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Inter-satellite Calibration of NOAA HIRS Level-1b Data for the Development of Climate Data Records

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Background

- 30 years of HIRS measurements are very useful for climate studies (Wylie et al, 2005 J.Clim.; Bates et al., 2001 JGR; Menzel et al., 2010 J. App. Met.&Clim.)

- Significant inter-satellite discrepancies in HIRS calibration have been found between NOAA series of satellites (Cao et al. 2009, Shi et al., 2009, Menzel et al., 2010)

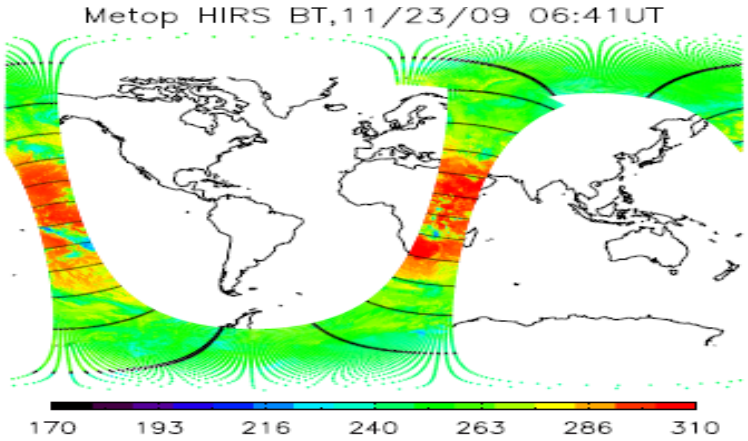
- This study intends to recalibrate historical HIRS data using hyperspectral sounders to make it more consistent and accurate to support climate applications – cloud time series by Menzel's team for NCDC's CDRP program

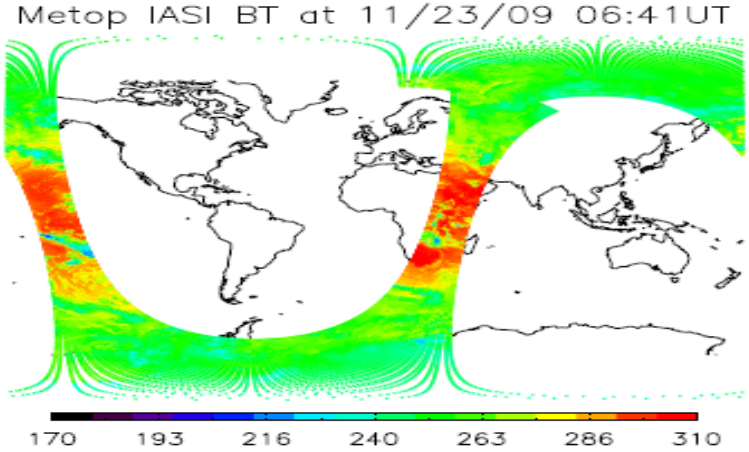
Methodology

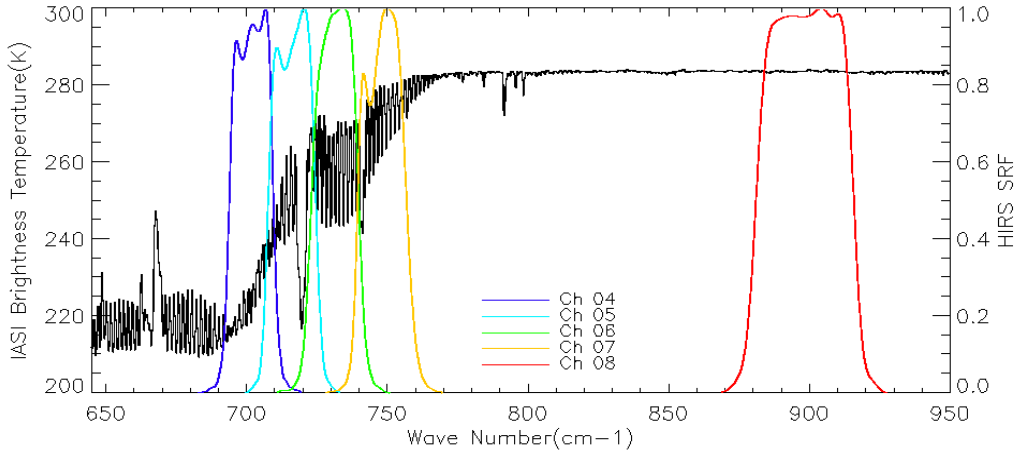
- Use measurements from IASI on MetOp as reference for recalibrating all HIRS data
  - o Comprehensive and physical approach to the recalibration of HIRS on MetOp with the IASI (both on the same satellite)
  - o Inter-satellite calibration of HIRS on-board successive NOAA and MetOp satellite using the SNO approach
  - o Comparison between HIRS on NOAA satellites and MetOp IASI at SNO locations
- Both radiometric and spectral calibration are evaluated
- Preliminary results for HIRS channels 4, 5, 6, and 7 (which are used for cloud time series studies) are presented

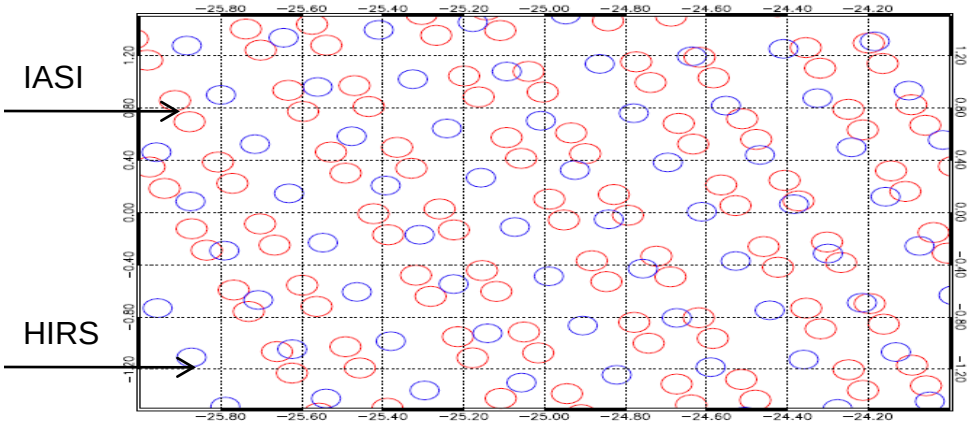
Recalibrating MetOp HIRS Using IASI

Matching MetOp HIRS with IASI



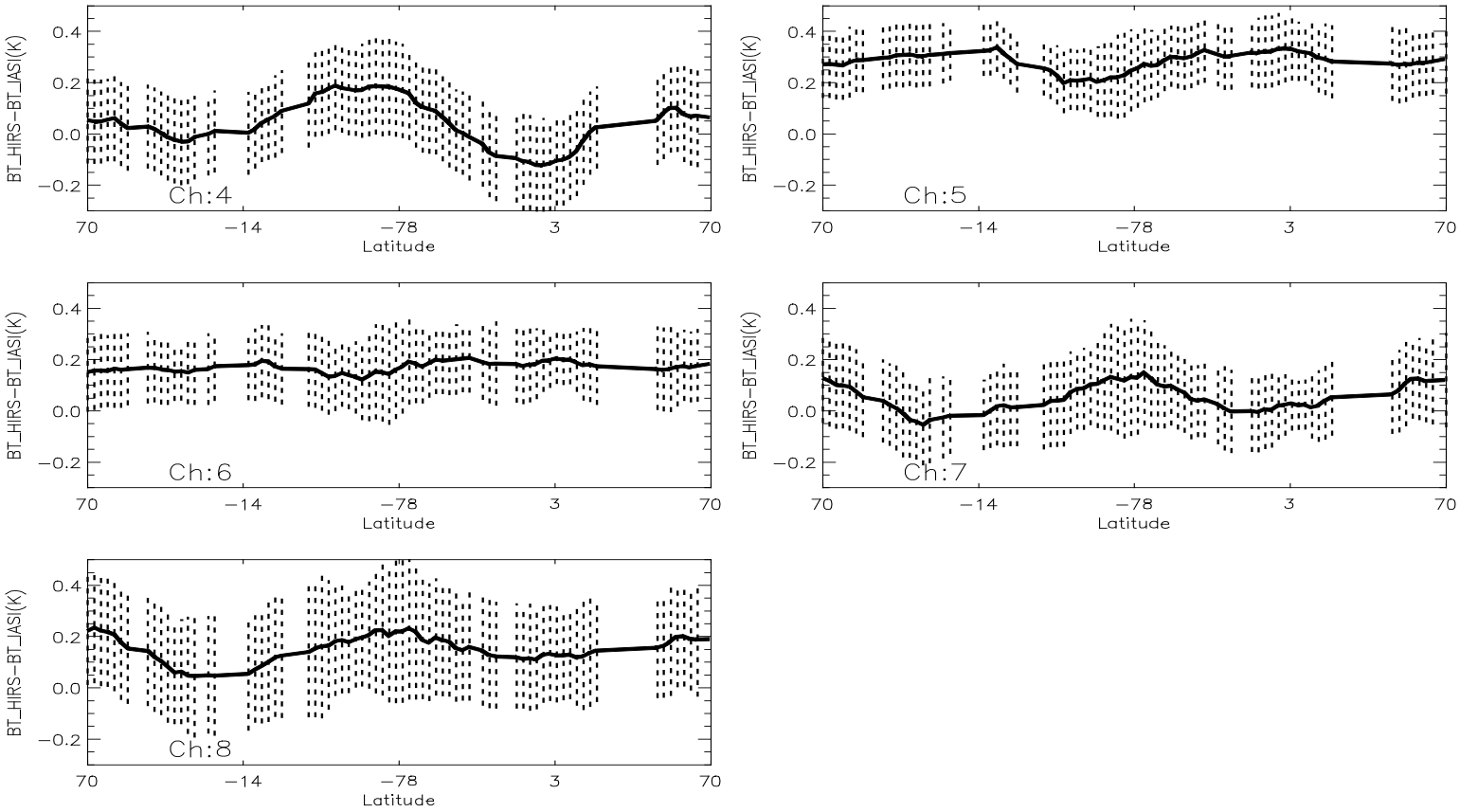






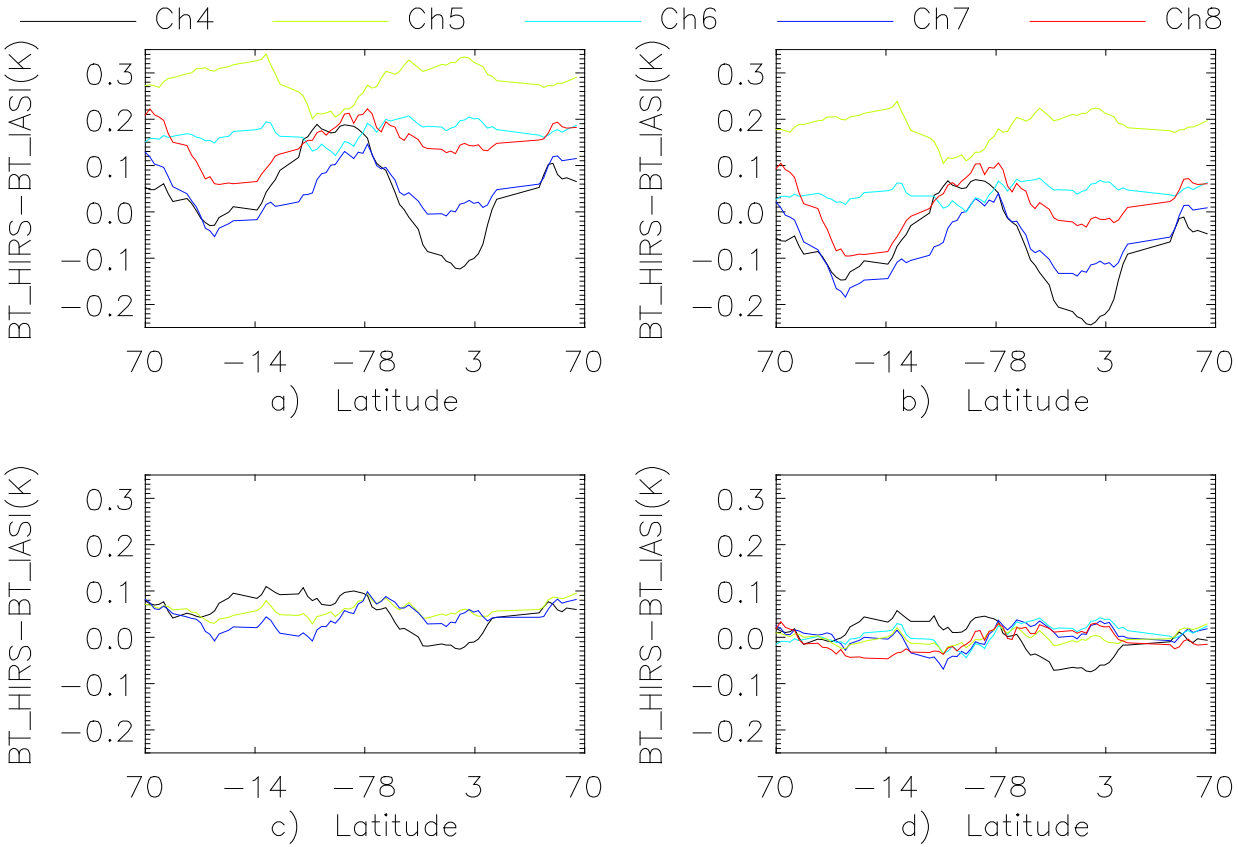
- MetOp IASI and HIRS measurements are spectrally and spatially matched.
- A MetOp sample orbit (06:41 11/23/09) is analyzed in detail to diagnose the HIRS calibration problems

HIRS – IASI BT Differences

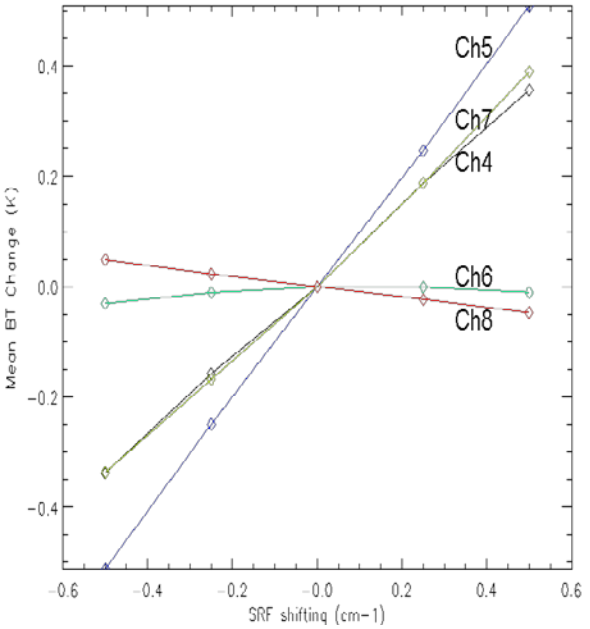


- BT differences between HIRS and IASI for the MetOp orbit start at 06:41 November 23, 2009. Solid lines represent 8-scanline average; Dash lines represent the standard deviation of the data samples for each 8-scanline area.
- Possible reasons – Blackbody bias, SRF error, non-linearity term, or space-view bias, etc.

HIRS Recalibration Process

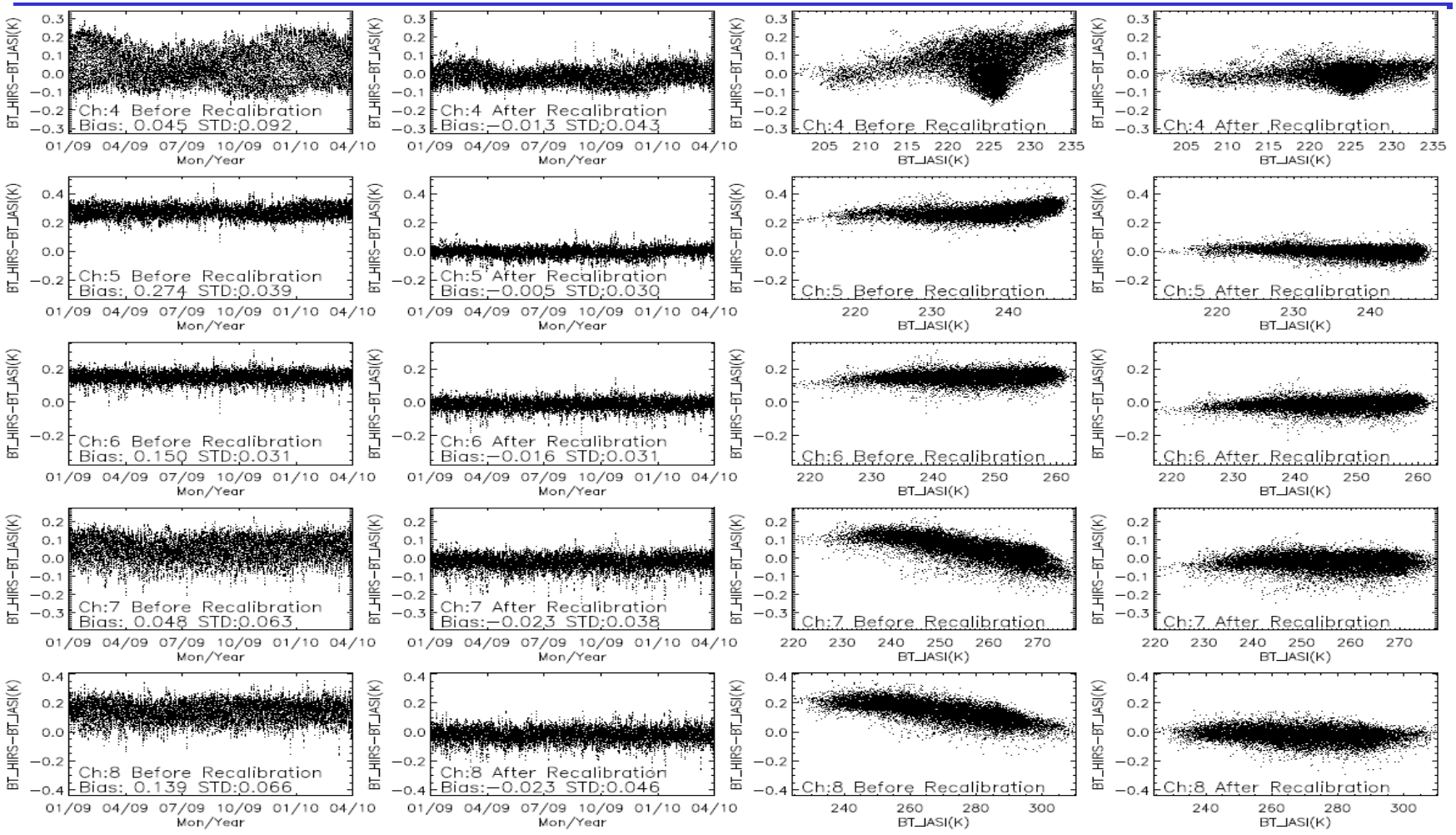


Impact of SRF shift on IASI-simulated HIRS brightness temperatures



- HIRS/IASI BT differences for the sample MetOp orbit
- a) Operational calibration;
- b) Correction of blackbody bias (0.14 K) using Thermal-Equilibrium analysis
- c) Correction of SRF error using optimal shifting (-0.13, 0.09, -0.15 cm^{-1} , for Ch 4, 5, and 7)
- d) Correction of calibration non-linearity term.
- Comprehensive physical analysis that separates spectral impact from radiometric impact.

Validation of HIRS Recalibration

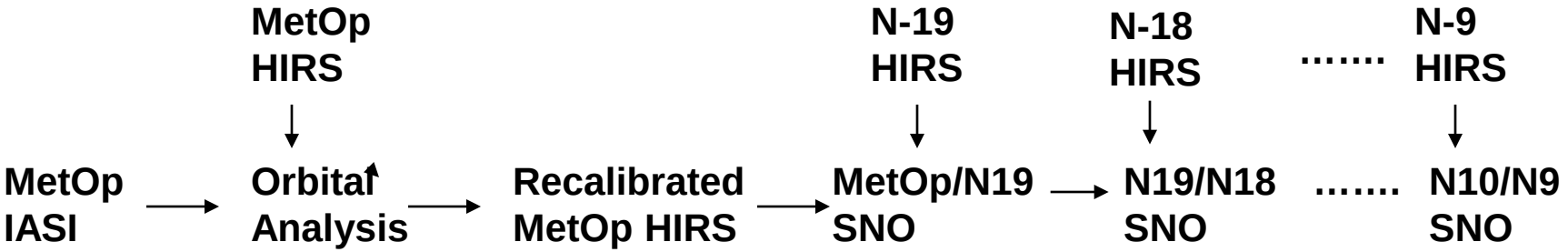


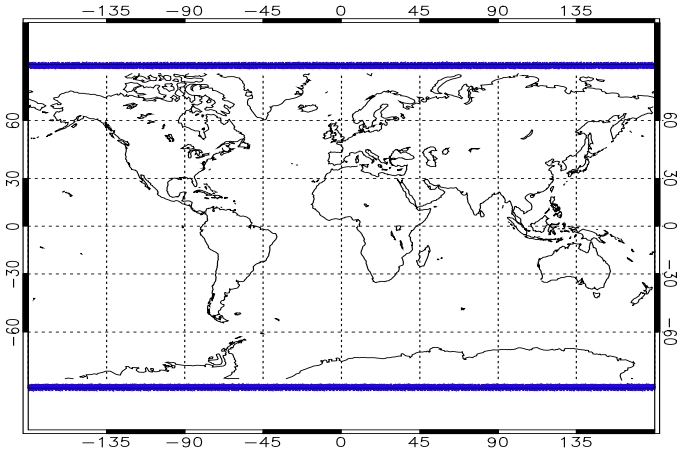
- Validated with 16 months sampled MetOp data (the fifth orbit of each day)
- Both mean bias and bias variation are significantly reduced (less than 0.1K)
- Both T-dependent and non-T-dependent biases are significantly reduced

Inter-satellite calibration of HIRS on NOAA satellites

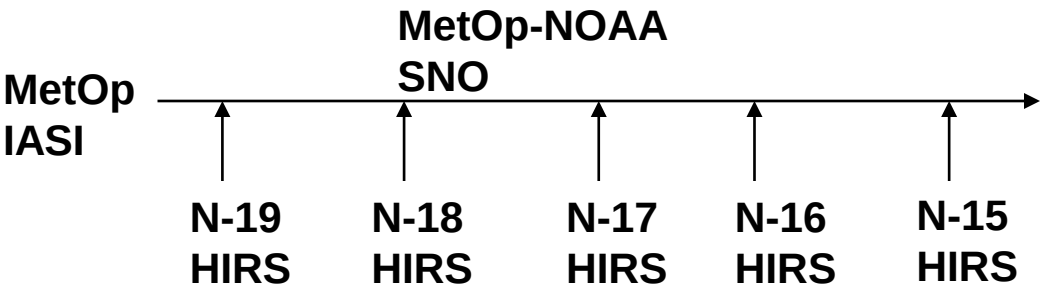
Methodology

- Recalibrate MetOp HIRS using IASI, then using MetOp HIRS as reference, the HIRS from every NOAA satellite is compared with the recalibrated HIRS measurements from the successive satellite at SNO locations.
- Directly compare the HIRS measurements from NOAA 15-19 with the matched IASI measurements at SNO locations.

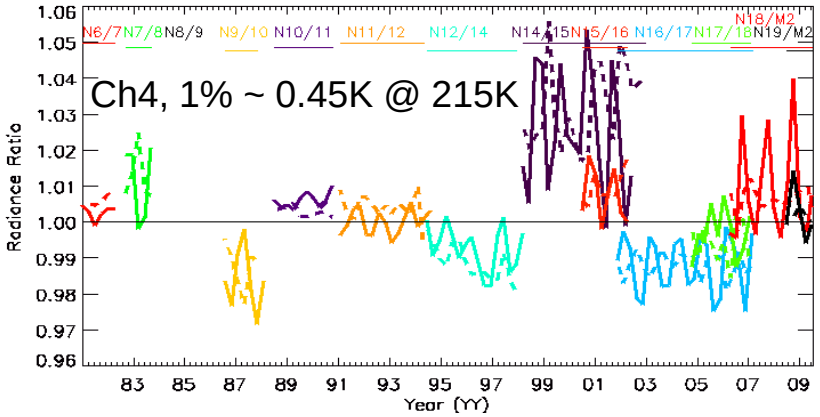


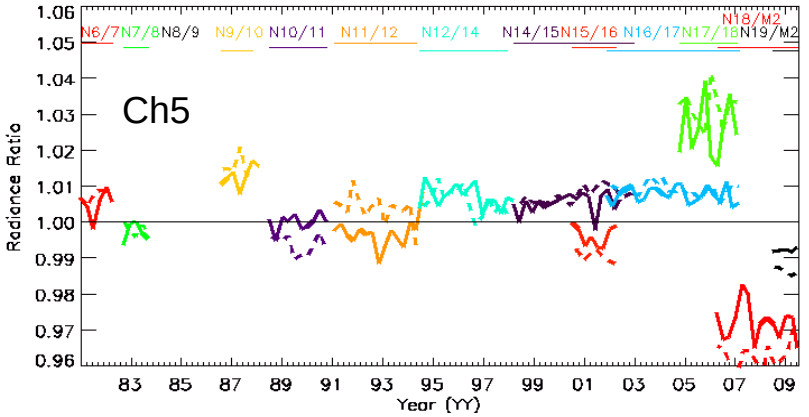


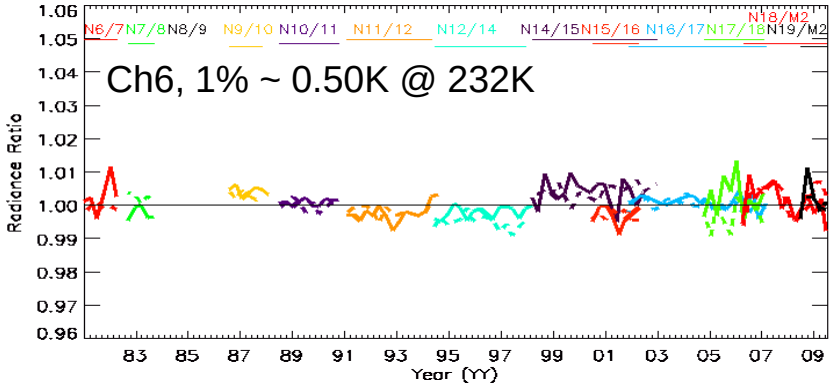
SNO events between NOAA-17 and MetOp

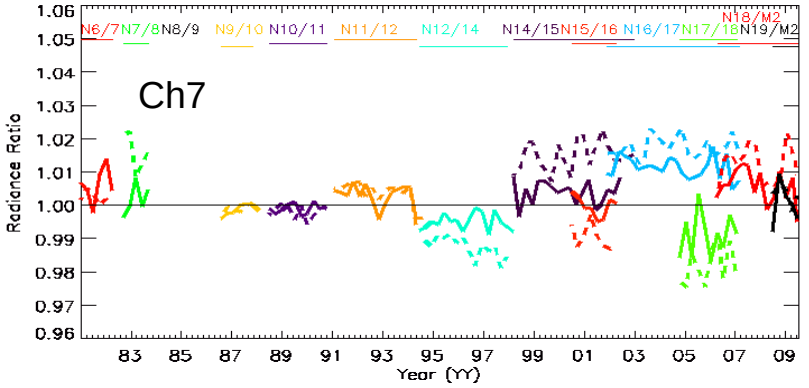


Inter-satellite Comparison of HIRS at SNO Locations



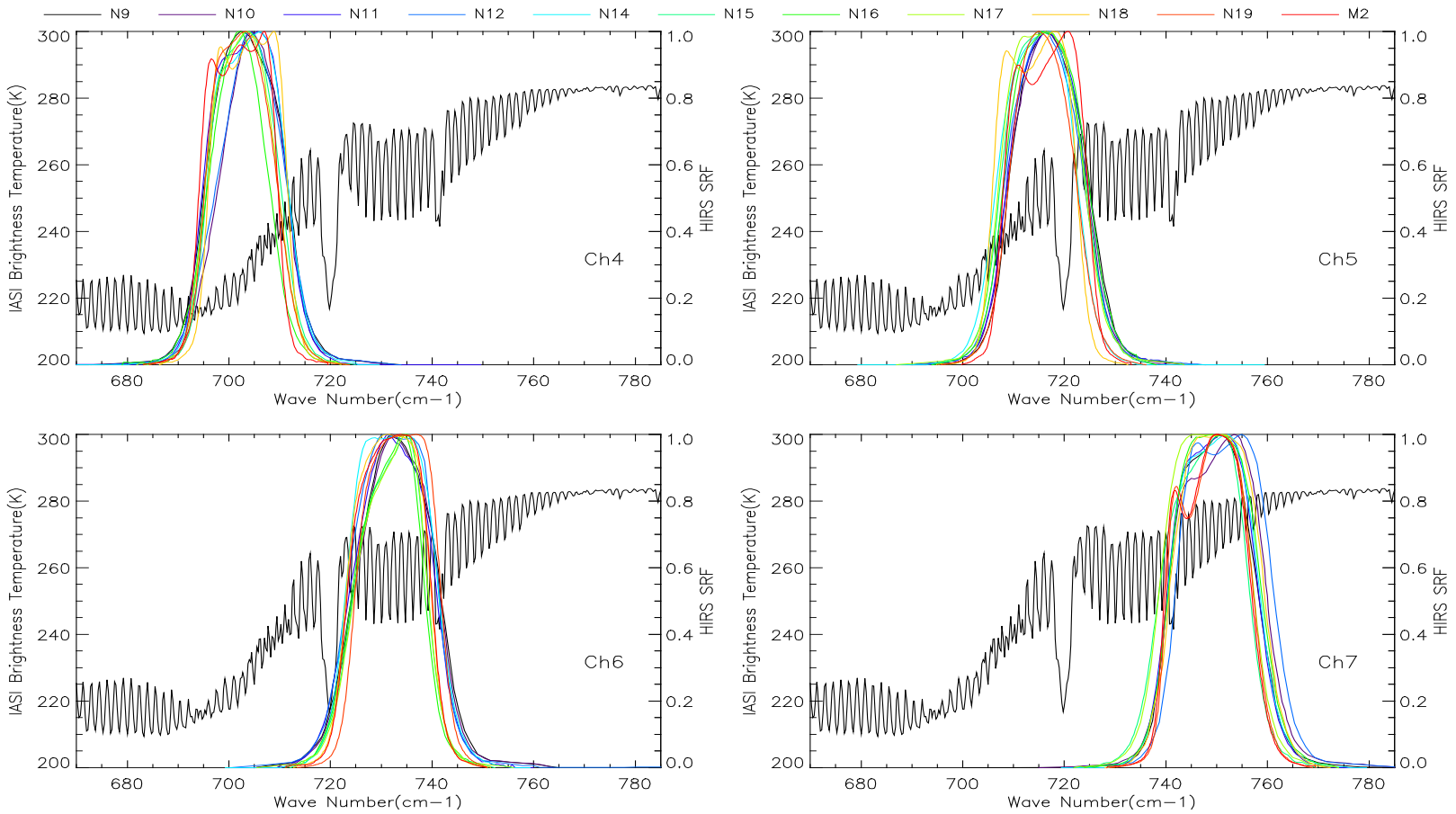






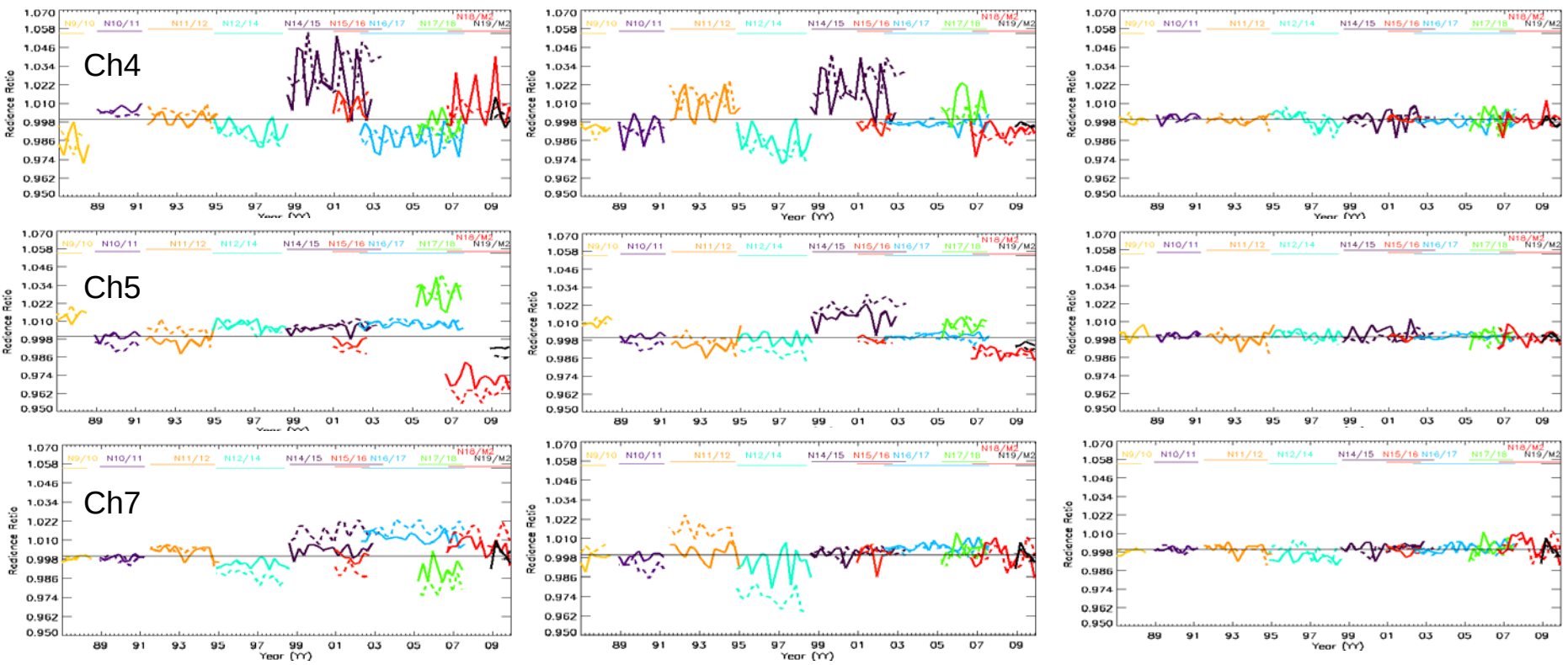
- Channels 4, 5, 7 show inter-satellite radiance biases with seasonal variations
- Simulation with IASI shows channel 6 is not sensitive to spectral error, while channel 4, 5, and 7 are sensitive to spectral error
- Small inter-satellite biases for Ch 6 (<1%) suggests the spectral differences are the main reasons for the inter-satellite biases

SRF Differences and Uncertainties



- There are inter-satellite differences in the pre-launch SRF measurements
- There are SRF uncertainties between pre-launch SRF measurements and true on-orbit SRFs

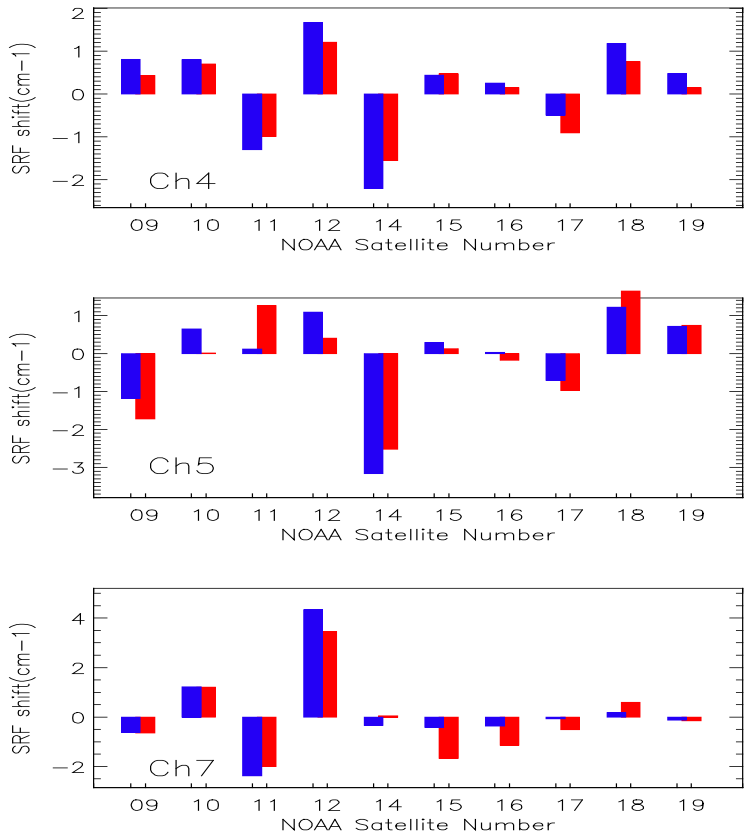
Process of HIRS Inter-satellite Calibration

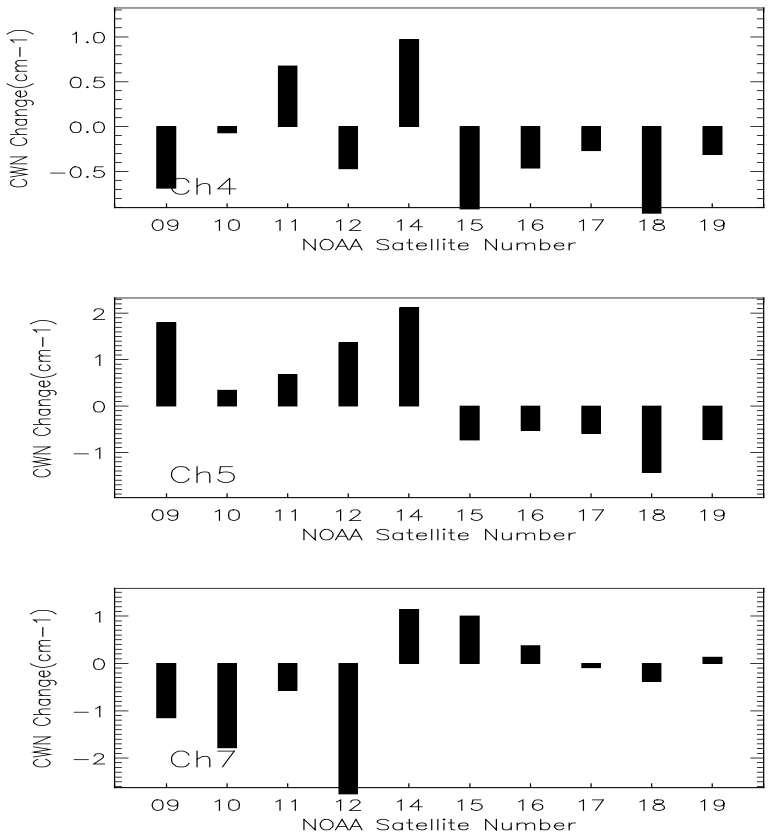


Original -Pre-launch SRF differences -Pre-launch SRF uncertainties

- IASI-simulated HIRS data are used to develop the linear models to estimate the impacts of SRF differences and uncertainties on inter-satellite radiance biases
- After accounting for the effect of pre-launch SRF differences, the inter-satellite biases can be either increased or decreased
- The optimized SRF shift minimizes the RMS biases with residual uncertainties less than 1%

NOAA HIRS Spectral Recalibration



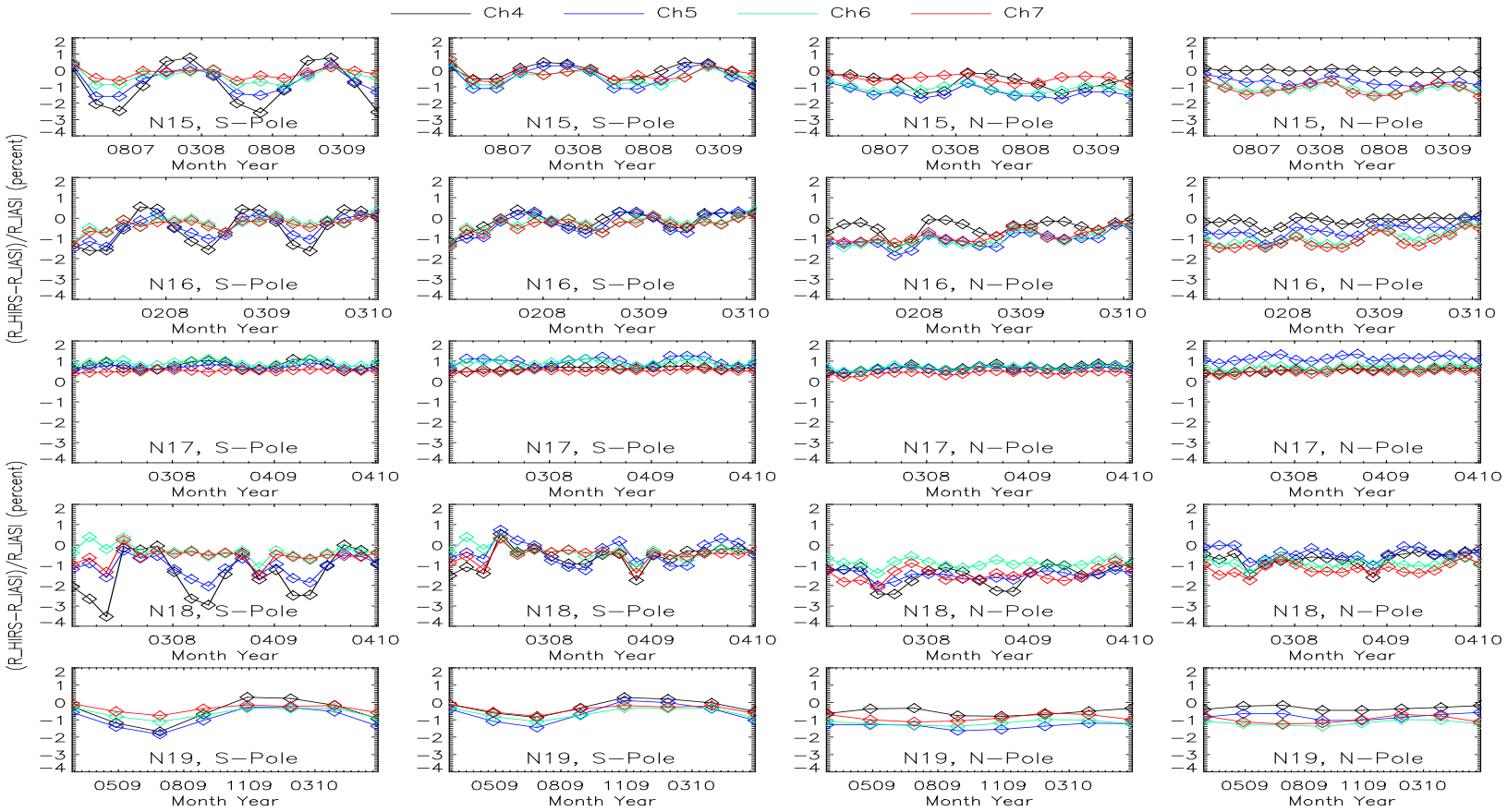


Inter-satellite SRF shifts, Blue-S Pole, Red-N Pole

Optimized HIRS CWN shifts

- Using the MetOp HIRS as a reference, the optimized SRFs for every NOAA HIRS is derived.
- Compared with pre-launch SRF measurements, the optimized shift of the SRF can be as large as 2.5 cm^{-1}.

Comparison between NOAA HIRS and IASI



- Direct comparisons between HIRS (N15 – N19) at SNO locations, Column1, 3 – Original comparison, Column2, 4 – After the optimized SRF shifts from the intersatellite HIRS calibration
- After the SRF shifts, the biases are significant reduced for most cases.
- There are a couple cases for which the optimized SRF shifts increase the HIRS biases. Notice the SRF shifts are empirically optimized by minimizing the inter-satellite biases between consecutive HIRS instruments.

Summary and Future Studies

- Inter-satellite radiance biases for the NOAA/HIRS long-wave CO_2 channels affect the cloud time series for climate change detection
- Our study shows that the HIRS spectral differences and uncertainties are the major causes for the biases. The HIRS SRF shifts can significant reduce the inter-satellite radiance biases for channel 4, 5, and 7
- IASI is used to recalibrated MetOp HIRS which is then used as the reference for calibrating historical HIRS at the SNOs
- IASI is also compared with NOAA HIRS (N15-N19) directly to verify the recalibration with positive results.
- Initial assessment of the recalibration by the HIRS CDR team shows positive impact on climate record
- Future work is needed to include HIRS on earliest NOAA satellites (N6-N8).
- More info can be found in publication: http://www.agu.org/pubs/crossref/2012/2011JD016427.shtml