CLARREO and IR Intercal

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Outline

1. Overview of UW studies of CLARREO IR Intercal
2. Expected on-orbit radiometric calibration performance for NPP CrIS
3. AIRS / IASI Intercal: updated results

CLARREO Intercal Study; Initial Question:

Given a candidate CLARREO mission optimized for producing the climate benchmark products, how well can we meet the CLARREO objective to serve as an inter-calibration reference for the operational IR sounders ?

The goal is to be capable of performing the inter-calibration with uncertainty comparable to the CLARREO radiometric accuracy, for the benefit of the operational sounders for their (primarily weather driven) goals as well as their use to intercalibrate colocated imagers (e.g. AIRS/MODIS) and geo senors (e.g. AIRS/GOES).

Study Approach:

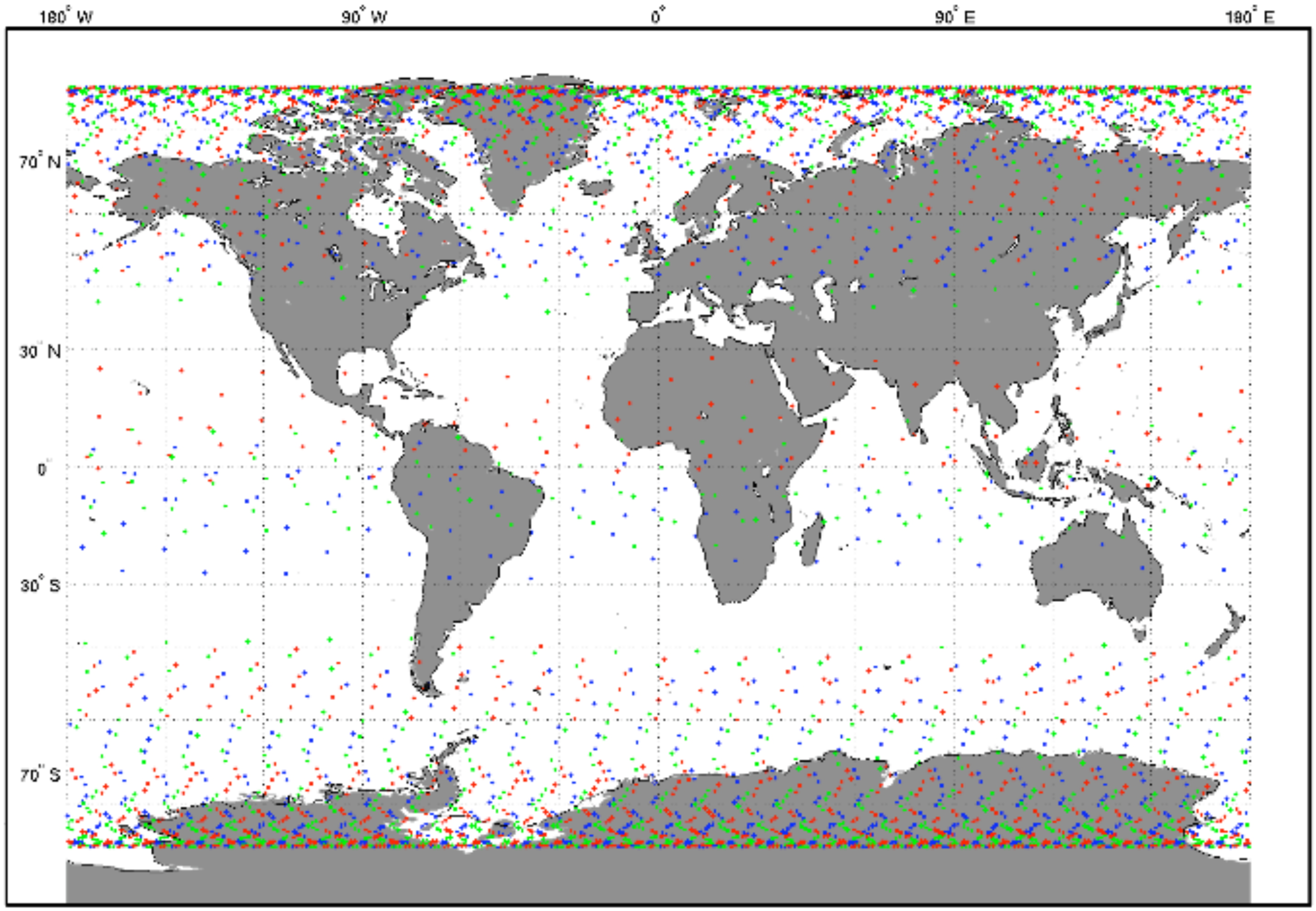
A simulation study using real MODIS data.

Find Simultaneous Nadir Overpasses (SNOs) of CLARREO and EOS Aqua for 2006, and for each SNO use MODIS radiances to estimate the spatial and temporal sampling differences between CLARREO and CrIS/AIRS or IASI.

Opposed to actual inter-comparison studies involving two sensors, this approach removes the unknown sensor biases and allows spatial and temporal inter-calibration differences to be examined.

CLARREO/Aqua SNOs in 2006

Three 90-degree CLARREO orbits with right ascension separated by 120 degrees are "launched" on January 1st, and the SNOs for CLARREO and EOS Aqua are identified for the year of 2006.

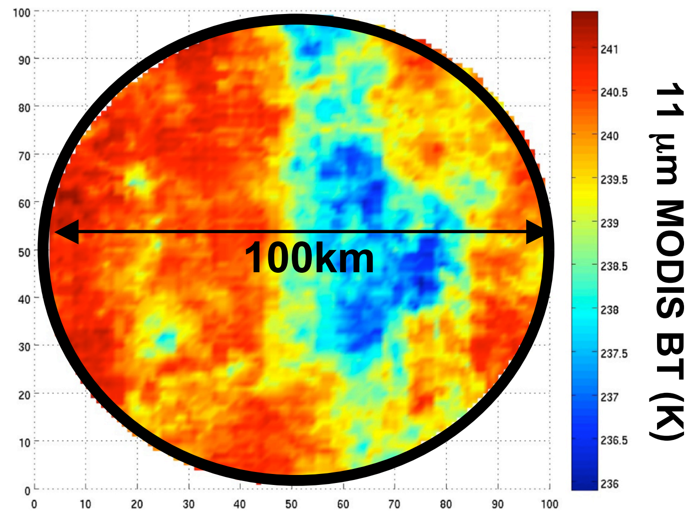


Spatial Sampling Differences

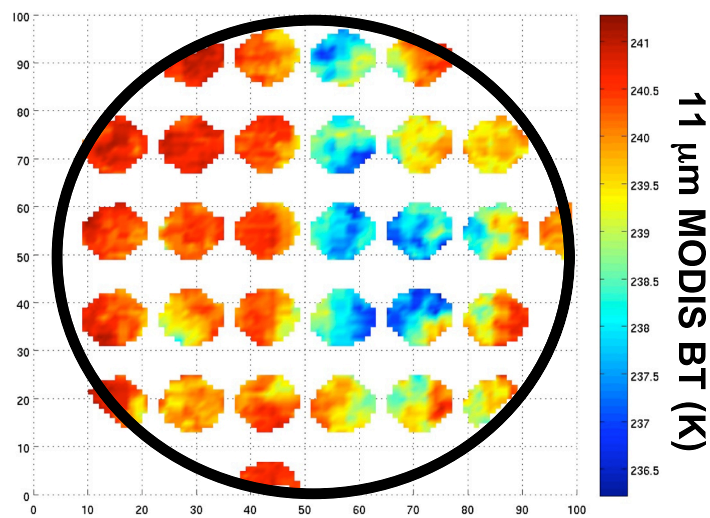
"spatial difference" (K) = mean w/in CLARREO FOV minus mean w/in CrIS/IASI FOVs

"BT STDEV" (K) = Standard deviation w/in CLARREO FOV

100 km CLARREO

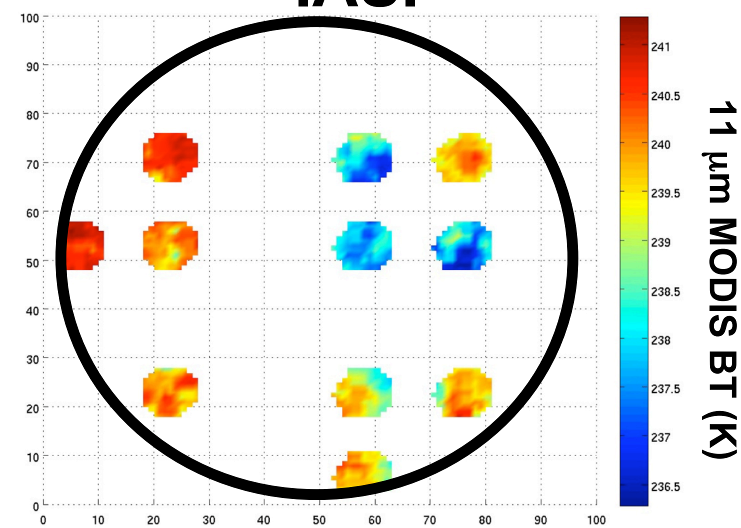


CrIS



~55% coverage

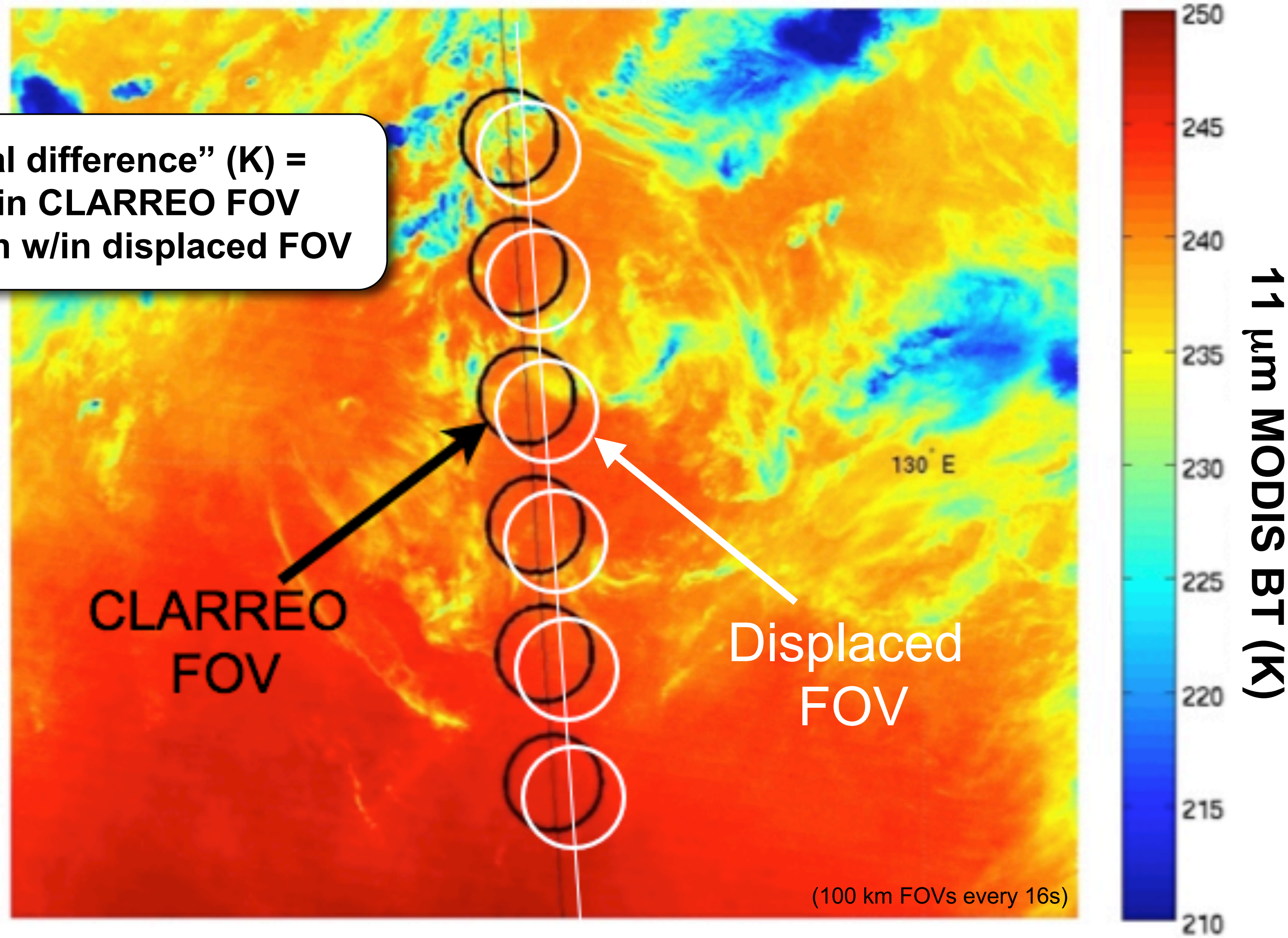
IASI



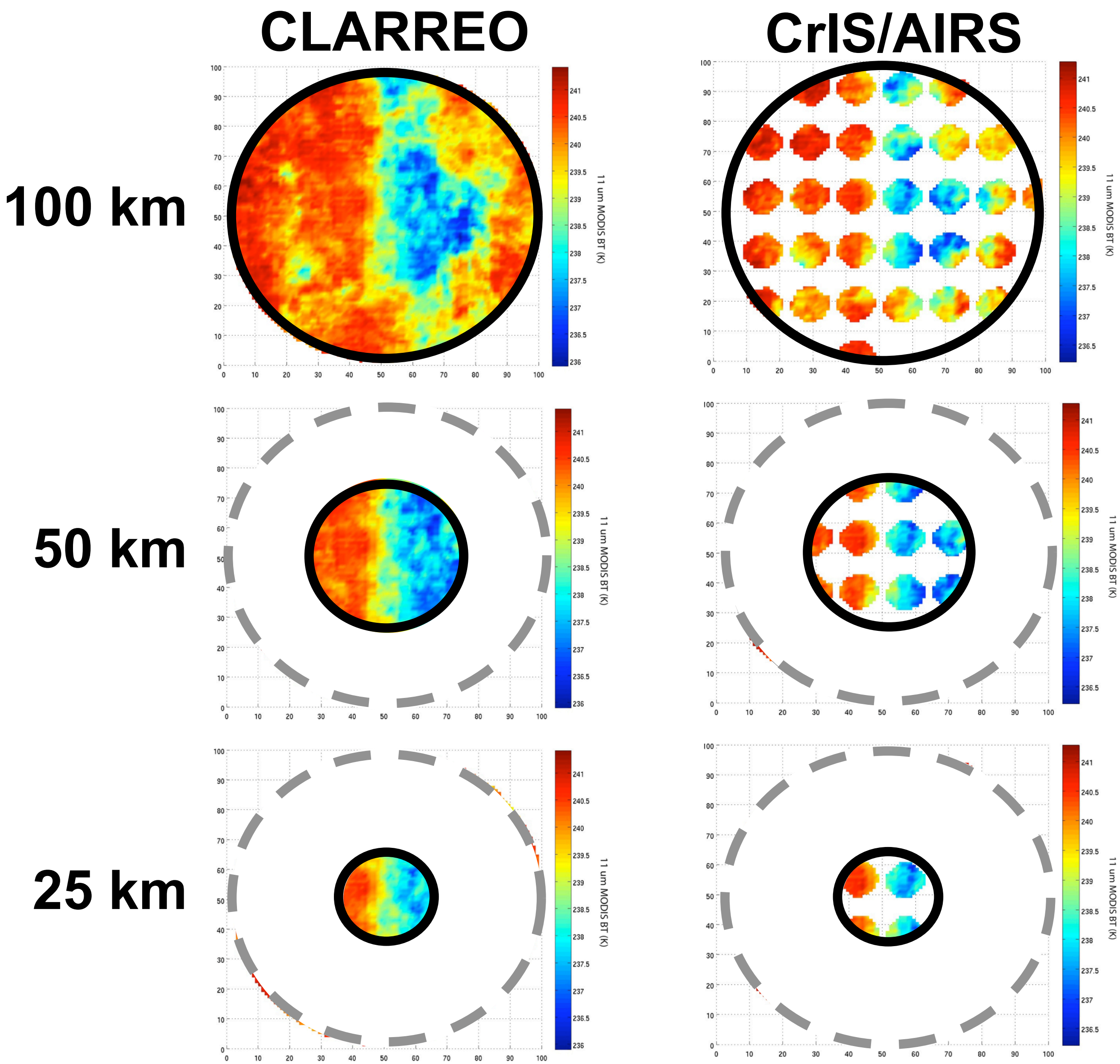
~18% coverage

Time Sampling Differences

"temporal difference" (K) =
mean w/in CLARREO FOV
minus mean w/in displaced FOV

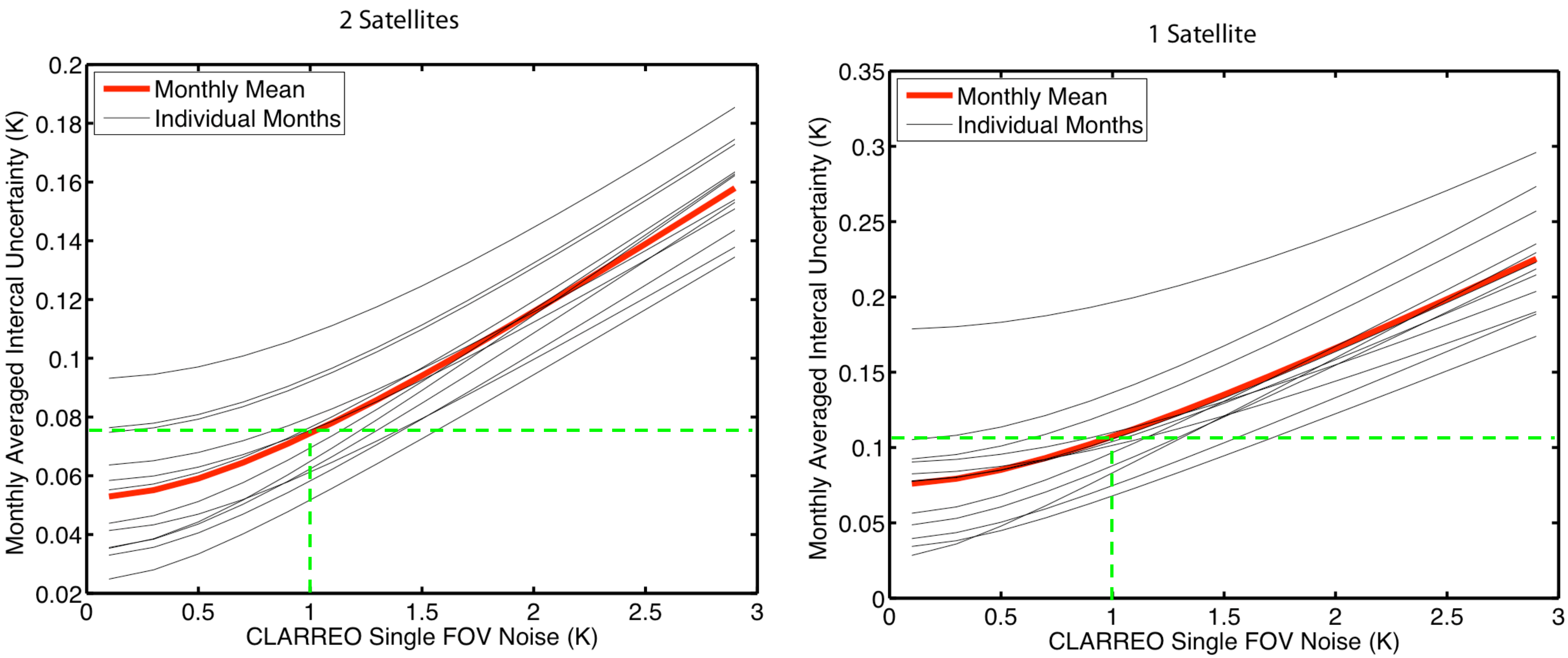


Footprint Size



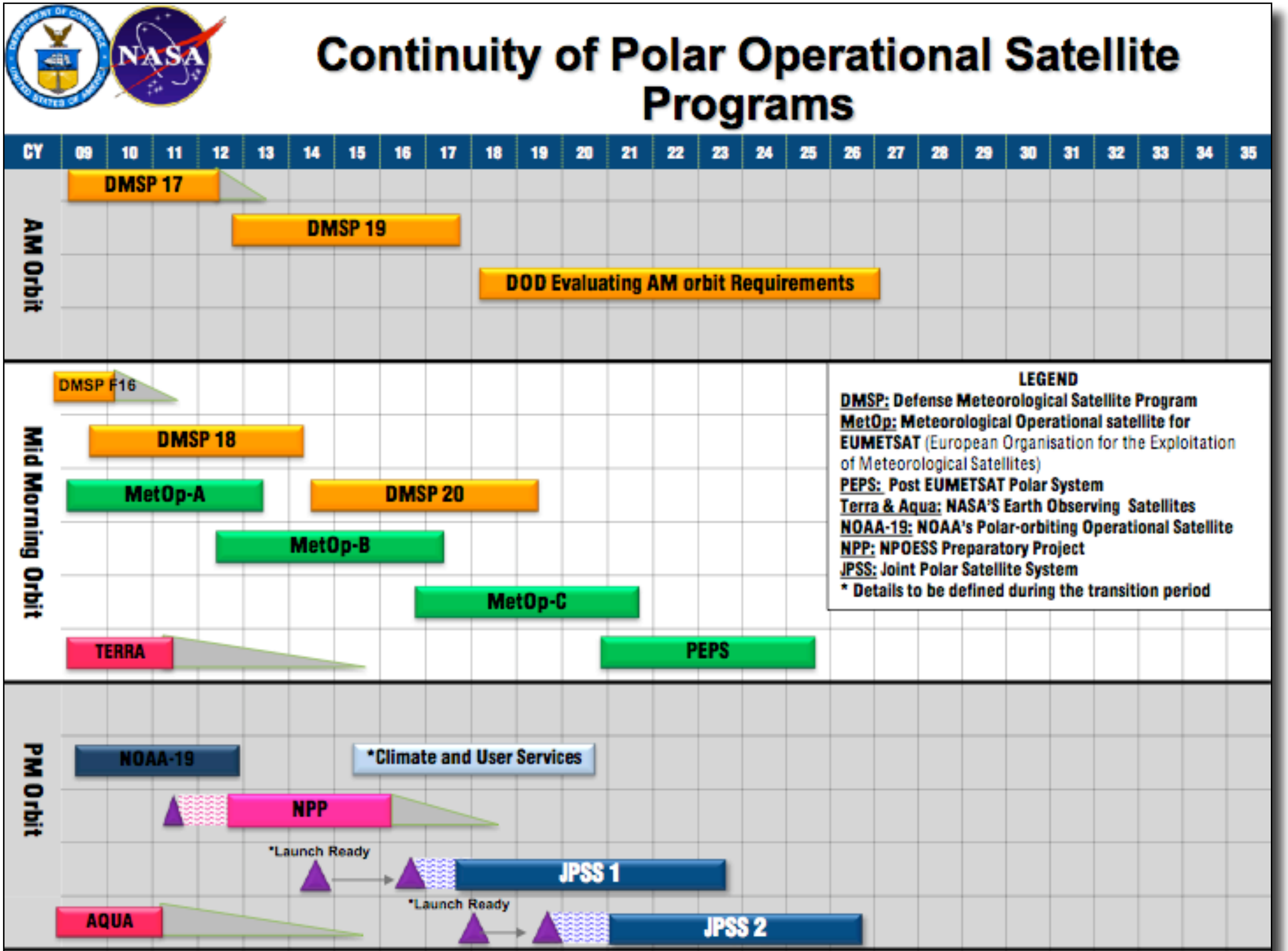
Sample Results

11μm 1-sigma monthly intercal uncertainty vs. NEDT:



The results are generated using 30 sec sampling, 25 KM (diameter) FOV, and for each SNO allowing FOVs with less then 10 deg scan angles to be included in the intercal. The red curve is the monthly mean uncertainty for 2006, with each black curve representing the individual months.

Summary of CrIS FM1 (NPP) Radiometric Performance



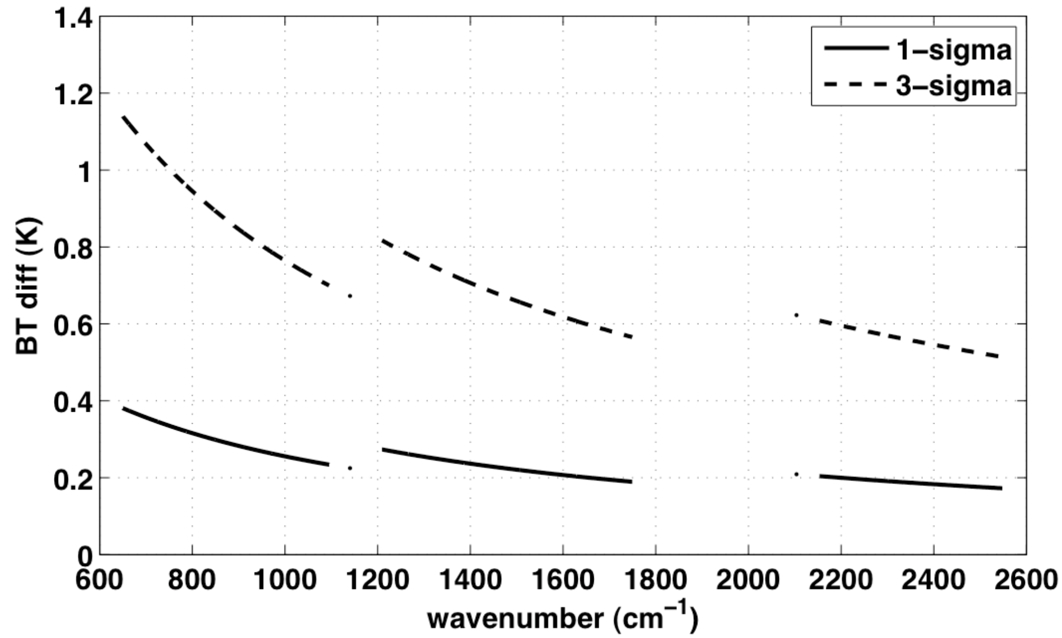
5/27/2010 POES Flyout Chart, NESDIS

CrIS Radiometric Uncertainty Spec

- **CrIS sensor Radiometric Specifications**
  Expressed as (1-sigma) percent radiance uncertainty with respect to Plank 287K radiance [i.e. 100•dR/B(287K)]:
  - Longwave: 0.45%
  - Midwave: 0.58%
  - Shortwave: 0.77%

  for B(233K) to B(287K)

CrIS Radiometric Uncertainty spec, expressed as 1 and 3 sigma brightness temperature differences



CrIS FM1 In-flight Radiometric Uncertainty

On-orbit radiometric calibration equation:

$$R_{Earth} = \mathcal{Re}\{(C'_{Earth} - C'_{Space})/(C'_{ICT}-C'_{Space})\}(R_{ICT}-R_{Space}) + R_{Space}$$

with:

$$R_{ICT} = \varepsilon_{ICT}\, B(T_{ICT}) + (1-\varepsilon_{ICT})\, R_{ICT,Reflected}$$

$$R_{Space} = B(T_{Space})$$

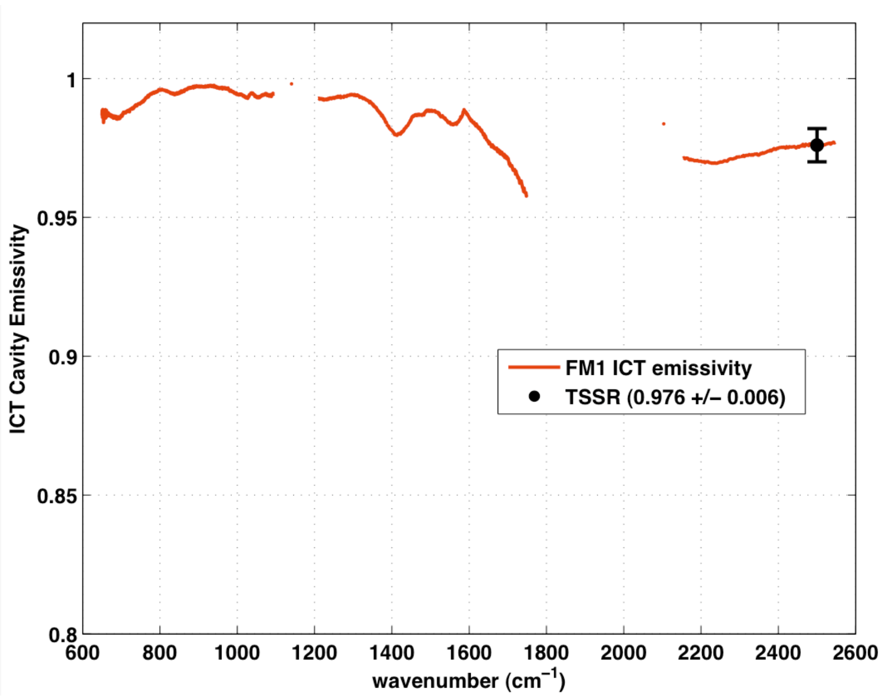
$$C' = C\,(1+2\, a_2 V_{DC})$$

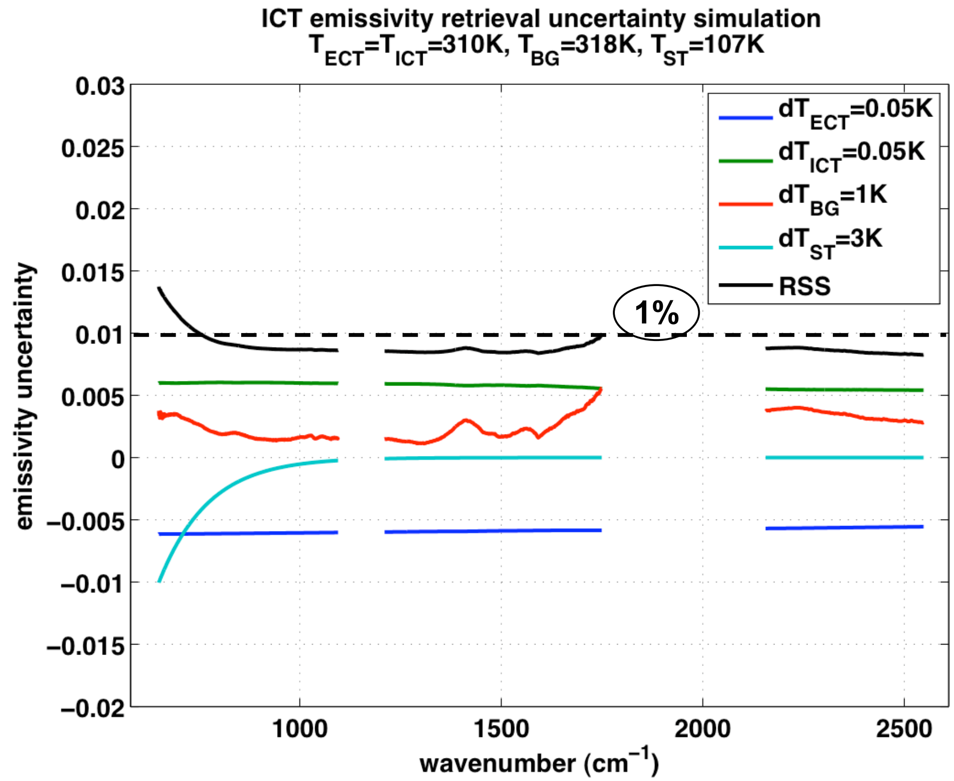
Parameter	1-σ uncertainty	3-σ uncertainty	Source/Comment
T_{ICT} (K)	37.5 mK	112.5 mK	Bomem/ITT eng. estimate (w/o known readout issue)
ε_{ICT} ( )	0.01	0.03	Independent measurement (TSSR) at 2500 cm^{-1} plus Analysis
$T_{refl,measured}$ (K)	0.5 K	1.5 K	Temperature monitored components (Frame, OMA, BS, ICT Baffle)
$T_{refl,modelled}$ (K)	2 K	6 K	Worst case estimate of unmonitored SSM Baffle T variations
a_2 (1/counts)	9.6% Longwave 15.5% Midwave	28.8% Longwave 46.5% Midwave	DM and ECT view analysis

Other contributions, such as scan mirror polarization and stray light, are not included here. Other studies, by ITT, show these do not contribute significantly to the total RU.

FM1 ICT emissivity

UW analysis of CrIS PQH@315K dataset to derive ICT emissivity and uncertainty:





Reflected Component of Predicted ICT Radiance

The predicted ICT Radiance, used in the calibration equation, is:

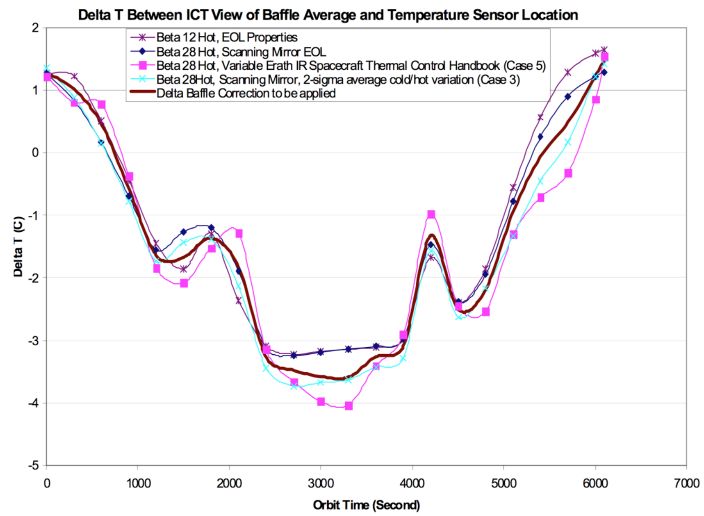
$$R_{ICT} = \varepsilon_{ICT} B(T_{ICT}) + (1-\varepsilon_{ICT}) R_{ICT,Reflected}$$

where $(1-\varepsilon_{ICT}) R_{ICT,Reflected}$ is the reflected term. Contributions to $R_{ICT,Reflected}$ fall into three groups:

1. Ambient temperature components with active temperature sensors, accounting for ~47.5% view factor.

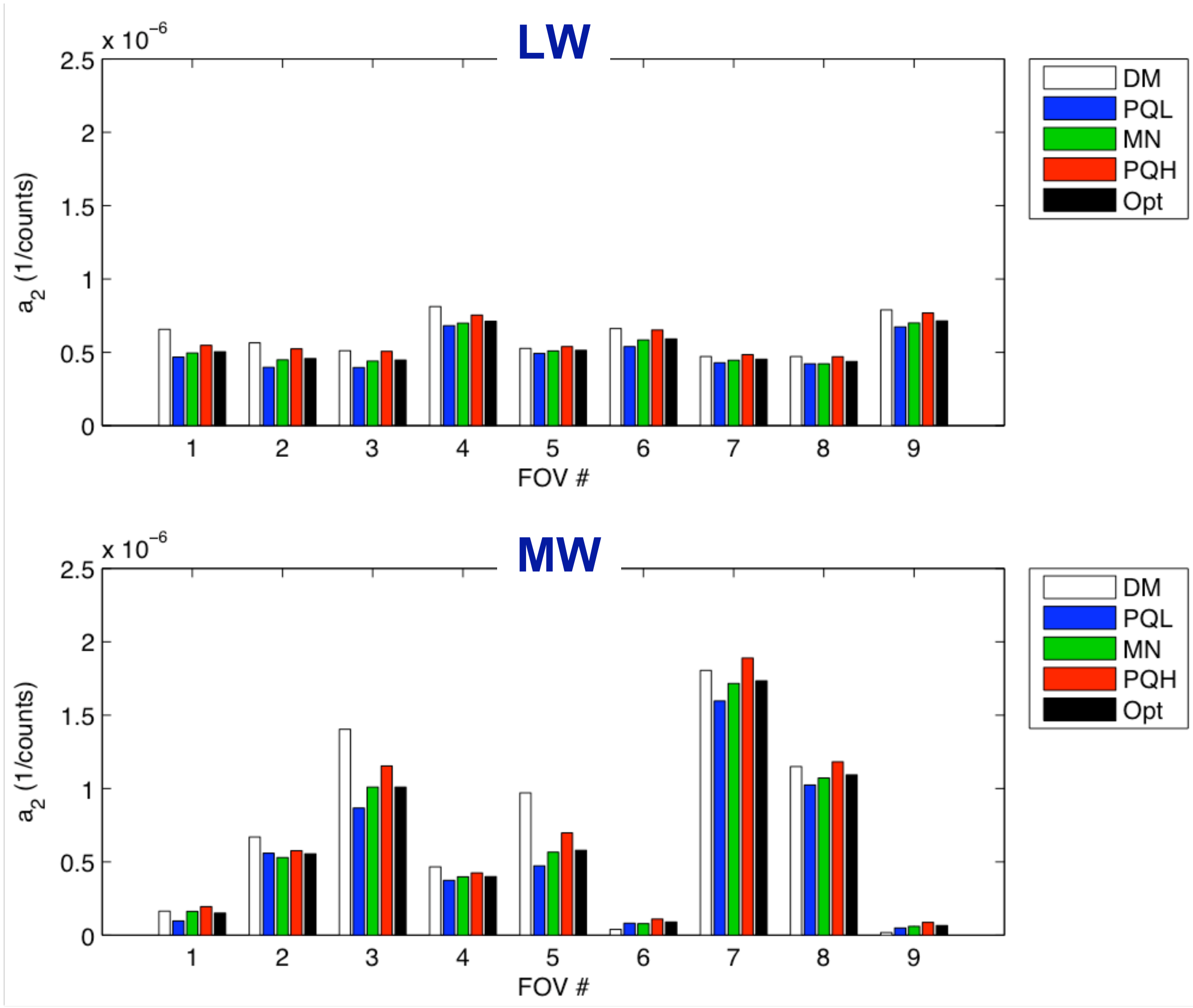
2. Near ambient temperature components without representative temperature monitoring, accounting for ~50.8% view factor. ITT thermal modeling predicts orbital variation of ~5.5K peak-to-peak variation in this component.

3. Cold view components, accounting for ~1.8% view factor.



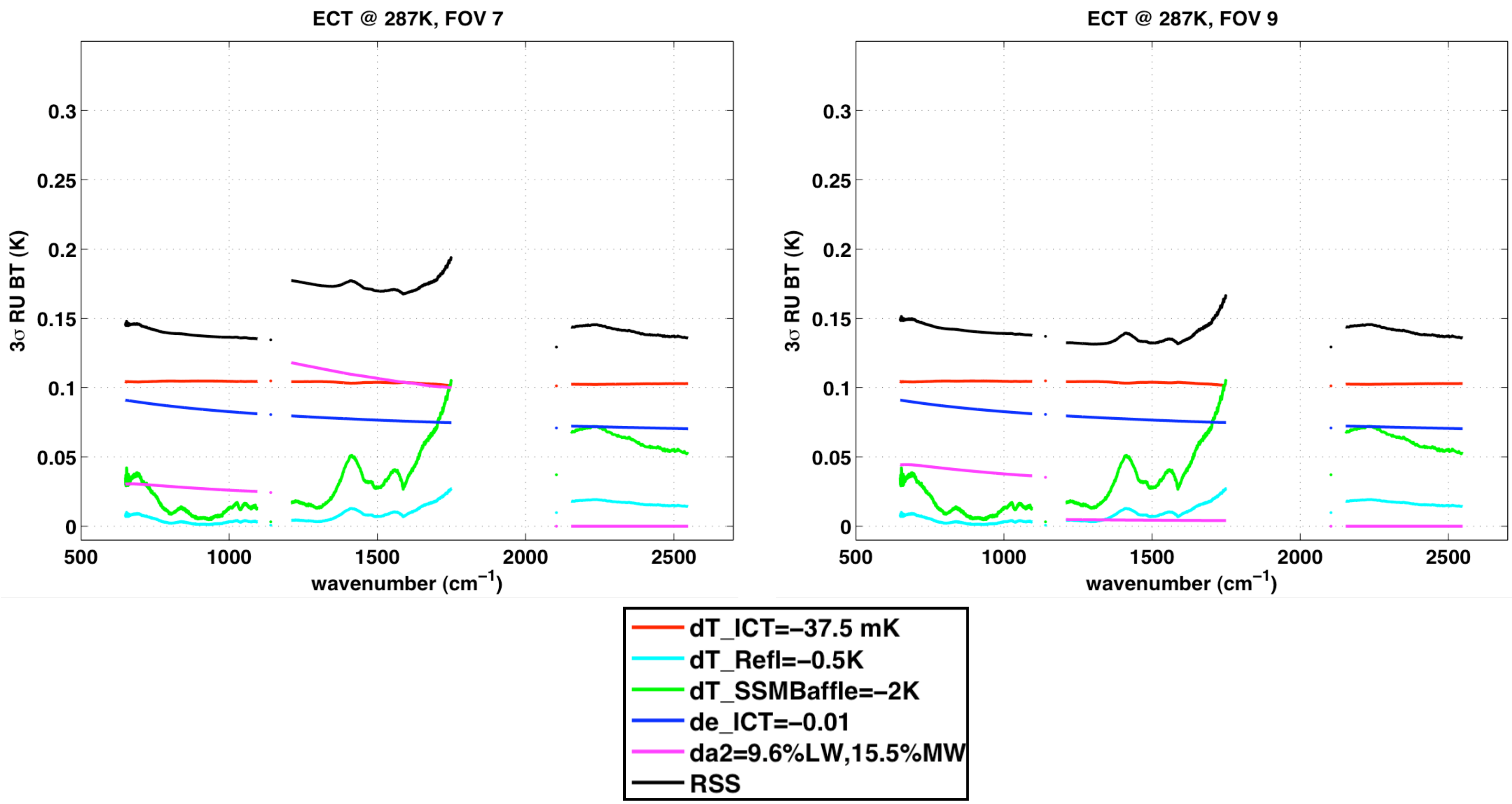
We put the full range of this expected variation into the uncertainty budget, even though the SDR algorithm will include orbital/thermal model estimates.

Summary of non-linearity correction coefficients, a_2



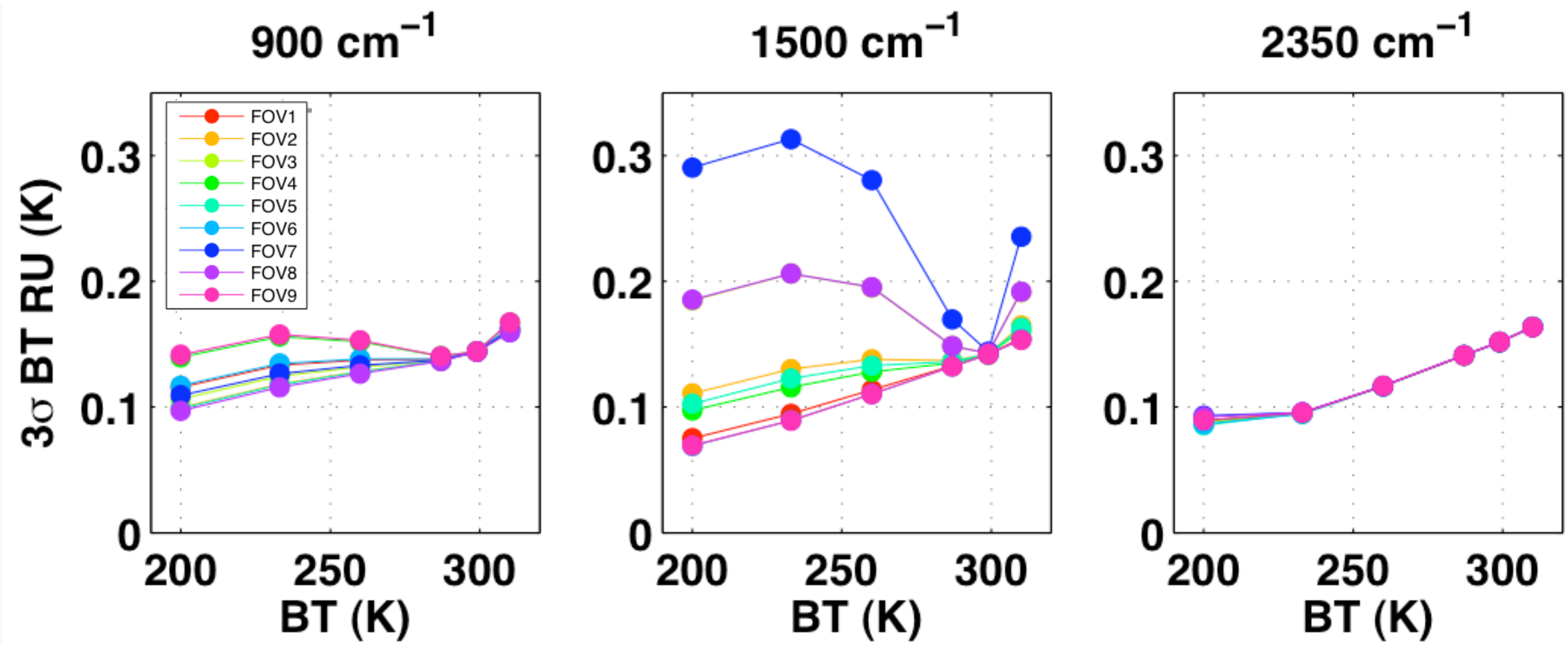
1-sigma uncertainty is computed from the variability of the various estimates: 9.6% for LW, 15.5% for MW.

CrIS FM1 In-flight Radiometric Uncertainty:
Examples for FOVs 7 and 9 for ECT@287K



CrIS FM1 In-flight Radiometric Uncertainty:

versus scene temperature for all FOVs for ~mid-band spectral channels



CrIS FM1 TVAC Testing Radiometric Uncertainty

TVAC calibration equation for ECT view:

$$R_{ECT} = \mathcal{R}e\{(C'_{ECT} - C'_{ST})/(C'_{ICT}-C'_{ST})\}(R_{ICT}-R_{ST}) + R_{ST}$$

with:

$R_{ST} = \varepsilon_{ST}\, B(T_{ST}) + (1-\varepsilon_{ST})\, B(T_{ST,Relected})$

$R_{ICT} = \varepsilon_{ICT}\, B(T_{ICT}) + (1-\varepsilon_{ICT})\, R_{ICT,Reflected}$

$C' = C\,(1+2\, a_2 V_{DC})$

Calibrated

↕

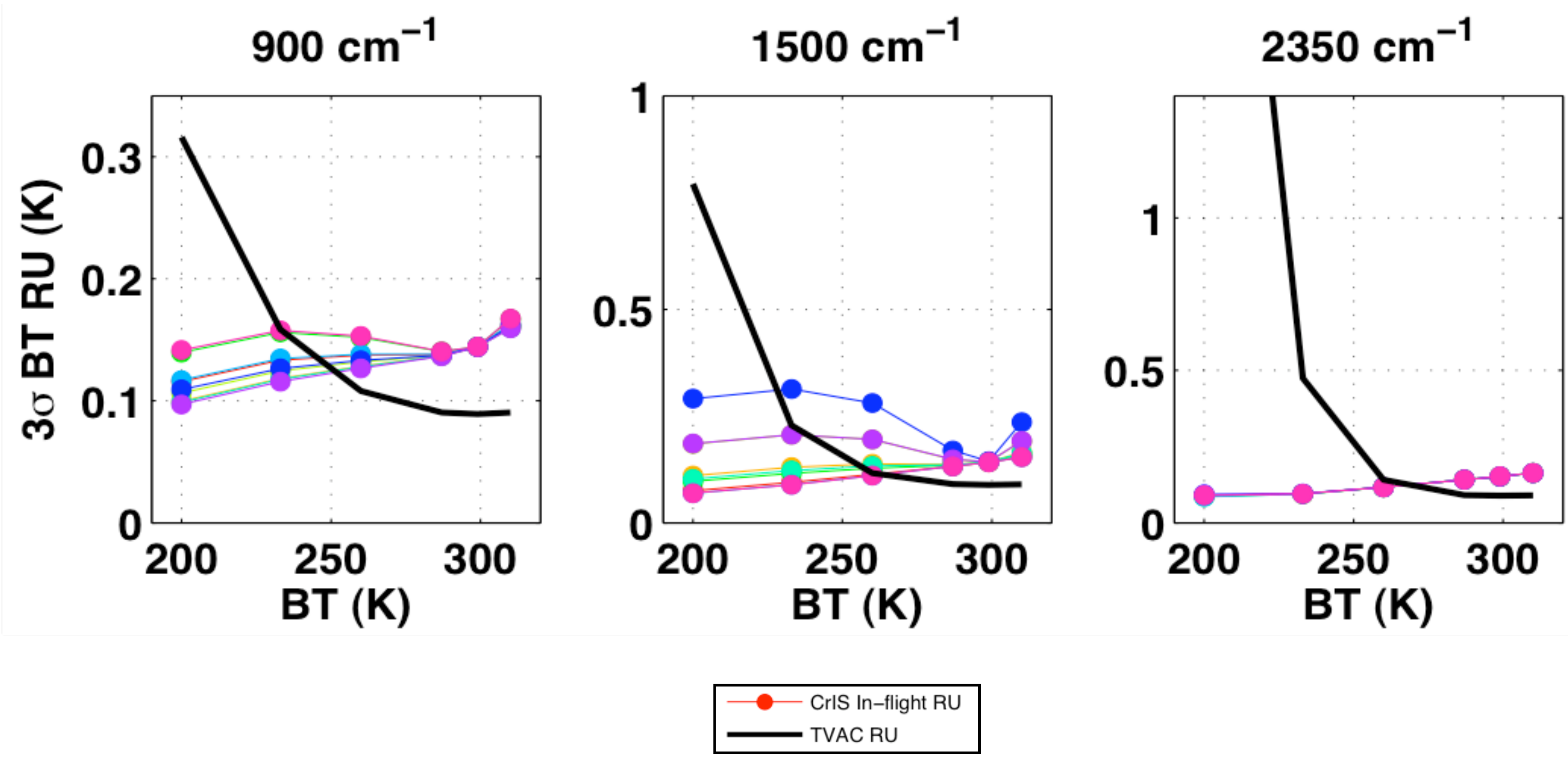
Predicted

TVAC “truth”: ECT view predicted:

$$R_{ECT} = \varepsilon_{ECT}\, B(T_{ECT}) + (1-\varepsilon_{ECT})\, B(T_{ECT,Relected})$$

Parameter	Value	1-σ uncertainty	3-σ uncertainty	Source/Comment
T_{ECT} (K)	200-310 K	29.7 mK	89.1 mK	Bomem/ITT estimate recent new Hart/UW absolute cal info, and without spatial gradients
ε_{ECT} ( )	0.9995	0.0003	0.0009	Bomem report
$T_{ECT,Reflected}$ (K)	T_{ICT}	3 K	9 K	Conservative estimate
T_{ST} (K)	105 K	2 K	6 K	Conservative estimate
ε_{ST} ( )	0.9995	0.0003	0.0009	Bomem report
$T_{ST,Reflected}$ (K)	T_{ICT}	3 K	9 K	Conservative estimate

CrIS FM1 TVAC Testing Radiometric Uncertainty



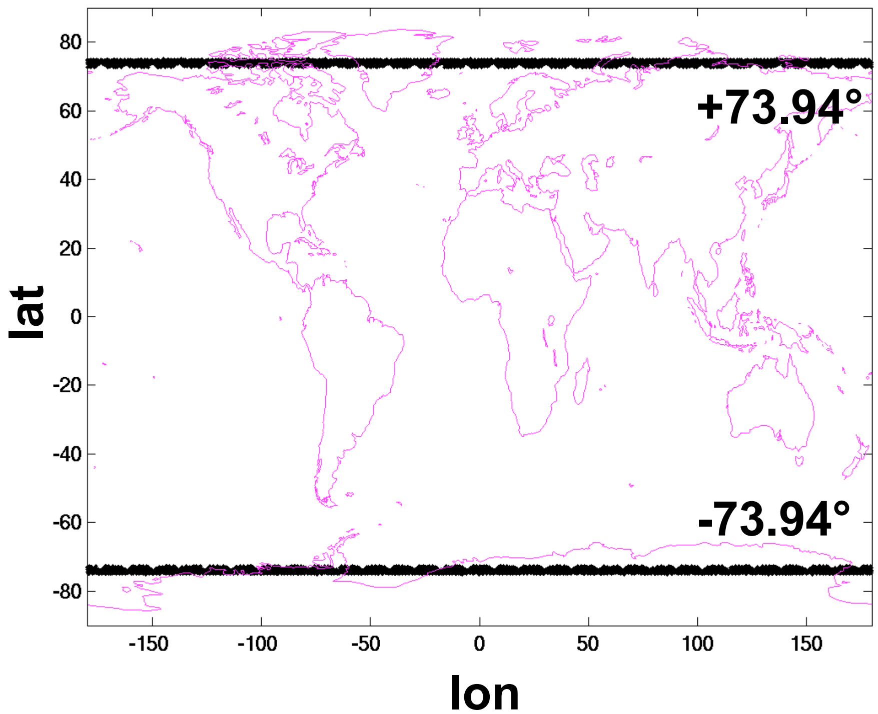
Evaluation of IASI and AIRS Spectral Radiances using Simultaneous Nadir Overpasses

SNOs

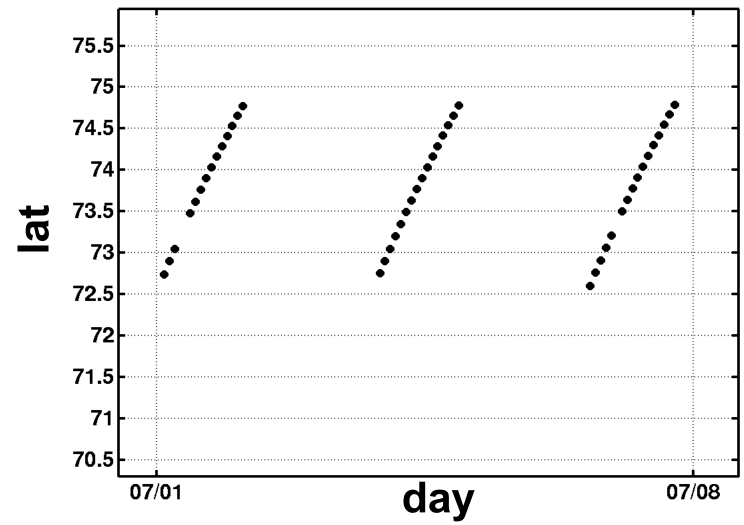
- “Simultaneous” “Nadir” Overpasses of AIRS and IASI
- SNOs based on the intersections of nadir ground tracks of METOP-A and Aqua (i.e. exact SNO locations)
- IASI and AIRS FOV selections for each SNO:
  - Time window: +/- 20 min from SNO time
  - Spatial window: 60 km from Nadir track intersection point to center of IASI/AIRS FOVs
- Resulting in:
  - ~45 AIRS FOVs, ~16 IASI FOVs per SNO
  - ~32 SNOs every ~3 days (16 North, 16 South)
  - 8102 SNOs in this study, covering May 2007 to Nov 2009

SNO characteristics

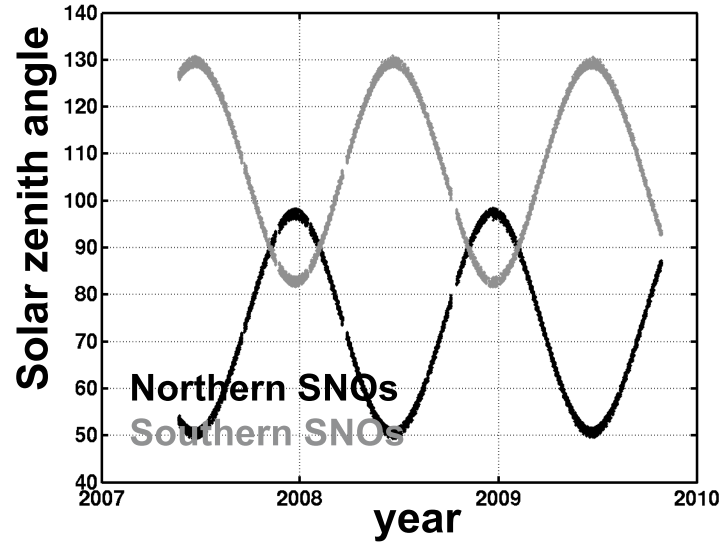
locations



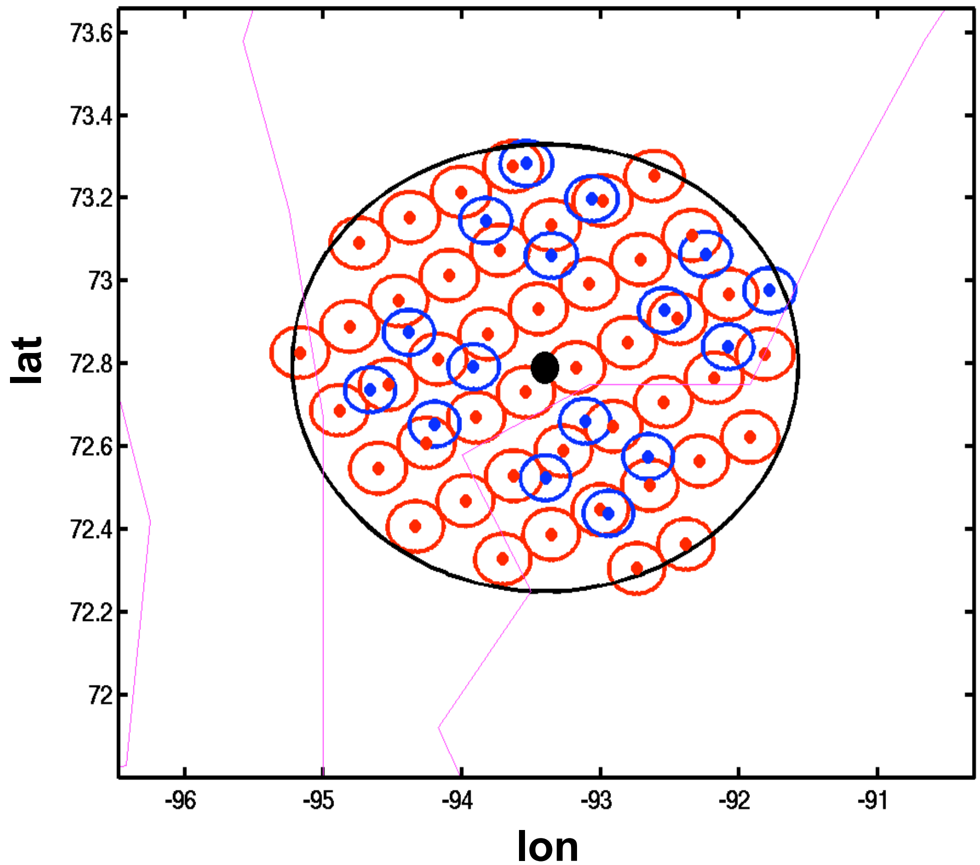
timing



seasons



Sample SNO

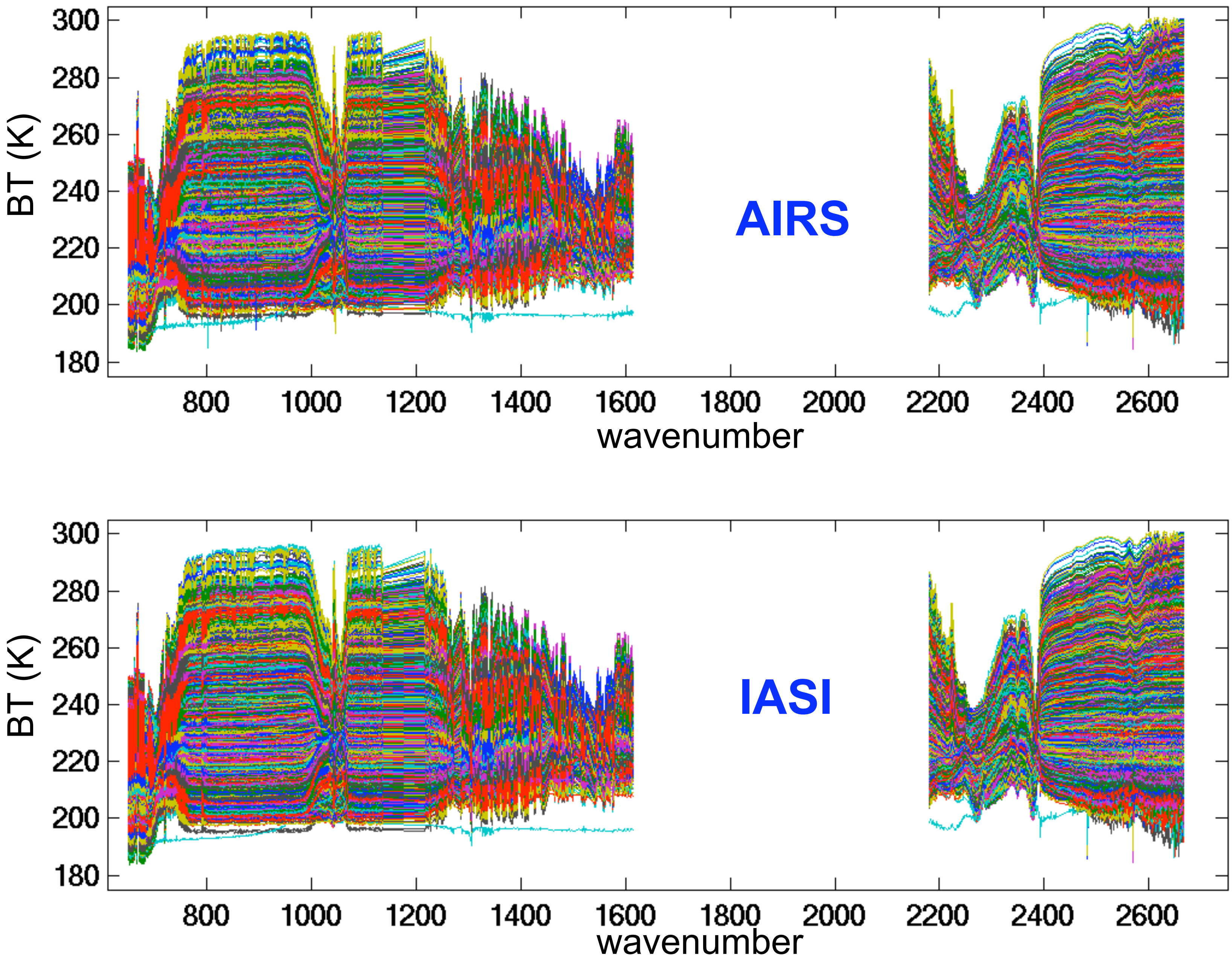


Nadir track intersection location and 60 km radius

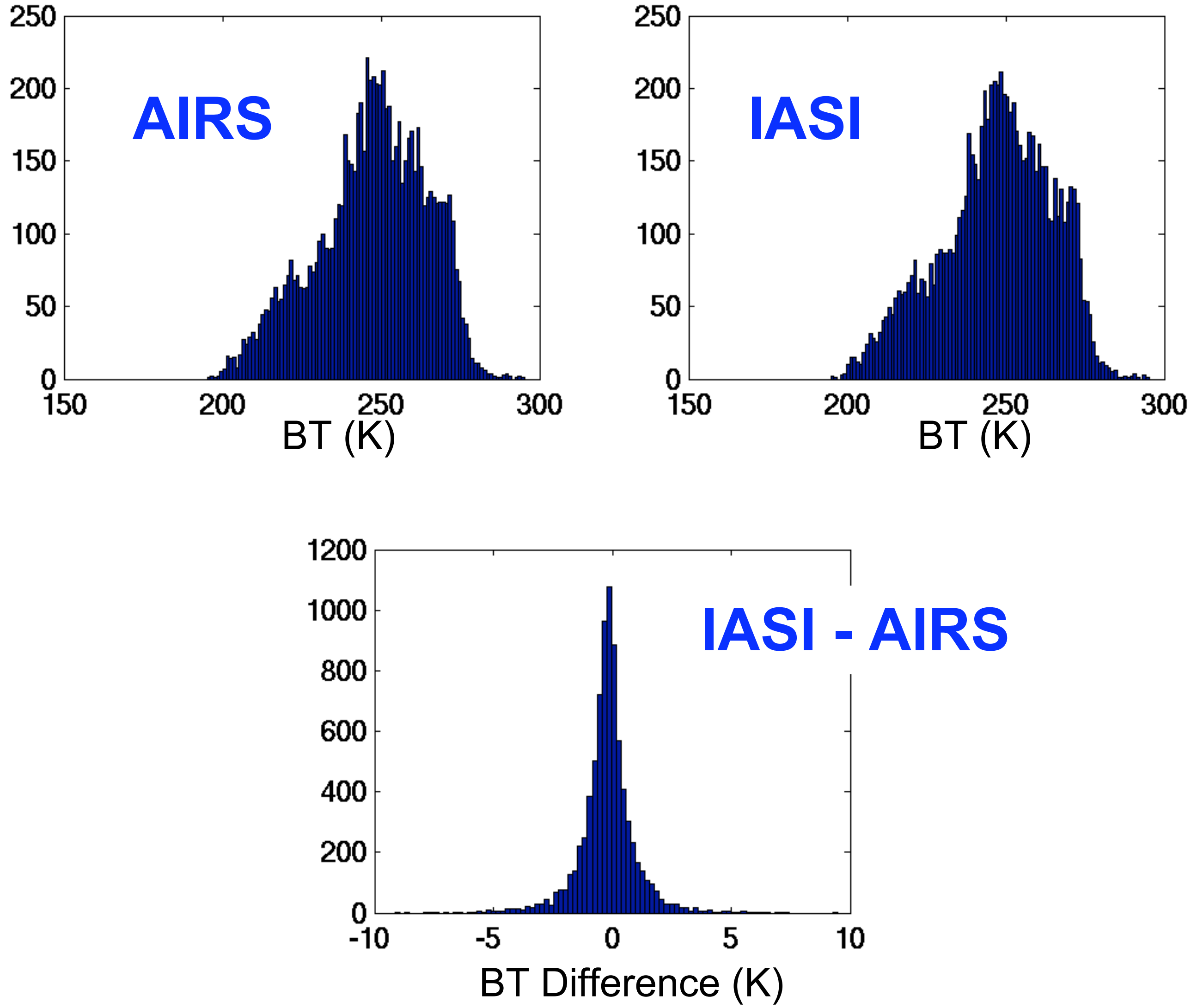
AIRS FOVs (L1B v5.0.0.0)

IASI FOVs

Mean Spectra

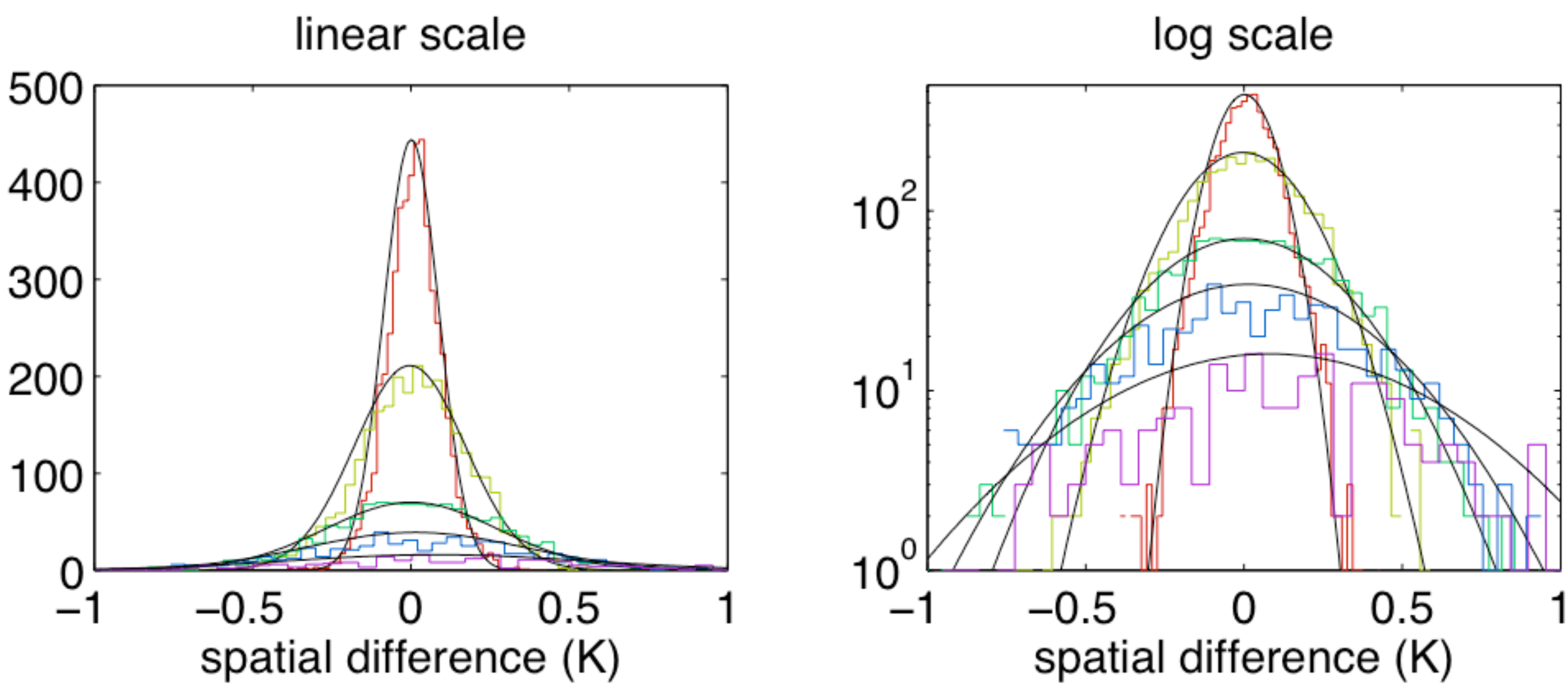


Sample spectral channel, 900.3 cm^{-1}



Spatial Sampling Differences

MODIS Band 31@11μm; 100km CLARREO FOVs every 14s; CrIS/AIRS



1 ≤ STDEV ≤ 2 (5074 pts, stdev=0.08)
3 ≤ STDEV ≤ 4 (2783 pts, stdev=0.18)
5 ≤ STDEV ≤ 6 (1179 pts, stdev=0.27)
7 ≤ STDEV ≤ 8 (563 pts, stdev=0.34)
9 ≤ STDEV ≤ 10 (211 pts, stdev=0.47)

Yes, Gaussian.

Analysis Approach

- For each SNO, the AIRS FOVs within 60 km of the SNO location are identified and the mean (MN) and standard deviation (SD) radiance spectra are computed. The same is done for IASI.
- For each SNO, the spectra are processed to have common spectral resolution and sampling and the difference between AIRS and IASI is computed

  $\delta_i = MN'_{AIRS,i} - MN'_{IASI,i}$
- The resulting primary source of comparison error for each SNO case is due to the difference in the sparse sampling of the scene radiance provided by AIRS (nearly contiguous 3x3 FOVs) and IASI (non-contiguous 2x2 FOVs). The 1-sigma uncertainty for each SNO case is therefore computed as

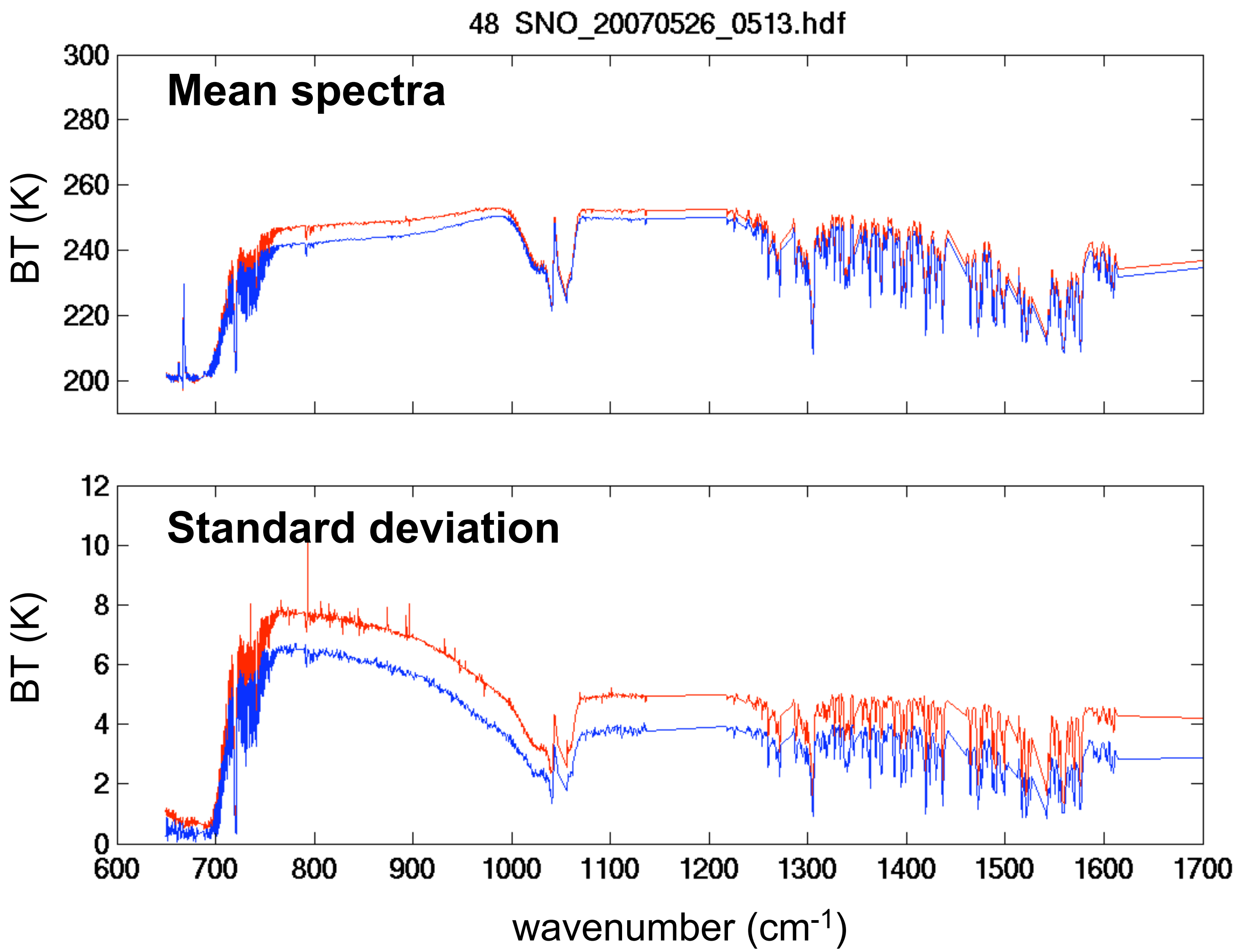
  $\sigma_i = [SD'^{2}_{IASI,i} + SD'^{2}_{AIRS,i}]^{1/2}$
- For ensembles of SNOs, the spatial sampling differences are found to be random from case to case. The mean differences between AIRS and IASI and their uncertainties are computed using weighted mean differences using the spatial standard deviations to compute the weights for each case:

Weights : $\omega_i = 1/\sigma_i^2$

Mean Difference : $\Delta = \sigma_\Delta^2 \, [\Sigma_{i=1:N}\, \omega_i\, \delta_i]$

Uncertainty : $\sigma_\Delta = [\Sigma_{i=1:N}\, \omega_i]^{-1/2}$

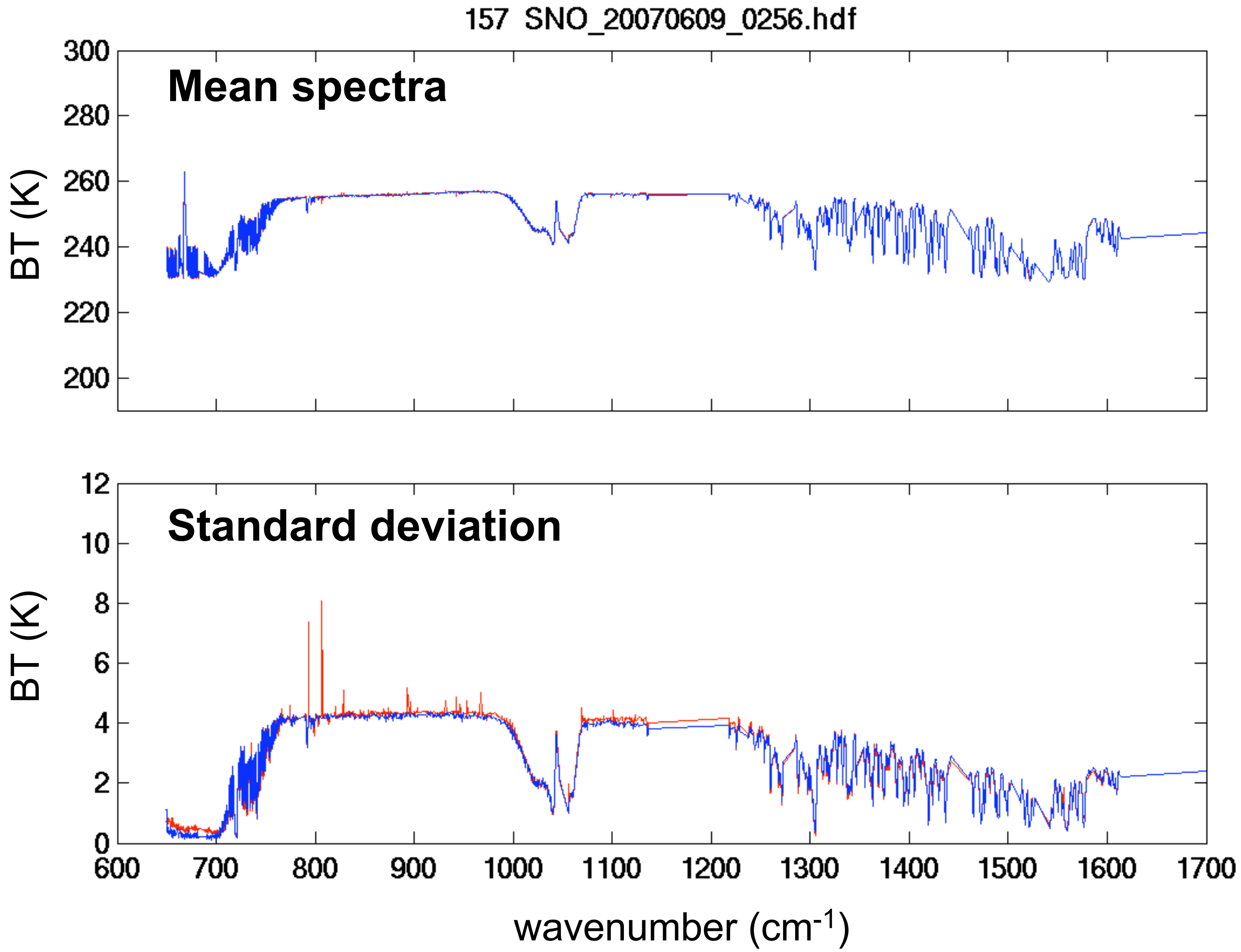
Sample SNO, #48



AIRS

IASI

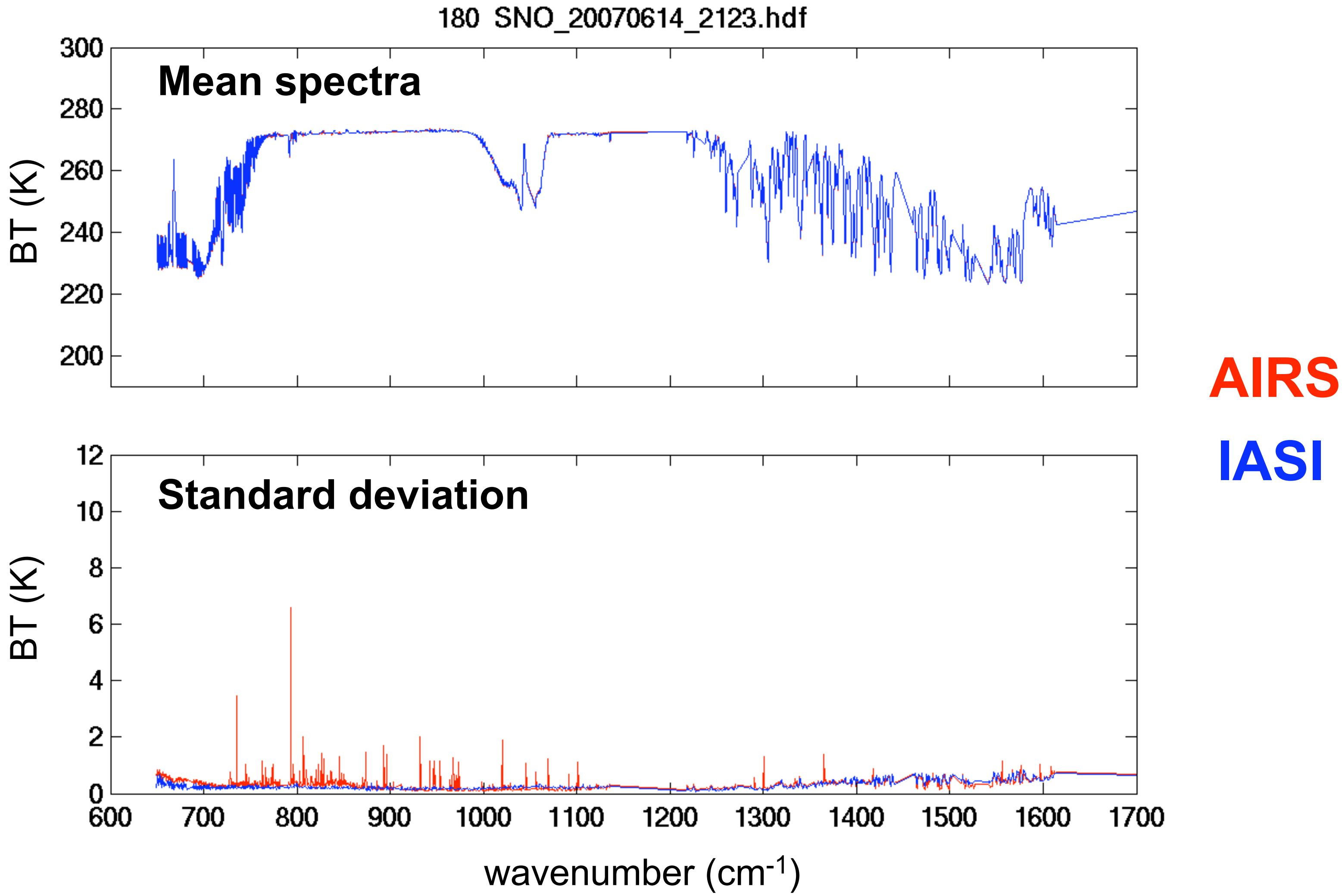
Sample SNO, #157



AIRS

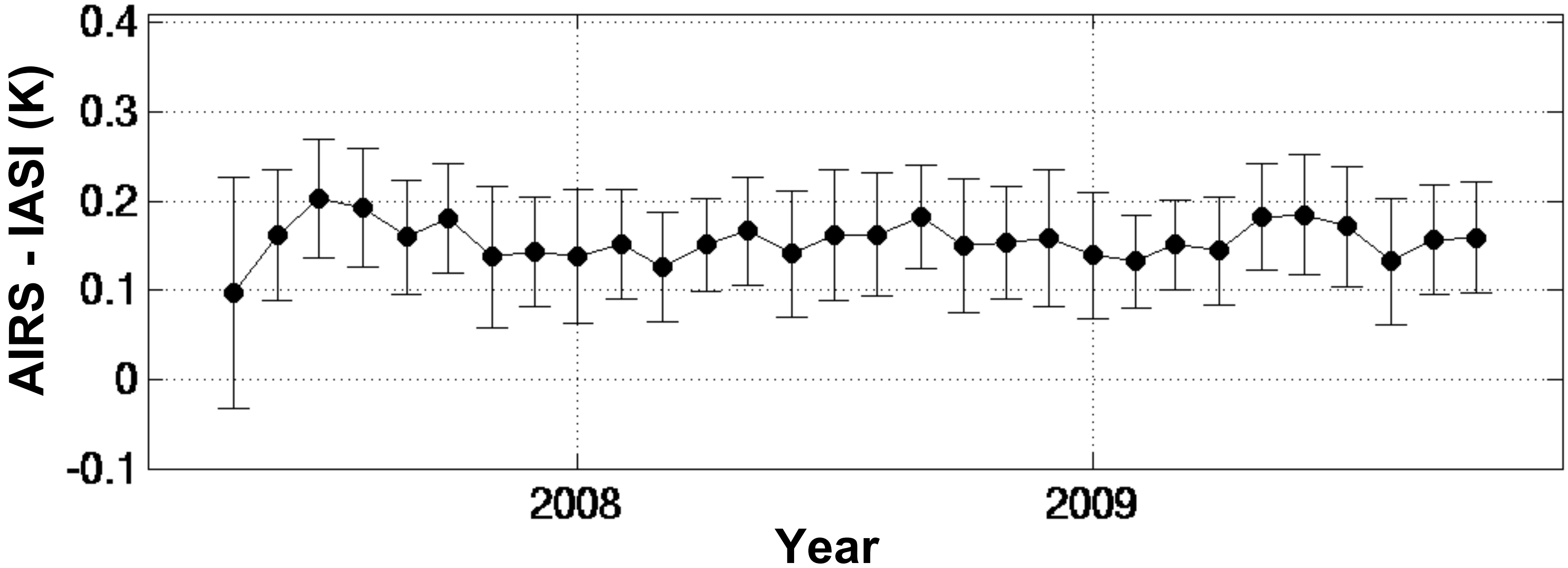
IASI

Sample SNO, #180



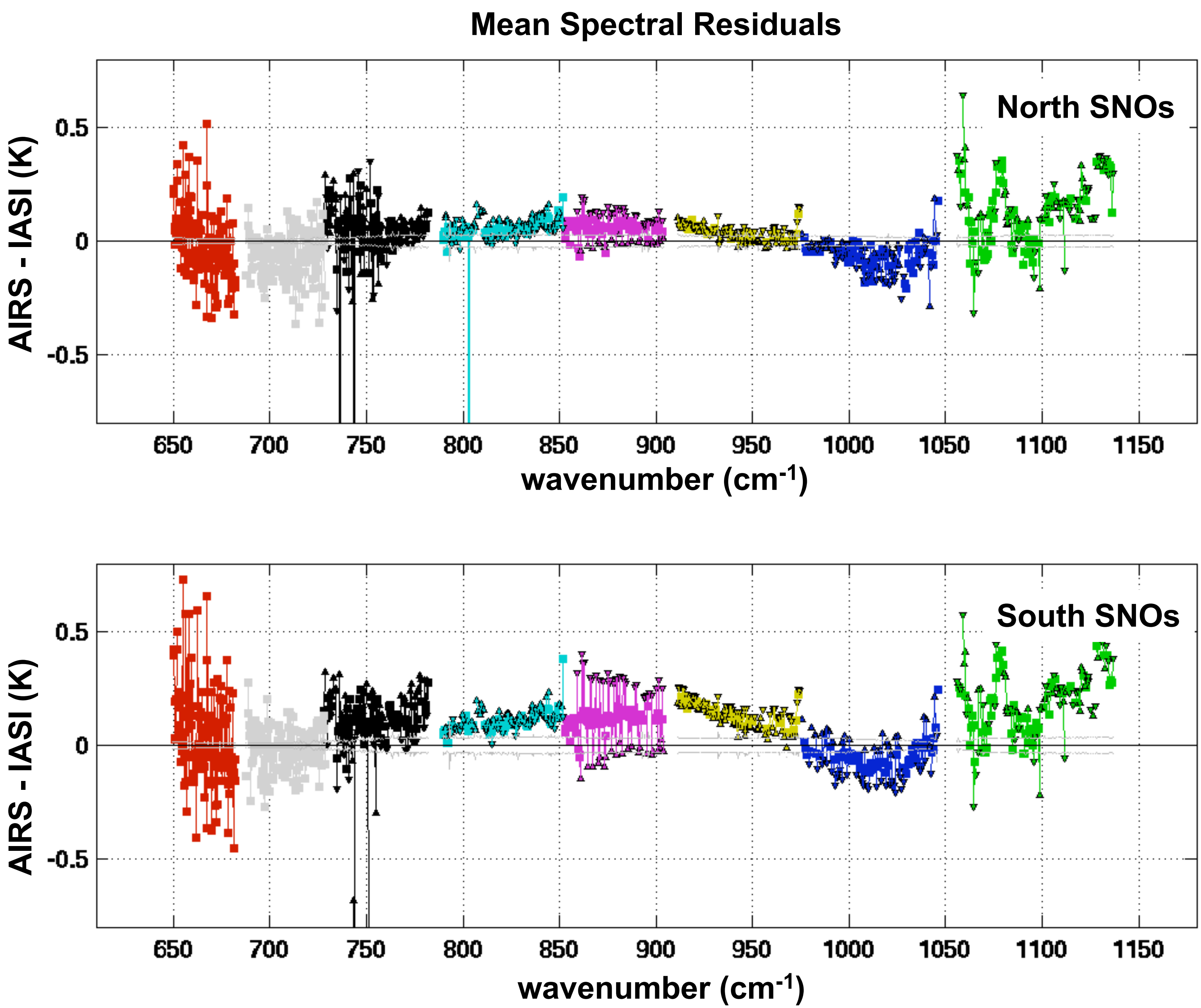
Time Series of Monthly Means

Module M-04b (1460-1527 cm^{-1})

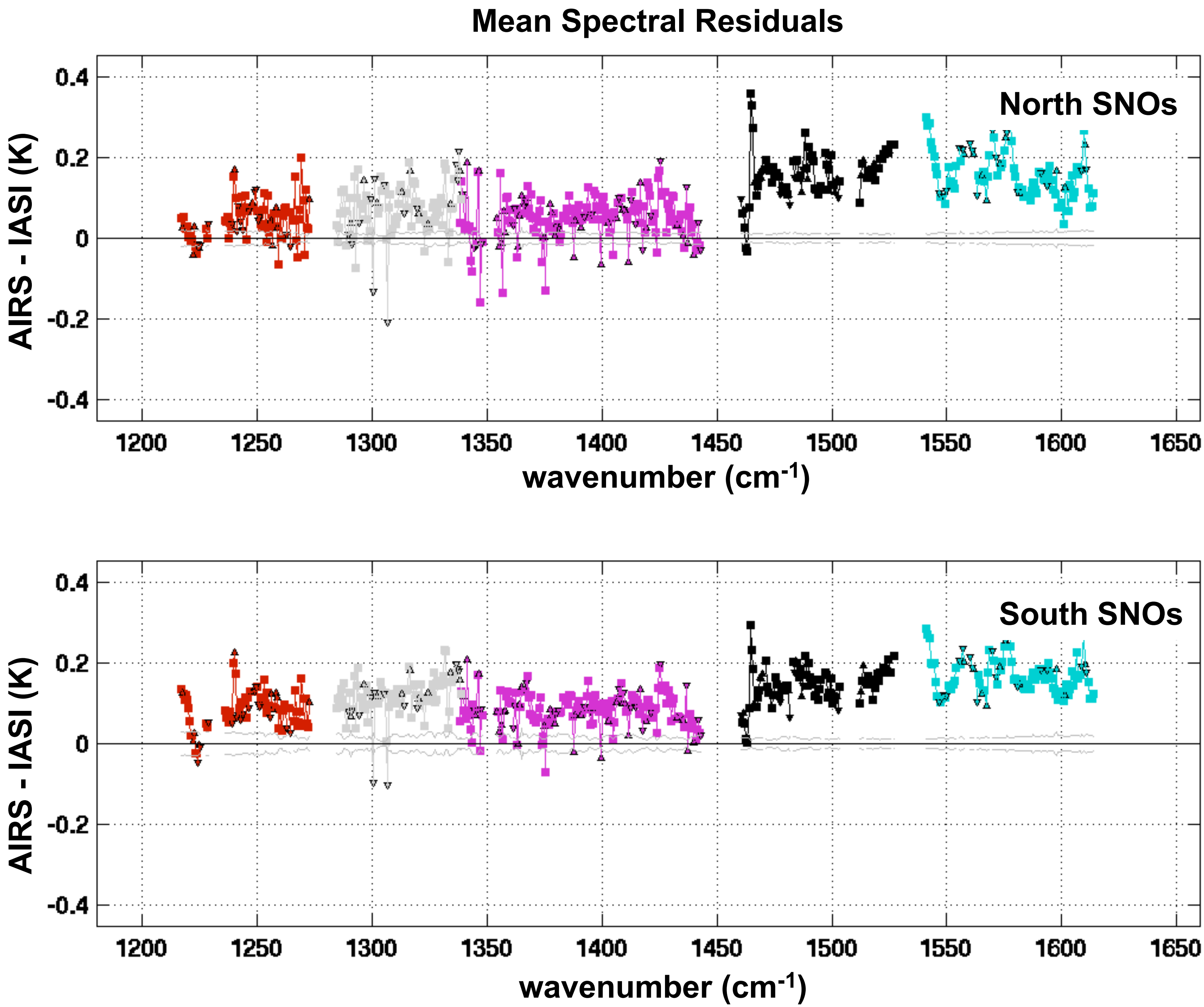


Mean difference is **150 mK (!)**

Slope is **0.9 +/- 5.6 (1 sigma) mK/year (!!)**



Mean Spectral Residuals
North SNOs
AIRS - IASI (K)
0.5
0
-0.5
650
700
750
800
850
900
950
1000
1050
1100
1150
wavenumber (cm-1)
South SNOs
AIRS - IASI (K)
0.5
0
-0.5
650
700
750
800
850
900
950
1000
1050
1100
1150
wavenumber (cm-1)


Mean Spectral Residuals
North SNOs
AIRS - IASI (K)
0.4
0.2
0
-0.2
-0.4
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
wavenumber (cm-1)
South SNOs
AIRS - IASI (K)
0.4
0.2
0
-0.2
-0.4
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
wavenumber (cm-1)

Summary

Radiometric accuracy and stability is important for operational IR sounder applications.

The radiometric calibration performance of today's high spectral resolution IR sounders is very good (better than requirement), yet there is room for improvement.

CLARREO has the potential to improve upon this by serving as a reference for intercalibration.