CrIS Full Resolution Processing and Validation System for JPSS

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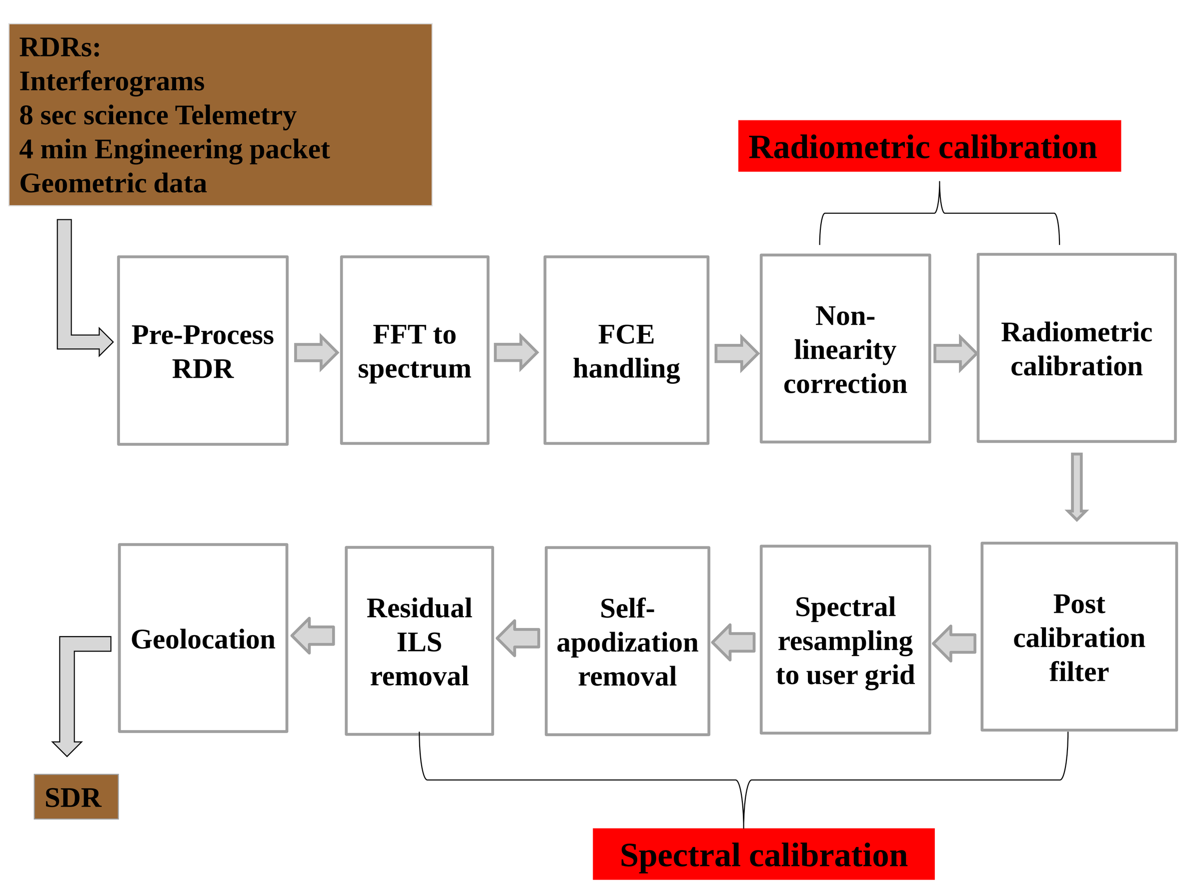
Abstract

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer and provides a total of 1305 channels in normal mode for sounding the atmosphere. CrIS can also be operated in the full spectral resolution (FSR) mode, in which the MWIR and SWIR band interferograms are recorded with the same maximum path difference as the LWIR band and with spectral resolution of 0.625 cm^{-1} for all three bands (total 2211 channels). NOAA intends to operate CrIS in FSR mode in the near future for SNPP and the Joint Polar Satellite System (JPSS). Up to date, the FSR mode has been commanded three times in-orbit (02/23/2012, 03/12/2013, and 08/27/2013). Based on CrIS Algorithm Development Library (ADL), CrIS full resolution Processing System (CRPS) has been developed to generate the FSR Sensor Data Record (SDR). We also are developing the CrIS FSR SDR Validation System (CRVS) to quantify the CrIS radiometric and spectral accuracy, since they are crucial for improving its data assimilation in the numerical weather prediction, and for retrieving atmospheric trace gases.

CrIS FSR Processing System (CRPS)



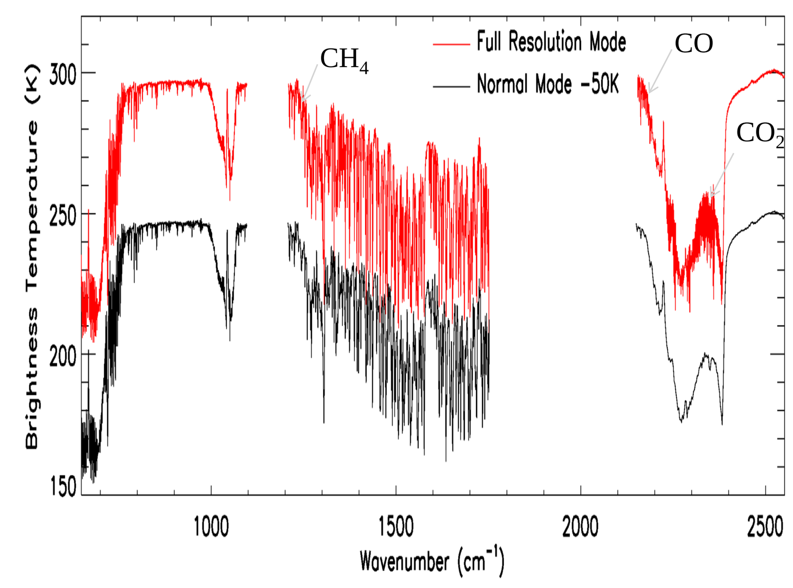
- CrIS SDR Algorithm product comprises the radiance, NEdN (noise), geolocation, and data quality flags.
- The CrIS SDR algorithm data flow is currently being reevaluated. The spectral resampling (to user's grid) step is performed before the Instrument line shape (ILS) correction which comprises the self-apodization removal. At the time of writing, 10 algorithm data flow candidates are being considered. The preferred new algorithm will reorder the steps such that the spectral resampling is performed after the ILS correction.
- In order to select the next algorithm for JPSS-1, Data set (such as full resolution of SDR) will need to be reprocessed multiple times.

CrIS Full Resolution SDR

Frequency Band	Spectral Range (cm^{-1})	Number of Channel (unapodized channel)	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

Red: Full resolution

- CrIS can be operated in the full spectral resolution (FSR) mode with 0.625 cm^{-1} for all three bands, total 2211 channels
- To Improve the retrieval of atmospheric greenhouse gases CO, CO_2, and CH_4
- NOAA intends to operate CrIS in FSR mode in the near future, up to date, the FSR mode has been commanded three times in-orbit (02/23/2012, 03/12/2013,and 08/27/2013)



- An example of CrIS SDR LWIR, MWIR, and SWIR normal and FSR spectra produced by ADL
- CH_4 absorption band (1210 – 1400 cm^{-1}), CO absorption band (2155-2190 cm^{-1}), and CO_2 absorption band (2300-2370 cm^{-1})

CrIS Radiometric Assessment

- Validation of August 27-28, 2013 high-spectral resolution data
- Assessment approach 1: Biases between CrIS observations and simulations using ECMWF analysis/forecast fields and forward model CRTM (Community Radiative Transfer Model)

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

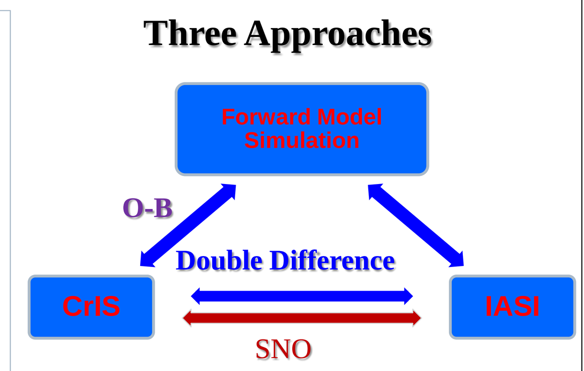
- Assessment approach 2: Double difference between CrIS and IASI on MetOp-a/b (converted to CrIS) using CRTM simulation as a transfer tool

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

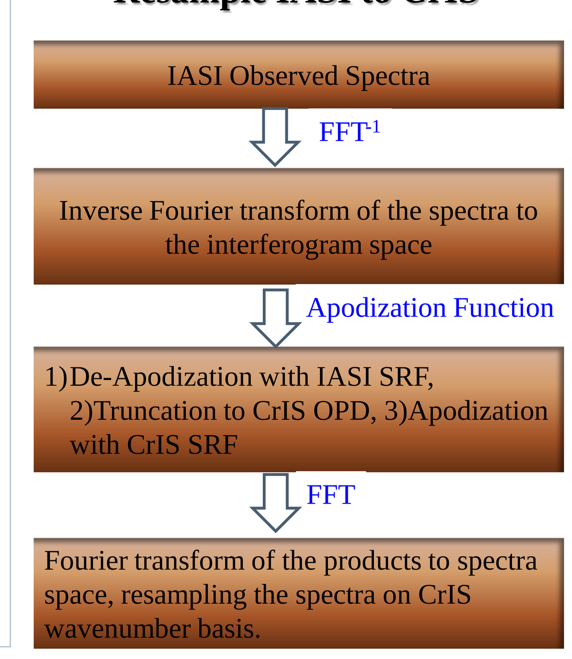
- Assessment approach 3: SNO difference between CrIS and IASI converted to CrIS

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

Three Approaches

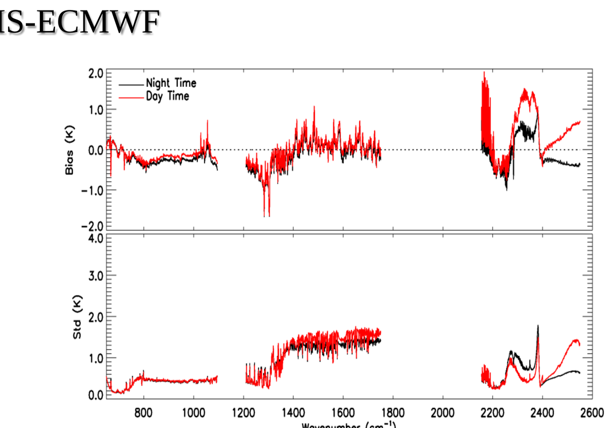


Resample IASI to CrIS



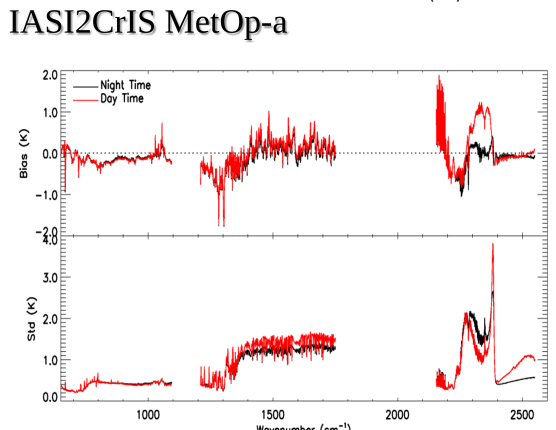
CrIS and IASI2CrIS NWP Biases: Clear Ocean Scenes

CrIS-ECMWF

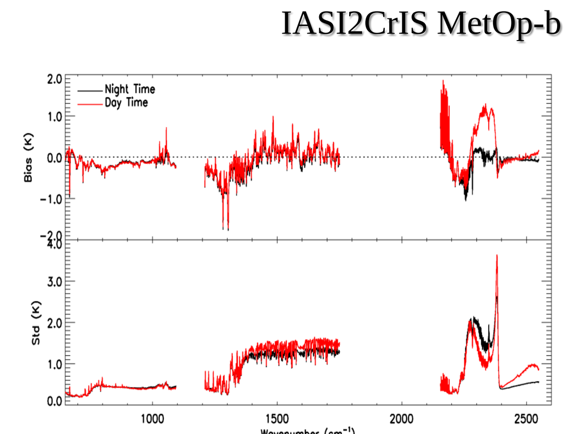


- Good agreement between CrIS observation and simulation using ECMWF
- Very good agreement between CrIS and IASI
- Smaller standard deviation for CrIS than IASI in band 3

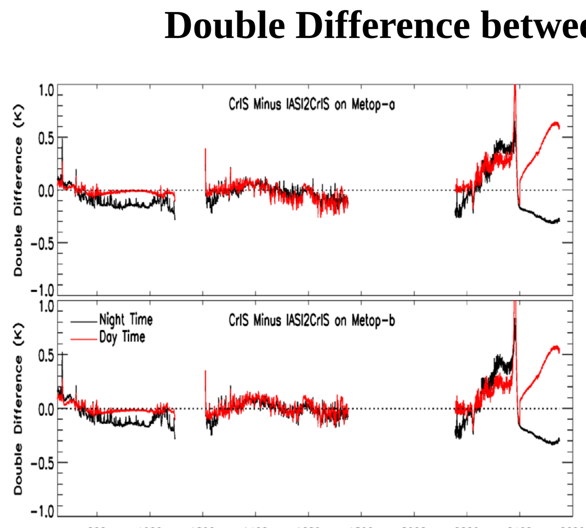
IASI2CrIS MetOp-a



IASI2CrIS MetOp-b

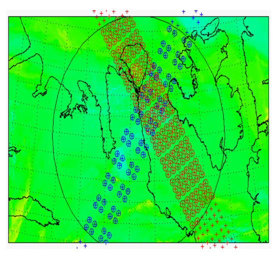


Double Difference between CrIS and IASI2CrIS



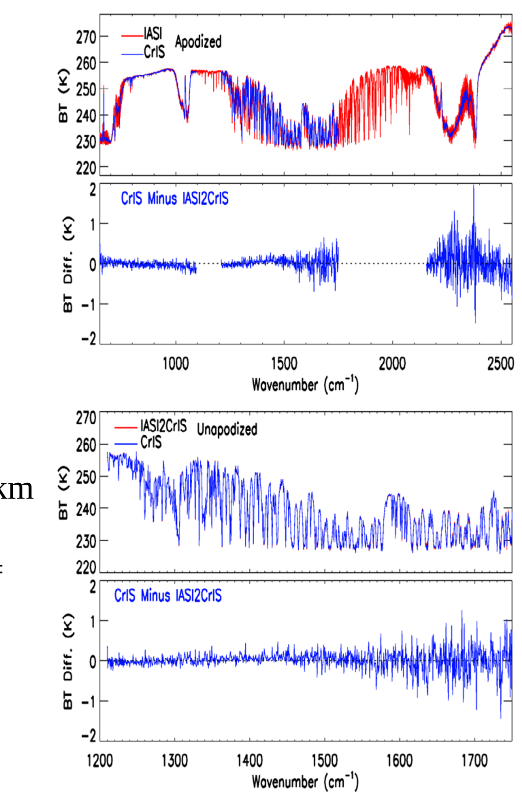
- Double differences of CrIS and IASI relative to CRTM calculated radiance are within ±0.3 K for most of channels
- For 4.3 µm CO_2 strong absorption region, CrIS is warmer than IASI about 0.3-0.5 K
- CrIS and IASI window channels differ by 0.1 K due to diurnal variation in the SST

SNOs between CrIS and IASI



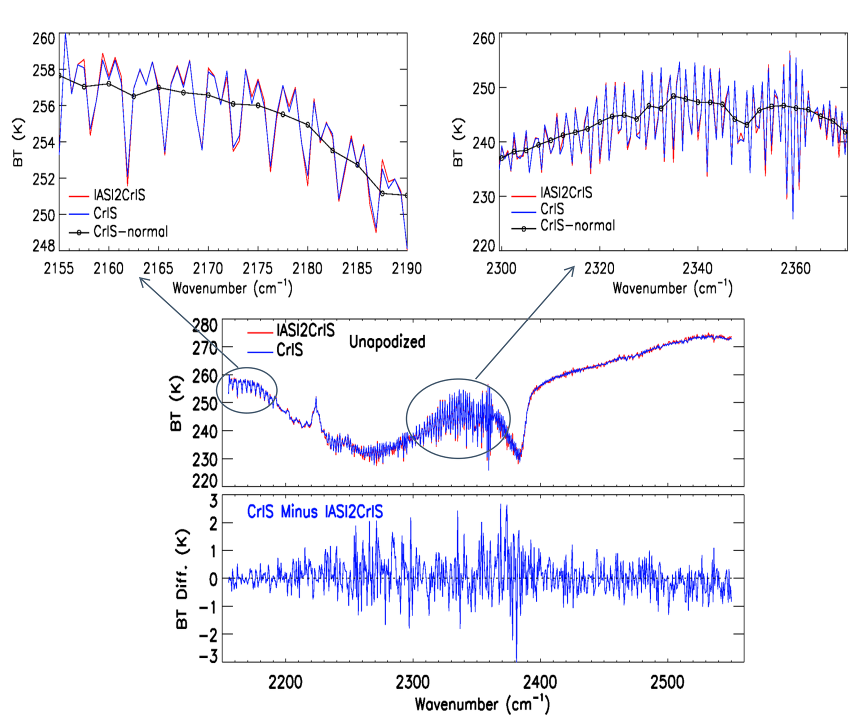
SNO Criteria

- 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 significant BT difference toward the end of band edge
- Significant BT differences in cold channels for band 3

SNOs between CrIS and IASI: Details



- Although there is significant BT differences in band 3, line structure in CO and CO_2 region agreement is very good for CrIS full resolution data
- 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

Correlation coefficient between the two spectra:

$$r_{S_1S_2} = \frac{\sum_{i=1}^{n}(S_{1,i}-\bar{S}_1)(S_{2,i}-\bar{S}_2)}{(n-1)D_{S_1}D_{S_2}} = \frac{\sum_{i=1}^{n}(S_{1,i}-\bar{S}_1)(S_{2,i}-\bar{S}_2)}{\sqrt{\sum_{i=1}^{n}(S_{1,i}-\bar{S}_1)^2(S_{2,i}-\bar{S}_2)^2}},$$

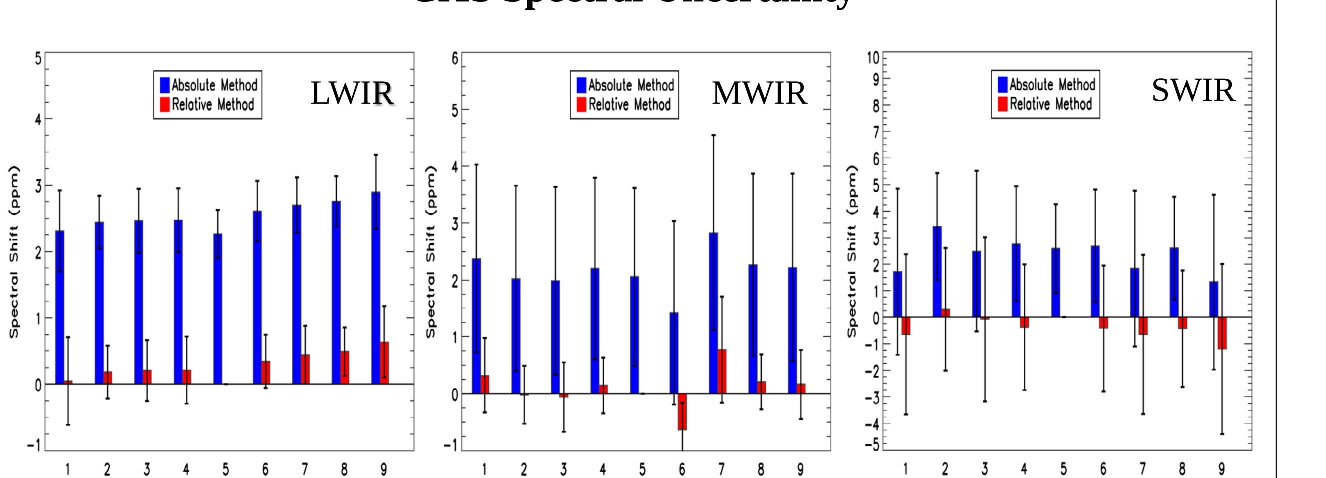
Standard deviation based on the difference of the two spectra:

$$D_{S_1S_2} = \sqrt{\sum_{i=1}^{n}[(S_{1,i}-\bar{S}_1)-(S_{2,i}-\bar{S}_2)]^2 \Big/ (n-1)}.$$

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.

- 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

CrIS Spectral Uncertainty



Conclusion

- CrIS full resolution Processing System has been developed to generate the full resolution SDRs. The SDRs were radiometrically and spectrally 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 significant 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