Inter-Comparison of Suomi NPP CrIS with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements

Likun Wang[1*], Yong Han[2], Yong Chen[1], Denis Tremblay[3], Xin Jin[4]

1. CICS/ESSIC/University of Maryland, College Park, MD
2. NOAA/NESDIS/STAR, College Park, MD
3. Science Data Processing, Inc, Laurel, MD
4. Earth Resources Technology, Inc., Laurel, MD

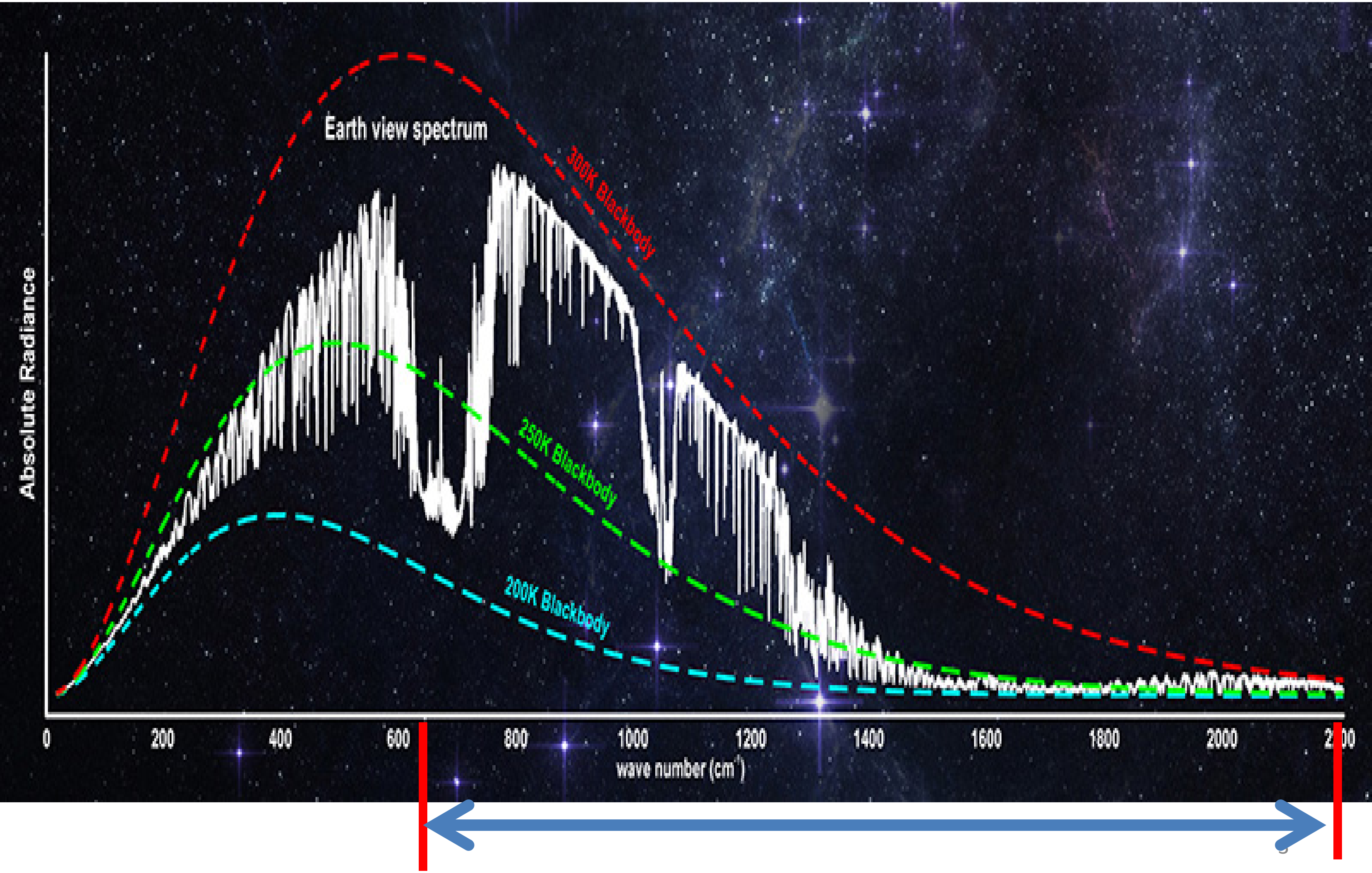
*Email: wlikun@umd.edu

2014 CICS Science Meeting November 12 2014; College Park, MD

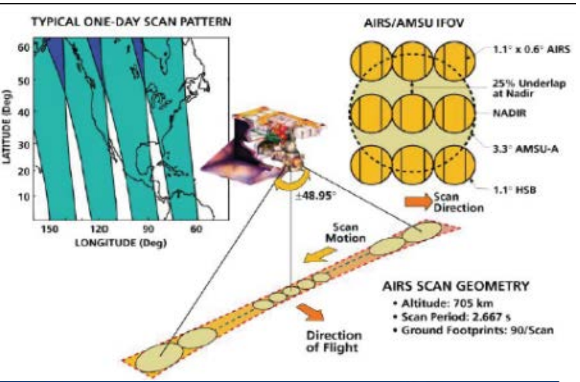
Outlines

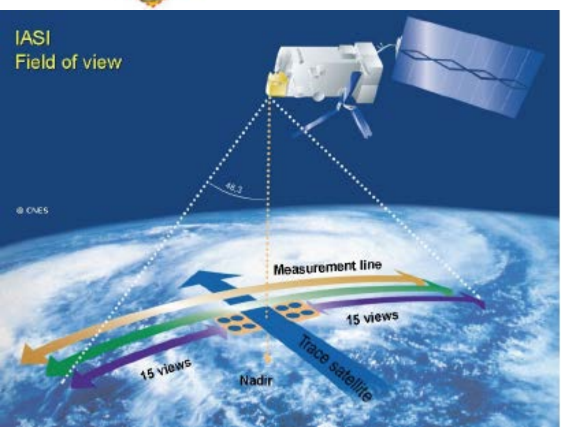
- Hyperspectral Instruments
- Importance of Infrared Hyperspectral Benchmark Radiance Measurements
- Inter-comparison methods
- Results
- Conclusion

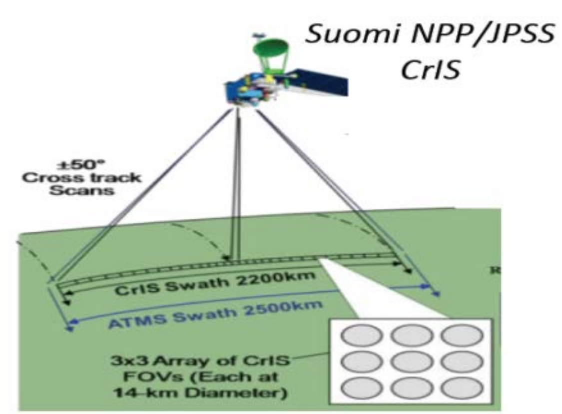
Earth IR Spectral Radiance



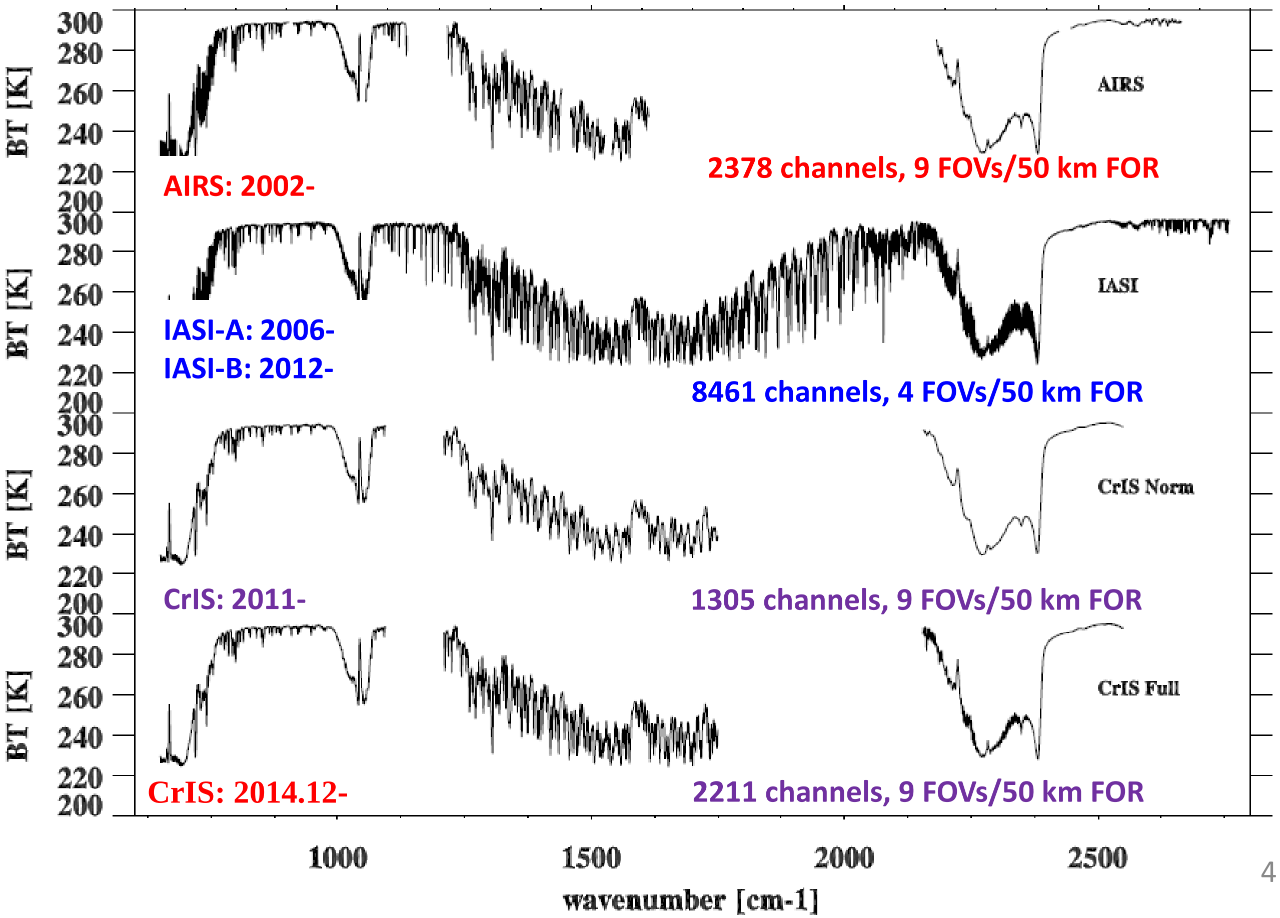
Hyperspectral IR instruments



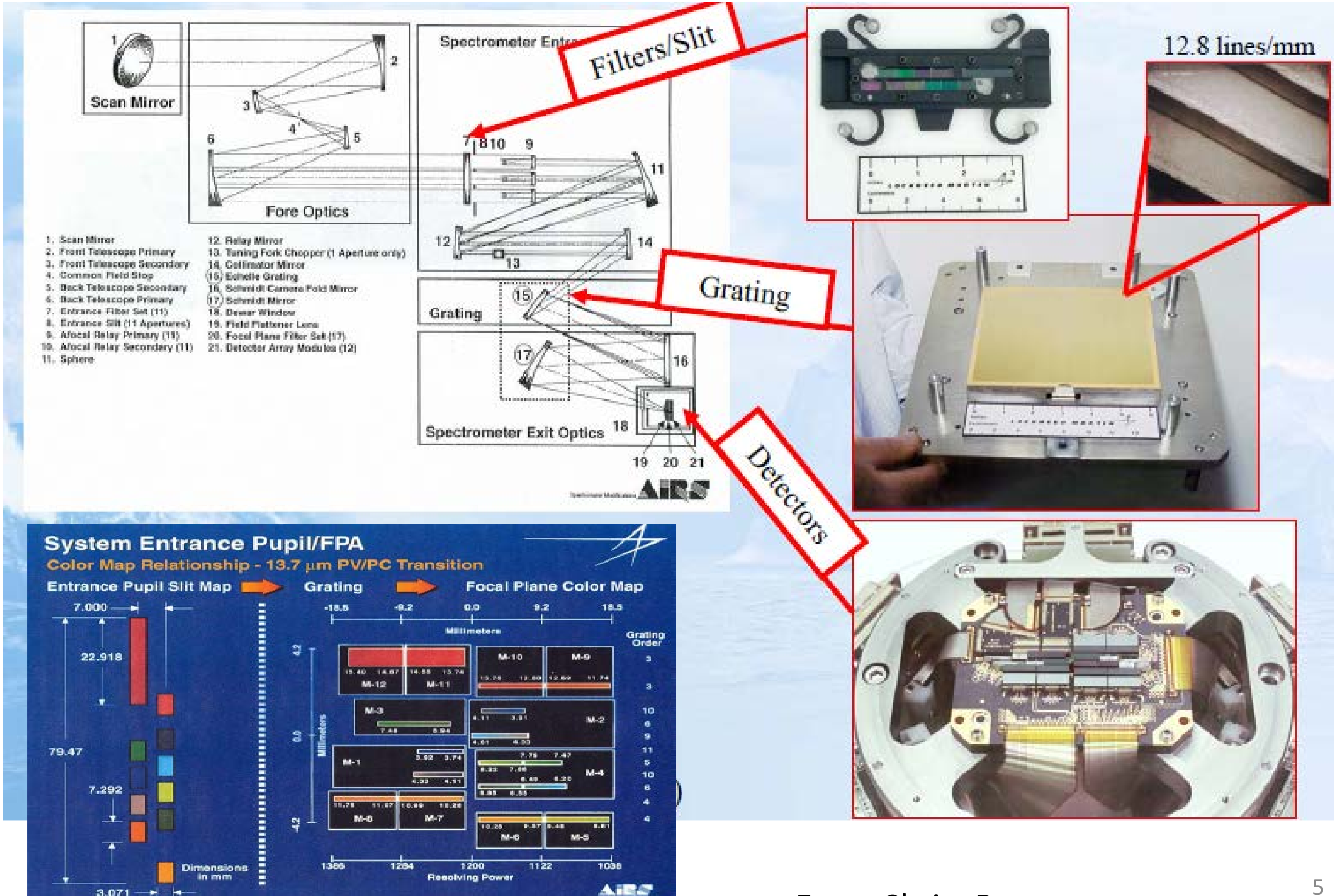




Spectral Coverage and Resolution of AIRS, IASI, and CrIS

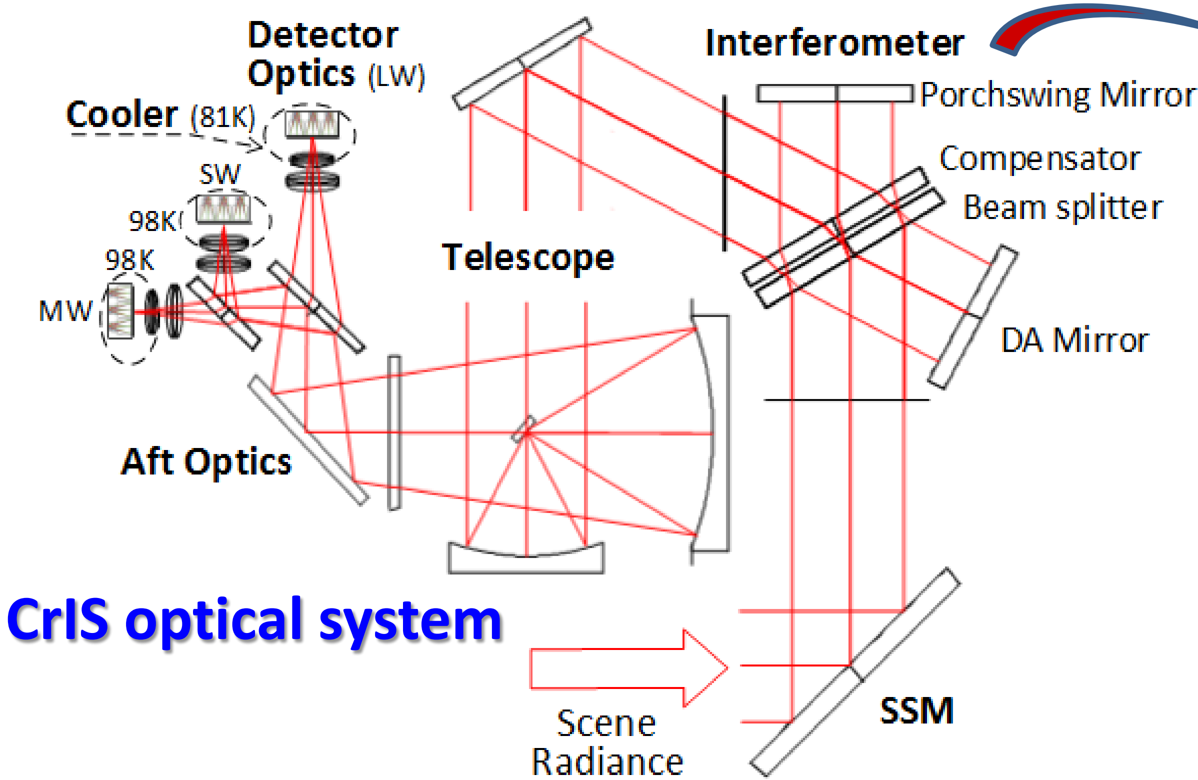


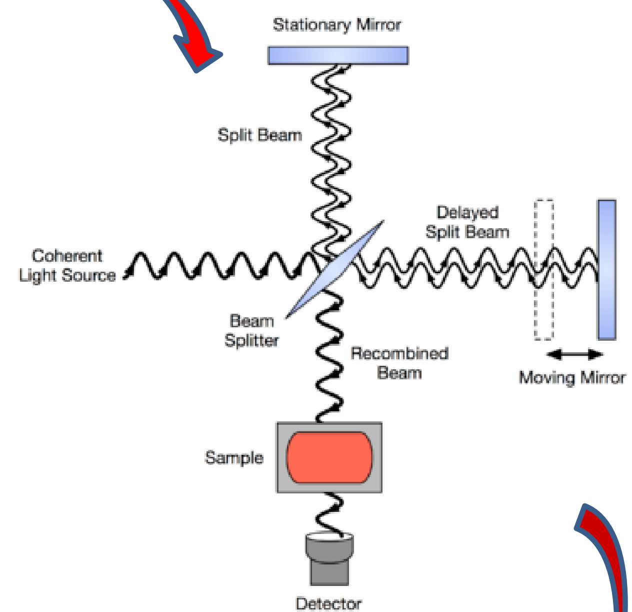
AIRS: Grating Spectrometer

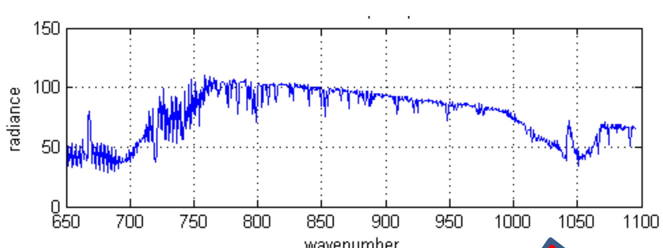


From Christ Barnet

IASI and CrIS: Interferometer

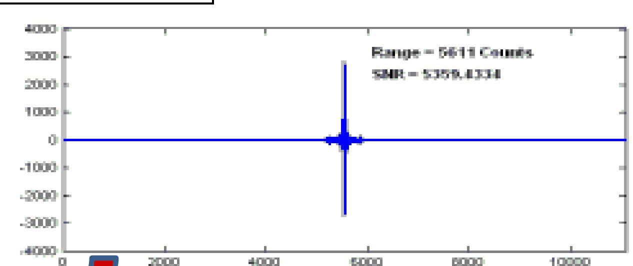






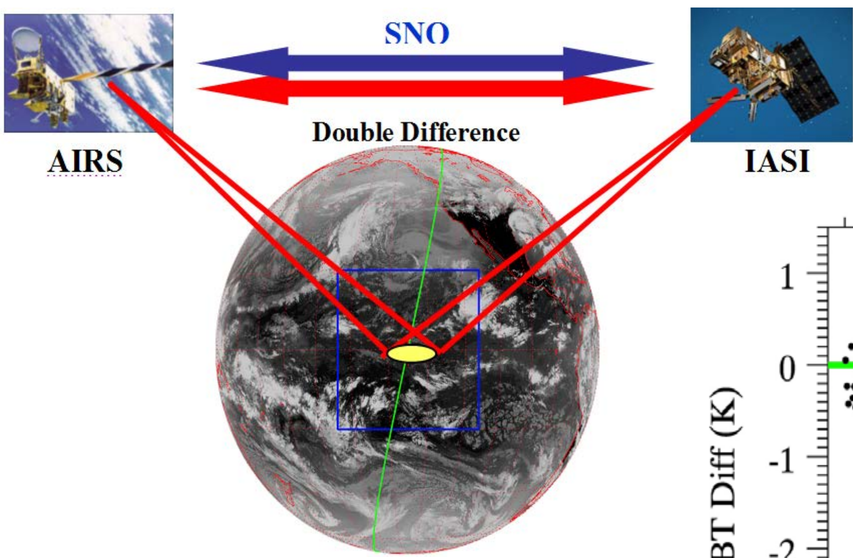
IR spectrum

Fourier Transform

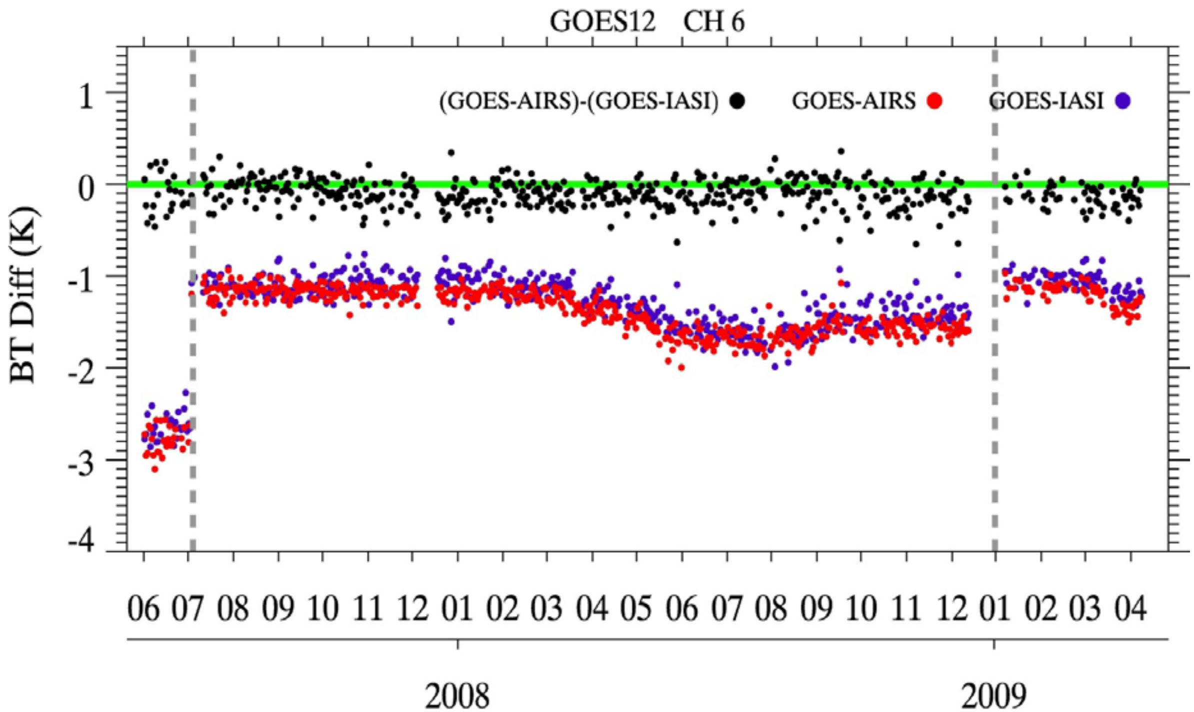


Interferogram

Radiances consistency of CrIS, IASI, and AIRS (1) Inter-calibration for other instrument



GSICS Framework:
Independent Calibration Assessment

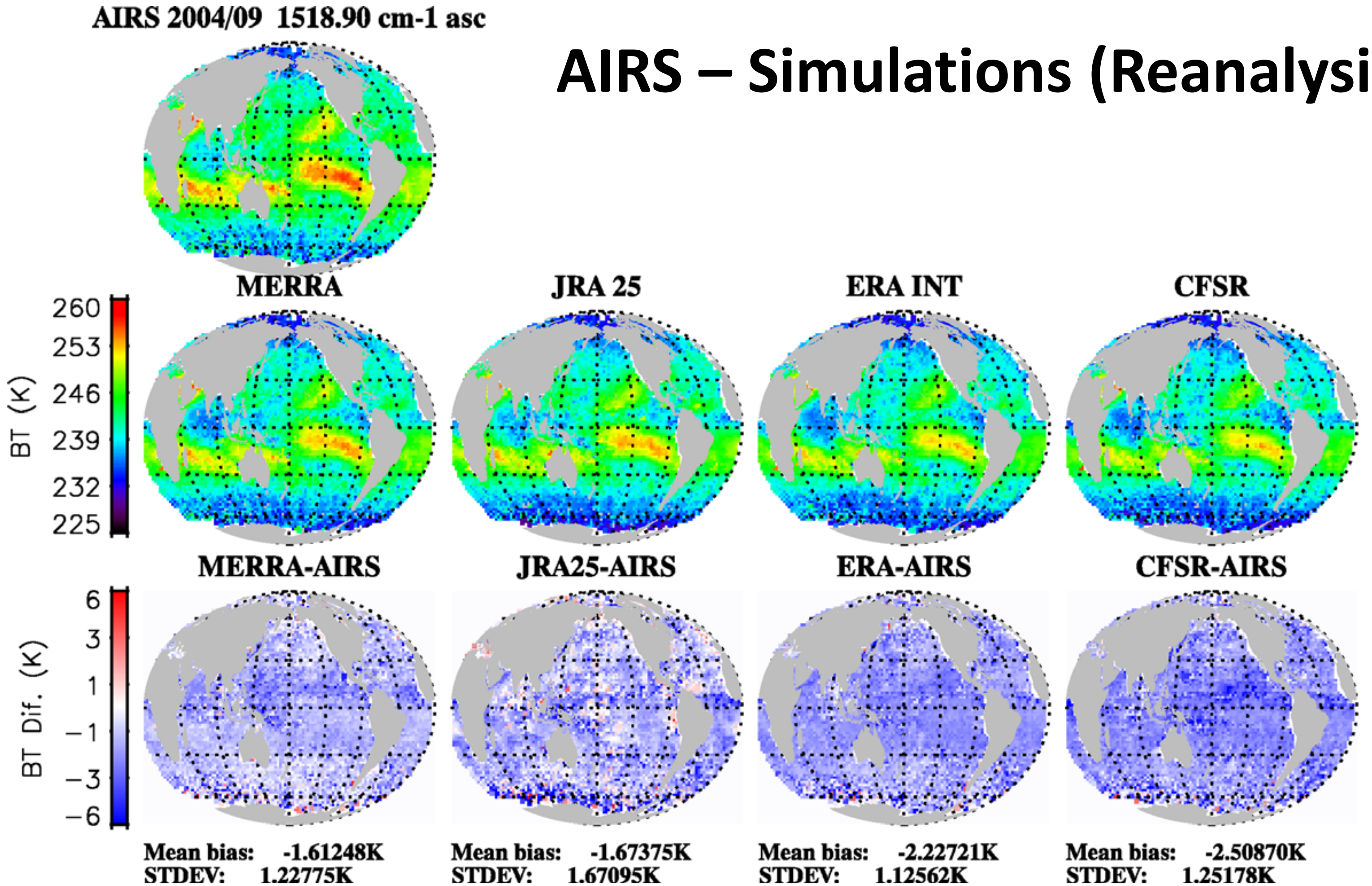


Each Agency routinely uses AIRS/IASI to assess calibration accuracy of its own geostationary instruments

Spectral and radiometric consistency among CrIS, AIRS and IASI is significant for GSICS community.

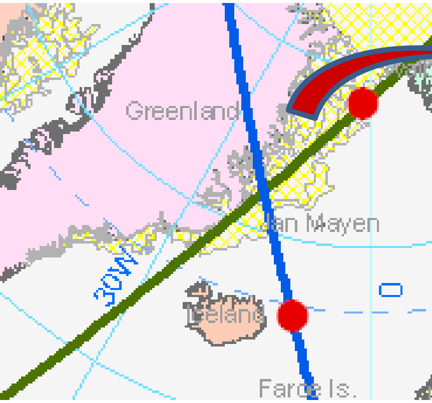
Radiances consistency of CrIS, IASI, and AIRS (2)
Model Verification

AIRS – Simulations (Reanalysis)



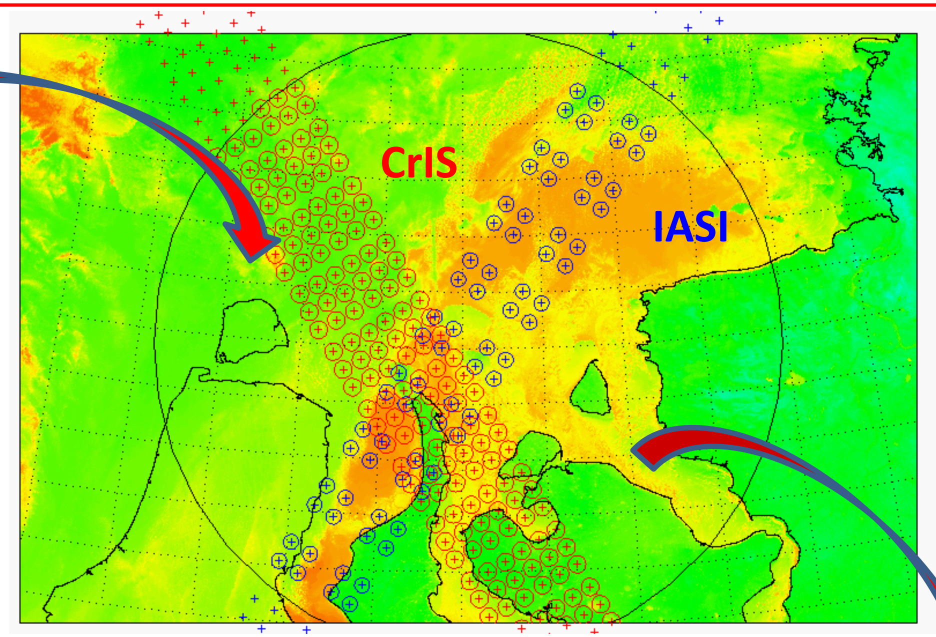
Hyperspectral radiance measurements can serve as a benchmark for model assessment, but the consistency is the key.

Simultaneous Nadir Overpass (SNO) Between CrIS and IASI



From Changyong Cao

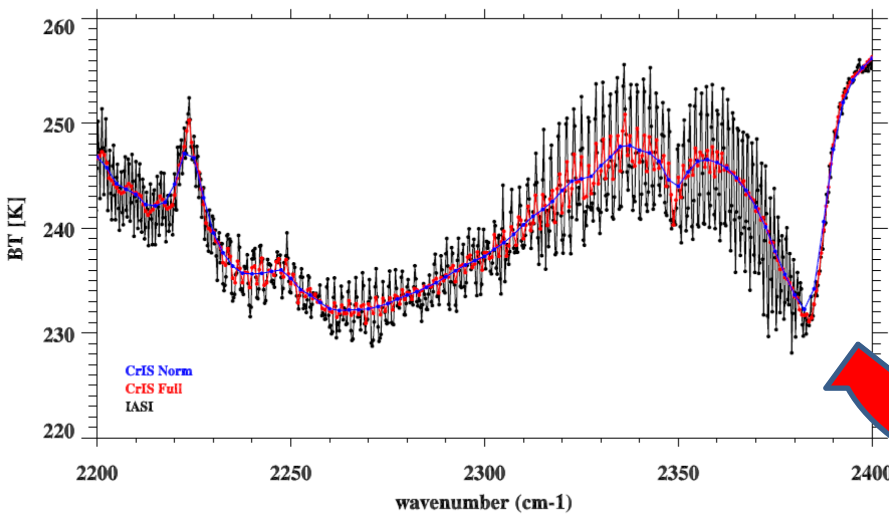
CrIS: Afternoon orbit
IASI : Morning orbit

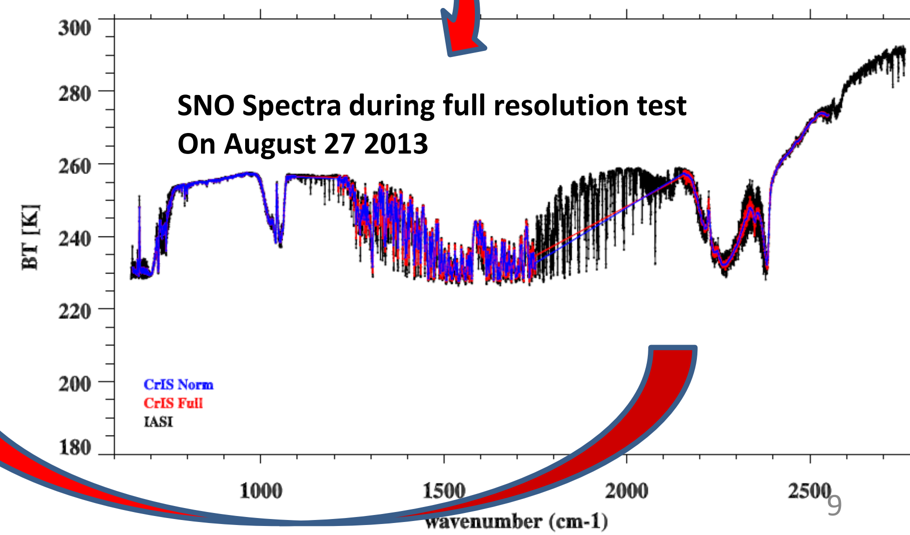


Time Difference: <= 120 Sec

FOV distance difference: <=(12+14)/4.0 km = 6.5 km

Angle Difference: ABS(cos(a1)/cos(a2)-1) <= 0.01

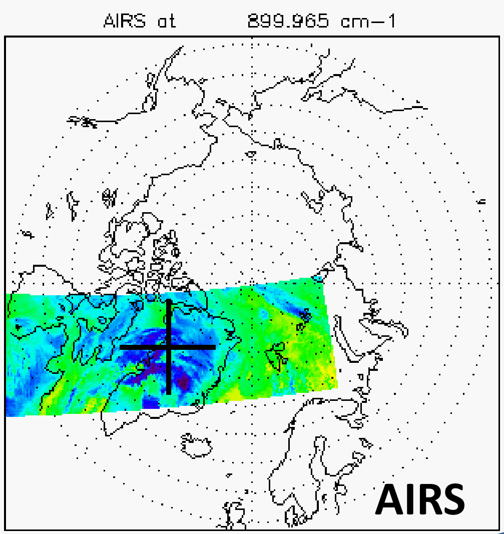


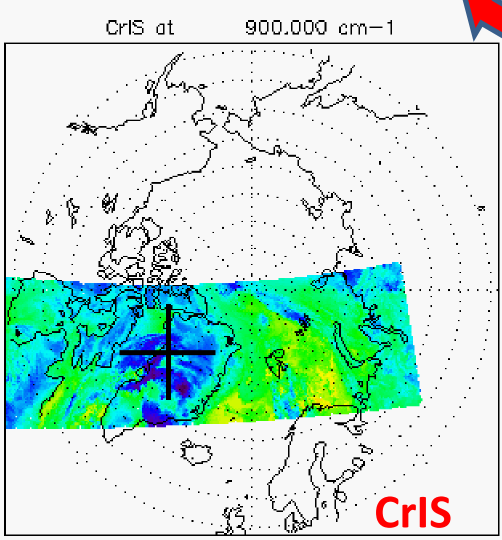


Simultaneous Nadir Overpass (SNO) Between CrIS and AIRS

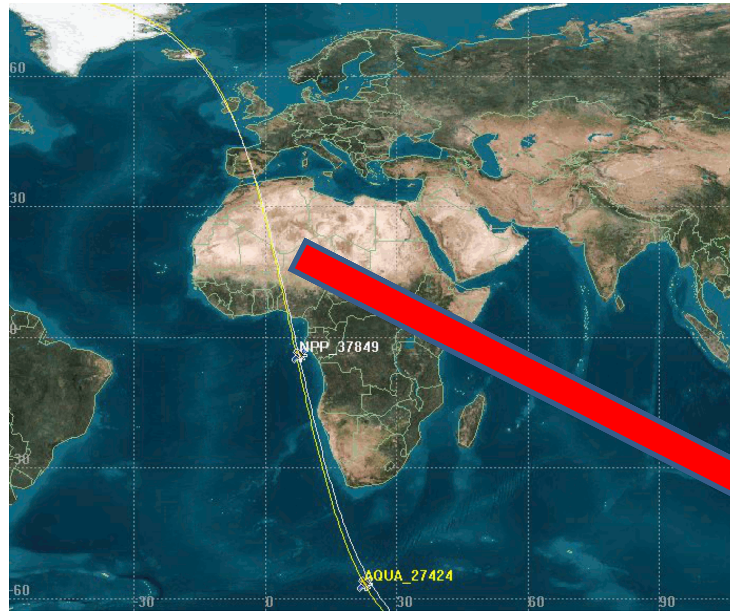
CrIS and AIRS: afternoon orbit

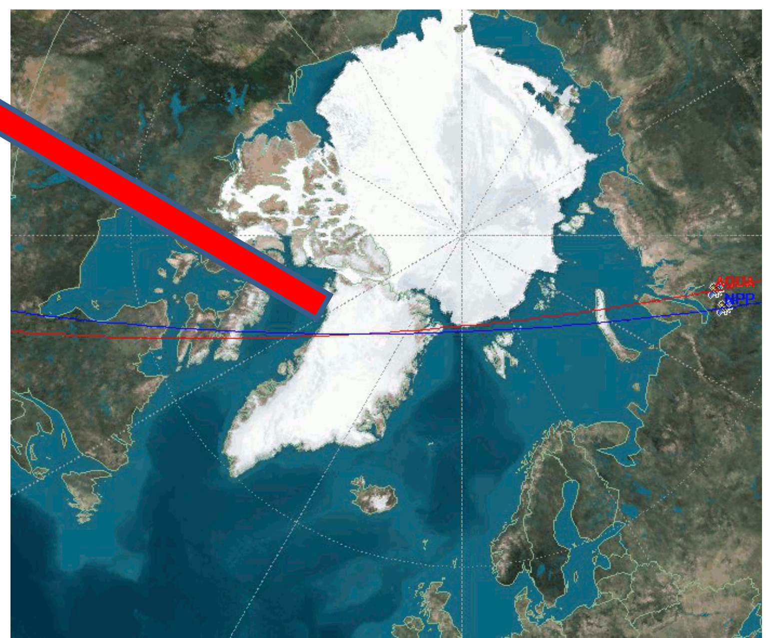
From Changyong Cao





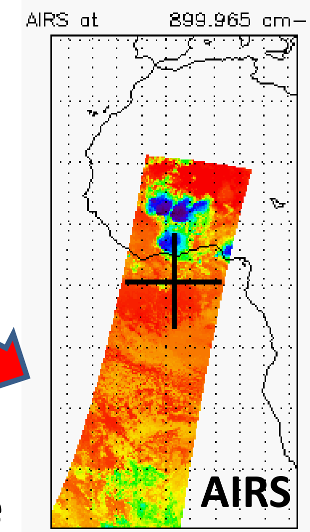
SNOs at Polar regions

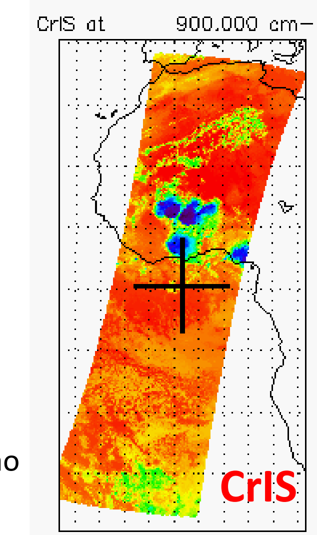




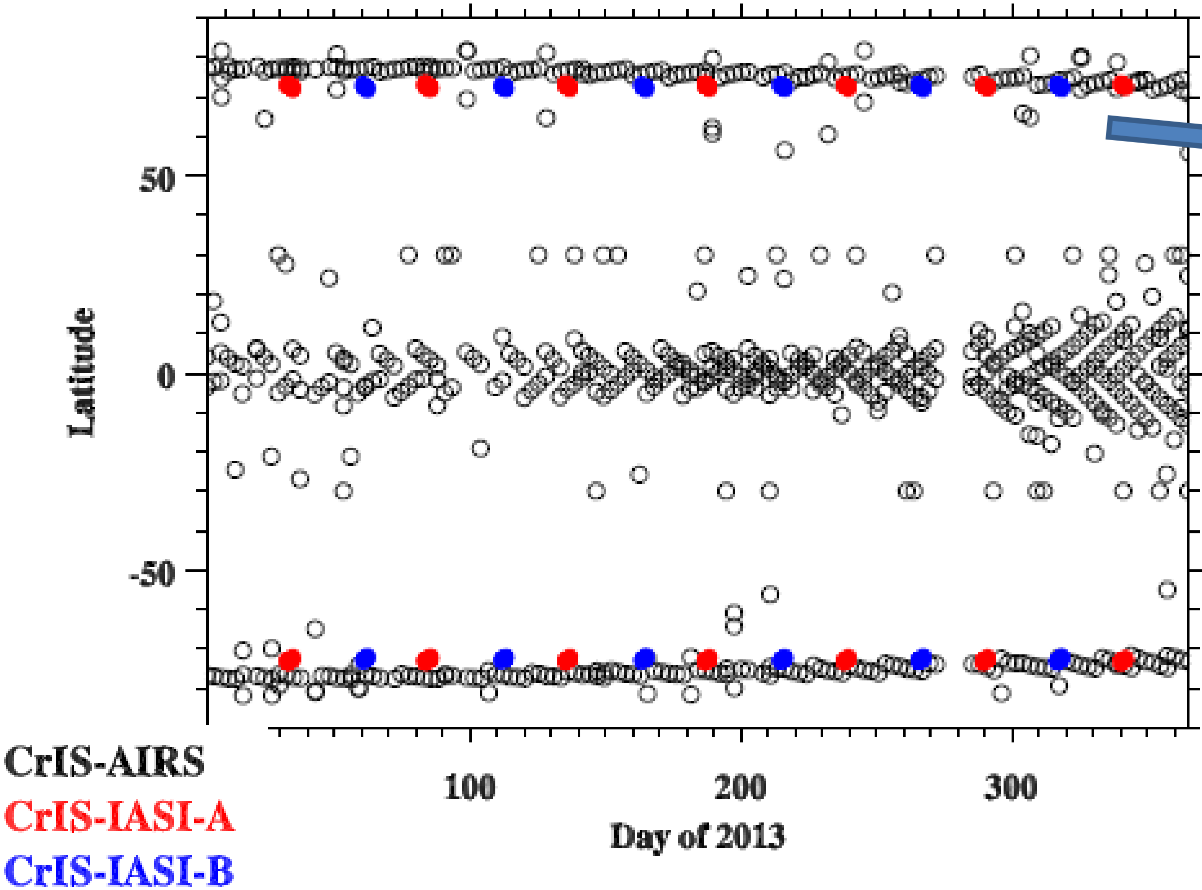
SNOs at the Tropics

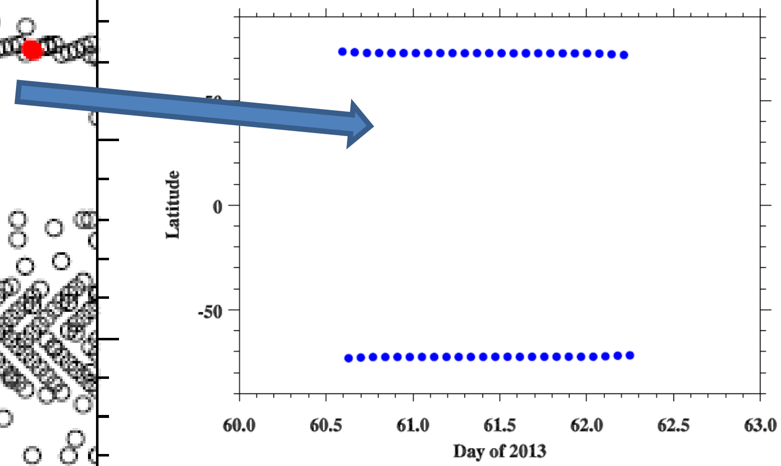
From Changyong Cao

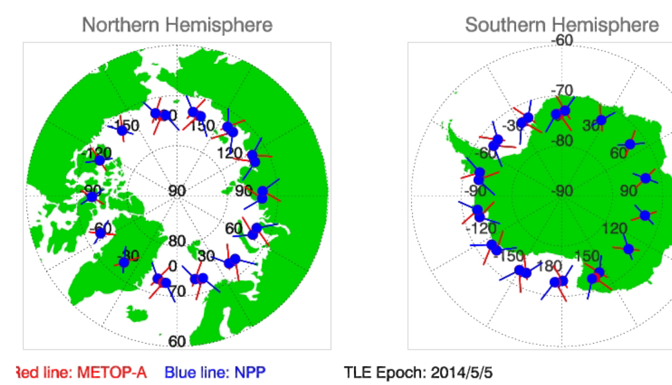




SNOs Latitude Distribution Time Series

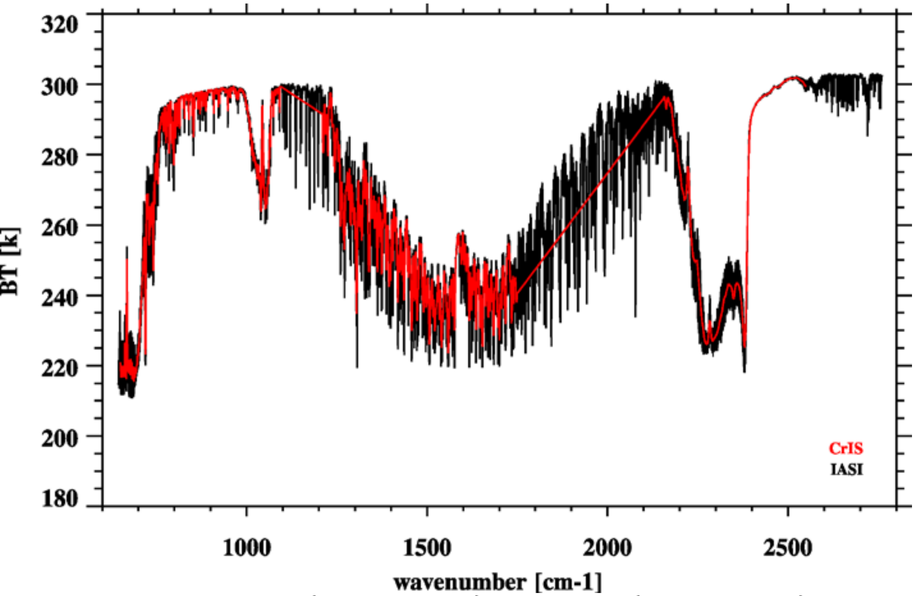




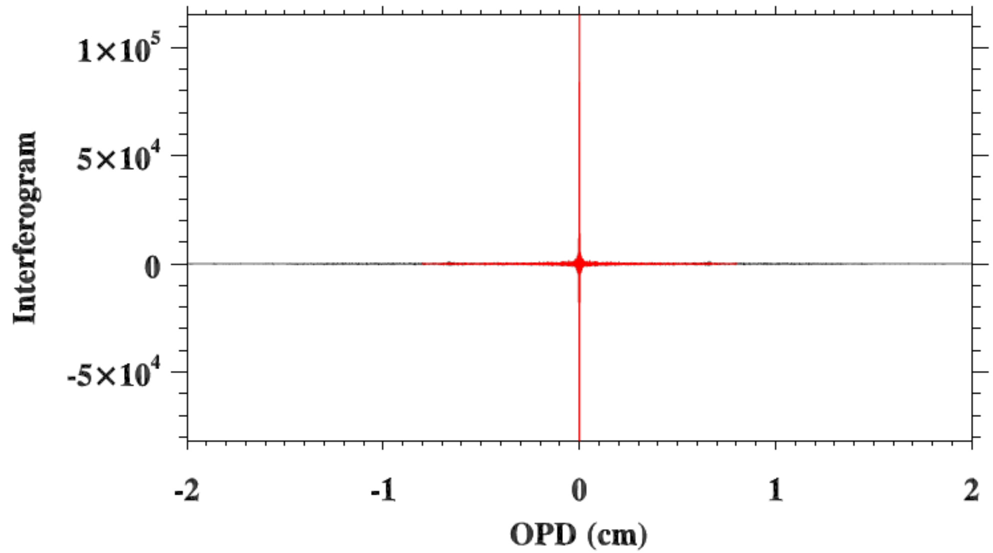


The SNOs between SNPP and Aqua occurred every days.
The SNOs between MetOp and SNPP occurred every 50 days.
Fortunately, once an SNO event occurs, their orbits will continuously cross each other every orbit.

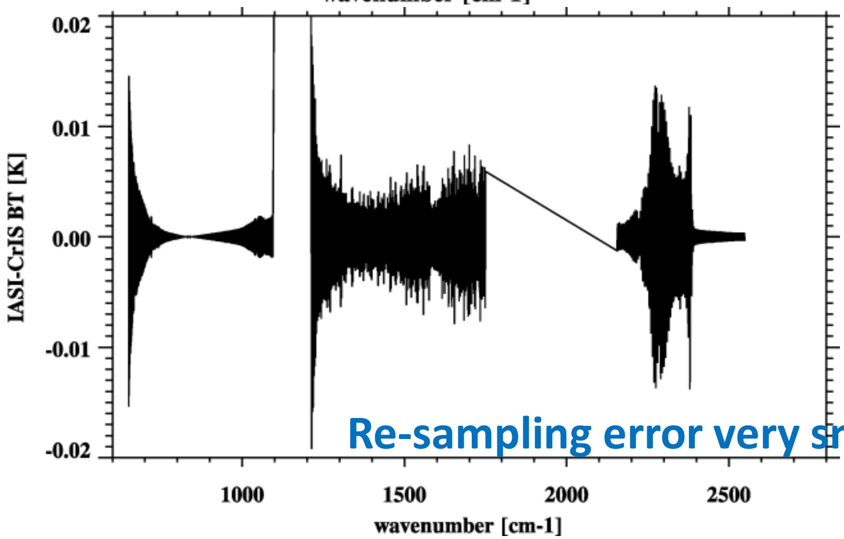
Resample IASI to CrIS



Fourier Transform



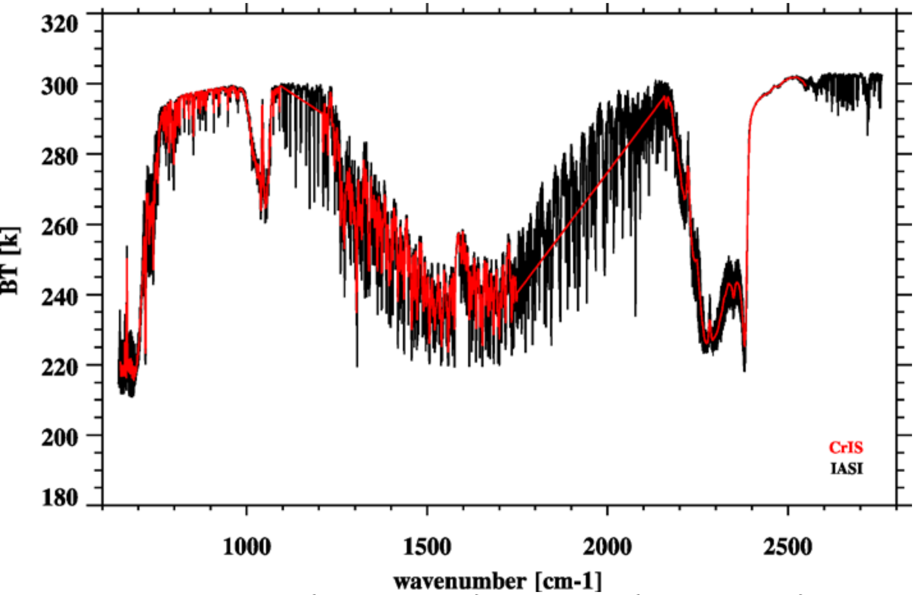
1) De-Apodization of IASI spectra
2) Truncation of IASI spectra
3) Apodization using CrIS Hamming Apodization function



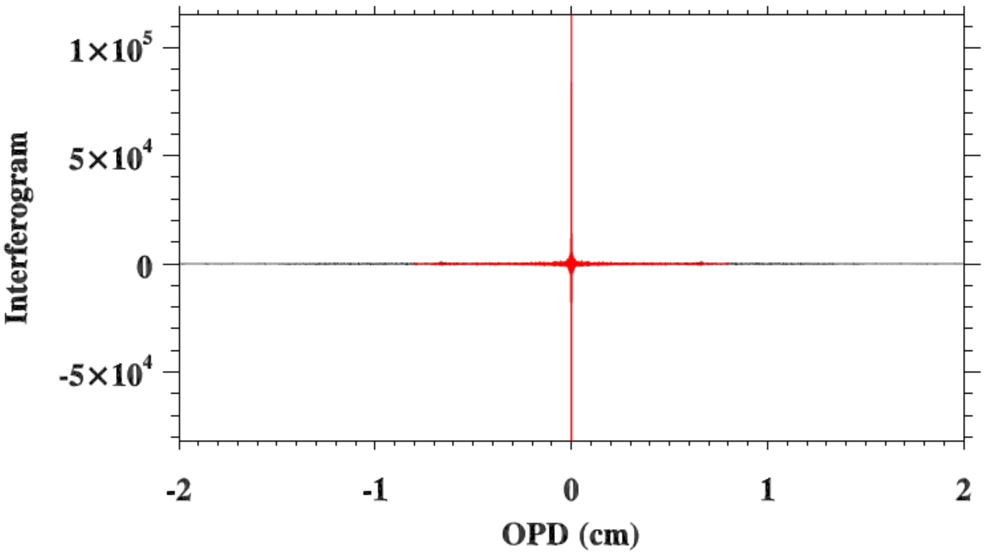
Re-sampling error very small

Inverse Fourier Transform

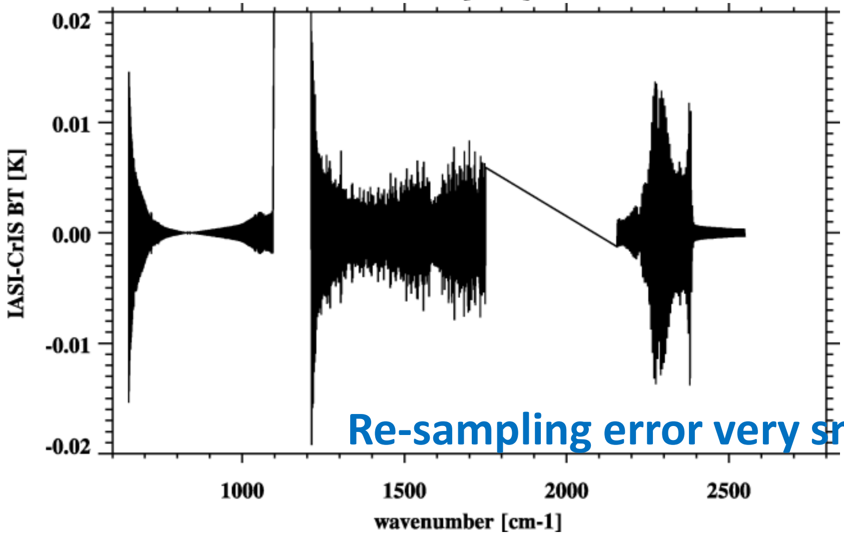
Resample IASI to CrIS



Fourier Transform



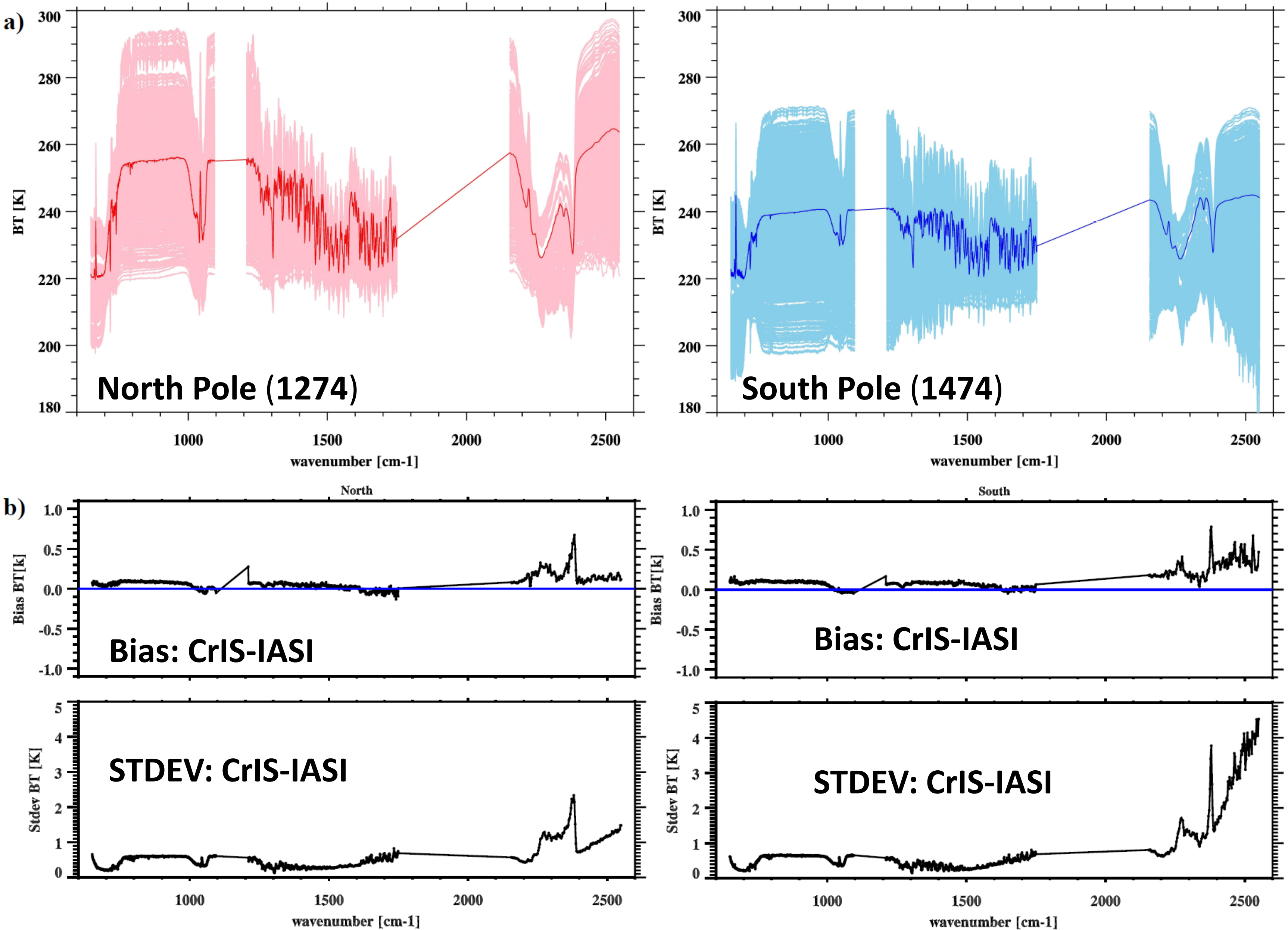
1) De-Apodization of IASI Interferogram
2) Truncation of IASI Interferogram
3) Apodization using CrIS Hamming Apodization function



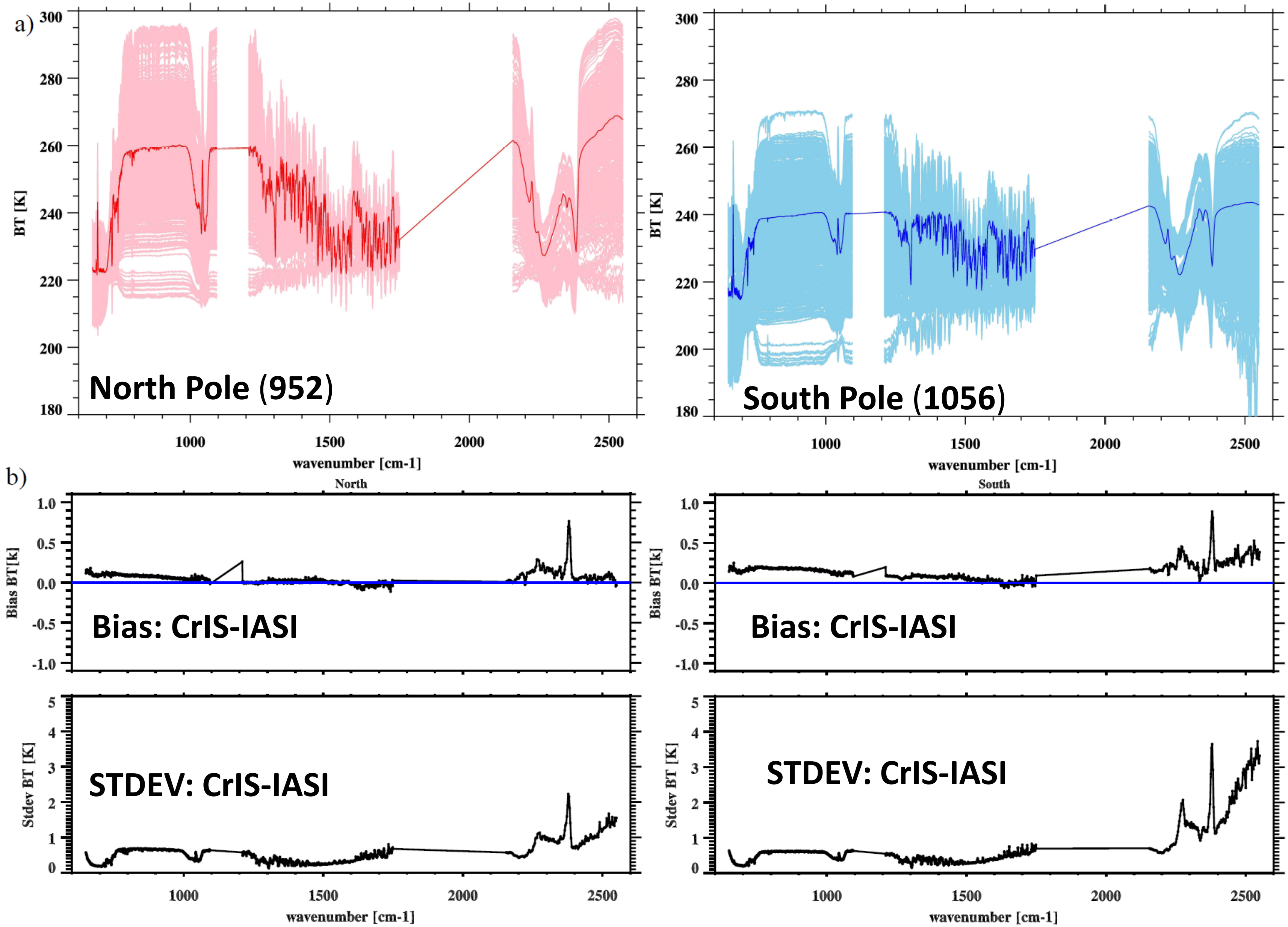
Re-sampling error very small

Inverse Fourier Transform

CrIS *vs.* IASI/MetOp-A

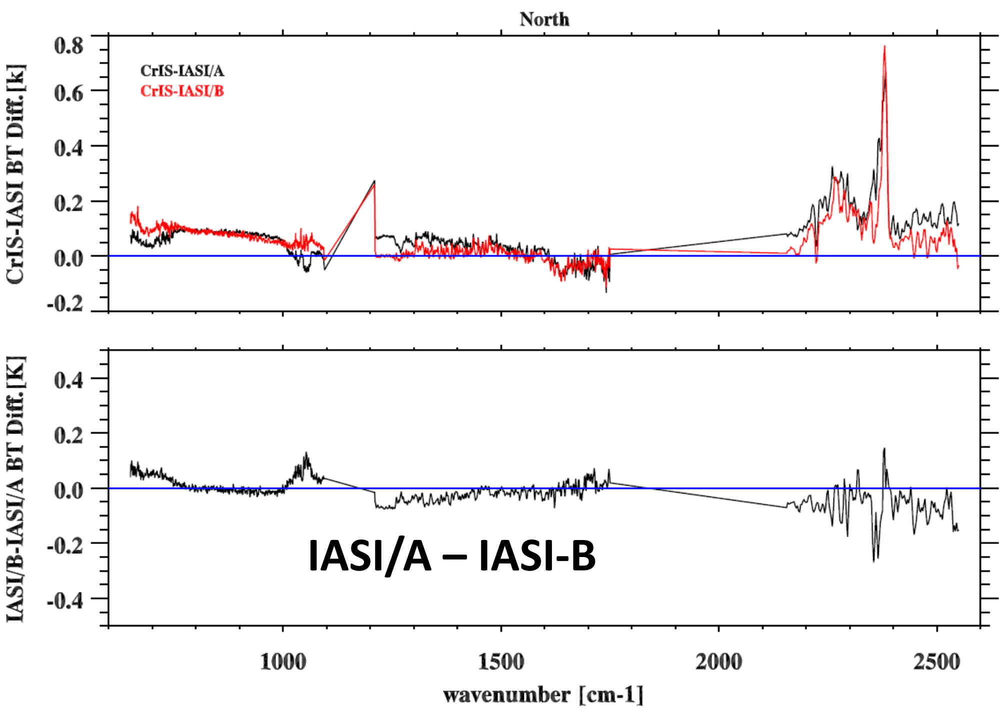


CrIS *vs.* IASI/MetOp-B

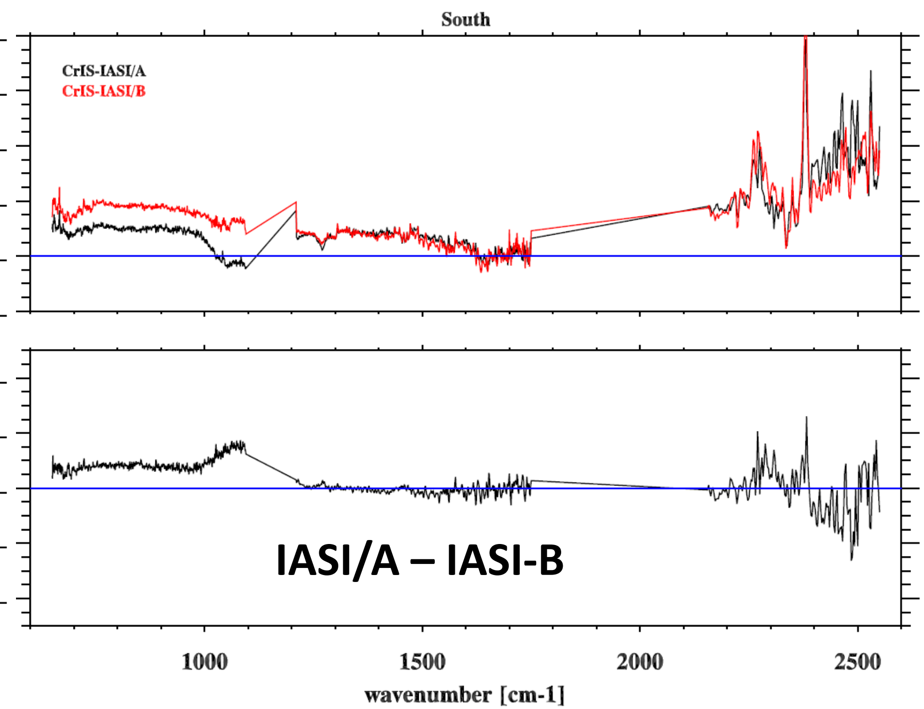


IASI/A minus IASI/B differences (CrIS-IASI/B)-(CrIS-IASI/A)

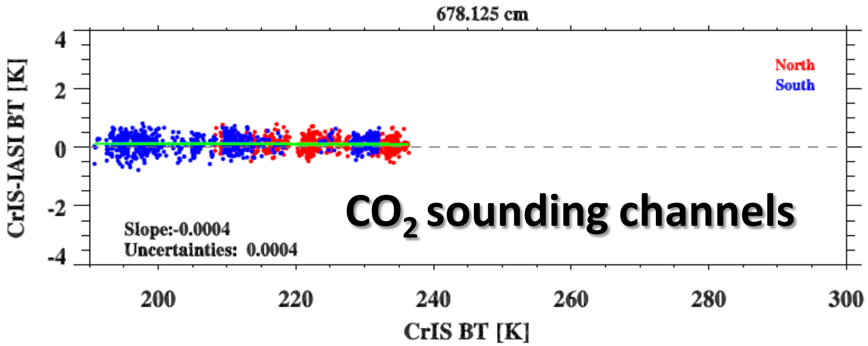
North Pole

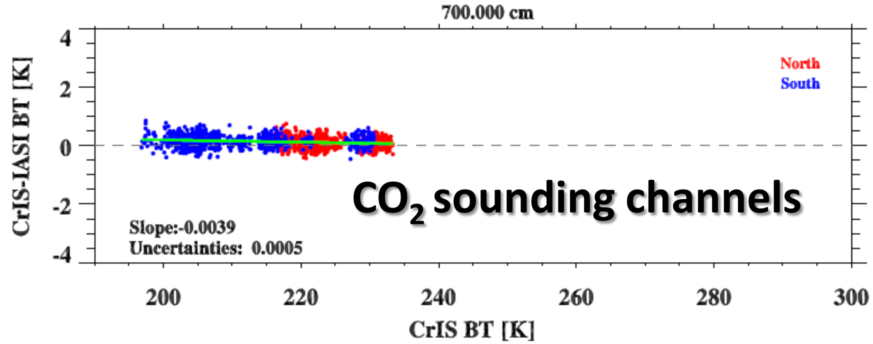


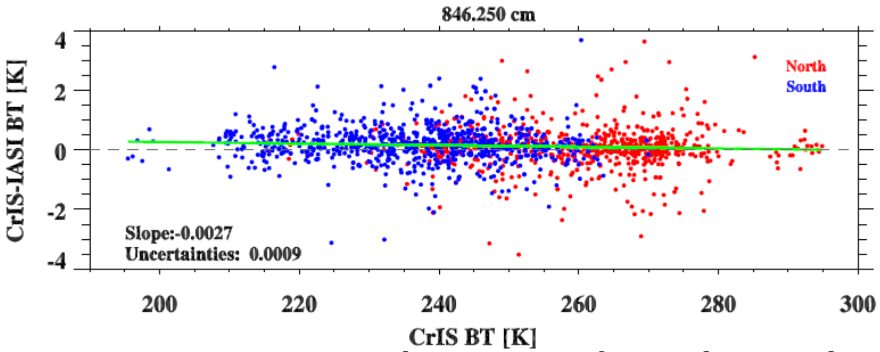
South Pole



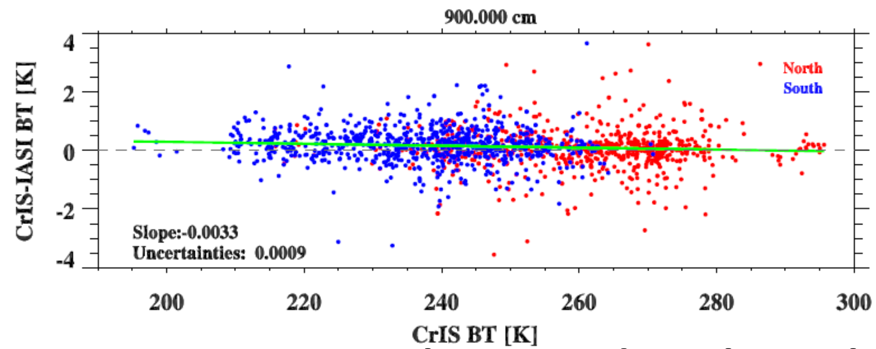
Scene-Dependent Bias



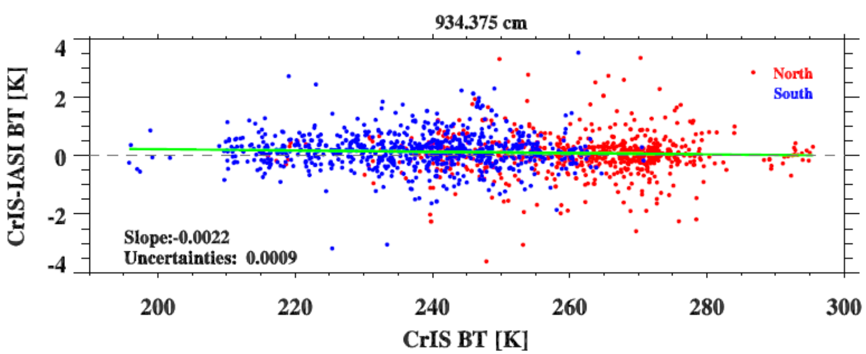




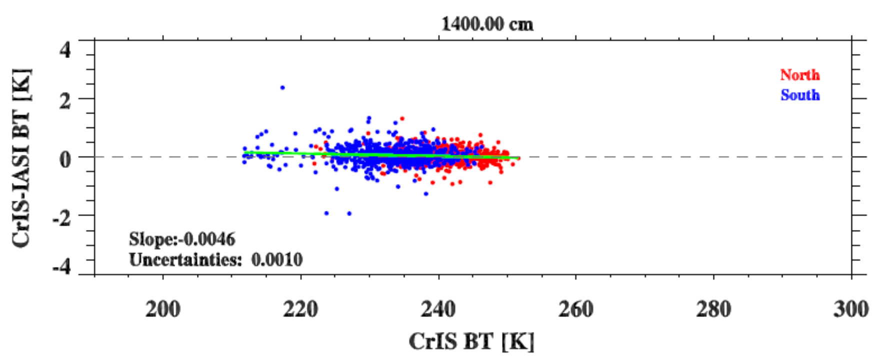
Atmospheric window channels



Atmospheric window channels

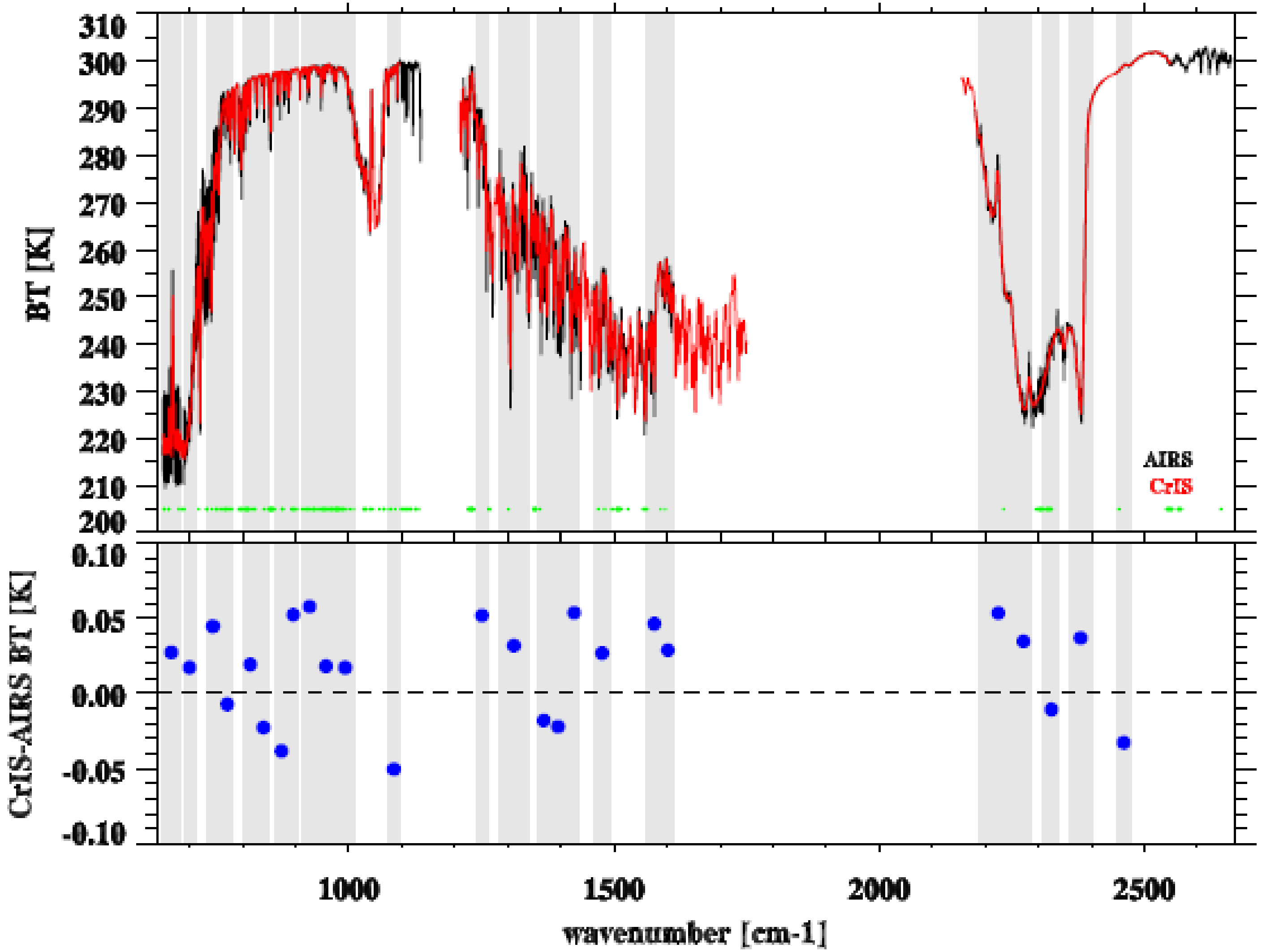


Atmospheric window channels



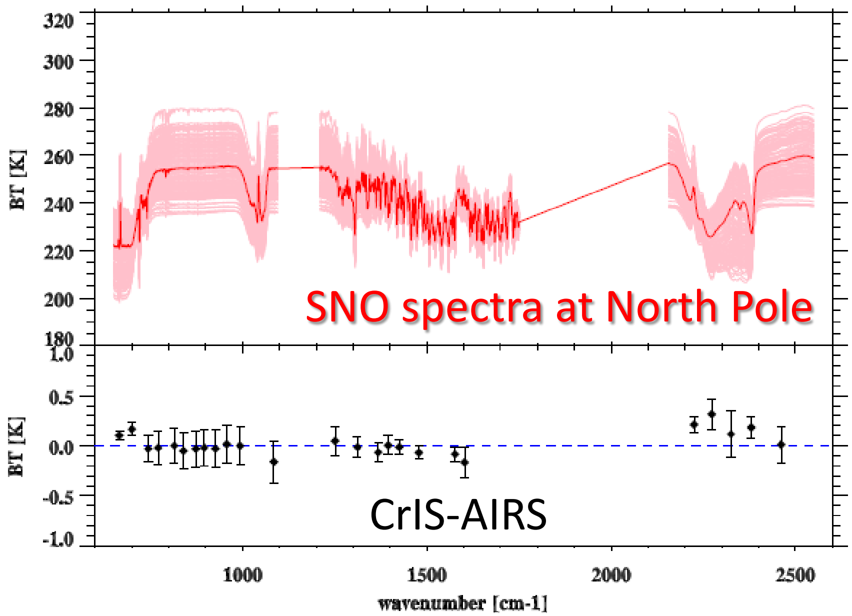
water vapor absorption channels

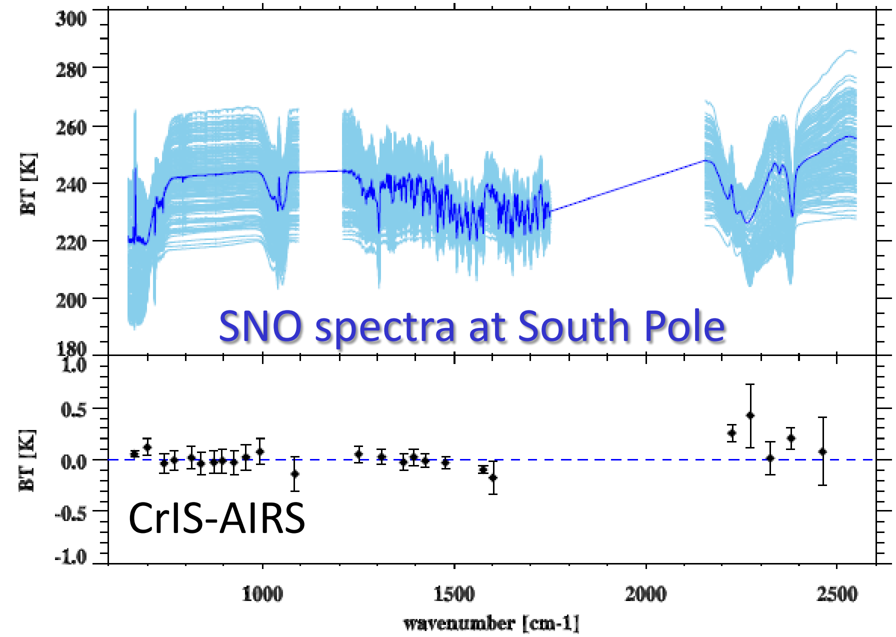
CrIS versus AIRS: Focus on 25 spectral regions

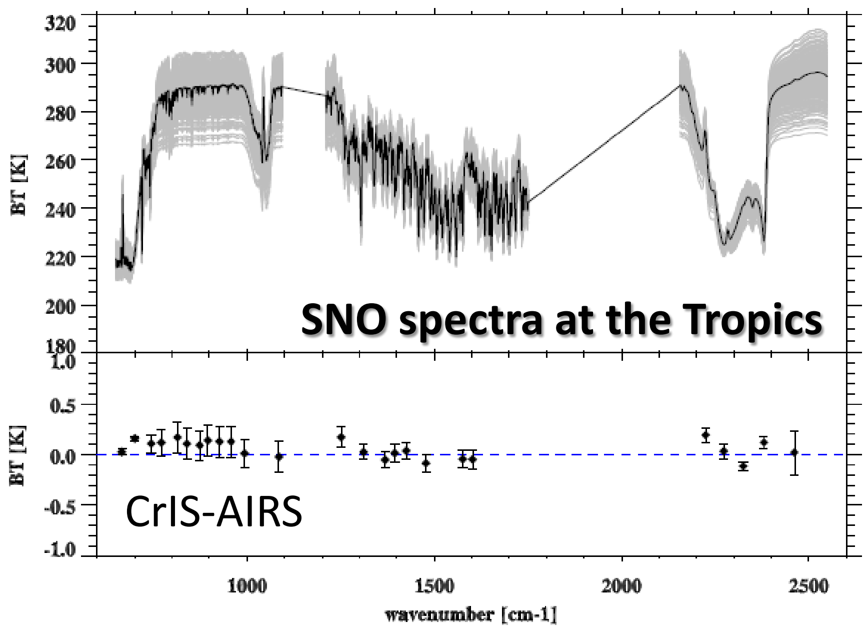


CrIS-AIRS reampling error is less than 0.06K with consideration of AIRS degraded channels.

CrIS vs. AIRS



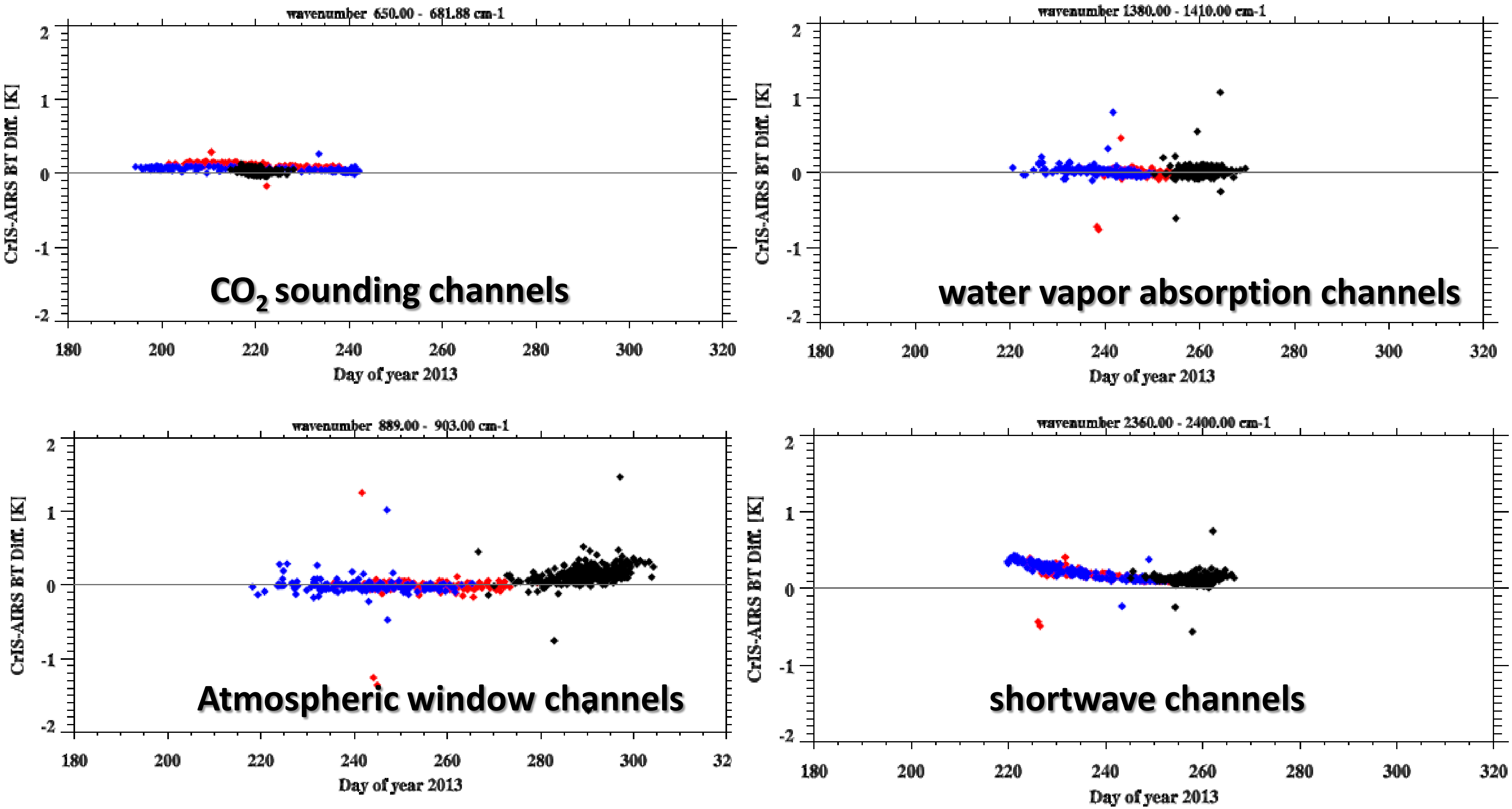




Longwave and middlewave: 0.1-0.2K

Shortwave: less than 0.4K

Scene-Dependent Bias



SNO spectra at North Pole

SNO spectra at South Pole

SNO spectra at the Tropics

Conclusion

- Radiometric and spectral consistency of four IR hyperspectral sounders is fundamental for inter-calibration and climate application.

- Inter-comparison of CrIS with IASI/Metop-A, IASI/Metop-B, and AIRS have been made for one year's of SNO observations in 2013.

- CrIS vs. IASI
  - IASI spectra are converted into CrIS spectral grid and the comparison is along CrIS spectral grid.
  - CrIS and IASI well agree each other at LWIR and MWIR bands with 0.1-0.2K differences
  - No apparent scene dependent bias.
  - At SWIR band, a sharp increases can be clearly seen at spectral transition region. The reason is still under investigation.

- CrIS vs. AIRS
  - CrIS and AIRS are integrated within 25 spectral regions.
  - CrIS and AIRS agree each other at LWIR and MWIR bands with the differences of 0.1-0.2 K .
  - At SWIR band, the differences is less than 0.4K.
  - scene dependent bias can be found for some regiones.

- The comparison will be continued until end of sensor mission, which will provide fundamental information about consistency of hyperspectral sounders to the community.

Dispersive versus Interferometer

Dispersive (*e.g.*, Grating)	Interferometer
Optics are solid state, grating is analogous to a solid state interferometer"	Requires moving mirror that is stable over 150 ms integration time.
Linear arrays w/ read out integrated circuits make a large number of detectors feasible and very fast to read out. Large number of detectors and read out circuits requires cooling.	Multiplex (Fellgett's) Advantage: all f's measured by one detector (rapid sampling in interferogram domain). Each time sample measures entire spectrum.
Detector noise is less sensitive to scene radiance. Focal plane requires coolingto achieve same signal to noise.	Throughput (Jacquinot's) Advantage: does not require a slit. One half of light strikes detector.
Frequencies are determined by geometry, therefore, instrument must be held constant in temperature. Small remnant frequency drift must be handled in radiative transfer.	Connes Advantage: Mirror distance (determines frequency of channels) can be measured with a reference laser that has a known frequency and is stable – therefore, a standard set of frequencies can be maintained.
Instrument design for multiple FOV's is too complex; however, low noise means fast integration time and having all FOV's measured by the same instrument is an advantage.	Multiple FOV's can be measured simultaneously. Sampling and resolution is determined by optical path and therefore, FOV's must be
Gratings are constant resolving power, therefore, both sampling and resolution change with frequency, $\Delta\nu = R/\nu$	Continuous spectrum at constant resolution that is Nyquist sampled, $\Delta\nu \cong 0.9/L$