Progress on CrIS Calibration and Recommendation for CrIS-NG

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Topics

1. **Poster introductions**

2. **JPSS-1 Post-launch Cal/Val tasks**

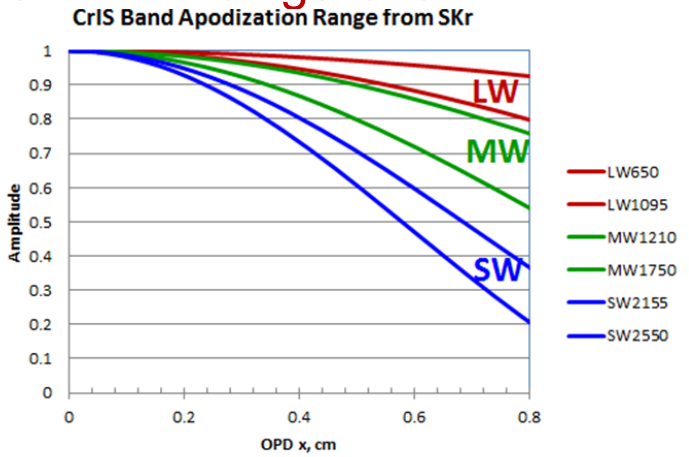
3. **Recommendations for “CrIS-NG”**

4. **Thank you**

CrIS Self-Apodization Correction: Basis for a new approach to reduce ringing

Hank Revercomb, Dave Tobin, Jon Gero, Bob Knuteson, Joe Taylor

- The well-known self-apodization affect broadens the Instrument Line Shape (ILS) of CrIS off-axis pixels. To make spectra from all 9 fields-of-view interchangeable, a well-defined matrix inverse is applied. While this approach works remarkably well, some ringing artifacts result and its absolute accuracy is hard to confirm.
- We have developed a new, rigorous correction to address both of these issues
- The poster shows that the correction in the interferogram domain takes the form of several terms of a Taylor series expansion
- Each term is rigorously expressed in terms of Fourier transformations
- The interferogram apodization shown in the figure is defined by a spectral Kernel in the new algorithm, and is corrected for using Fourier transformations and a separate well-defined spectral scale shift



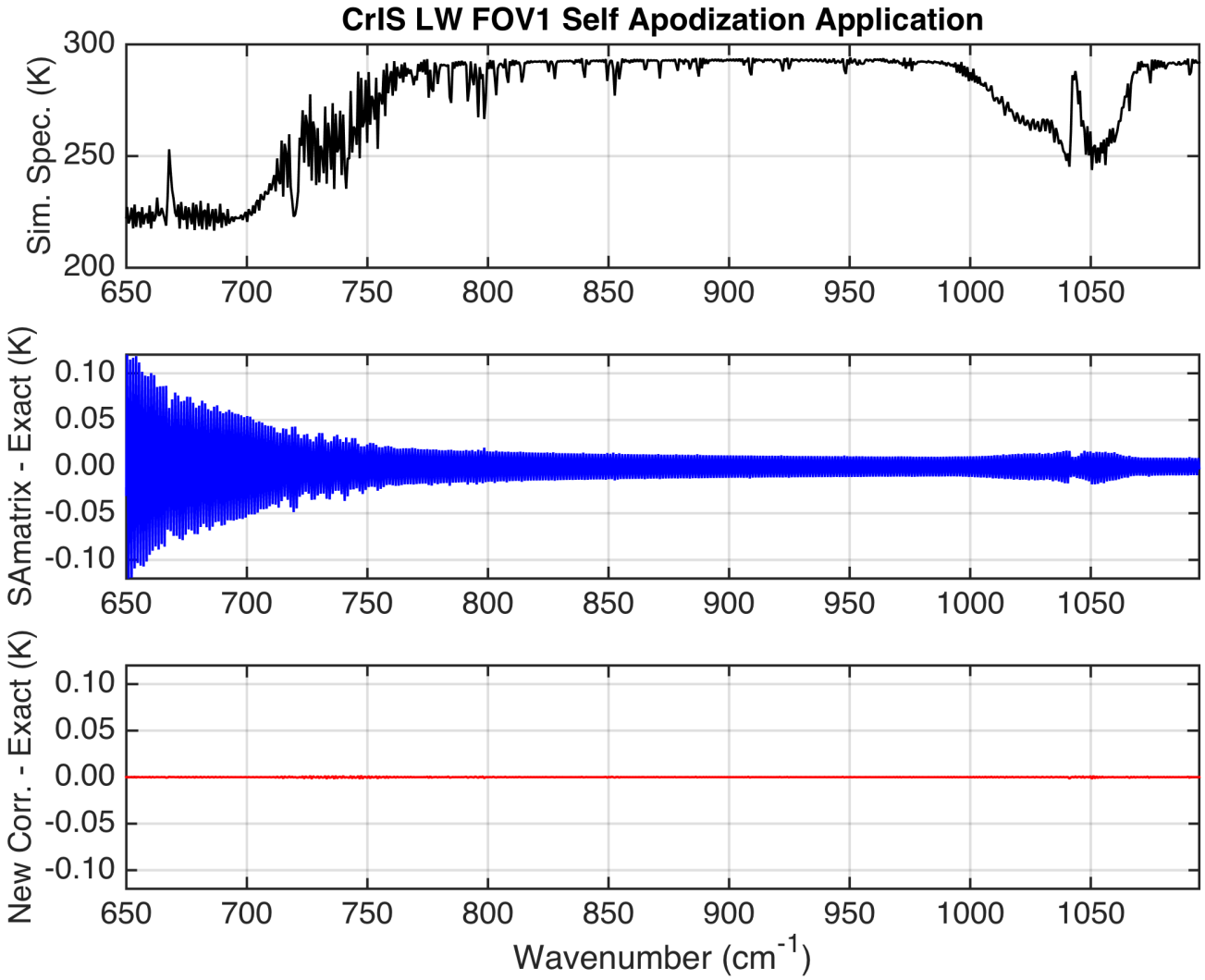
The OPD axis is actually the product x(cm) $\nu(cm^{-1})/1000\ cm^{-1}$ and thereby fully defines all 3 spectral bands of CrIS

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CrIS Self-Apodization Correction: Basis for a new approach to reduce ringing

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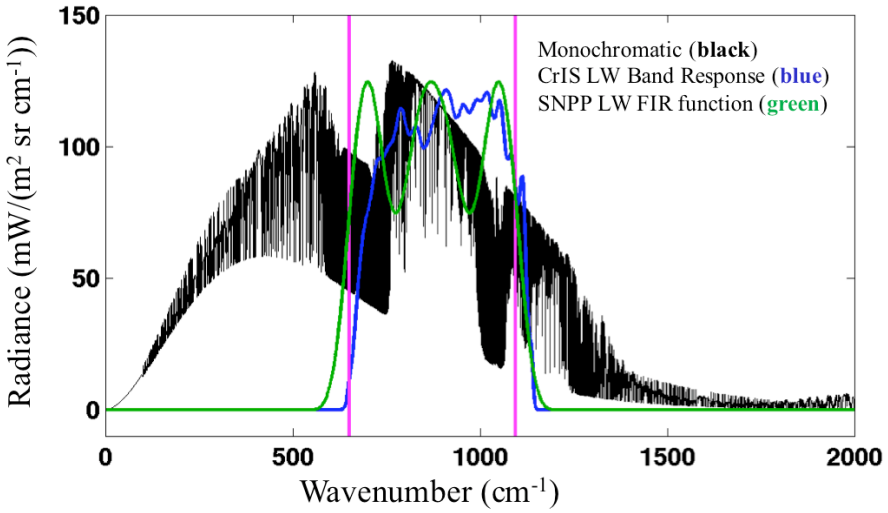


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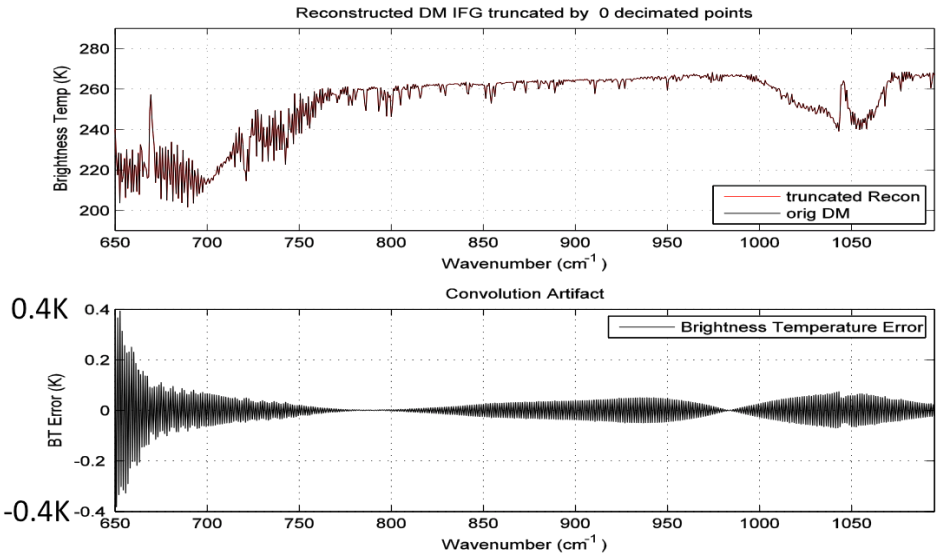
Suomi-NPP Cross-track InfraRed Sounder (CrIS) Spectral Ringing Correction and Validation

Robert Knuteson, Lori Borg, Michelle Feltz, Graeme Martin, Henry Revercomb, Joseph Taylor, David Tobin, and Yong Han*
Cooperative Institute for Meteorological Satellite Studies (CIMSS), Space Science and Engineering Center (SSEC), University of Wisconsin-Madison
*NOAA NESDIS STAR

Earth Top of Atmosphere Radiance



Convolution Correction

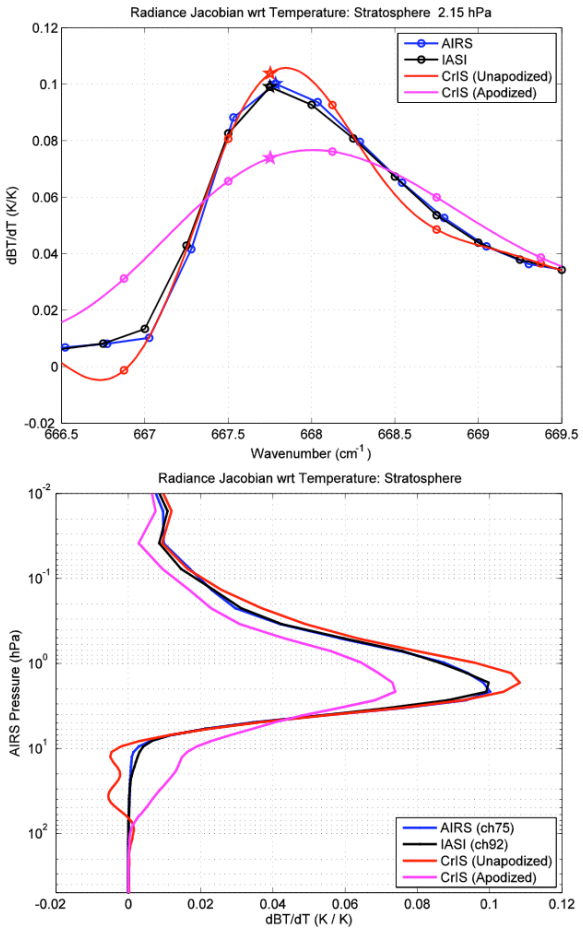


- The CrIS Fourier Transform Spectrometer (FTS) measures the IR spectrum in three broad bands (LW, MW, and SW).
- The CrIS LW detector response falls rapidly to zero near the center of the 15 micron CO2 band.
- This causes issues near the longwave band edge in the raw radiances, requiring apodization to remove ringing.
- The poster illustrates a method to correct for LW band edge errors thereby improving the unapodized SDR product.

Suomi-NPP Cross-track InfraRed Sounder (CrIS) Spectral Ringing Correction and Validation

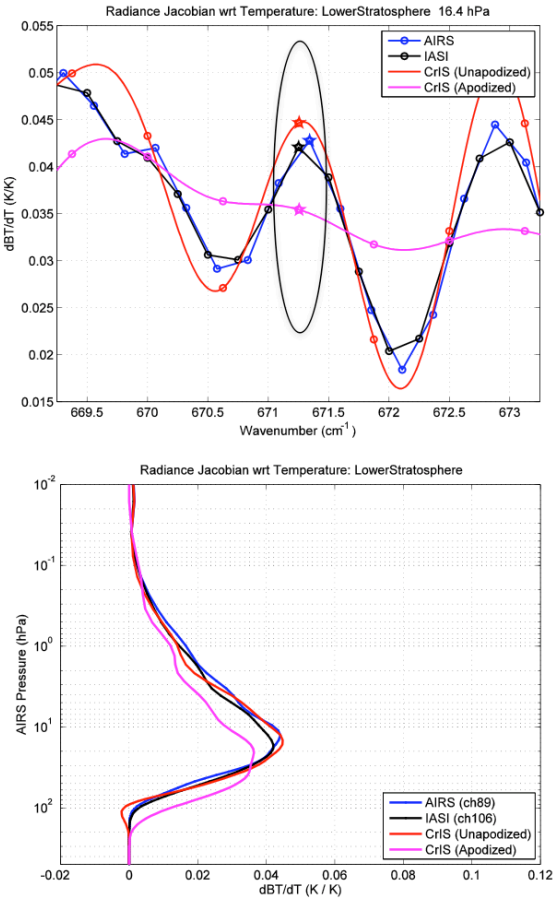
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Upper Stratosphere (2 hPa; 667.8 cm^{-1})



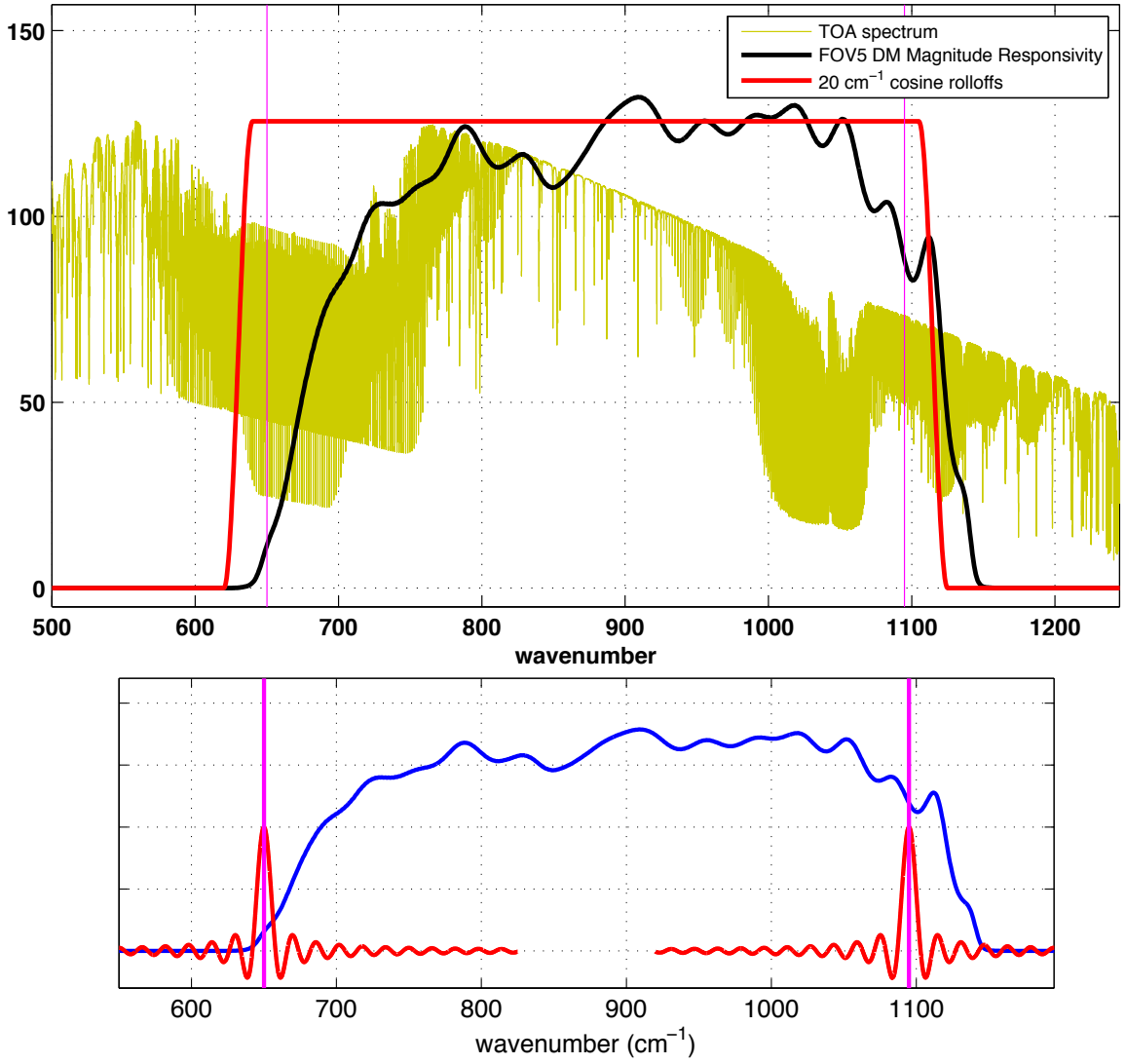
- NWP centers apply a mathematical apodization function which effectively averages a channel with neighboring channels. This reduces the spectral resolution as shown in the upper figures.
- However, apodization also broadens the weighting function by smearing vertical information and shifting peak sensitivity to lower altitudes.
- The improvements in the SDR product will facilitate NWP assimilation of full resolution CrIS.

Lower Stratosphere (16 hPa; 671.25 cm^{-1})



Removal of CrIS Spectral ILS Dependence on Responsivity: Status of development

Hank Revercomb, Dave Tobin, Joe Taylor, Bob Knuteson, Jon Gero



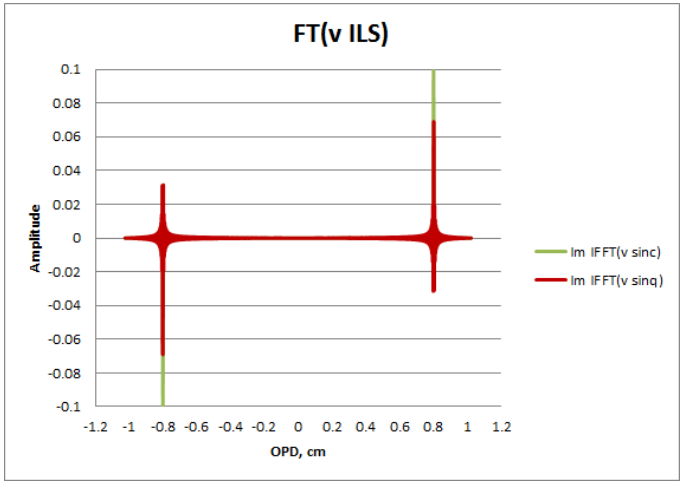
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Removal of CrIS Spectral ILS Dependence on Responsivity: Status of development

Hank Revercomb, Dave Tobin, Joe Taylor, Bob Knuteson, Jon Gero

- CrIS radiances currently have a spectral Instrument Line Shape (ILS) with a very weak dependence on responsivity, arising from the non-flatness of the responsivity and its finite bandpass
- The effect adds subtle ringing to CrIS spectra (referred to as "true" ringing)
- To avoid errors from this "true" ringing, calculated spectra used for retrievals and assimilation must also use the responsivity
- For MTG-IRS, techniques to eliminate this type of responsivity dependence are being developed in Europe
- This poster presents a new approach that promises to be more efficient and more accurate
- Correction terms modify the ends of interferograms, I(x), as needed to remove ringing (e.g. to right)



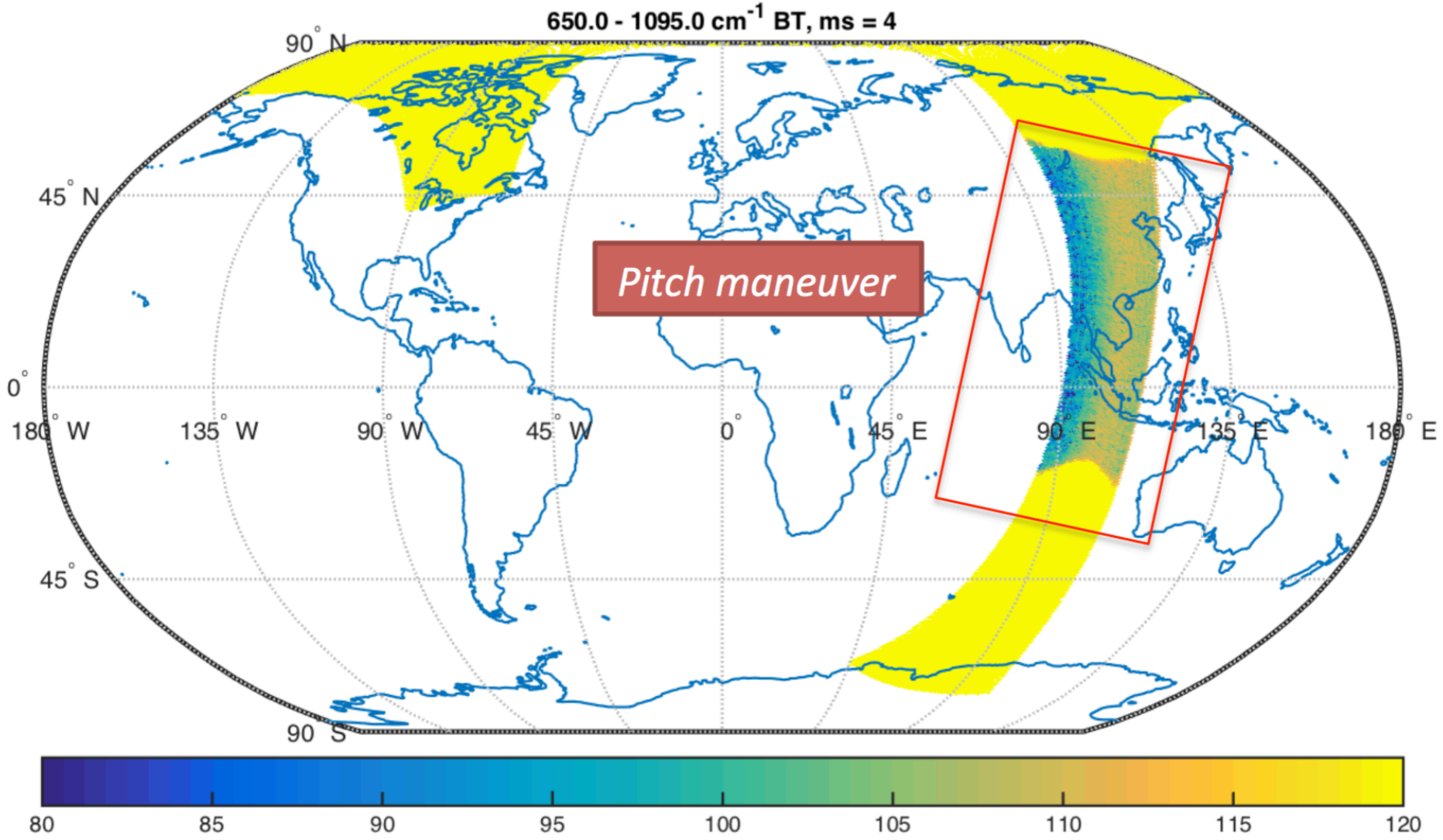
example multiplicative mod to I(X) for 1st correction term

- Included are the mathematical formalism, initial exploration of the nature of the correction terms, remaining issues, and development plans

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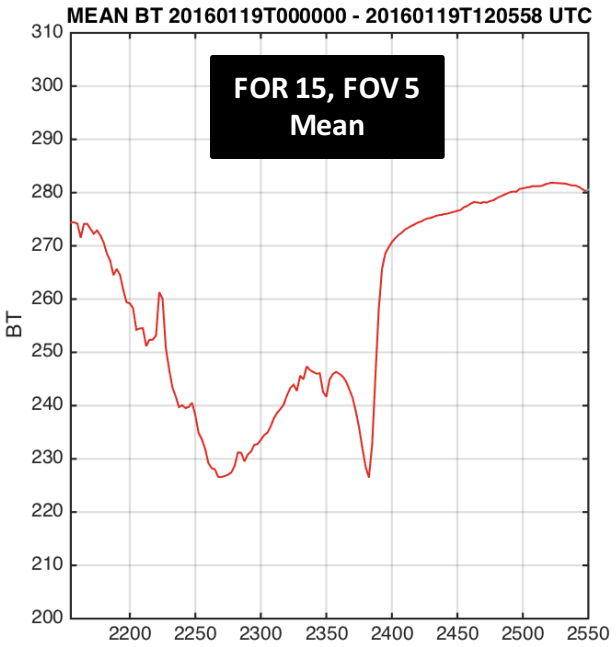
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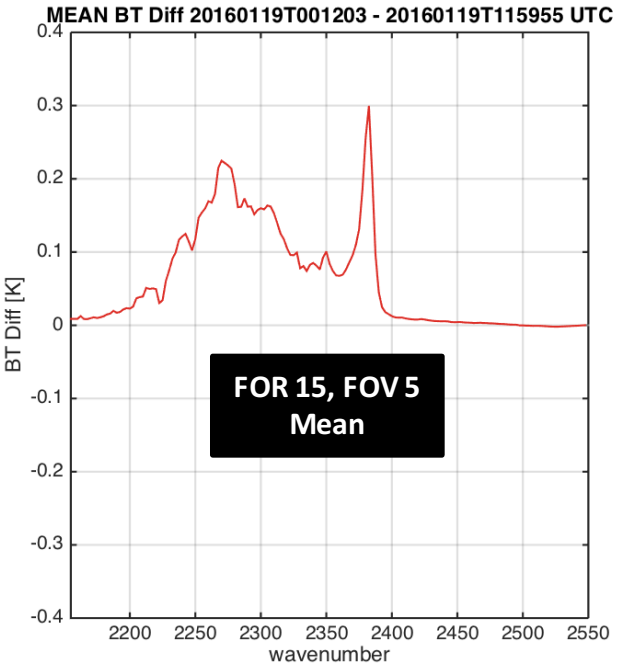
S-NPP Pitch Maneuver on 20 Feb 2012

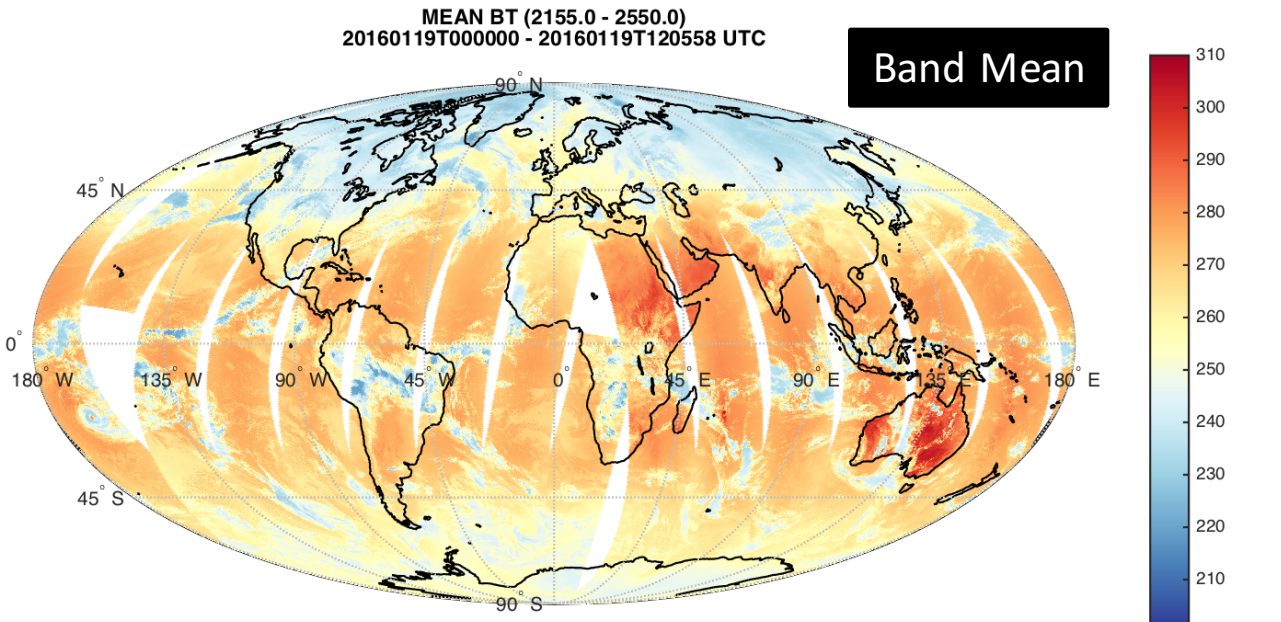


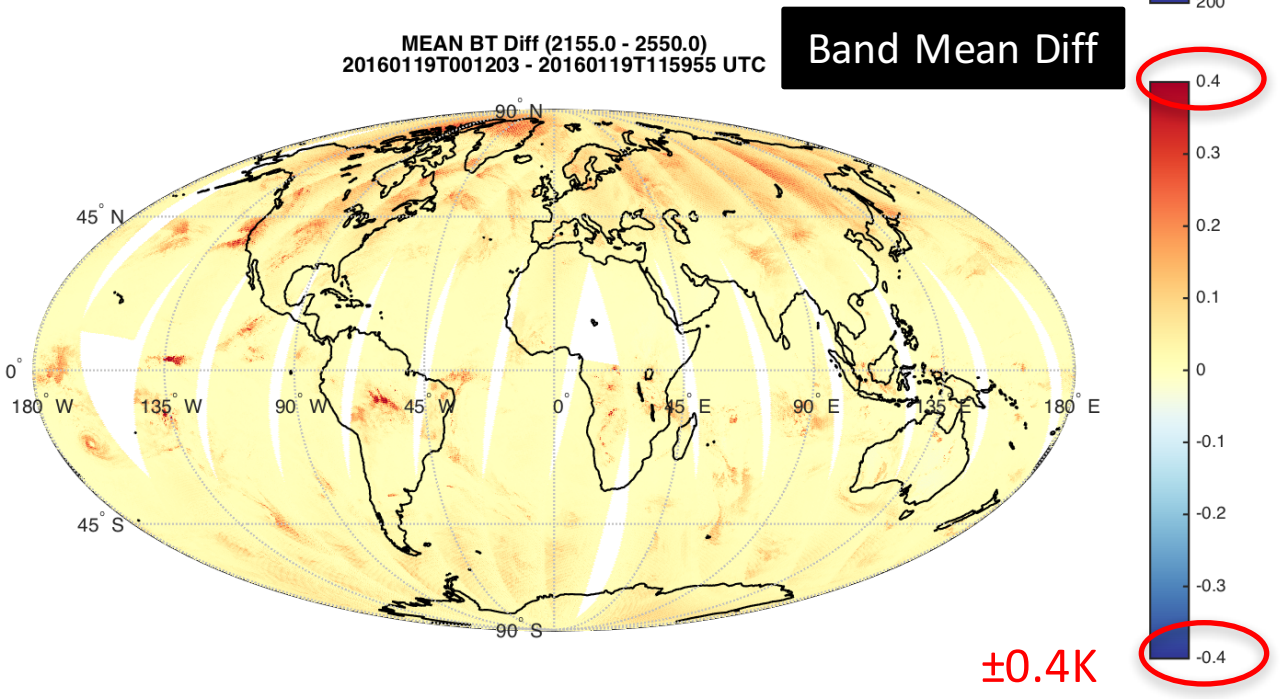
"Earth view" data of deep space at multiple view angles collected during the spacecraft pitch maneuver has been used to characterize the polarization effects of S-NPP CrIS

Example of Preliminary SW Polarization Correction (Diff = Uncorrected – Corrected), 2016-01-19 T0000 to T1206





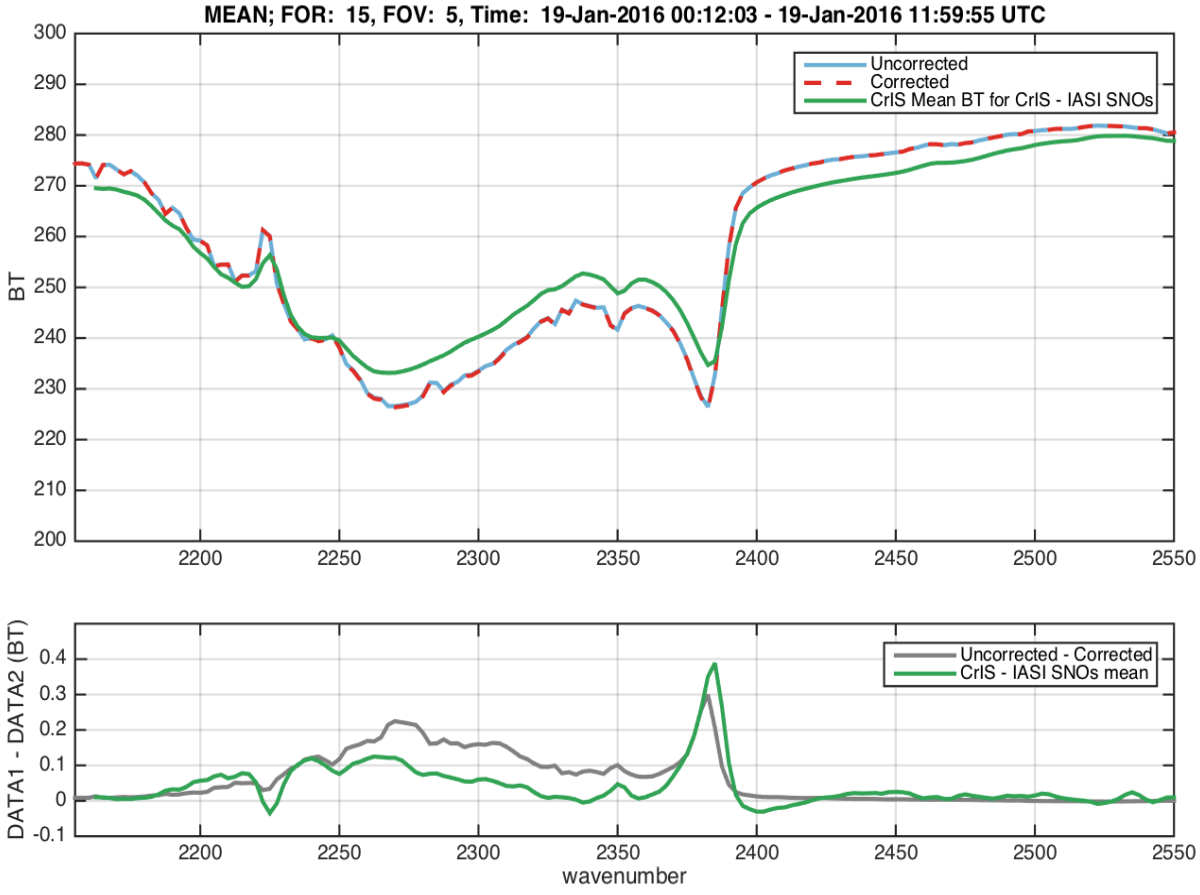




Polarization Correction Status and Next Steps

- A polarization correction module has been integrated into our processing
  - preliminary $p_r p_t$ and α values derived from pitch maneuver data
- Mean results in SW show very similar behavior to CrIS – IASI SNO residual.
- Mean results in LW and MW are relatively small.

Mean BT and Uncorr - Corr Diff; wiith CrIS – IASI SNOs Residual Example

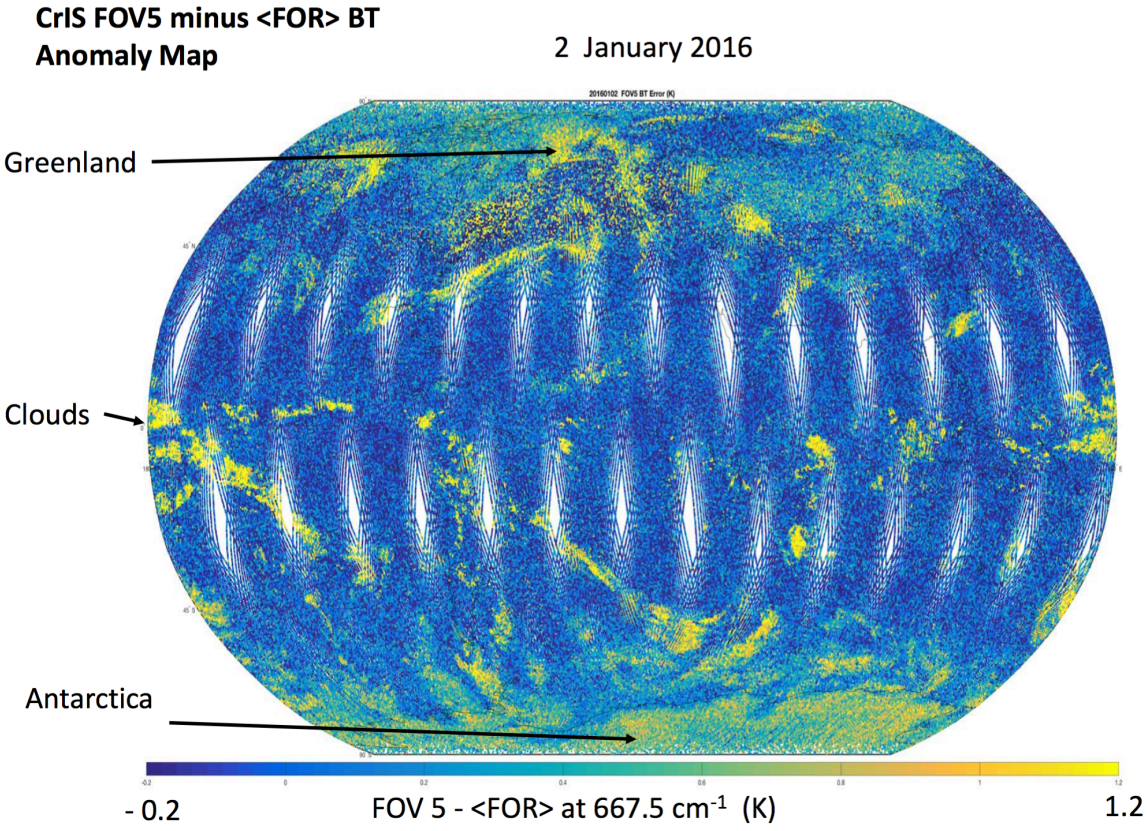


Next Steps:

- Test impact on SNOs, CrIS – VIIRS, and obs-calc
- Further refinements to α and $p_r p_t$. (1) Improve QC of data to omit outliers from analysis (2) Improve interpolation of DS/IT/ES spectra to better account for detector and instrument temperature changes
- Radiometric uncertainty analysis for correction

LW FOV5 anomaly correction

- Anomalously warm observations for small subset of LW spectral channels for cold scenes, for FOV5 (see figure for example); root cause still not determined
- Currently pursuing a statistical (PCA based) correction, which will also take care of non-uniform scene ILS effects.

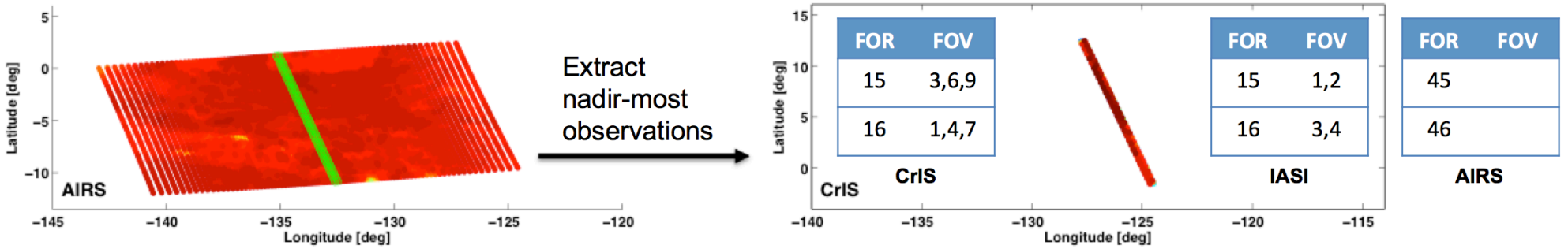


- *The anomaly occurs for scenes with window BT < 270K.*

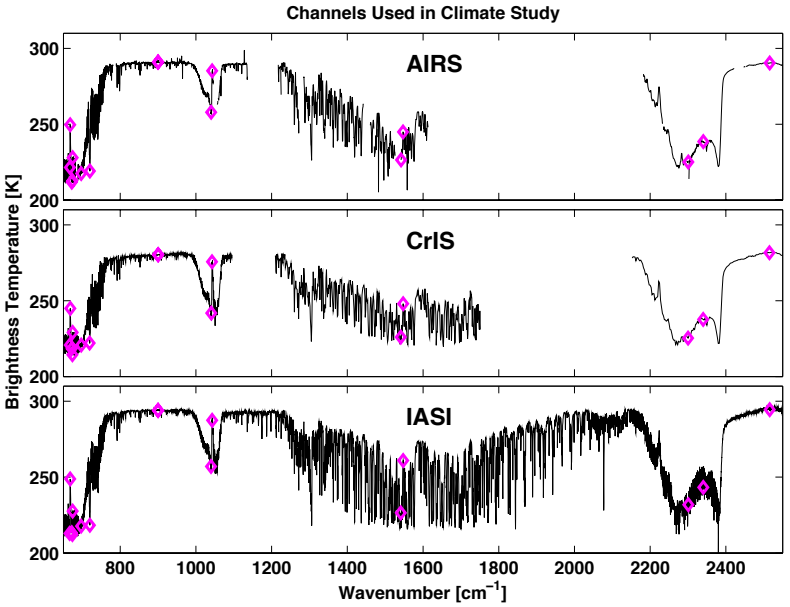
Detecting Climate Trends Using AIRS, IASI and CrIS Brightness Temperature Spectra

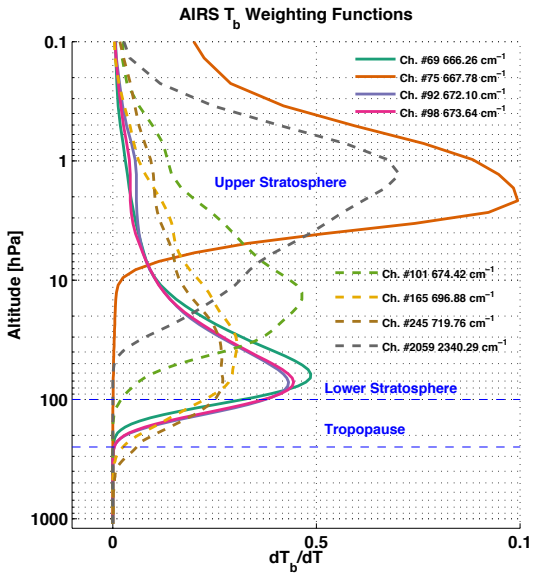
Approach

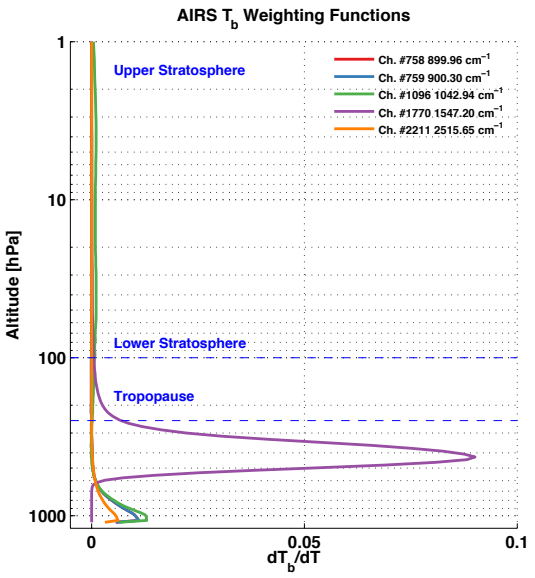
- Extract near-nadir observations (AIRS field-of-regard 45 & 46; CrIS and IASI FOR 15 & 16 using the innermost FOVs); full-resolution stored into daily files



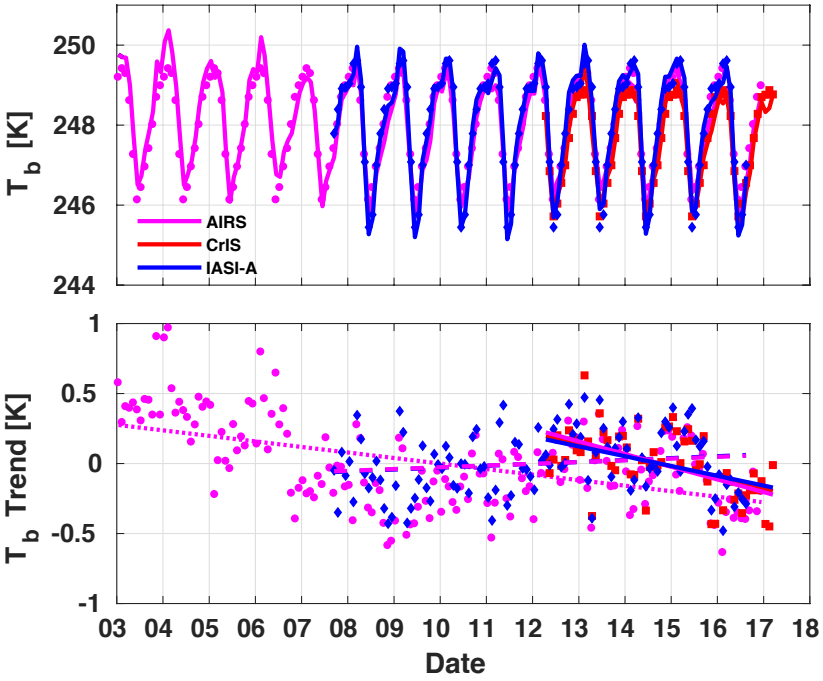
- Select AIRS/CrIS/IASI channels for analysis (16 comparable spectral channels)







Brightness Temperature Trend Example: Upper Stratosphere (667.8 cm^{-1}) – Global Mean



- Top panel: global monthly mean brightness temperature (solid line) and cumulative monthly average (dots)
- Bottom panel: Monthly anomalies and respective fit per Weatherhead formalism (tabulated below for given case)
- IASI-a spectra were resampled to AIRS and CrIS SRFs
- Data limited to yearly ensemble for each instrument

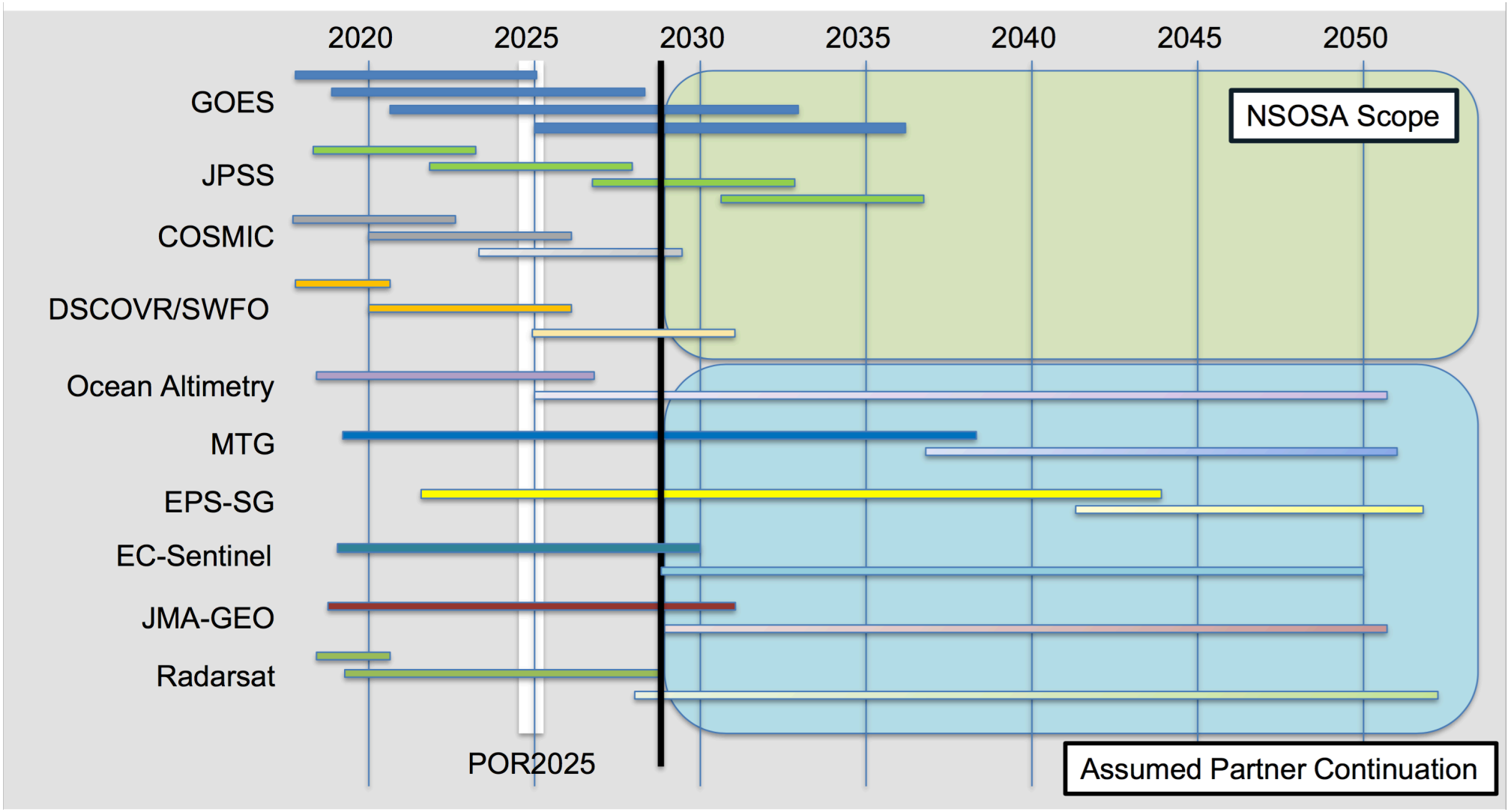
Units: ω (K/year); δ_ω (K/year at k= 2σ); n* (years)

Upper Stratosphere (Night) 667.8 cm^{-1}	AIRS Annual $\omega \pm \delta_\omega$ (n*)	IASI-a Annual $\omega \pm \delta_\omega$ (n*)	CrIS Annual $\omega \pm \delta_\omega$ (n*)
AIRS (200201-201612)	-0.040 ± 0.014 (15.5)		
IASI (200709-201608)	0.012 ± 0.014 (21.7)	0.014 ± 0.013 (19.5)	
CrIS (201204-201703)	-0.090 ± 0.042 (6.7)	-0.070 ± 0.035 (7.0)	-0.080 ± 0.035 (6.5)

JPSS-1 Post-launch Cal/Val tasks

1. **Radiometric Nonlinearity Evaluation and Refinement (CSCV-7, T23-UW)**
2. **Internal Consistency Checks on Radiometric Calibration (CSCV-22, T24-UW)**
3. **Internal Consistency checks on spectral calibration, self-apodization corrections, and resampling (CSCV-6, T25-UW)**
4. **Comparisons of S-NPP and JPSS-1 CrIS Spectral Radiances (CSCV-16, CSCV-17, T46-UW)**
5. **SDR Evaluations Using SNO Comparisons with IASI and AIRS (CSCV-17, T47-UW)**
6. **CrIS/VIIRS Radiance Comparison (CSCV-7-22, T48-UW)**
7. **Clear Sky Observations and Forward Calculations from NWP Analyses to Support Cal/Val Activities(CSCV-15, T49-UW)**
8. **Spectral Ringing Evaluation and Refinement(CSCV-23, T50-UW)**
9. **Polarization Characterization(CSCV-22, T51-UW)**
10. **Assess Spectral Artifacts in Earth View Spectra via Principal Component Analysis (CSCV-15, T52-UW)**
11. **Estimation of In-orbit Radiometric Uncertainty (CSCV-18, T53-UW)**

Flyout chart, from the NOAA Satellite Observing System Architecture (NSOSA) Study Update, Apr 2017:



Also:

- GIIRS on FY-4 since late 2016
- IKFS-2 (IASI-like) on Meteor-M series, first launch was in 2014
- HIRAS (CrIS-like) on FY-3 series starting in late 2017, and including dawn/dusk (0600 asc) orbit in 2018
- IASI-NG on EPS-SG, IRS on MTG-S in 2022
- GOES and JPSS payloads are currently fixed through ~2038 (i.e. flying early 90s CrIS design 50 years later, and no sounder on GOES).

Recommendations for CrIS-NG

- **Smaller (and contiguous) Footprints**

Thank You to Yong Han

