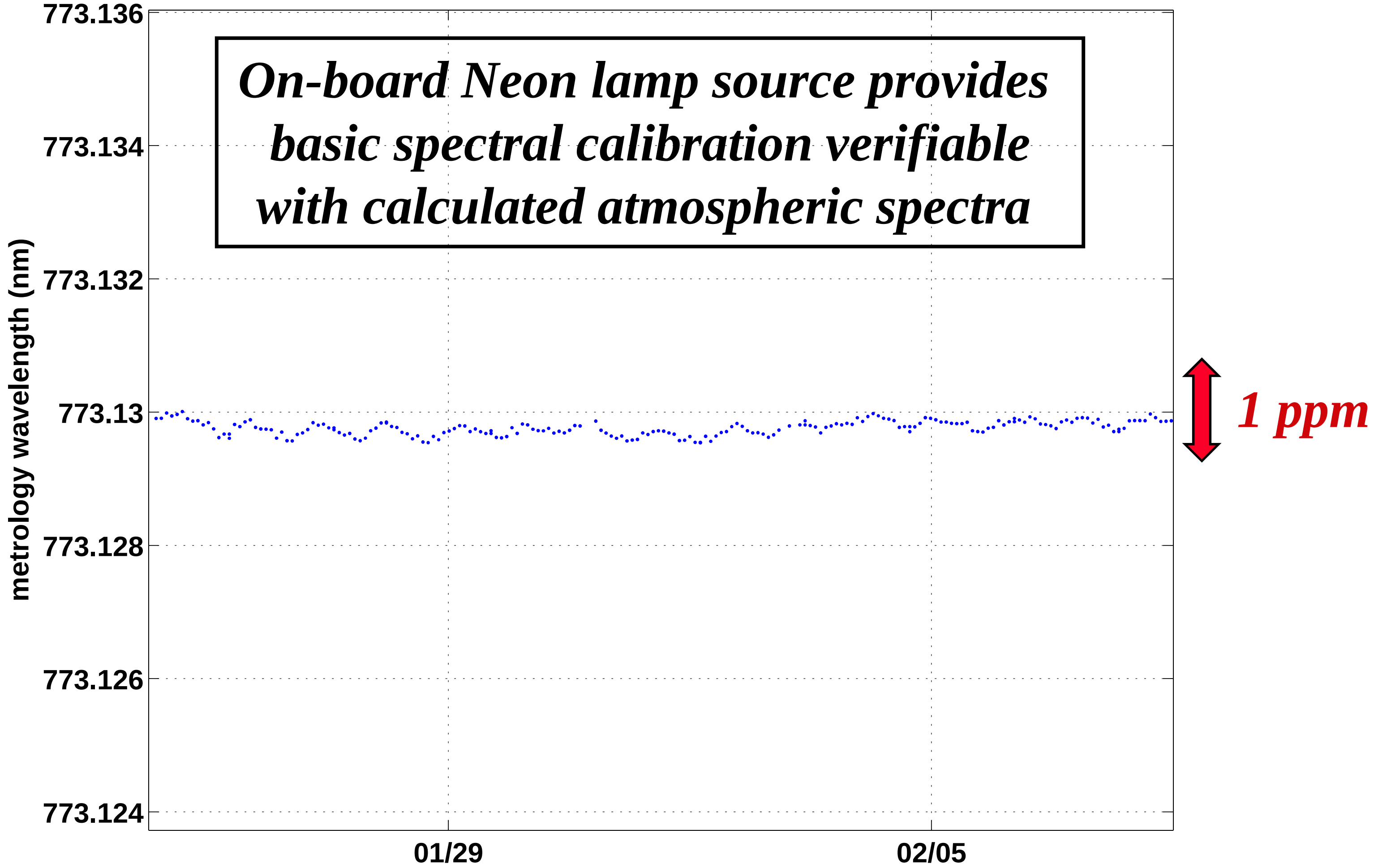


CSPP (ADL)-CCAST params



Neon Spectral Calibration Stability

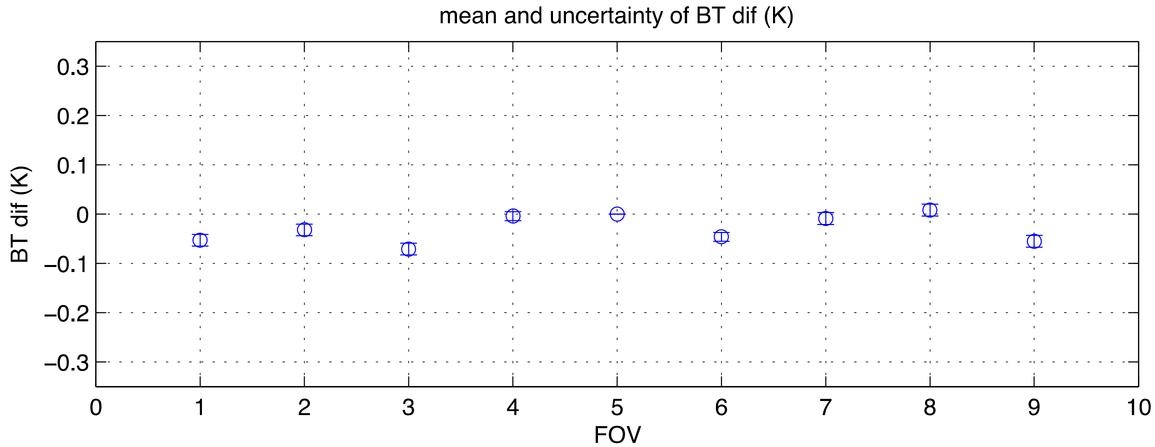
Better than 1 ppm!

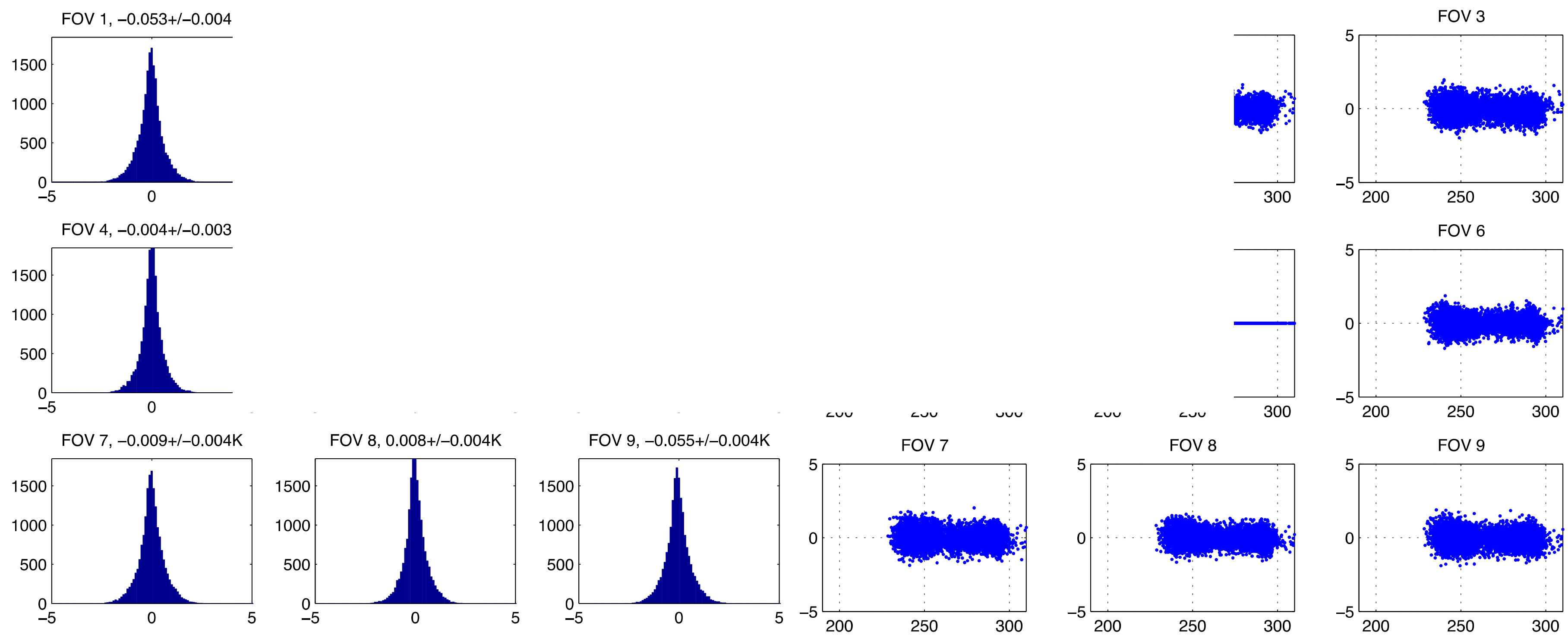


Imperfections

- Shortwave
  - **3 FOV outliers by ~0.06 K**
  - **Very Consistent—correction should be possible**
- Cross-track Striping
  - **Every other 3x3 FOR differ consistently by up to ~0.1 K**
  - **Correlates with FTS Optical Path Difference scan direction**
  - **Caused by FTIR filtering for data volume reduction**
  - **<u>Expect correction soon</u>**

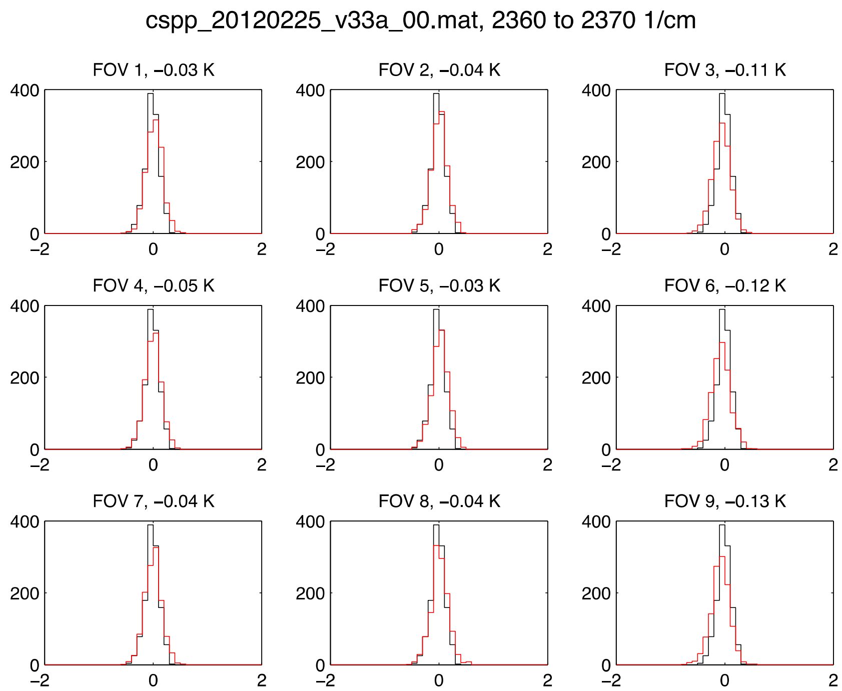
SW @ 2425 cm^{-1} wrt FOV5



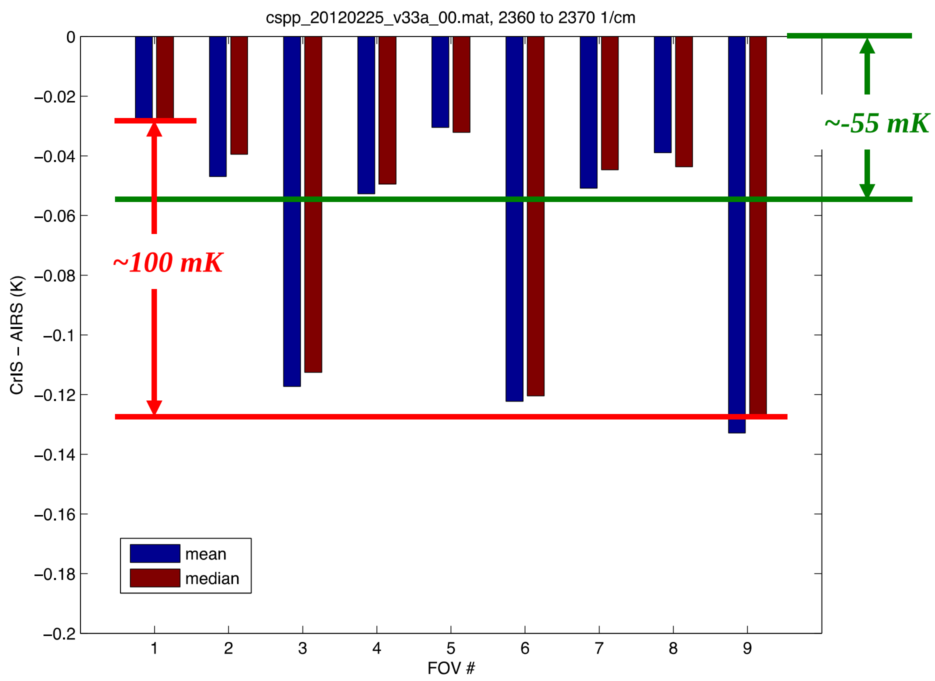


CrIS minus AIRS BT(K) Verifies SW Effect

SW @ 2360-2370 cm^{-1}



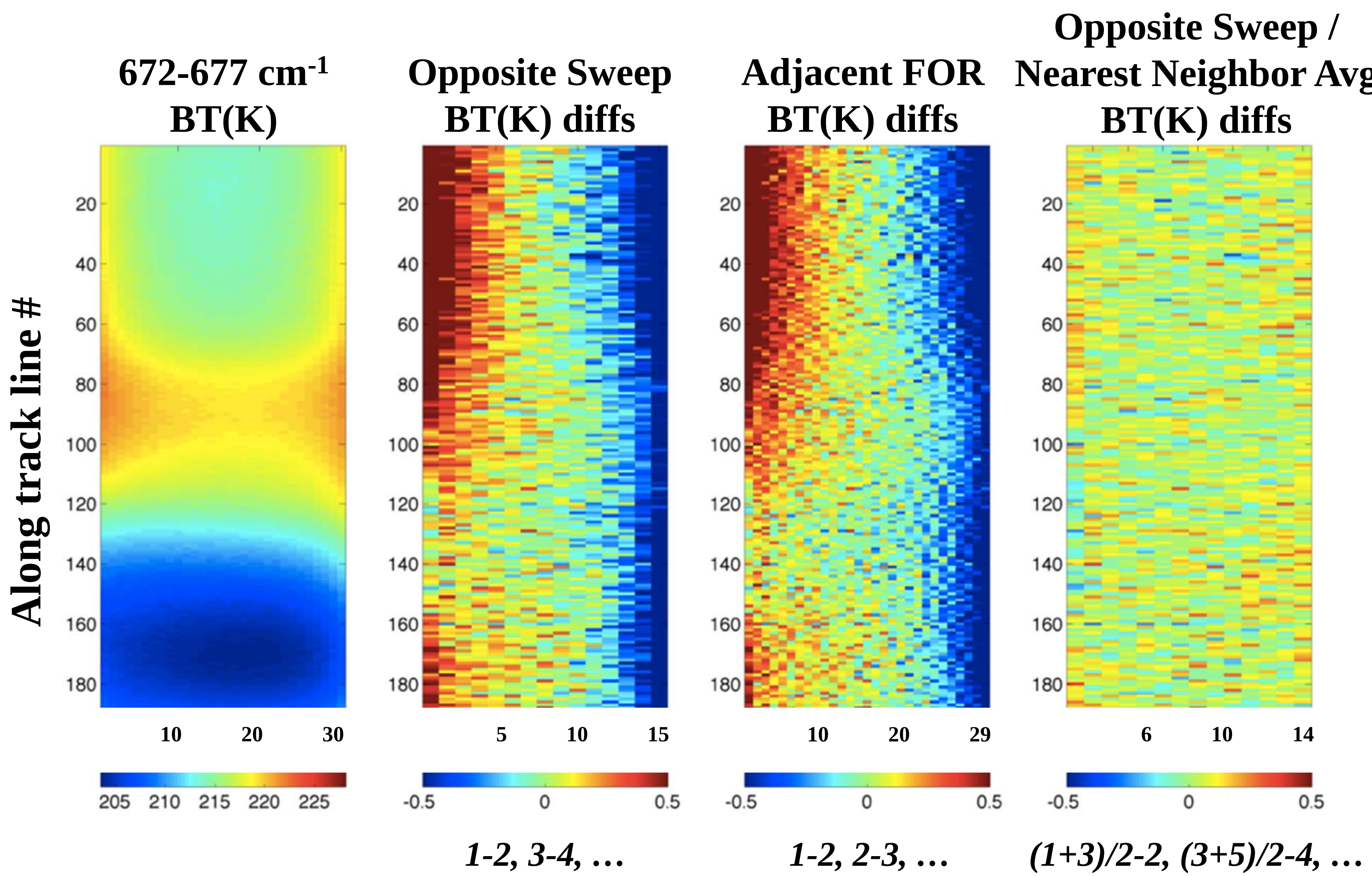
Black = All FOVs (same in all panels)



FOV-2-FOV range *and*
median difference from AIRS

Unfiltered CrIS Data Shows no Striping

New filter function can be uploaded



Looking Ahead: Future US Polar Sounding

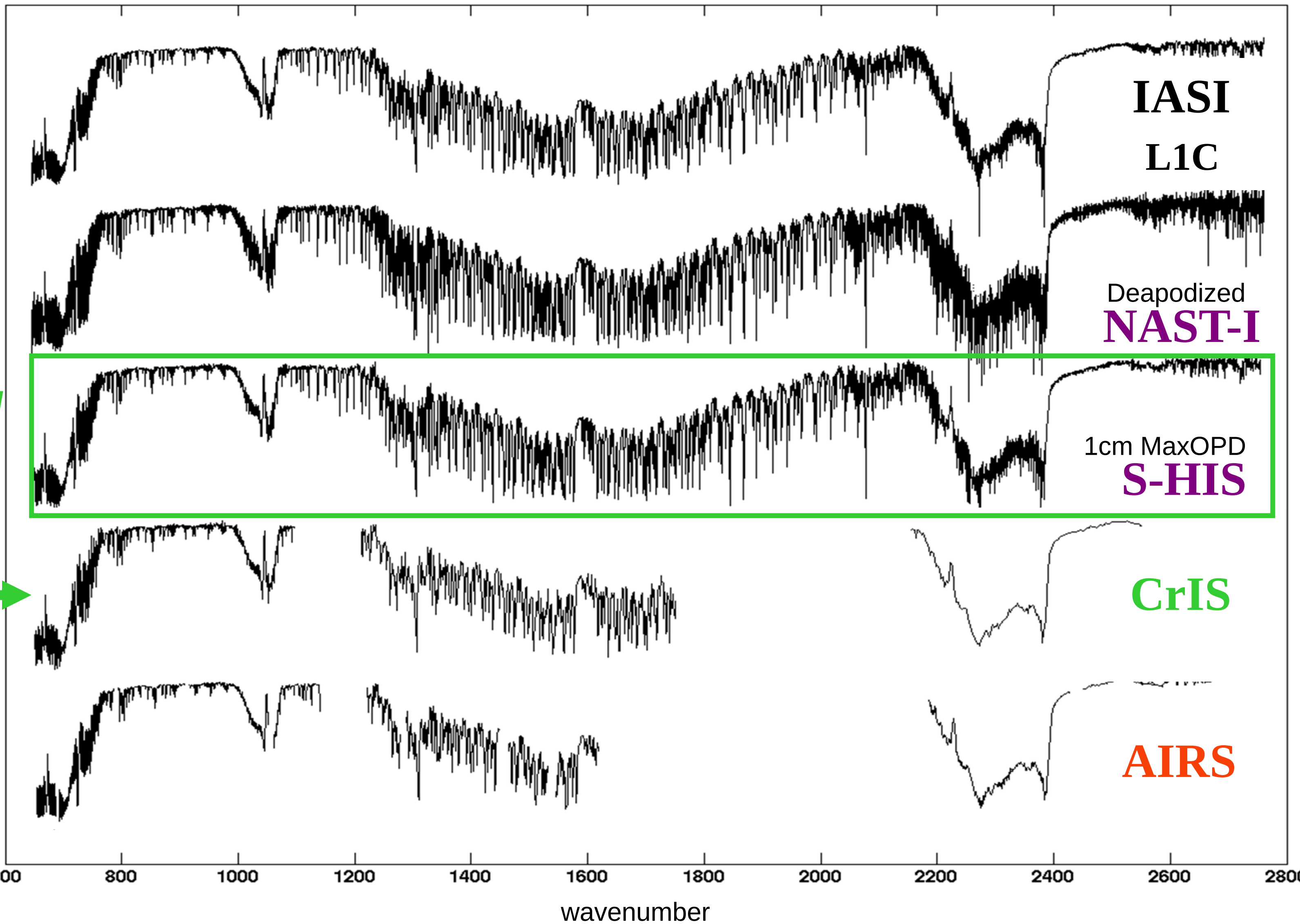
The CrIS sensor provides a foundation that is well suited to the upgrades needed for Next generation US Weather, GHG monitoring, & Climate Monitoring

Spectral Coverage of Advanced CrIS

Compared to IASI, CrIS, AIRS, S-HIS & NAST-I

Advanced CrIS (?)

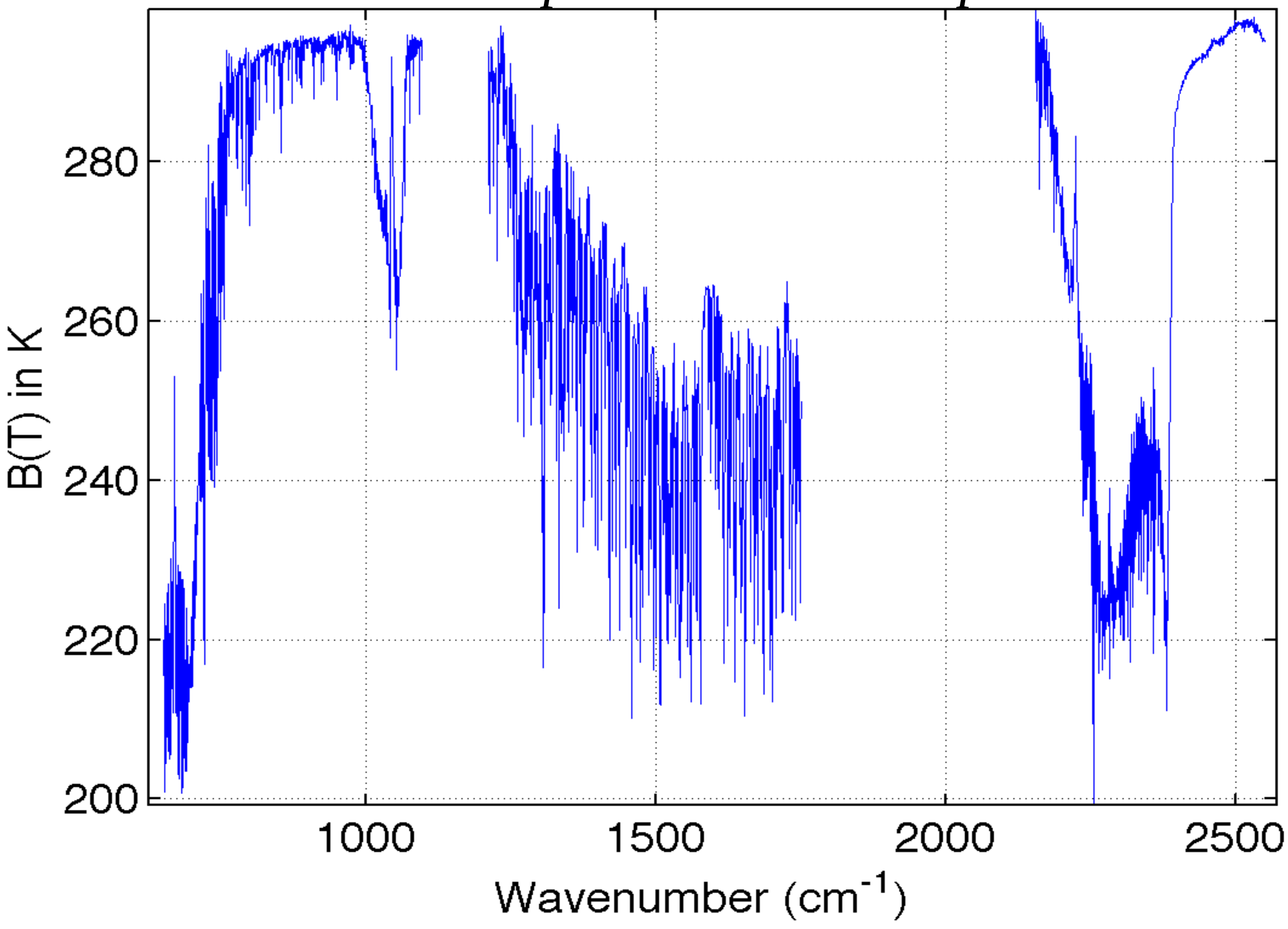
Current CrIS



Full Resolution CrIS with current gaps

Gaps can be quite easily removed in the future—largely a data rate issue

Clear Tropical Ocean Example



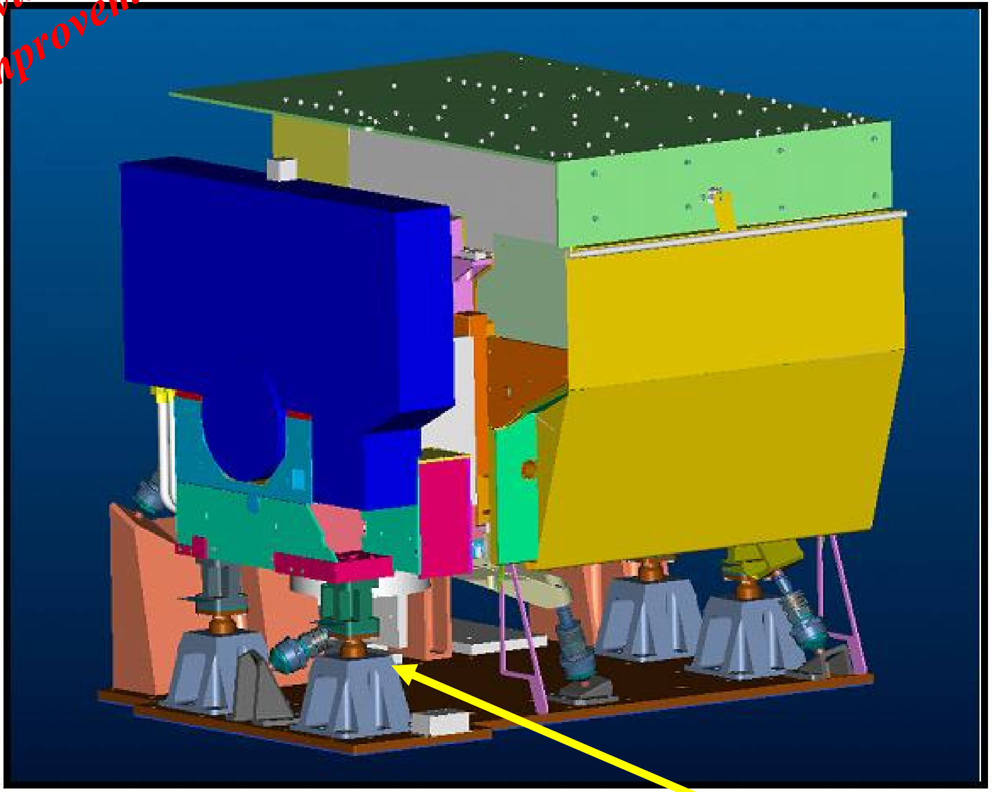
Calibrated with UW/UMBC CCAST—thanks to Larrabee Strow

CrIS Utilizes Innovative Technologies to Achieve High Performance

CrIS Sensor Features

- Large 8 cm Clear Aperture
- Three Spectral Bands
  - LWIR: 650-1095 cm^{-1}
  - MWIR: 1210-1750 cm^{-1}
  - SWIR: 2155-2550 cm^{-1}
- 1305 Total Spectral Channels
- 3x3 FOVs at 14 km Diameter
- Photovoltaic Detectors in All 3 Bands
- 4-Stage Passive Detector Cooler
- Plane-Mirror Interferometer With DA
- Internal Laser Wavelength Calibration (Neon bulb)
- Deep-Cavity Internal Calibration Target
- Extended Radiator Supports 1394a
- Passive Vibration Isolation System Allows Robust Operation in 50 mG Environment
- Modular Construction

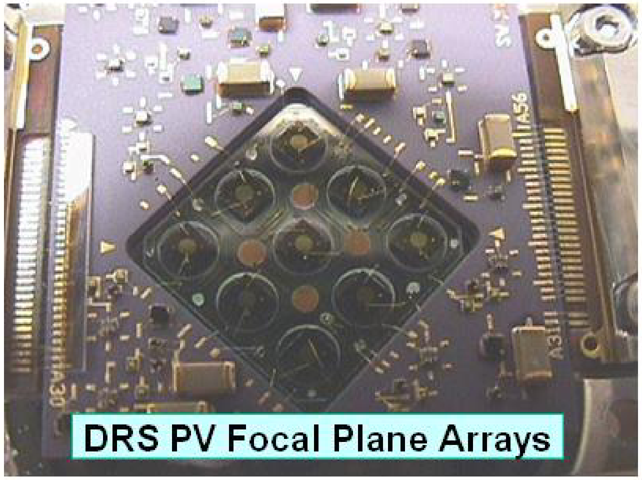
Advances: detector arrays & mechanical cooler will allow spectral and spatial improvement

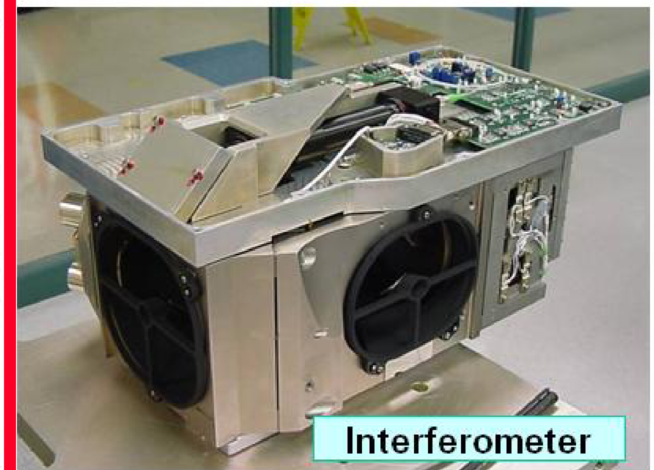


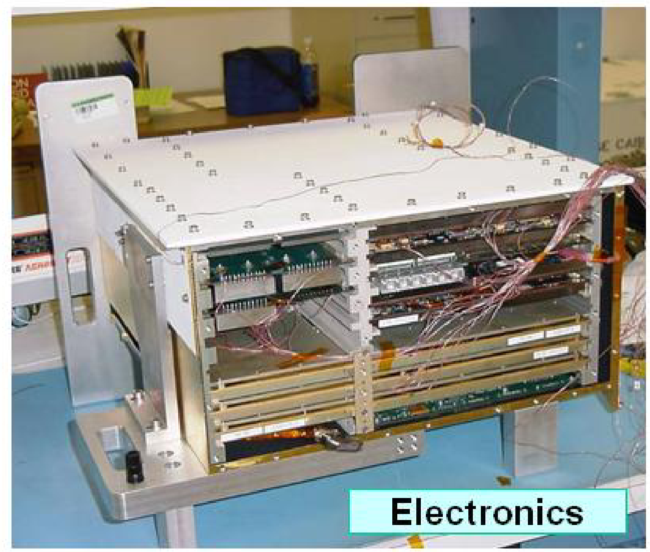
vibration isolation mount (not needed on NPP)

Volume: < 71 x 80 x 95 cm
Mass: < 152 kg
Power: < 124 W
Data Rate: <1.5 Mbps

CrIS Modular Subsystems (EDU3 shown)





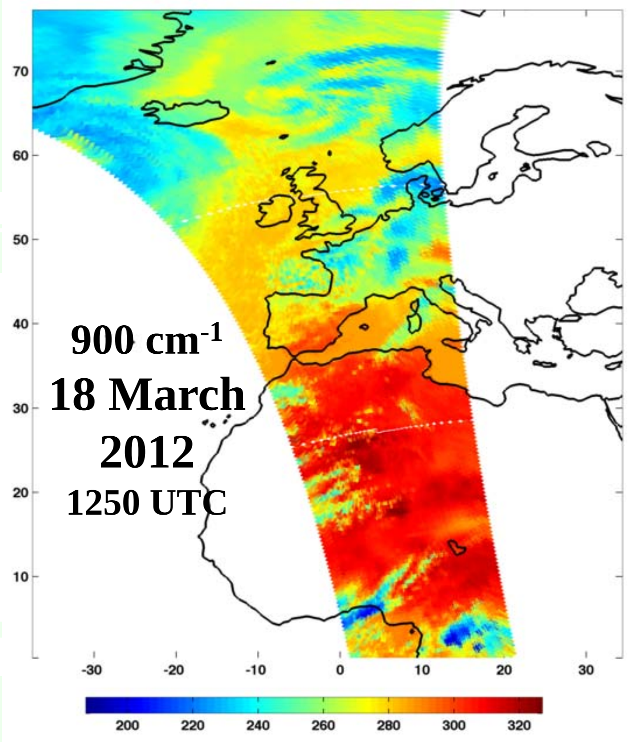


Modify to improve spatial resolution and spatial sampling

from Williams, Glumb and Predina, ITT, August 2005 SPIE

Summary

- **CrIS instrument performance is exceptional**
  - **Very low noise**
  - **Very stable and accurate**
  - **Provides excellent baseline for future upgrades**



- **Initial configuration activities are almost complete**
  - **Review planned for 4 April**
  - **Hopefully, high quality operational data will be available in that time frame**
  - **CSPP data will definitely be available from UW-Madison/SSEC**
  - **Further refinements expected at a later date**

CrIS on Suomi NPP is part of a fitting tribute to Verner Suomi