Intercomparison of Hyperspectral Infrared Sounders with Simulated Radiances from GNSS-RO Inputs

Erin Lynch[1], Flavio Iturbide-Sanchez[2], Ben Ho[2], Changyong Cao[2], Xi Shao[1]

1: University of Maryland/ESSIC/CISESS

2: NOAA/NESDIS/STAR

Outline

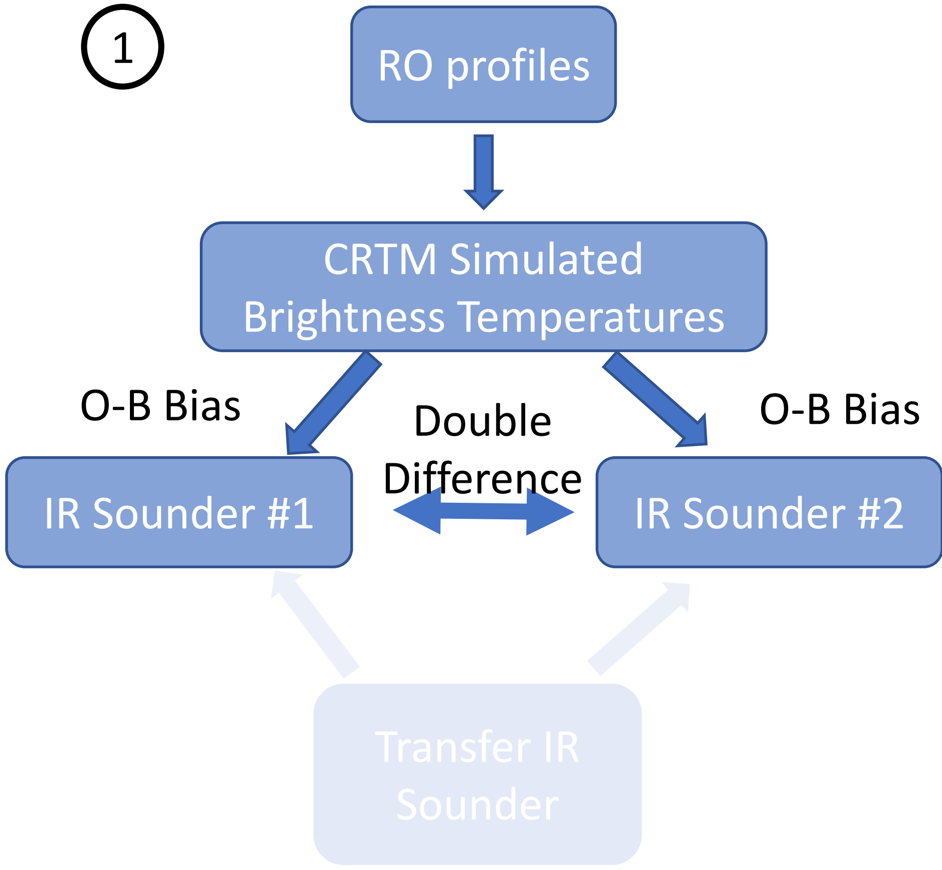
- Motivation
- Approach
- Intercomparison methods used in this study
- Suomi-NPP CrIS Side-2 Intercomparison
- MetOp-C IASI Intercomparison
- Summary and Conclusions

Motivation

- GNSS Radio Occultation (RO) measurements provide a stable reference for use in numerical weather prediction (NWP) and anchor dataset to perform bias correction for other types of atmospheric sounding data
- Hyperspectral radiometric sounders, like CrIS (Cross-track Infrared Sounder) also serve as on-orbit calibration reference standards for other broad- or narrow-band infrared (IR) observations as well as contributing to NWP
- Both are accurate, stable, and based on SI traceable standards (Atomic Frequency Standard vs. Radiance respectively)
- In this study, GNSS RO data from COSMIC, KOMPSAT-5, and the MetOp-A and B GRAS instruments provide high resolution profiles of atmospheric variables that are used as a reference to validate the brightness temperatures observed by IR sounders.
- In addition, intercomparisons between IR sounds are also used to validate.

Approach

- Assess the radiometric consistency of two hyperspectral IR sounders:
  - The Cross-track Infrared Sounder (CrIS) onboard Suomi-NPP before and after the switch to the redundant electronics
  - The Infrared Atmospheric Sounding Interferometer (IASI) onboard the recently launched MetOp-C compared to the IASI instrument on MetOp-B
- Two methods:
  1. Comparison between observed brightness temperatures and simulated brightness temperatures from a radiative transfer model with RO data providing the temperature and water vapor inputs
  2. Comparison to other well calibrated hyperspectral IR sounders during Simultaneous Nadir Overpasses (SNO)



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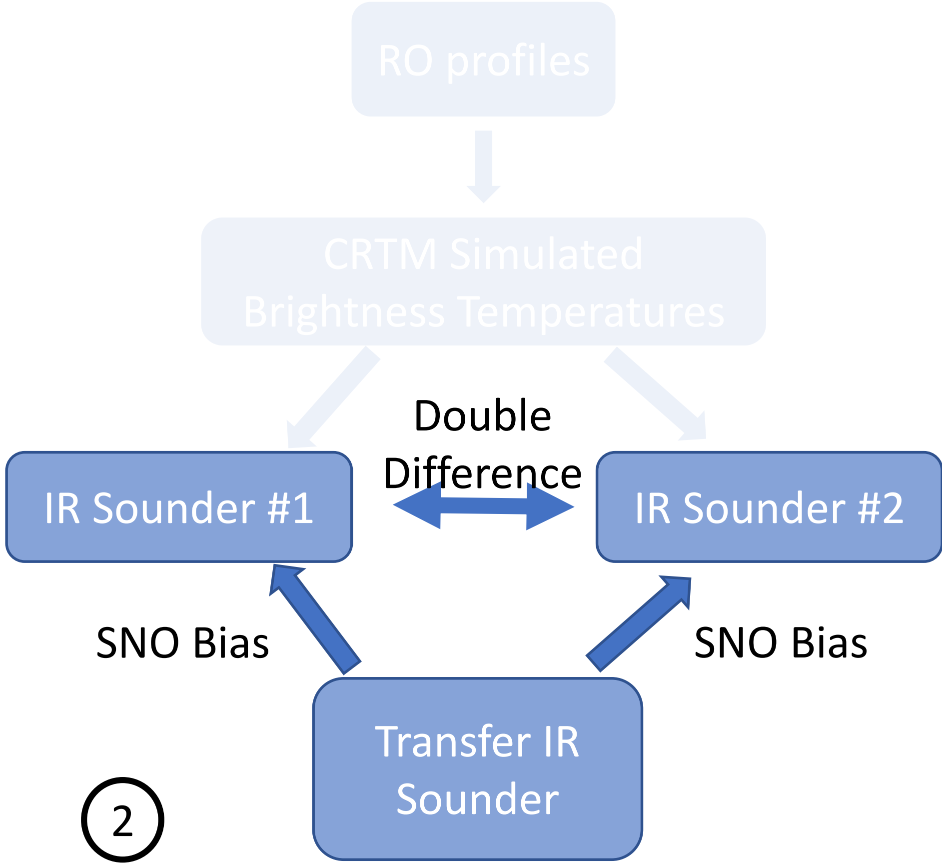
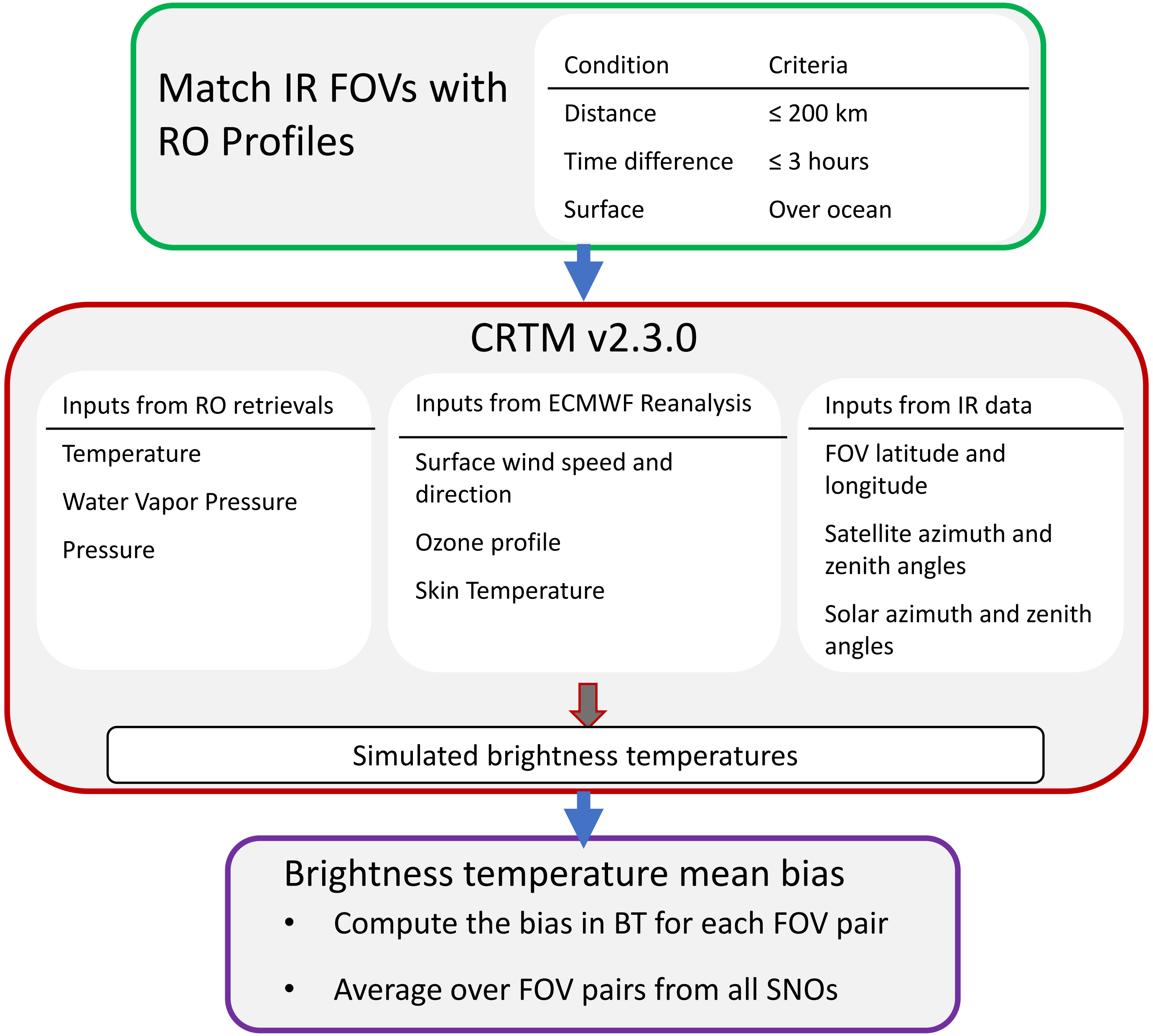


CRTM Based Intercomparison

- Radio Occultation wetPrf data from CDAAC
  - COSMIC
  - KOMPSAT-5
  - MetOp-A and –B GRAS

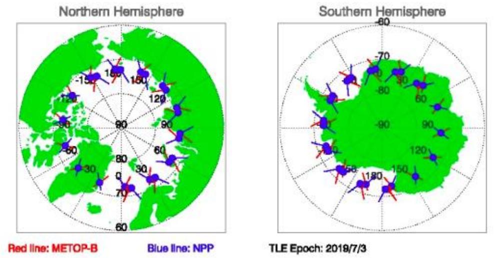
- Each RO profile is collocated with a single clear sky FOV over ocean. Cloud cover assessed using ECMWF reanalysis cloud cover and threshold cutoff for biases in surface channels.

- Community Radiative Transfer Model (CRTM) v2.3.0 developed by JCSDA used.

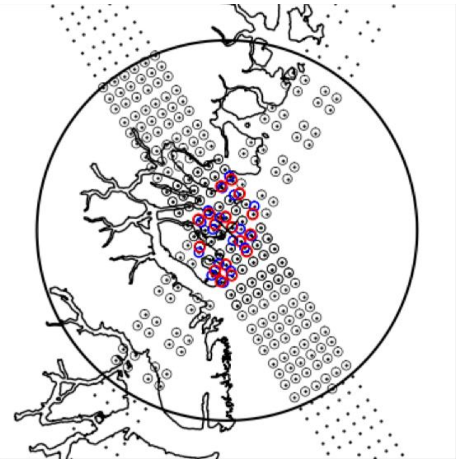


SNO Based Intercomparison

- SNO opportunities with <2 min separation nadir overpasses occur every ~50 days between Metop-B and S-NPP and last for ~2 days with ~48 SNOs during that period



- Overlapping pairs of CrIS and IASI FOVs are found. Only homogeneous scenes are considered to minimize collocation errors.



- IASI has higher spectral resolution and no gaps between bands. IASI spectra can be deconvolved to match the CrIS spectral grid and make a direct comparison.

Match CrIS FOVs with IASI FOVs

Condition	Criteria
FOV distance	≤ 13 km
Time difference	≤ 3 min
View angle difference	abs(cos(zen_cris)-cos(zen_iasi)) ≤ 0.01
Homogeneity	Mean(Stdev(CrIS FOVs in FOR)/Mean(CrIS FOVs in FOR)) < 50%

IASI-to-CrIS Deconvolution

1. Remove Gaussian apodization
2. Inverse Fourier Transform to interferogram
3. Truncate to CrIS OPD
4. Fourier Transform to CrIS spectrum
5. Apply Hamming apodization

BT mean bias

- Compute the bias in BT for each FOV pair
- Average over FOV pairs from all SNOs

Challenges

- Viewing geometry: Limb vs. nadir
- Time difference
- Colocation uncertainties
- Sample limitations in RO
- Errors in the RO temperature and vapor pressure retrievals
- Errors introduced by the radiative transfer model
- RO uncertainties in the upper atmosphere due to small bending angle
- Low troposphere uncertainties due to water vapor SNR, and turbulence
- Infrared sounding limited to clear sky conditions (clouds)
- SNOs occur relatively infrequently – every ~50 days

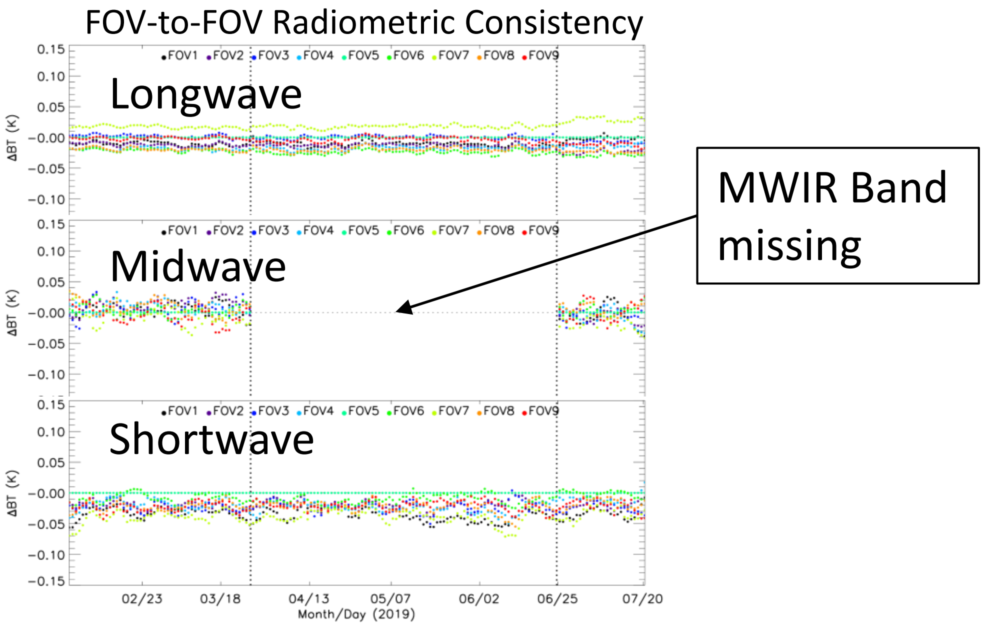
Suomi-NPP CrIS Side-1 vs Side-2

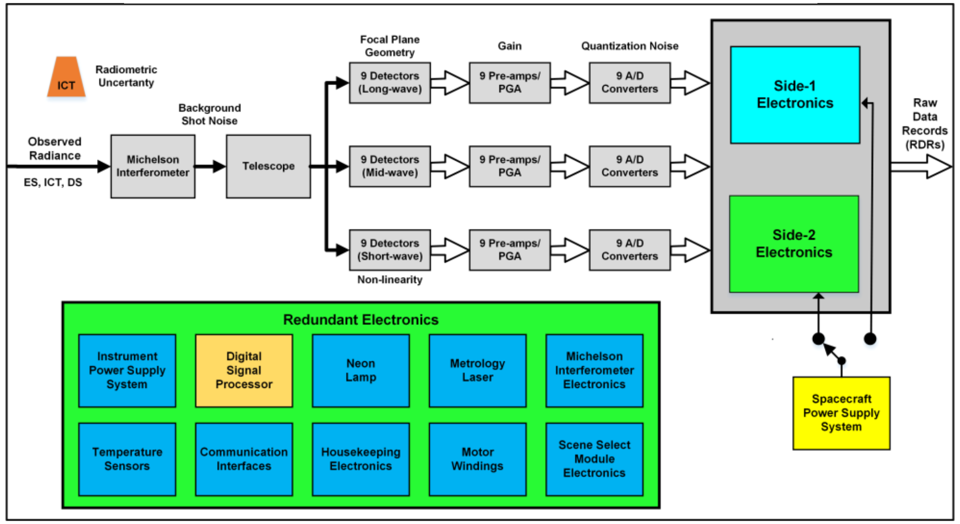
Assess the radiometric consistency of S-NPP CrIS Side-2 compared to Side-1 using transfer targets:

1. Simulated CRTM brightness temperatures with RO inputs
2. SNOs with MetOp-B IASI

Suomi-NPP CrIS Midwave Band Recovery

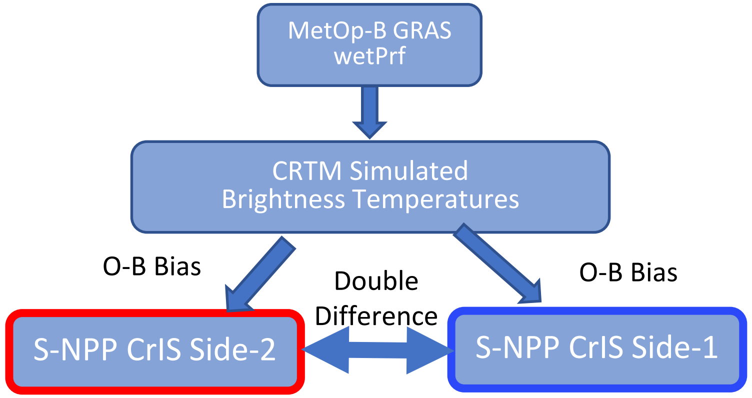
- On March 23, 2019, an anomaly resulted in the loss of the Midwave Ifrared (MWIR) band in the S-NPP CrIS raw data record (RDR) interferograms.
- The root cause was likely a failure in the MW signal processor field programmable gate array and surrounding circuitry.
- To recover the missing band, a switch to the redundant side electronics was made on June 24, 2019.
- The redundant electronics replace several existing instrument components with a different version, including temperature sensors required for radiometric calibration.
- The redundant electronic were characterized pre-launch and little change to the spectral and radiometric performance of the instrument was expected.
- Following an update to the calibration parameters improving the geoloction accuracy, S-NPP CrIS SDR product reached provisional maturity on August 1, 2019.
- To compare the Side-1 sensor data record (SDR) product to Side-2, data from August 2018 and August 2019 will be used.

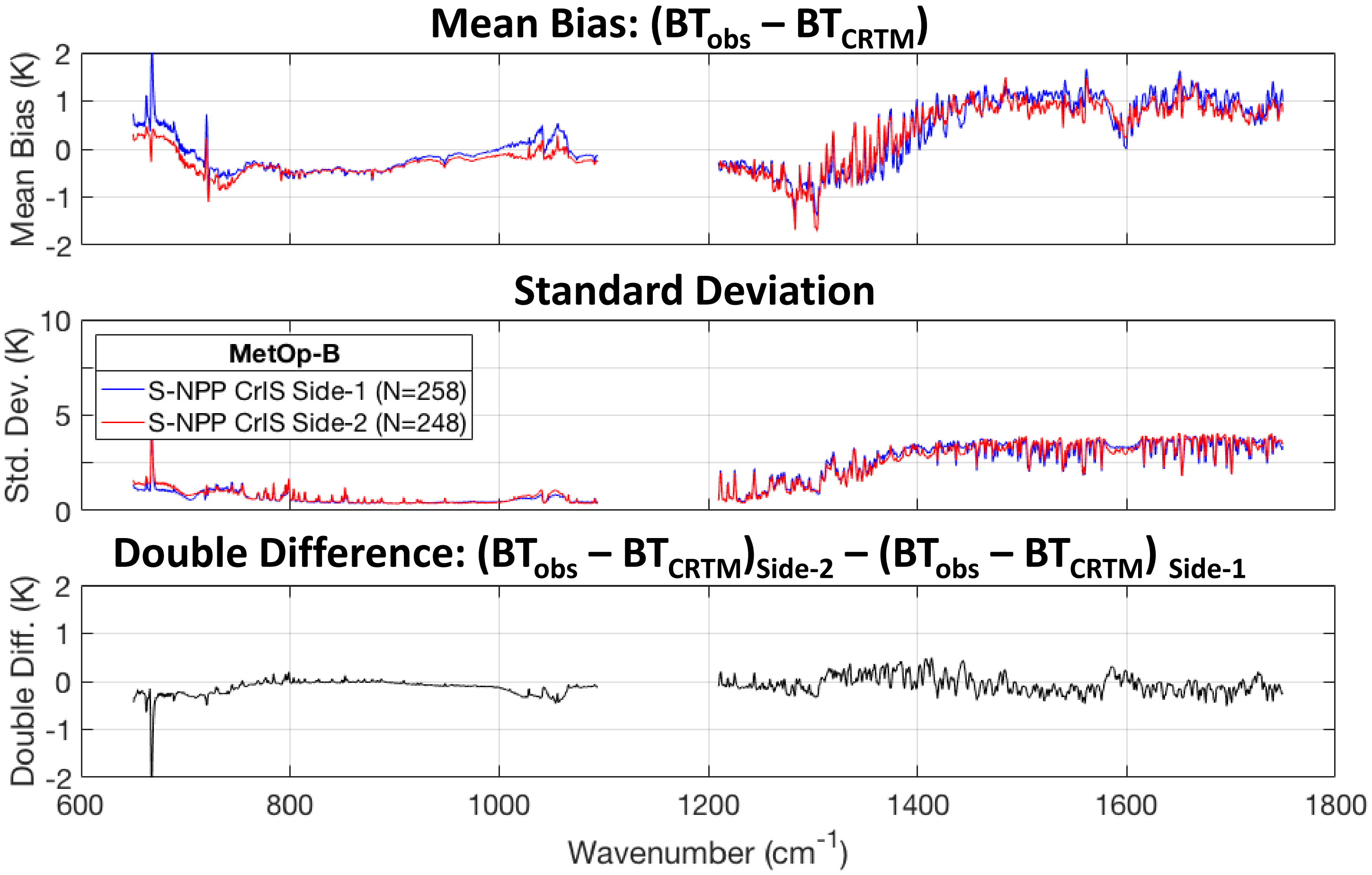




S-NPP CrIS Side-1 vs Side-2 Intercomparison

CRTM BT with RO Input as Transfer Target





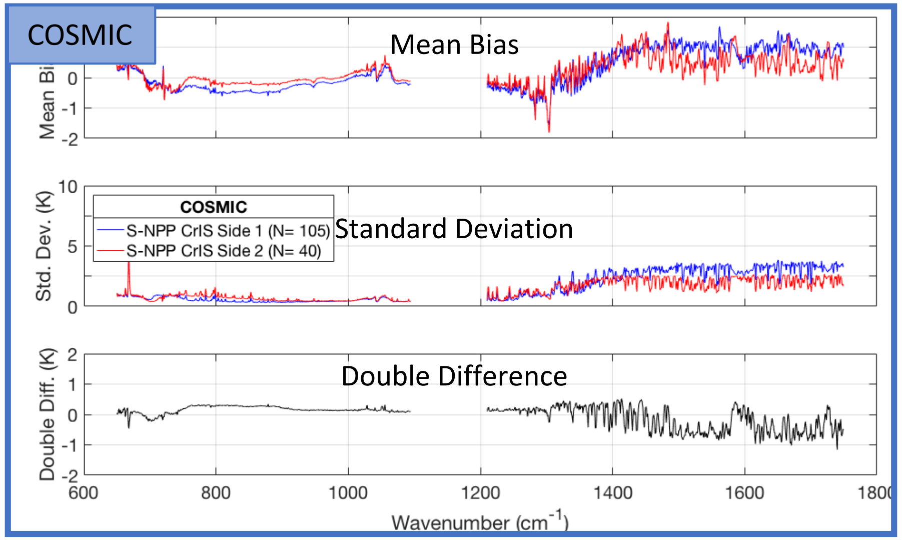
- S-NPP Side 1: August 2018
- S-NPP Side 2: August 2019

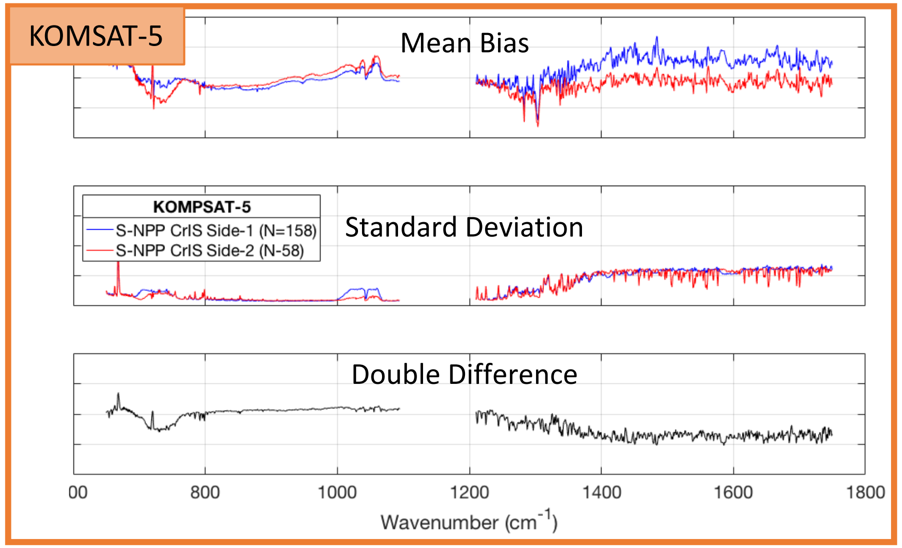
- Small negative bias in the LW window channels consistent and ~1 K positive bias in the water vapor channels of the midwave are both consistent with CRTM simulated BT.
- The larger bias in the midwave suggests there may be errors in the moisture variables input to the CRTM.
- Double difference shows nearly all LW channels within 0.1 K and nearly all MW channels within 0.25 K.

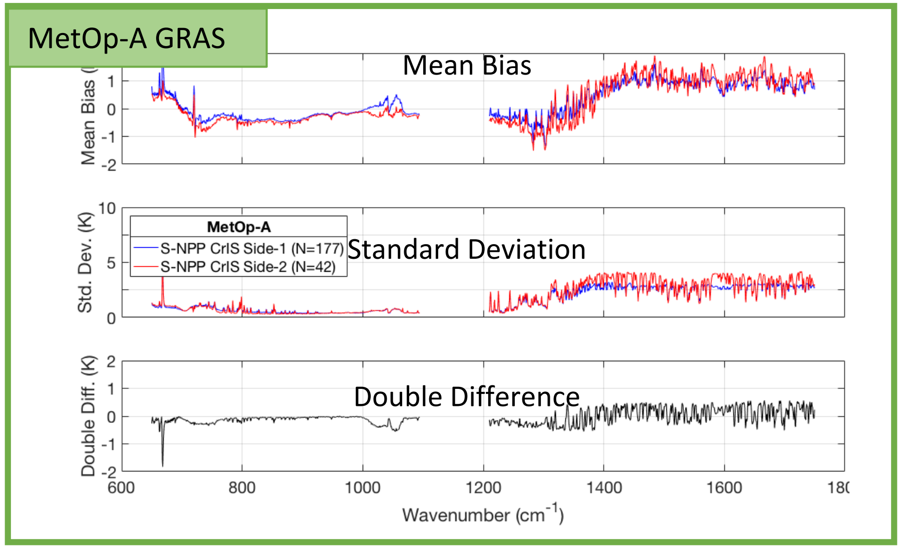
S-NPP CrIS Side-1 vs Side-2 Intercomparison

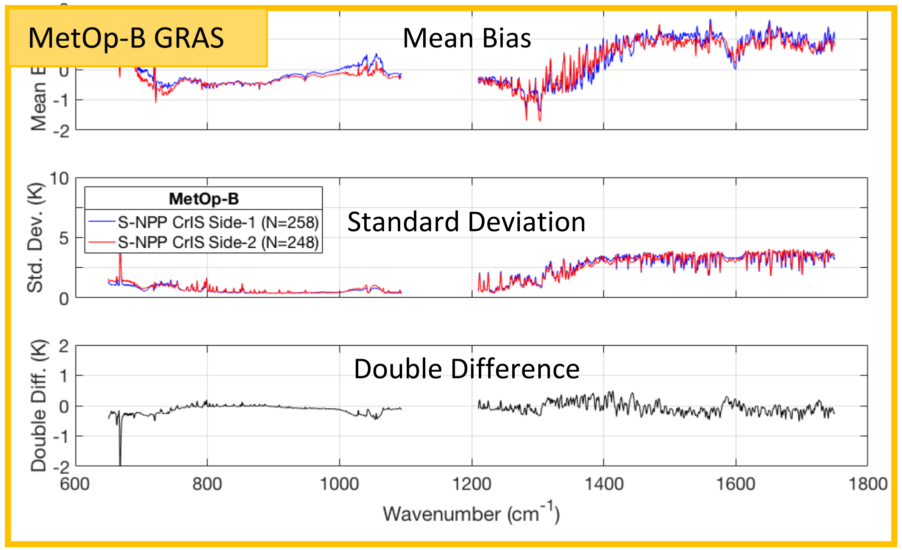
Comparison of RO Inputs

- All missions show large positive biases in the MW.
- For aging missions, counts between years are inconsistent.
- Low counts in 2019 compared to 2018 could cause differences in MW biases.
- MetOp GRAS both show consistency between years, despite low counts for MetOp-A GRAS in 2019.



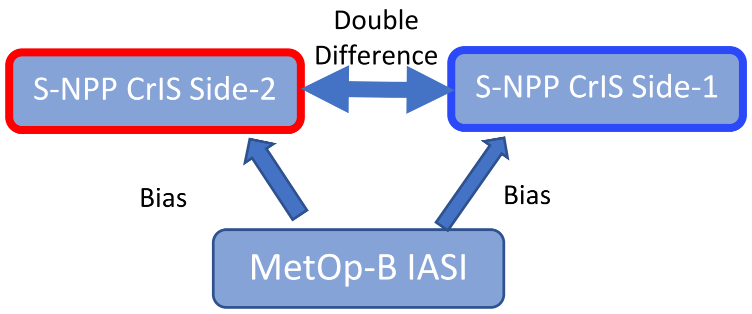






S-NPP CrIS Side-1 vs Side-2 Intercomparison

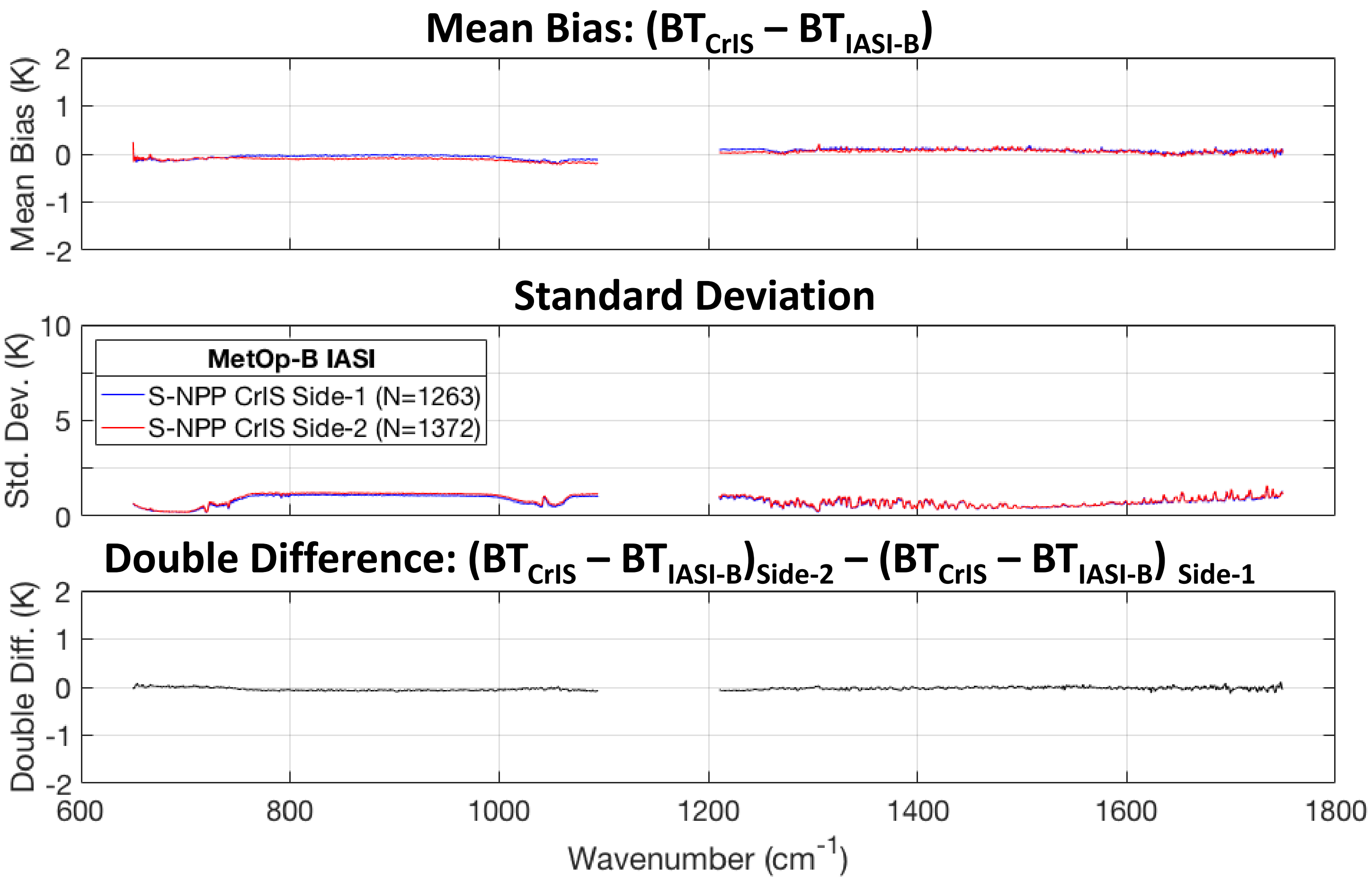
IASI-B SNOs as Transfer Target



- S-NPP Side 1: August-December 2018
- S-NPP Side 2: August-December 2019

- Excellent agreement between the Side-1 and Side-2 longwave and shortwave bands.

- Double differences are within 0.05 K for the shortwave and 0.1 K for the midwave for most channels.



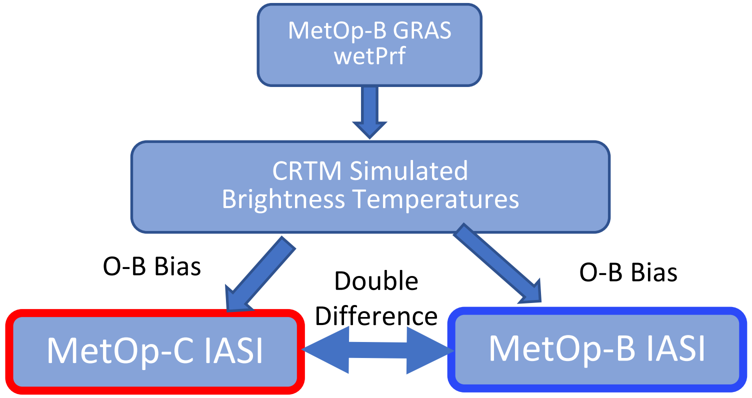
MetOp-C IASI

Assess the radiometric consistency of MetOp-C IASI compared to MetOp-B IASI using transfer targets:

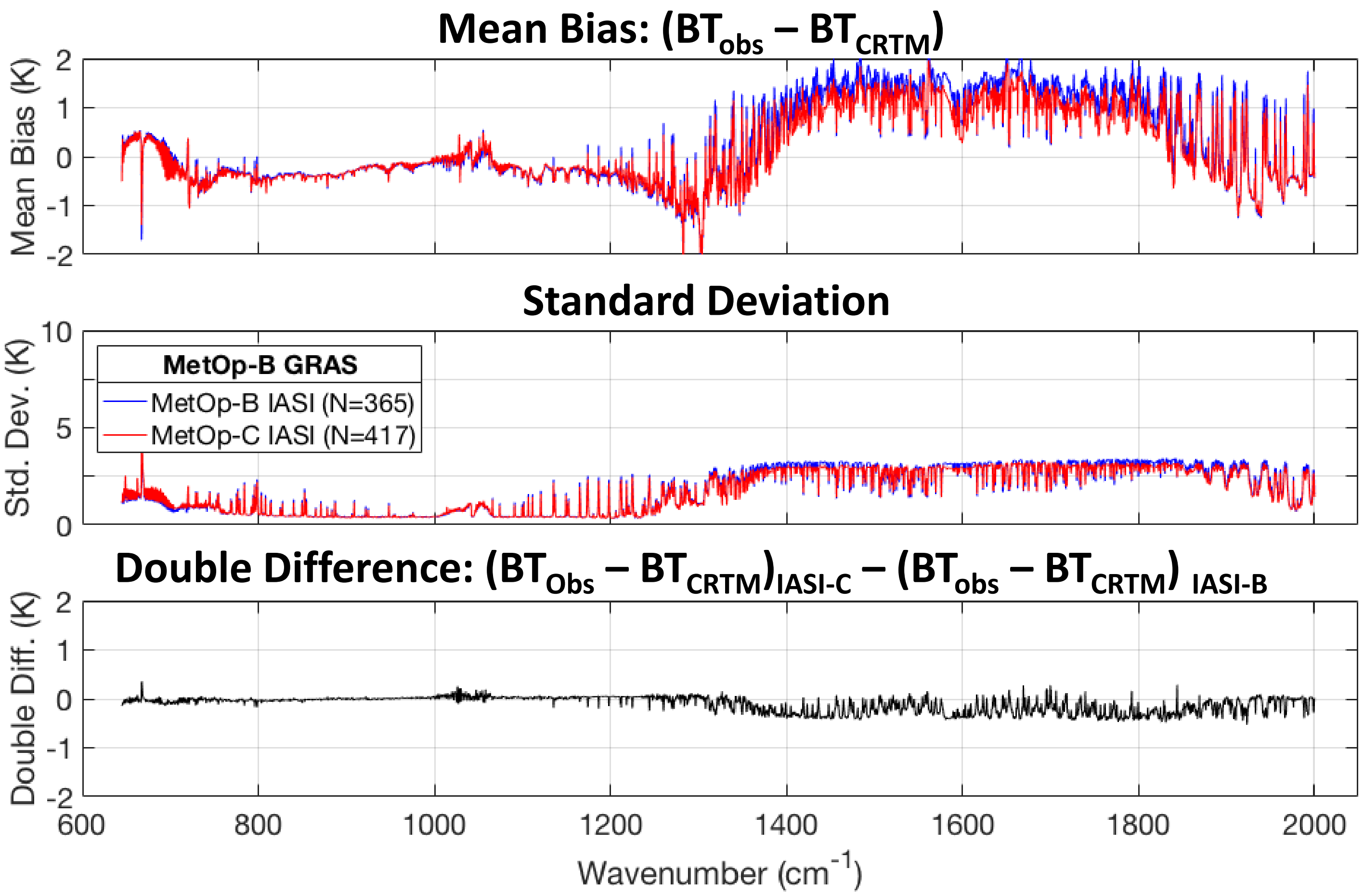
1. Simulated CRTM brightness temperatures with RO inputs
2. SNOs with S-NPP CrIS

MetOp-C IASI vs MetOp-B IASI Intercomparison

CRTM BT with RO Input as Transfer Target



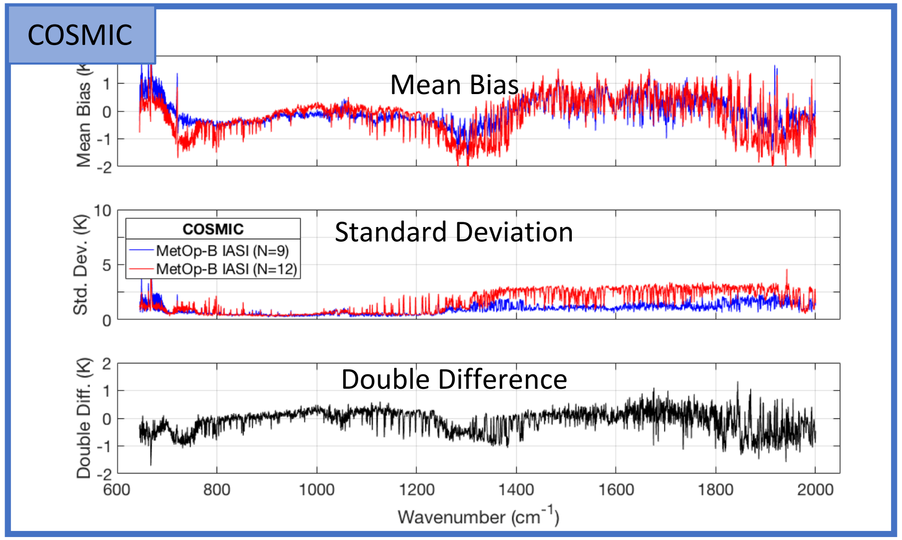
- MetOp-C launched on November 7, 2018 carrying the third IASI instrument
- IASI-C reached operational status in July 2019.
- Comparisons made to IASI-B via RO input to CRTM with IASI-C coefficients
- Most LW channels are within 0.1 K and most MW channels are within 0.5 K. There is a slight negative bias between IASI-C and IASI-B in the midwave.

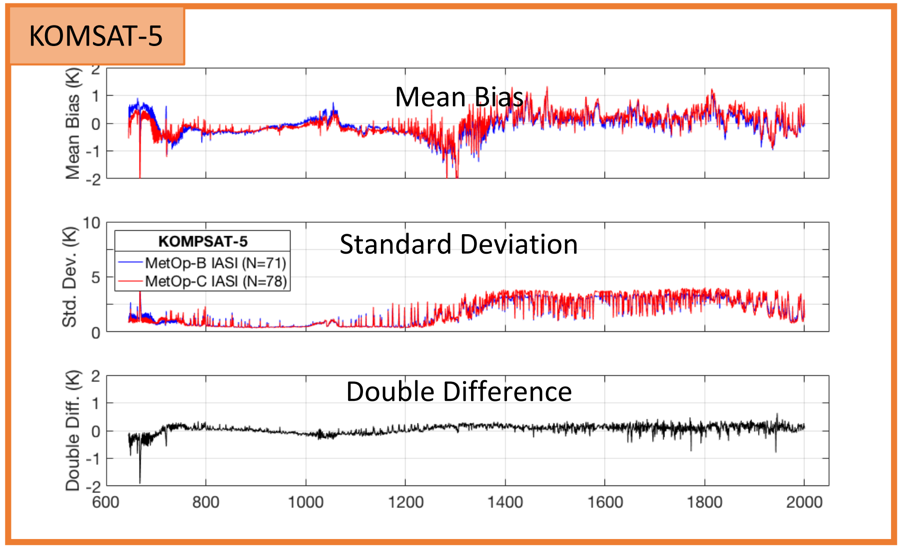


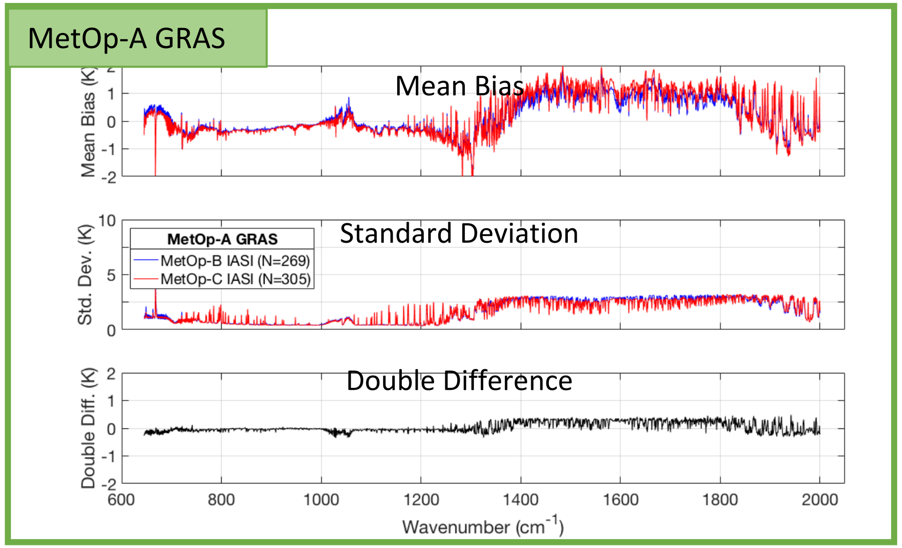
MetOp-C IASI vs MetOp-B IASI Intercomparison

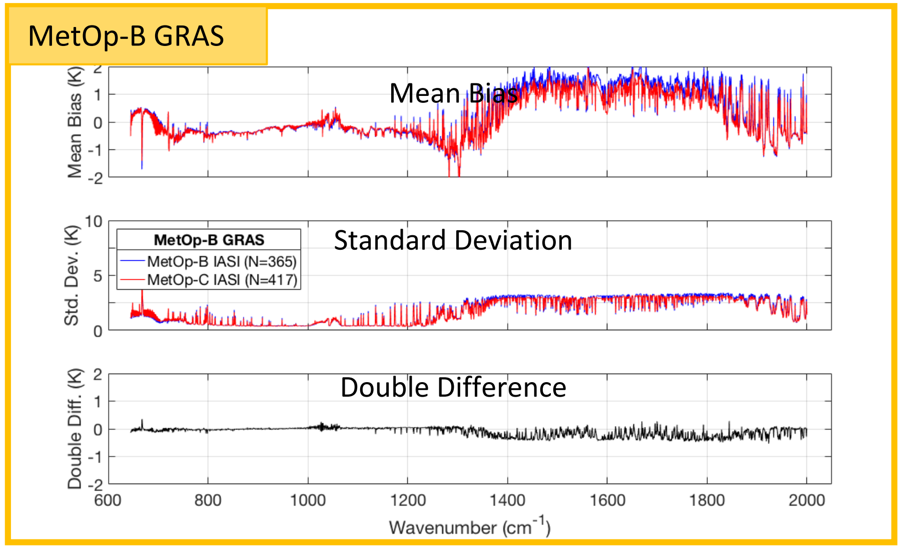
Comparison of RO Inputs

- Since data for each comparison comes from the same month, results from different missions are more consistent.
- COSMIC suffers from diminished counts in 2019 so there were very few matchups.
- The double differences using MetOp-A GRAS simulated BTs and MetOp-B GRAS simulate BTs show different signs.



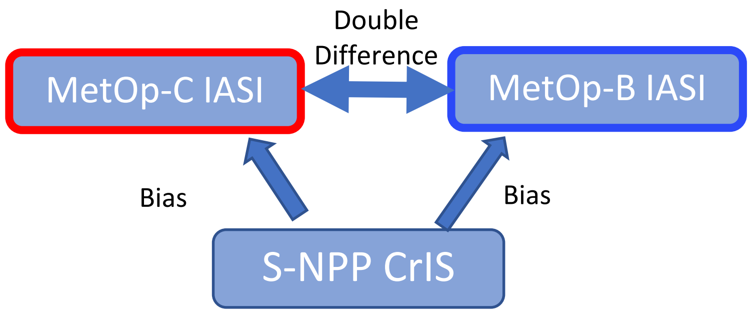




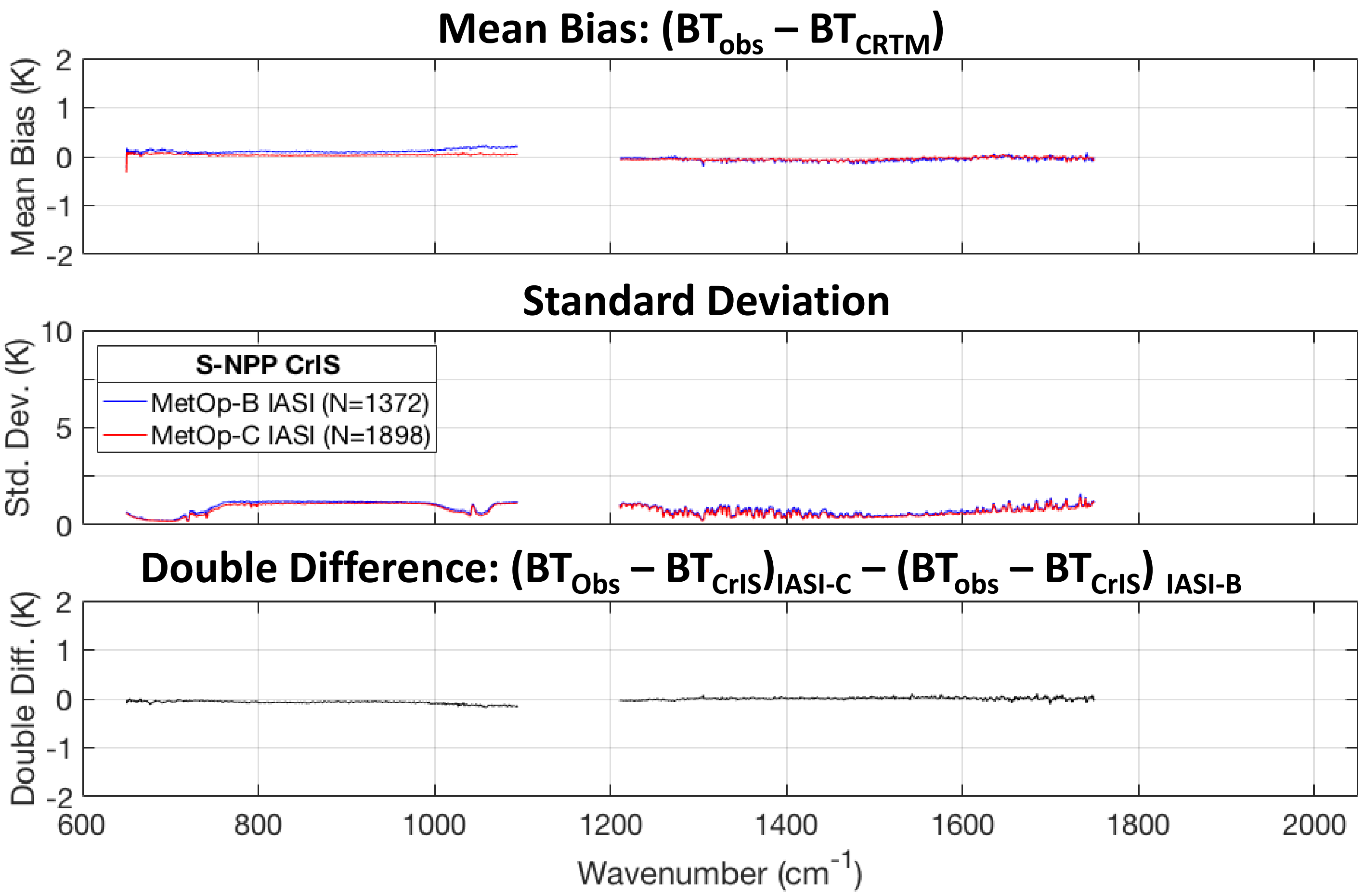


MetOp-C IASI vs MetOp-B IASI Intercomparison

S-NPP CrIS SNOs as Transfer Target



- SNOs with S-NPP CrIS serve as a transfer target for IASI-C and IASI-B intercomparison.
- The comparison made on CrIS spectral grid (lower resolution and gaps compared to IASI spectrum)
- High degree of consistency between IASI-C and IASI-B in both the short wave and midwave double differences.



Summary of Results

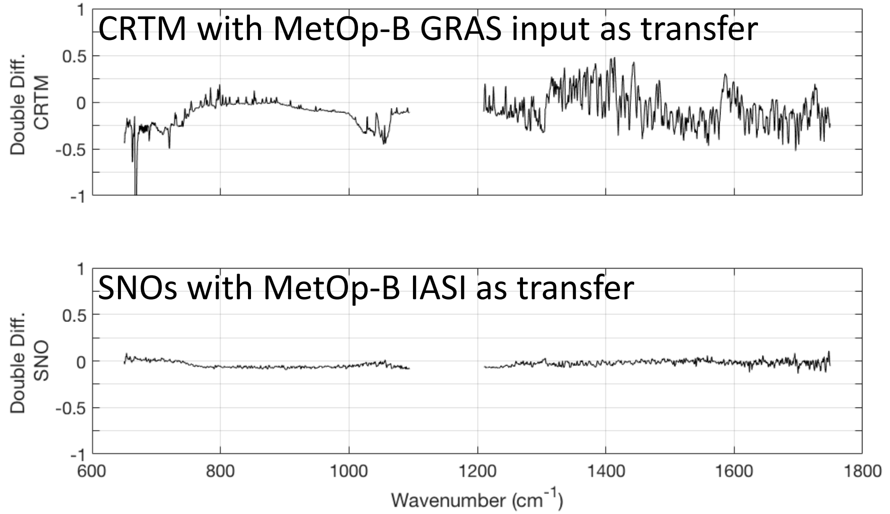
Suomi NPP CrIS Side-2

- Shows excellent agreement with S-NPP CrIS Side-1
- Intercomparison with CRTM simulated BT with MetOp-B GRAS profiles as input:
  - 0.1 K in LW
  - 0.25 K in MW
- Intercomparison with MetOp-B IASI SNOs:
  - Within 0.05 K in the LW and MW.

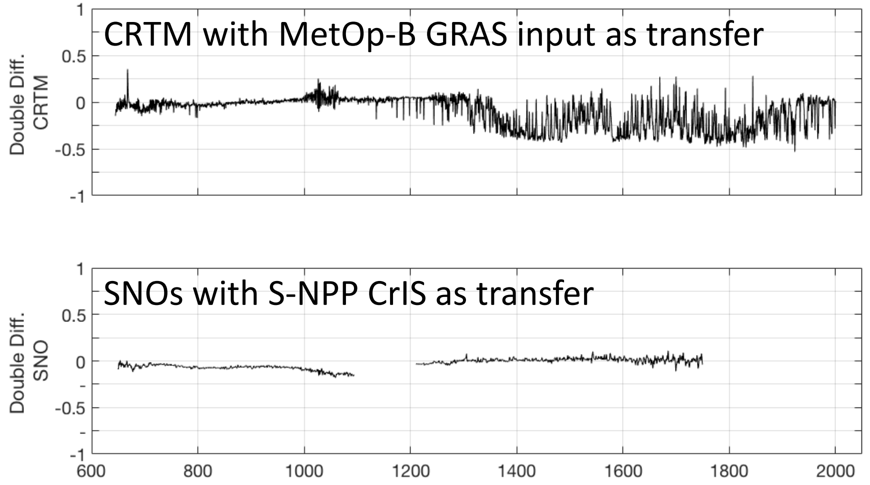
MetOp-C IASI

- Shows excellent agreement with MetOp-B IASI
- Intercomparison with CRTM simulated BT with MetOp-B GRAS profiles as input:
  - 0.1 K in LW
  - 0.5 K in MW
- Intercomparison with MetOp-B IASI SNOs:
  - Within 0.05 K in the LW and MW

Double differences: Side-2 – Side-1



Double differences: IASI-C – IASI-B



Conclusions

- Intercomparisons between IR sounders using simultaneous nadir overpasses (SNOs) is a well established method. The method demonstrates excellent consistency between S-NPP CrIS Side-2 and Side-1 and between the IASI instruments on MetOp-C and MetOp-B.

- Intercomparisons between observed brightness temperatures and simulated brightness temperatures using a radiative transfer model such as the CRTM are also well established. This method introduces some uncertainty from the radiative transfer model itself.

- GNSS-RO measurements provide high resolution retrieved temperature and moisture profiles. These data can serve as inputs to a radiative transfer model for intercomparisons; however additional uncertainties are introduced due to the matchup criteria and potential errors in the retrievals.