S-NPP CrIS Full Resolution Sensor Data Record Processing and Evaluations

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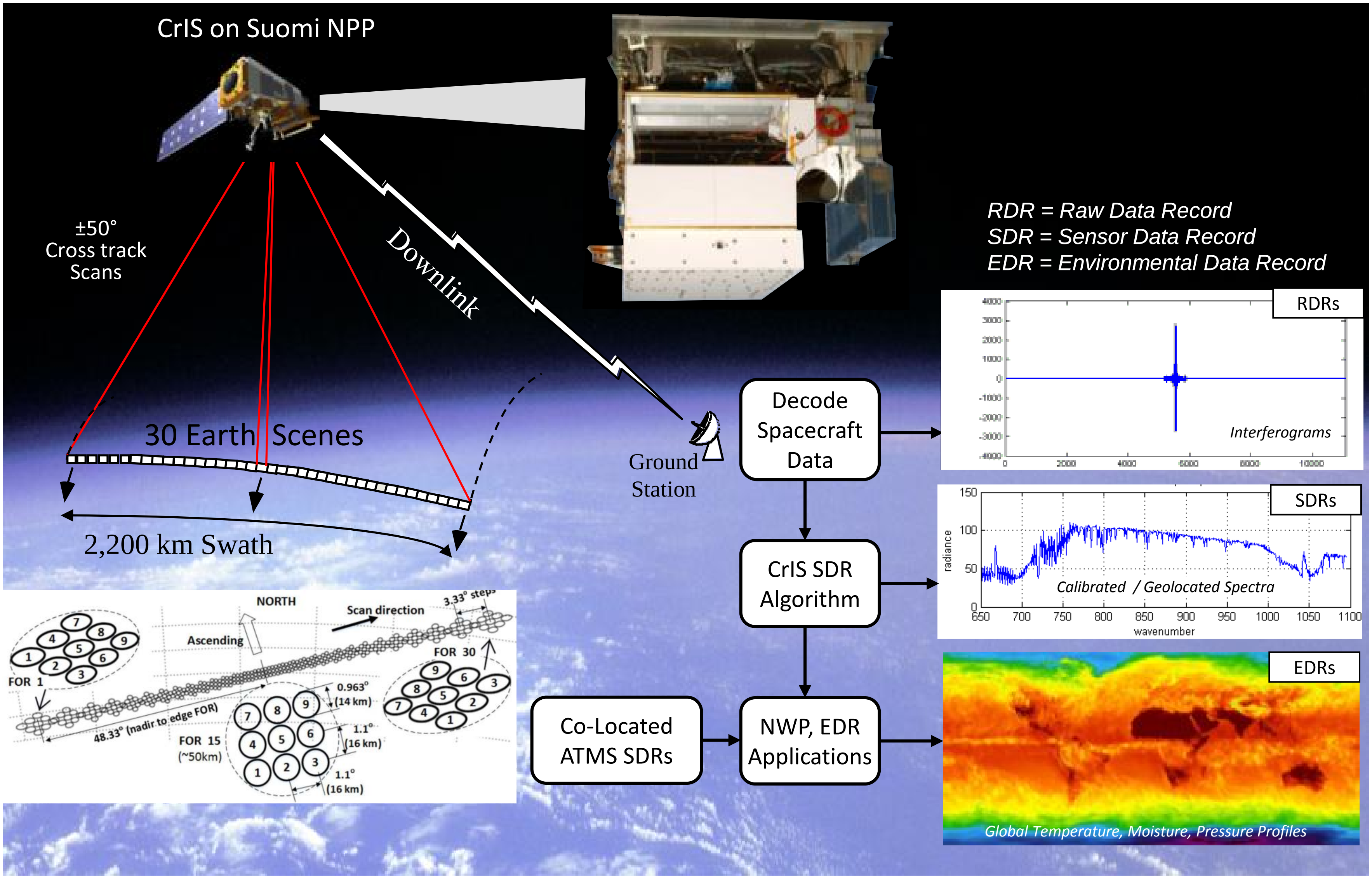
Outlines

- Upgraded ADL to generate CrIS full resolution mode Sensor Data Records (SDR)
- Radiometric accuracy assessment
  - Difference between observation and forward model simulation
  - Double difference (DD) between CrIS and IASI
  - Simultaneous Nadir Overpass (SNO) between CrIS and IASI
- Spectral accuracy assessment
  - Absolute spectral validation
  - Relative spectral validation
- Summary

CrIS Operational Concept

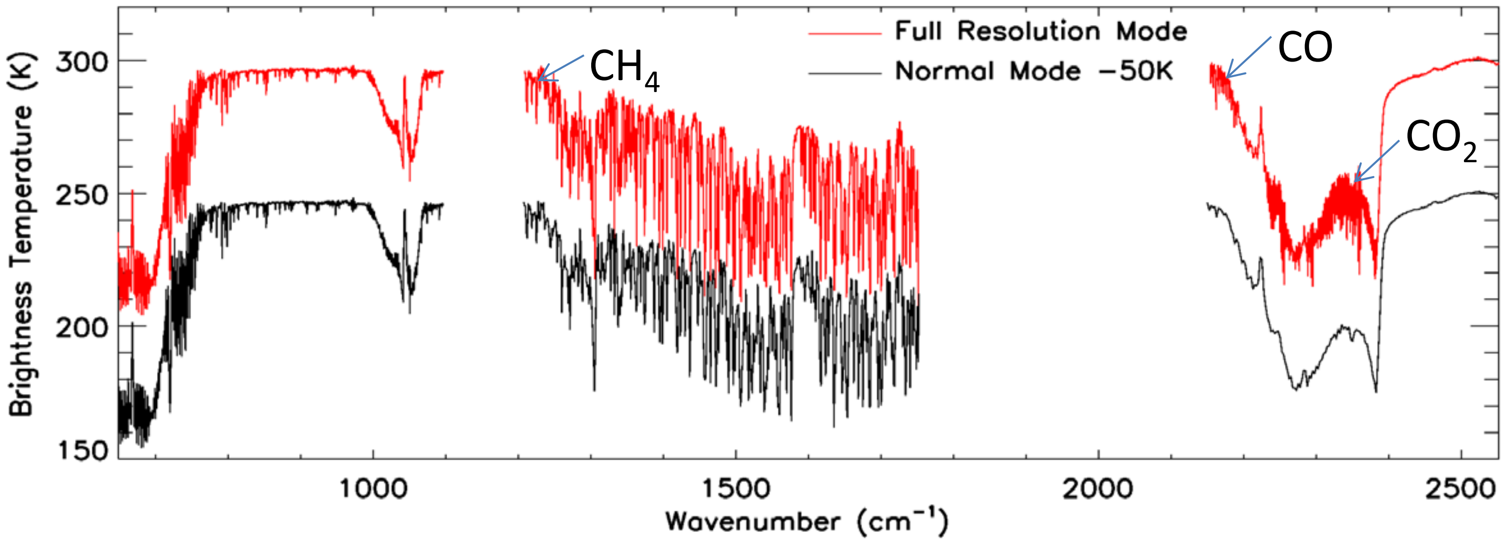


CrIS Normal Resolution and Full Resolution SDR

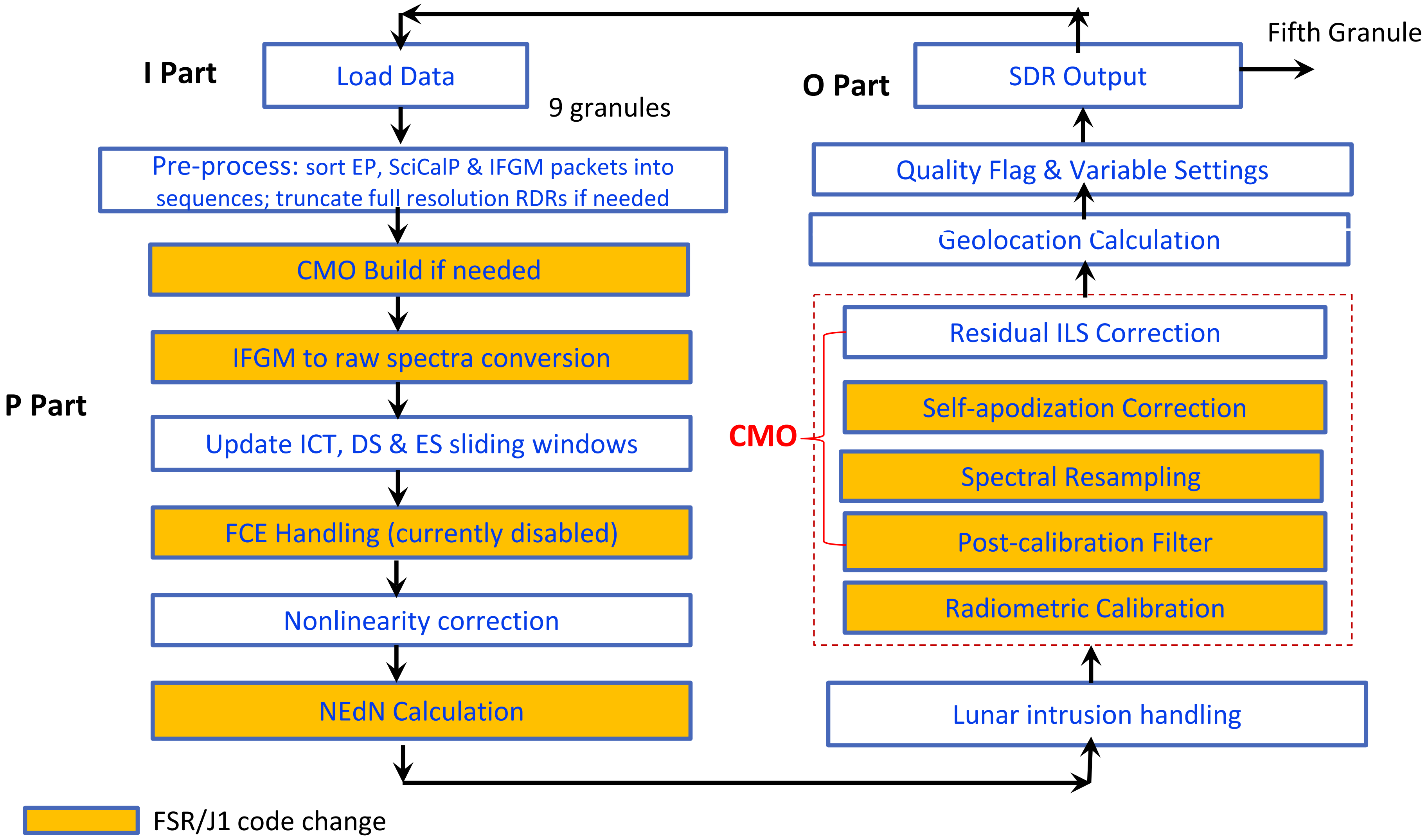
- CrIS can be operated in the full spectral resolution (FSR) mode with 0.625 cm^{-1} for all three bands, total 2211 channels, in addition to normal mode with 1305 channels
- NOAA will operate CrIS in FSR mode in December 2014 to improve the profile of H_2O, and the retrieval of atmospheric greenhouse gases CO, CO_2, and CH_4

Red: Full resolution

Frequency Band	Spectral Range (cm^{-1})	Number of Channel (unapodized)	Spectral Resolution (cm^{-1})	Effective MPD (cm)
LWIR	650 to 1095	713* (717)	0.625	0.8
MWIR	1210 to 1750	433* (437)	1.25	0.4
		865* (869)	0.625	0.8
SWIR	2155 to 2550	159* (163)	2.5	0.2
		633* (637)	0.625	0.8

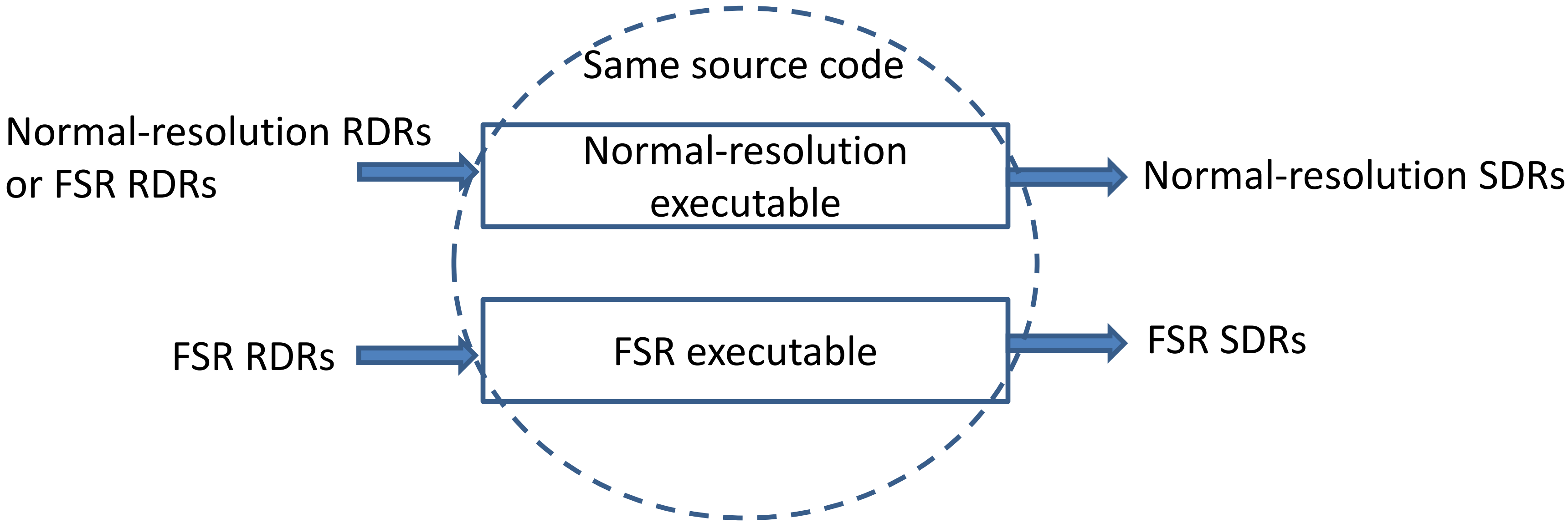


CrIS SDR Processing Major Modules



CrIS Full Resolution SDR ADL Code

- The FSR ADL code is based on the IDPS Block 2.0, Mx8.5
- Different calibration approaches are implemented in the code in order to study the ringing effect observed in CrIS normal mode SDR and to support to select the best calibration algorithm for J1
- Code is modularized and flexible to run different calibration approaches
- The same source code can be compiled into normal-resolution executable or FSR executable:

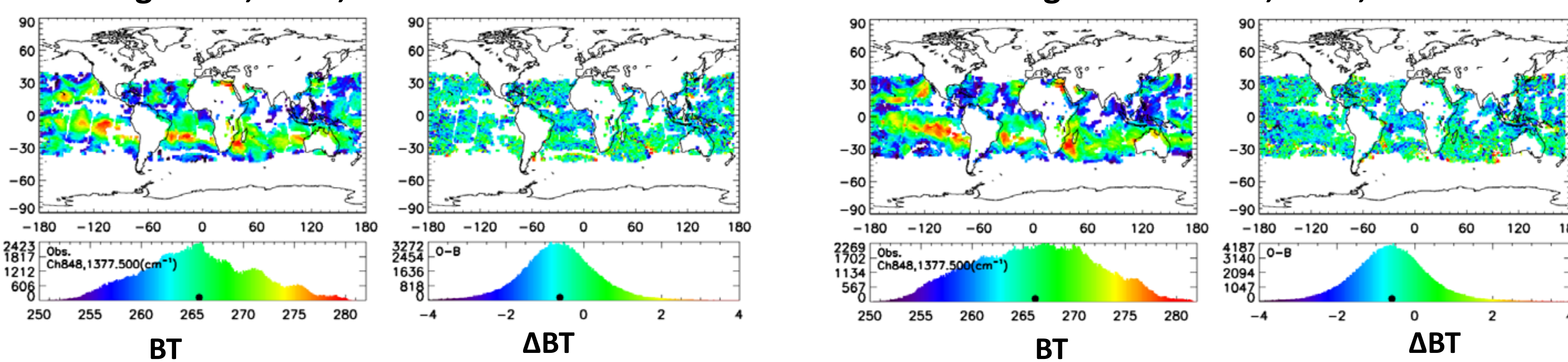


- The FSR ADL code is completed and delivered to CrIS SDR science team members and Raytheon Company to test

FSR SDR Processing Plan

- S-NPP CrIS will be switched from the normal spectral resolution mode to the full spectral resolution mode in early December, 2014
- IDPS and CLASS will continue producing and archiving normal resolution SDRs
- NOAA/STAR will routinely process the full resolution data and generate the FSR SDRs with a latency of ~24 hours, beginning on the first day of the CrIS FSR mode operation
- The data will be available on a STAR FTP site using the upgraded ADL CrIS SDR code
- Up to date, the FSR mode has been commanded three times in-orbit (02/23/2012, 03/12/2013, and 08/27/2013)

August 27, 2013, before FSR **August 27 and 28, 2013, FSR**



Ch 848, 1377.5 cm^{-1}, water vapor channel

Results show that the SDR from FSR has similar features compared to SDR generated from low resolution RDR

CrIS Radiometric Assessment

- Validation of August 27-28, 2013 full spectral resolution data
- Upgraded ADL code used to generate full spectral resolution SDRs with updated non-linearity coefficients, ILS parameters, and sincq function for Correction Matrix Operator (CMO) for IDPS calibration approach.
- Assessment approach 1: Biases between CrIS observations and simulations using ECMWF analysis/forecast fields and forward model CRTM (Community Radiative Transfer Model)

$$BIAS = \overline{(Obs - CRTM)}$$

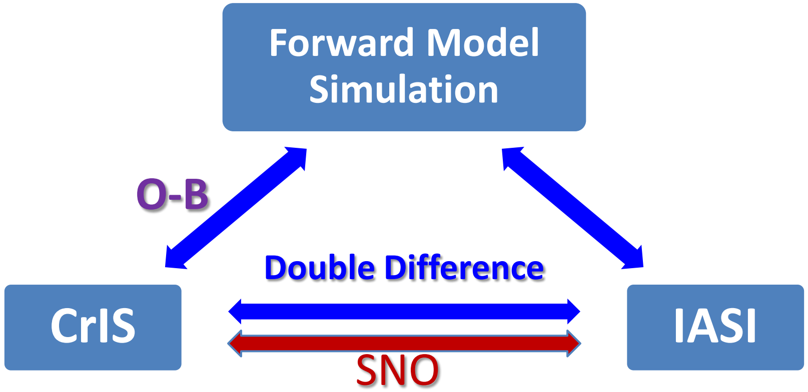
- Assessment approach 2: Double difference between CrIS and IASI on MetOp-a/b (converted to CrIS) using CRTM simulation as a transfer tool

$$DD = \overline{(Obs - CRTM)_{CrIS}} - \overline{(Obs - CRTM)_{IASI2CrIS}}$$

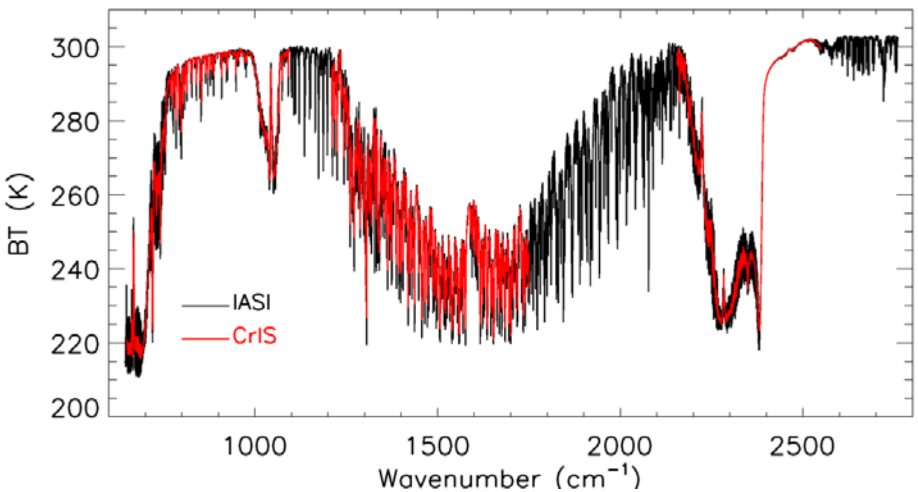
- Assessment approach 3: SNO difference between CrIS and IASI converted to CrIS

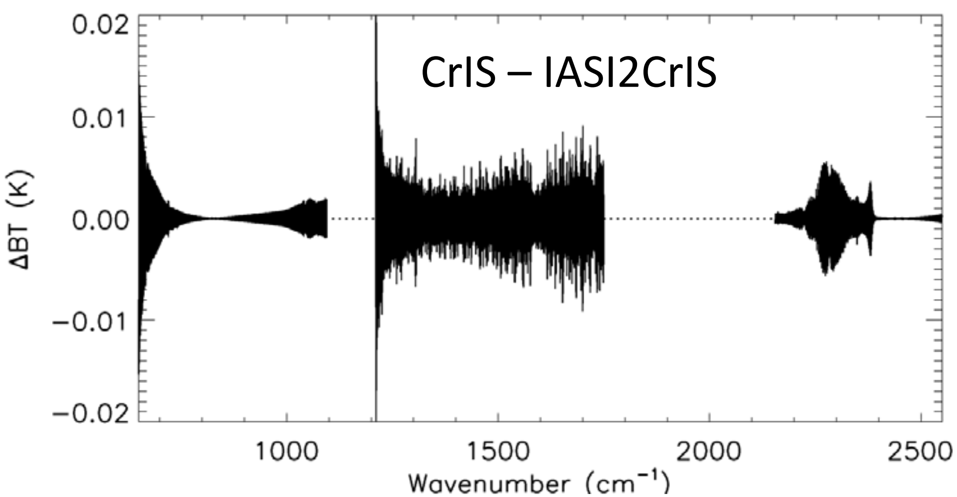
$$BT_{diff} = BT_{CrIS} - BT_{IASI2CrIS}$$

Three Approaches



Resample IASI to CrIS





IASI Observed Spectra

FFT^{-1}

Inverse Fourier transform of the spectra to the interferogram space

Apodization Function

1) De-Apodization with IASI SRF
2) Truncation to CrIS OPD
3) Apodization with CrIS SRF

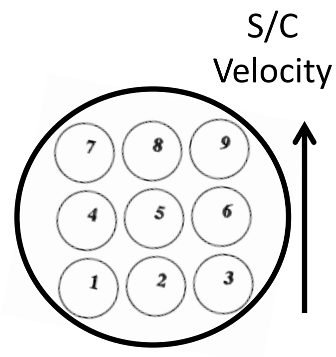
FFT

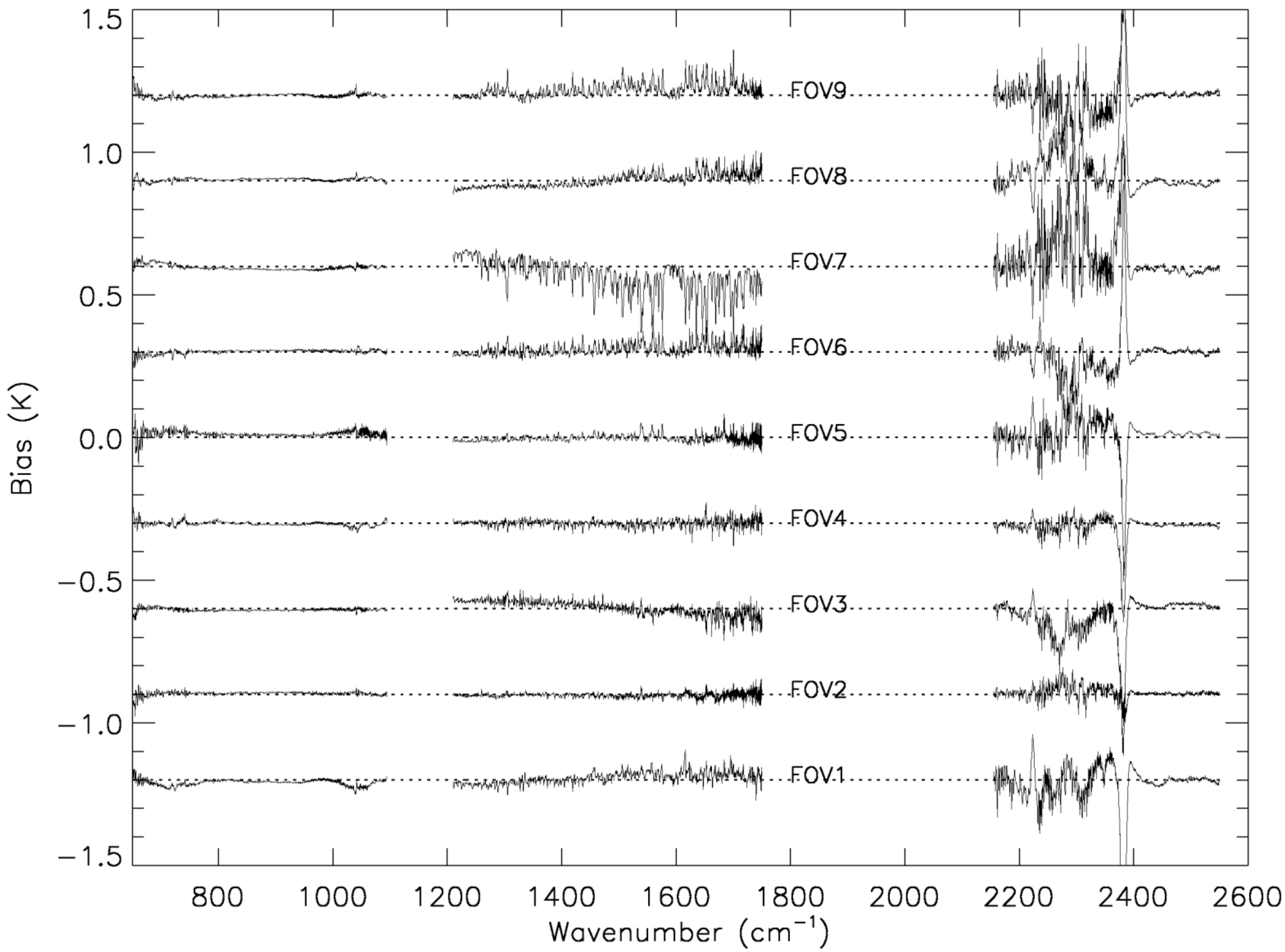
Fourier transform of the products to spectra space, resampling the spectra on CrIS wavenumber basis.

- Resampling error from IASI to CrIS resolution is very small (less than 0.02 K) since IASI spectra cover CrIS spectra for all three bands

CrIS Nadir FOV-2-FOV Variability (FOR 15 and 16) for Clear Sky over Oceans

$$BIAS_{FOV_i} = \overline{(Obs - CRTM)_{FOV_i}} - \overline{(Obs - CRTM)_{all}}$$

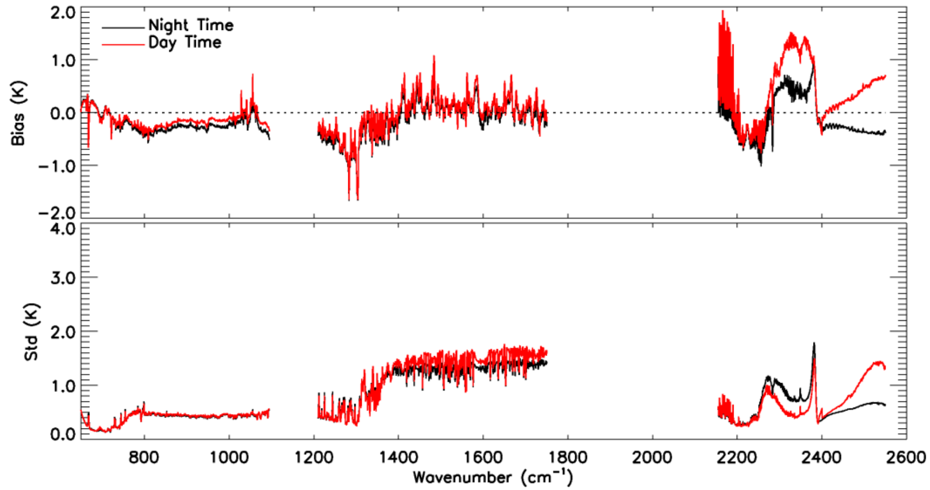




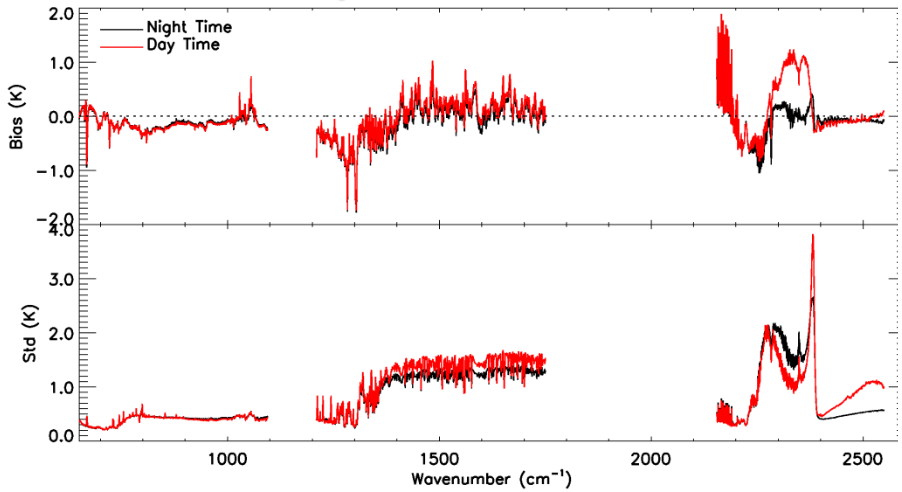
- **FOV-2-FOV variability is small, within ±0.3 K for all the channels**

CrIS and IASI2CrIS NWP Biases: Clear Ocean Scenes

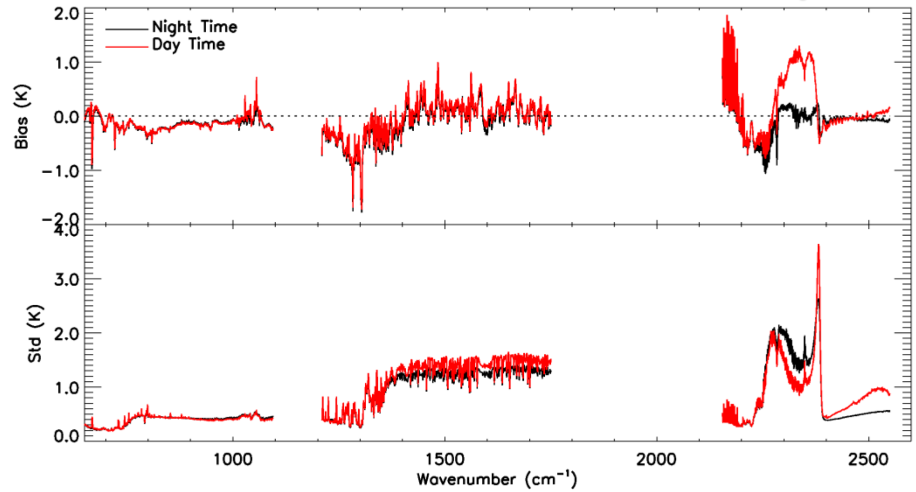
CrIS



IASI2CrIS MetOp-a



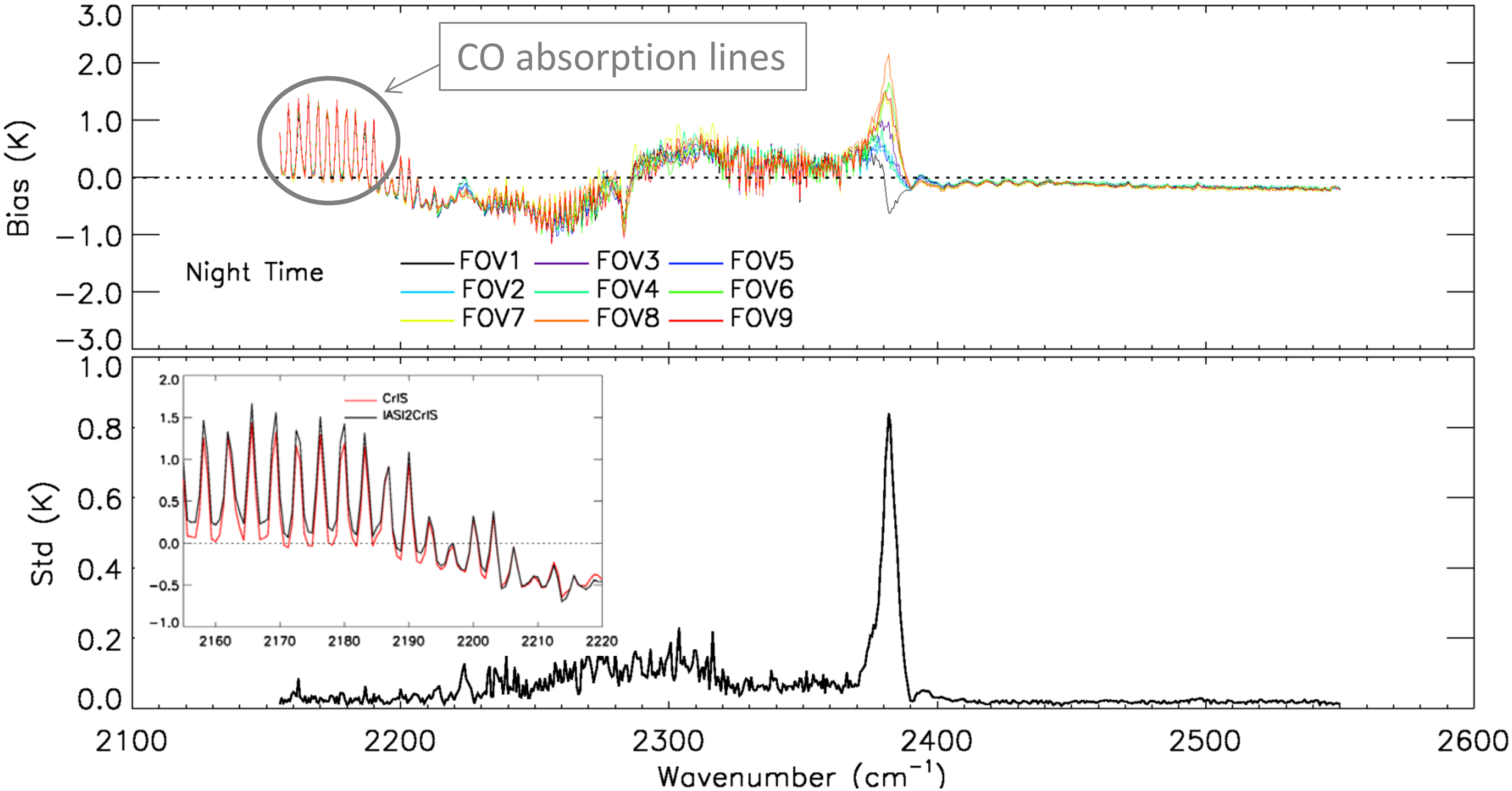
IASI2CrIS MetOp-b



- Good agreement between CrIS observation and simulation using ECMWF
- Very good agreement between CrIS and IASI
- Smaller standard deviation for CrIS than IASI in band 3

CrIS Nadir Bias for Shortwave

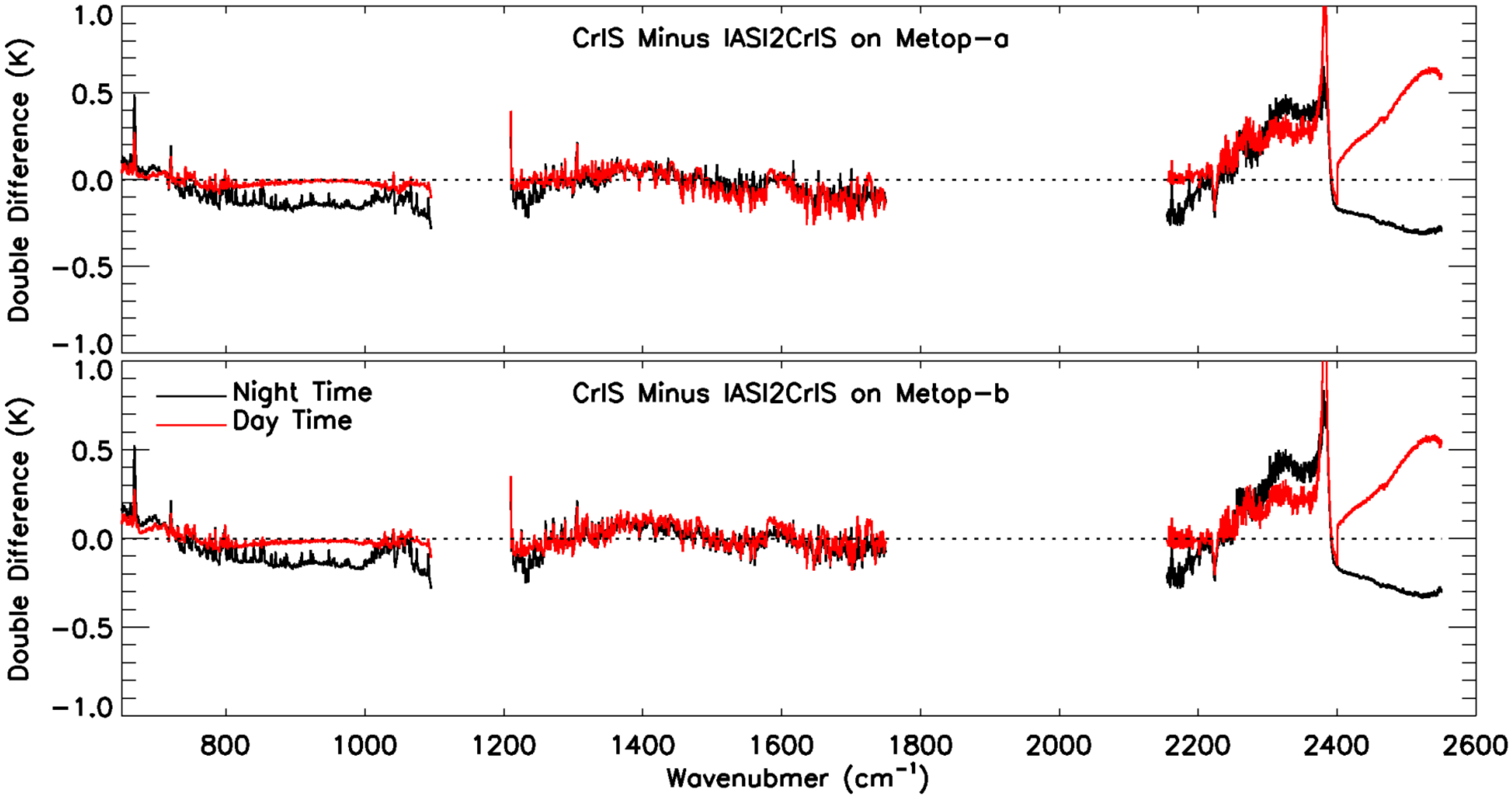
$$BIAS_{FOV_i} = \overline{(Obs - CRTM)_{FOV_i}}$$



- Good agreement between IASI and CrIS, better than bias with CRTM
- CO high bias errors due to CO default profile in CRTM
- CrIS and IASI window channels differ by 0.1 K due to diurnal variation in the SST

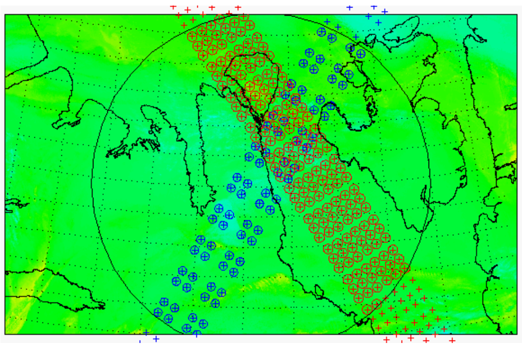
Double Difference between CrIS and IASI2CrIS

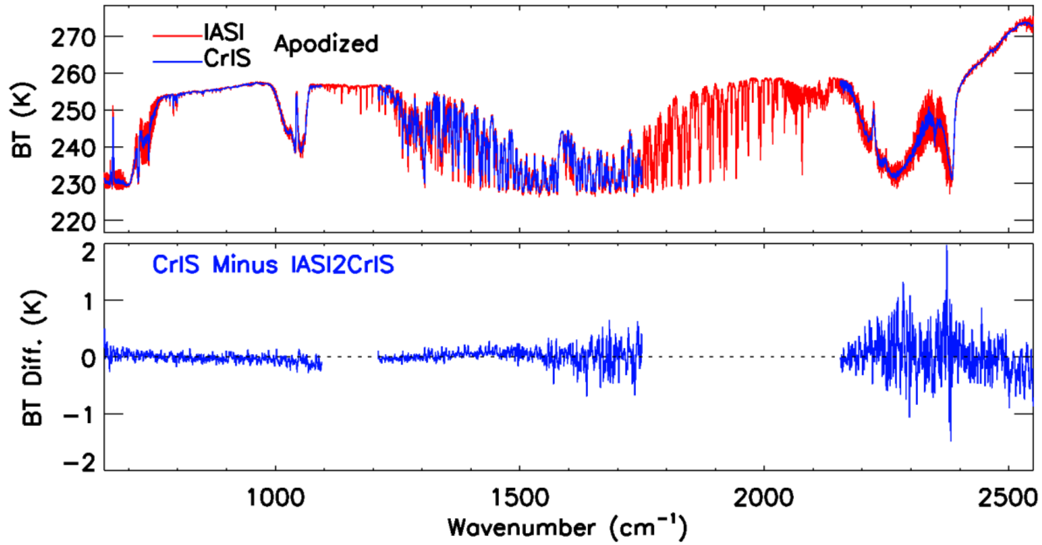
$$DD = \overline{(Obs - CRTM)_{CrIS}} - \overline{(Obs - CRTM)_{IASI2CrIS}}$$



- Double difference between CrIS and IASI using CRTM simulations as transfer target are within ±0.3 K for most of channels
- For 4.3 µm CO_2 strong absorption region, CrIS is warmer than IASI about 0.3-0.5 K
- CrIS and IASI window channels differ by 0.1 K due to diurnal variation in the SST

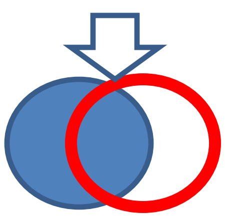
SNOs between CrIS and IASI

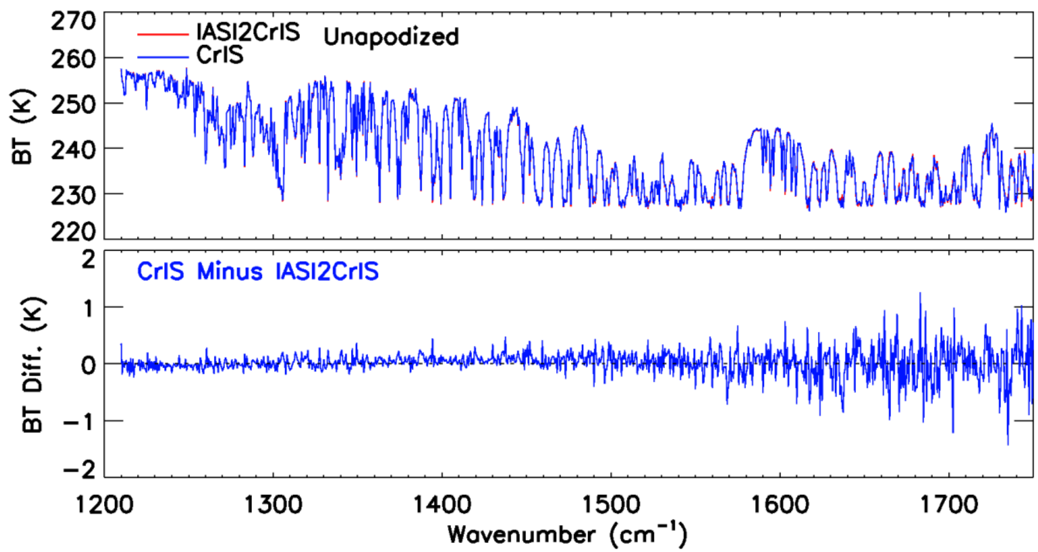




SNO Criteria

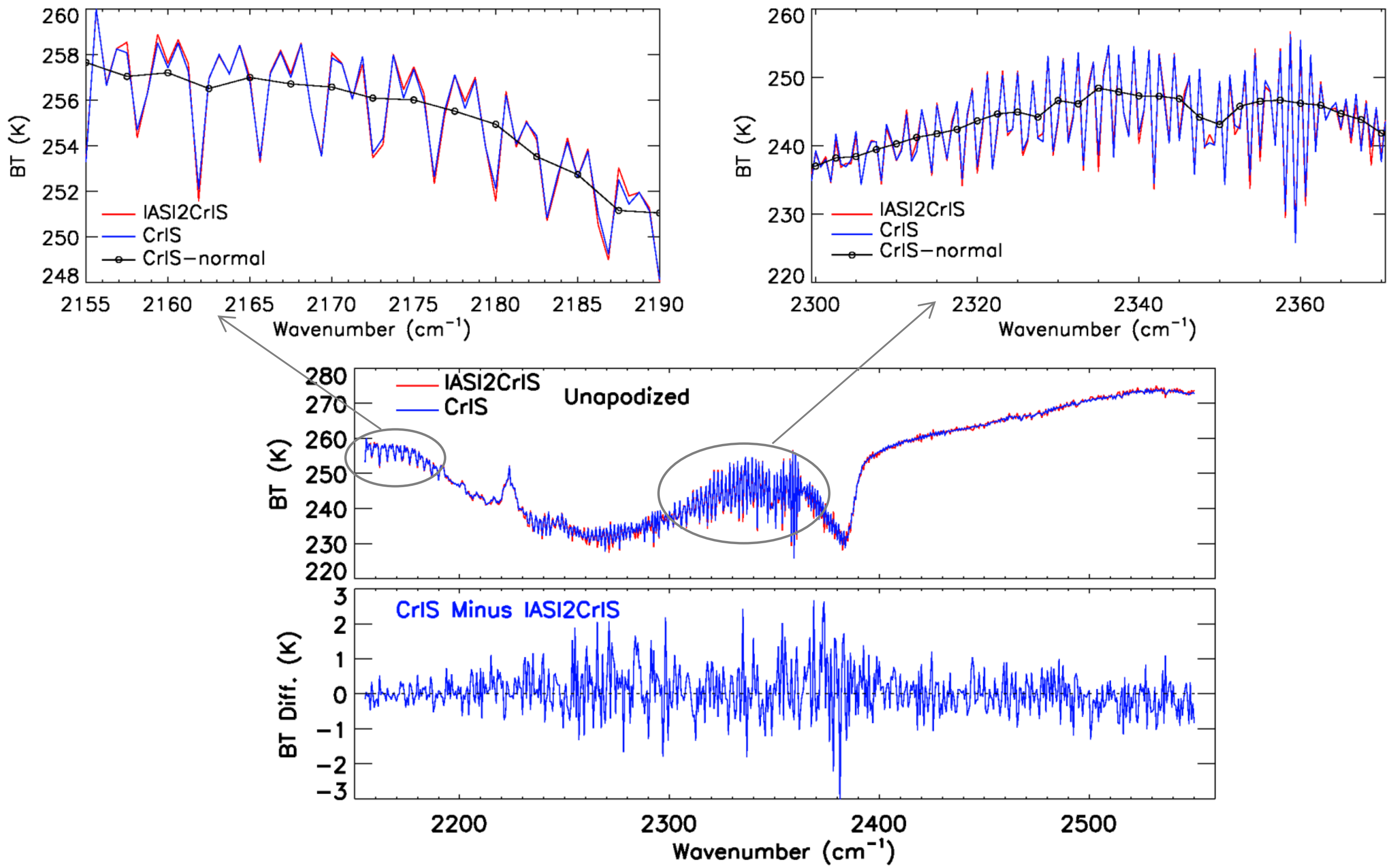
- Time difference: <= 120 seconds
- Pixel distance: <=(12+14)/4.0 km = 6.5 km
- Zenith angle difference: ABS(cos(a1)/cos(a2)-1) <= 0.01





- SNO agreement is very good for band 1. Also good for band 2, but larger BT difference toward the end of band edge
- Large BT differences in cold channels for band 3

SNOs between CrIS and IASI: Details



- Although there is large BT difference in band 3, line structures in CO and CO_2 regions show very good agreement between CrIS and IASI
- Line structure in CO (2155-2190 cm^{-1}) region provides very good information to retrieve CO amount, and line structure in CO_2 absorption band (2300-2370 cm^{-1}) provides very good spectral calibration information

CrIS Spectral Assessment: Cross-Correlation Method

- Two basic spectral validation methods are used to assess the CrIS SDR spectral accuracy
- Relative spectral validation, which uses two uniform observations to determine frequency offsets relative to each other
- Absolute spectral validation, which requires an accurate forward model to simulate the top of atmosphere radiance under clear conditions and correlates the simulation with the observed radiance to find the maximum correlation

Correlation coefficient between the two spectra:

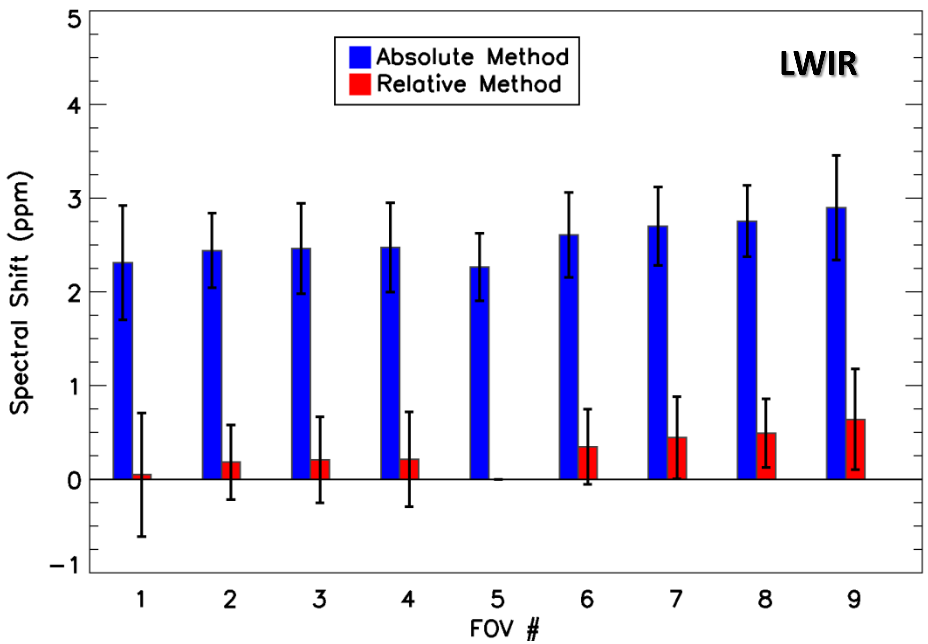
$$r_{S_1 S_2} = \frac{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})(S_{2,i}-\overline{S_2})}{(n-1)D_{s_1}D_{S_2}} = \frac{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})(S_{2,i}-\overline{S_2})}{\sqrt{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})^2(S_{2,i}-\overline{S_2})^2}},$$

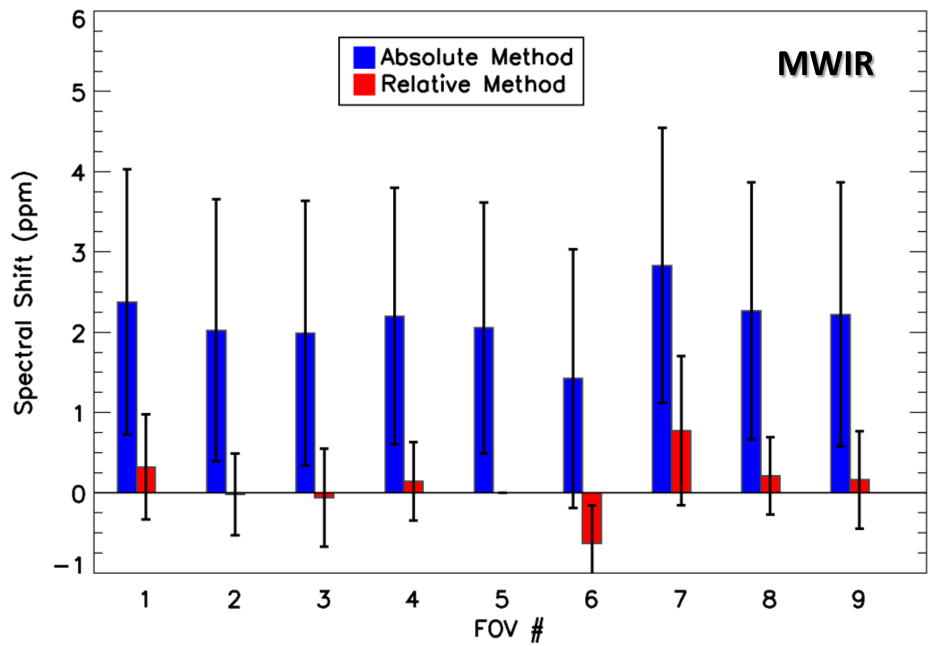
Standard deviation based on the difference of the two spectra:

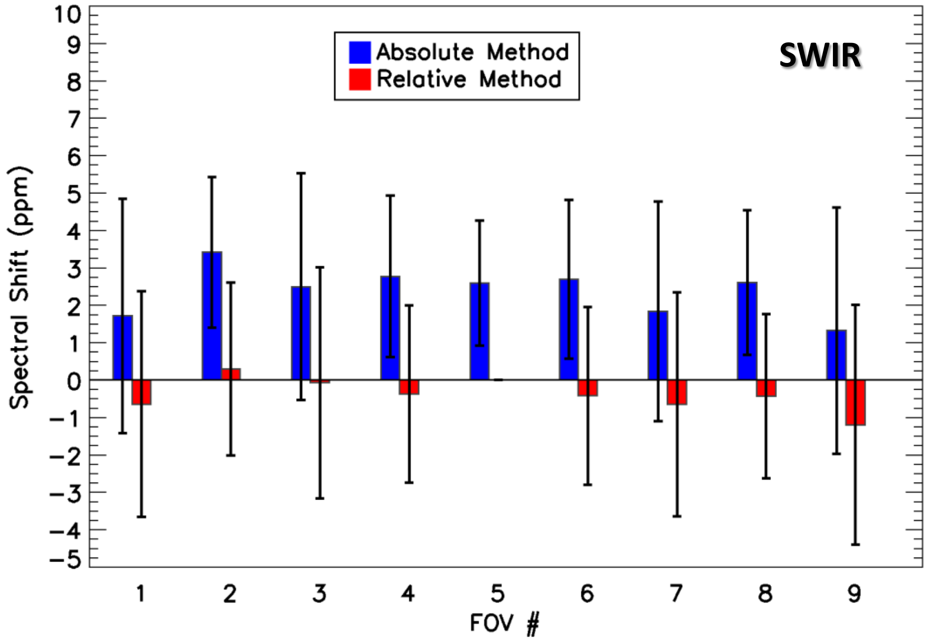
$$D_{S_1 S_2} = \sqrt{\sum_{i=1}^{n}[(S_{1,i}-\overline{S_1})-(S_{2,i}-\overline{S_2})]^2 \Big/ (n-1)}.$$

The cross-correlation method is applied to a pair fine grid spectra to get the maximum correlation and minimum standard deviation by shifting one of the spectra in a given shift factor

CrIS Spectral Uncertainty







- Absolute cross-correlation method: between observations and CRTM simulations under clear sky over oceans to detect the spectral shift
- Relative method: observations from FOV 5 to other FOVs
- Frequency used: 710-760 cm^{-1} , 1340-1390 cm^{-1} , and 2310-2370 cm^{-1}
- **Spectral shift relative to FOV5 are within 1 ppm**
- **Absolute spectral shift relative to CRTM within 3 ppm**

Summary

- The CrIS full resolution SDRs generated from the upgraded ADL were assessed

- CrIS full resolution SDR radiometric uncertainty:
  - FOV-2-FOV radiometric differences are small, within ±0.3 K for all the channels
  - Double difference with IASI are within ±0.3K for most of channels
  - SNO results versus IASI show that agreement is very good for band 1 and band 2, but large BT differences in cold channels for band 3

- CrIS full resolution SDR spectral uncertainty:
  - Spectral shift relative to FOV5 are within 1 ppm
  - Absolute spectral shift relative to CRTM simulation are within 3 ppm

- Future Work: assessing different calibration approaches which are implemented in ADL to study the ringing effect to choose the best one for J1