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FY-3D HIRAS Radiometric Calibration and Accuracy Assessment

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ITSC 22 Meeting, Saint-Sauveur, Canada 2019

Outline

1. HIRAS Introduction
2. Calibration method
3. Validation
4. Future work and Summary

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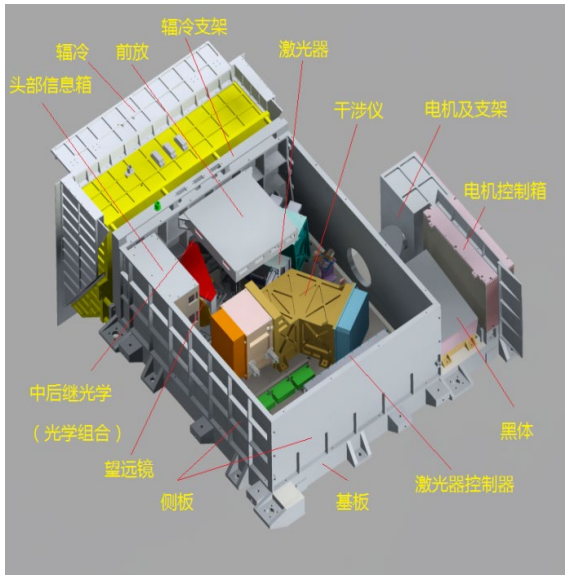
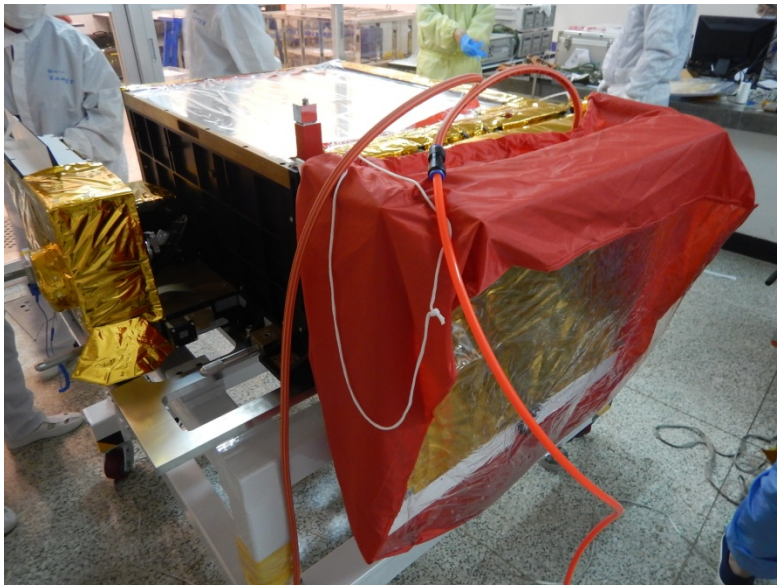
HIRAS Introduction

- HIRAS: High spectral InfraRed Atmospheric Sounder
- Designed and manufactured completely by Shanghai Institute of Technical Physics (SITP), Chinese Academy of Sciences (CAS) .
- FY-3D Satellite launched on 15 Nov, 2017.
- 3 month outgassing; HIRAS powered on 1st Mar, 2018.



Instrument structure



HIRAS

A New member of High Spectral IR Sounders, along with AIRS, IASI, and CrIS

HIRAS Introduction

- HIRAS is a Fourier transform interferometer which posses of high spectral resolution, low radiometric noise and high spectral and radiometric accuracy.

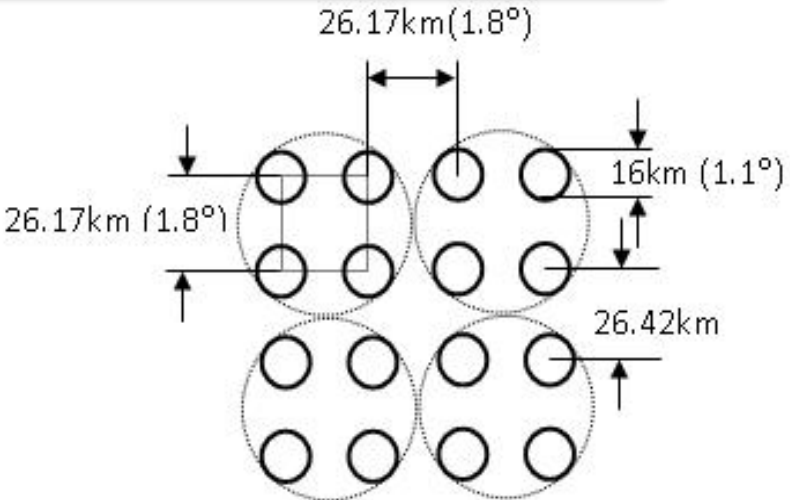
HIRAS instrument requirements

Parameters	Specification
Scan Period	10s
View Angle	1.1°
Pixels per scan line	116 (4 FOVs x 29 FORs)
Maximum scan angle	± 50.4°
Radiometric calibration accuracy	< 0.7K
Spectral calibration accuracy	< 7ppm
Direction pointing bias	＜±0.25°

HIRAS Introduction: Specifications

◆ 40 steps each scan line, including 29 Earth Scene (ES), 2 Deep Space (DS) & 2 Internal Calibration Target (ICT)

- ✓ **HIRAS scan, field-of-regard (FOR), field-of-view (FOV)**
- ✓ 2×2 Four detectors define 1 FOR
- ✓ **Nadir spatial resolution is 16km**



Band	Spectral Range (cm^{-1})	Spectral Resolution (cm^{-1})	Sensitivity (NEΔT@280K)	No of Channels
LW	650*～1136 (15.38μm～8.8 μm)	0.625	0.15～0.4K	778
MW	1210～1750 (8.26μm～5.71 μm)	1.25	0.1～0.7K	433
SW	2155～2550 (4.64μm～3.92 μm)	2.5	0.3～1.2K	159

- DR： Designed Resolution, international direct received data processing
- FR： Full Resolution , operational version

Band	Spectral Range (cm^{-1})	Spectral Resolution (cm^{-1})		MPD（cm）		Ch No	
		FR	DR	FR	DR	FR	DR
LW	650~1135	0.625	0.625	0.8	0.8	781	781
MW	1210~1750	0.625	1.25	0.8	0.4	869	433
SW	2155~2550	0.625	2.5	0.8	0.2	637	159

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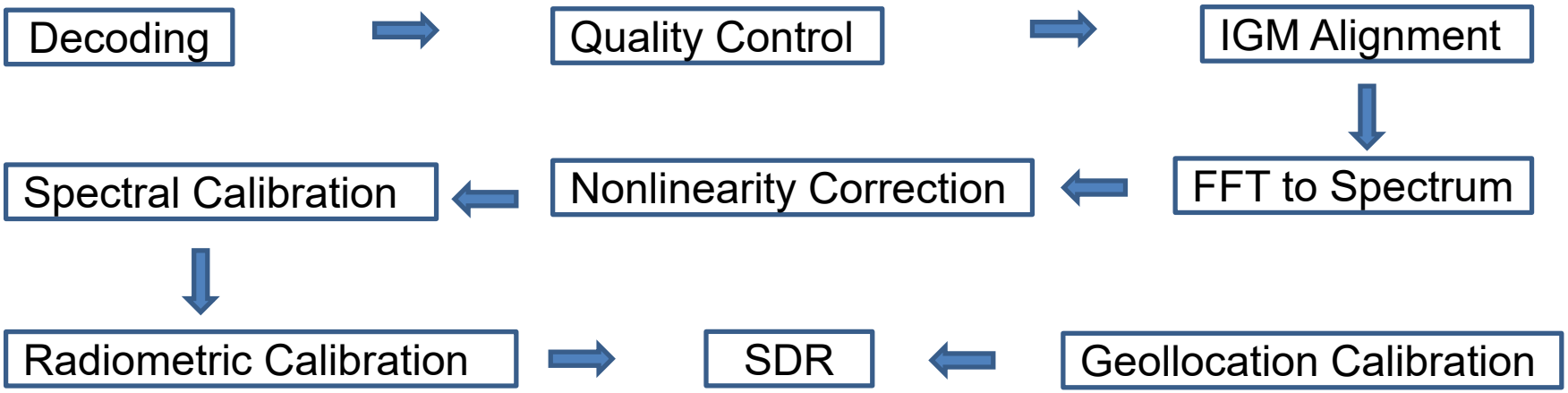
Calibration: Overview

- Complex calibration method proposed by Revercomb et al. 1989 is used
- The processing sequence of HIRAS is as follow:



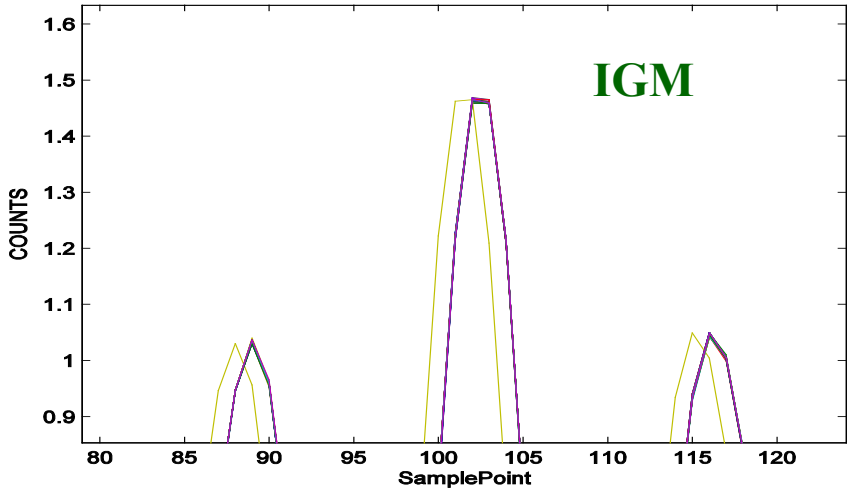
COMMON Sequence with difference:

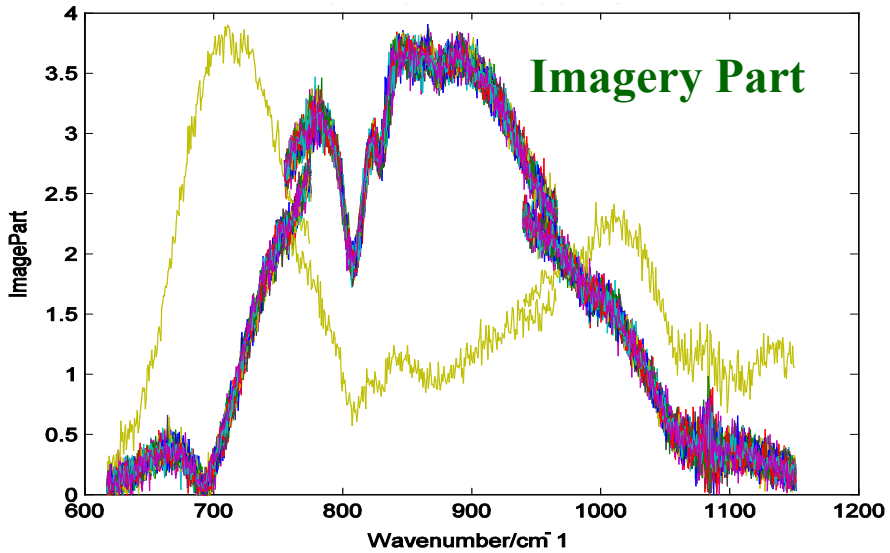
- ◆ No hardware equipped to guarantee IGM for 3 targets are well match
- ◆ No DC output, and large uncertainties in Gains
- ◆ No reference FOV to separate Laser uncertainty to SA
- ◆ Large polarization effect in some band..

Method: IGM alignment

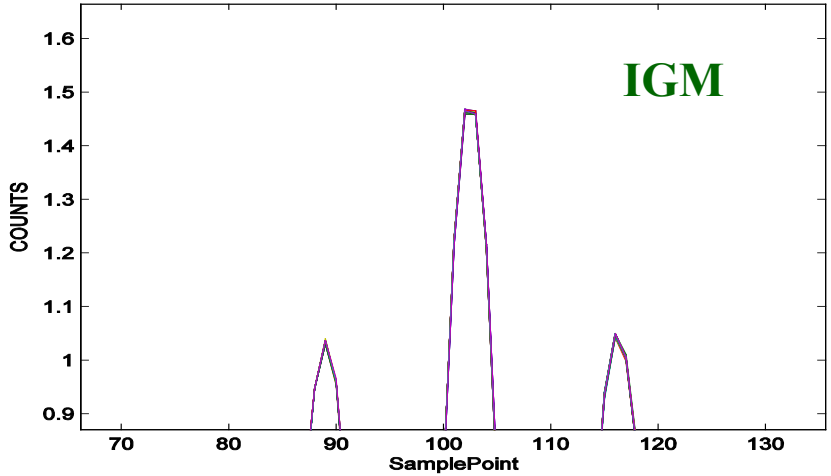
Two methods are proposed: a) relationship between phase and ZPD
b) the phase of calibrated spectrum

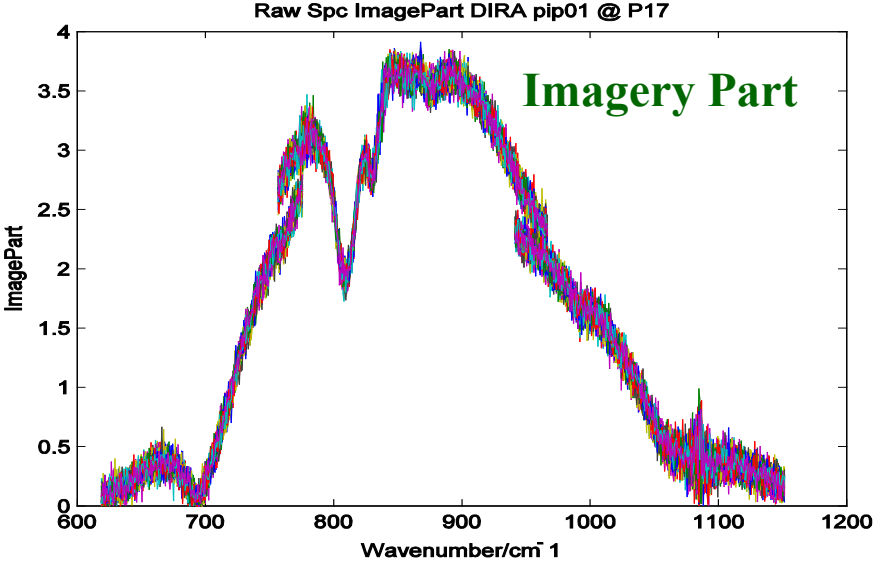
Before Alignment



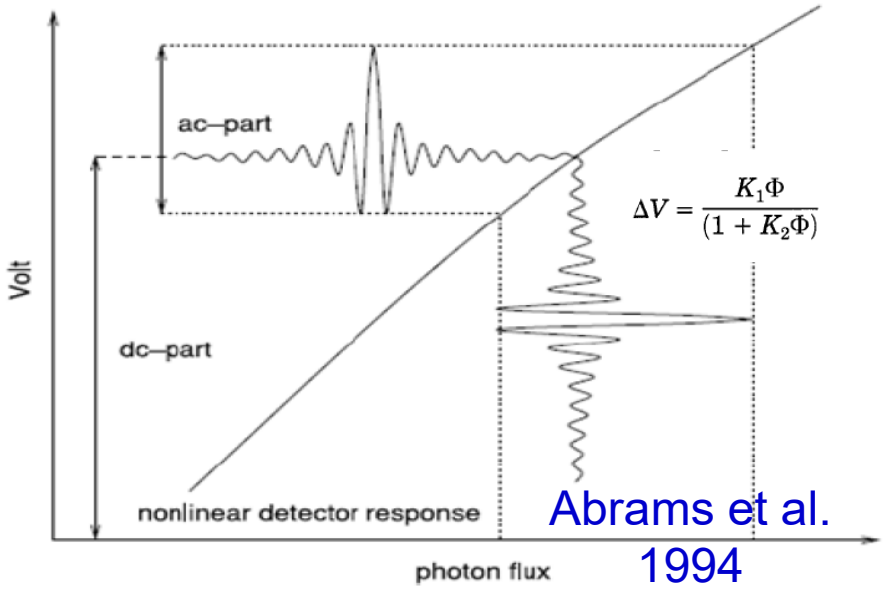


After Alignment



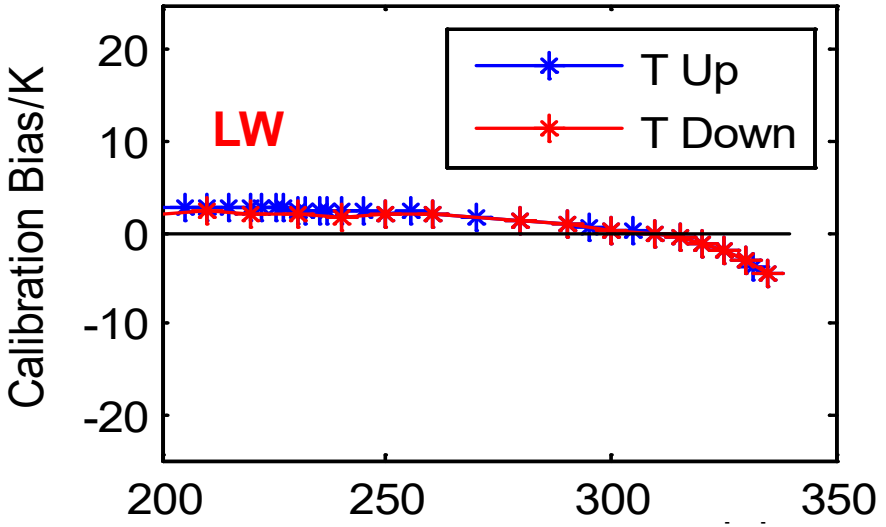


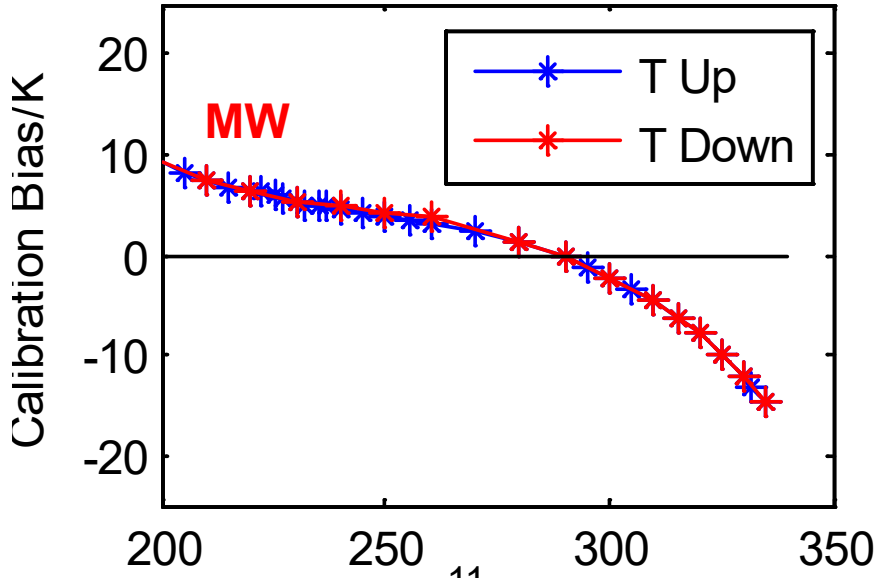
Method: Nonlinearity Correction



Abrams et al. 1994

Measured and Predicted BT Diff





HIRAS LW and MW bands show nonlinear phenomenon, more significant for the MW band.

Two NL correction methods are used:

1, NL Correction performed on Spectrum, following the method used by CrIS.

2, NL Correction performed on Interferagram, high order correction term can be considered.

Method: Nonlinearity Correction

Follow CrIS ATBD2013

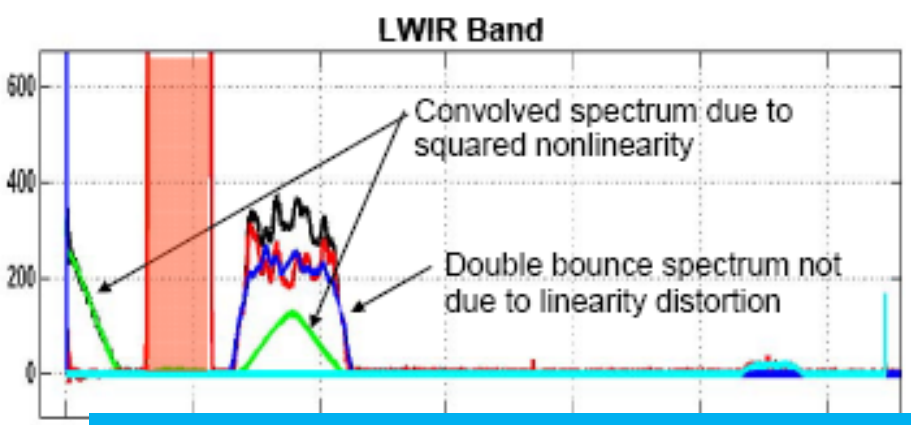
$$IGM_{ideal} + V_{ideal} = (IGM_{measure} + V) + a_2 * (IGM_{measure} + V)\text{^}2 + \ldots.$$

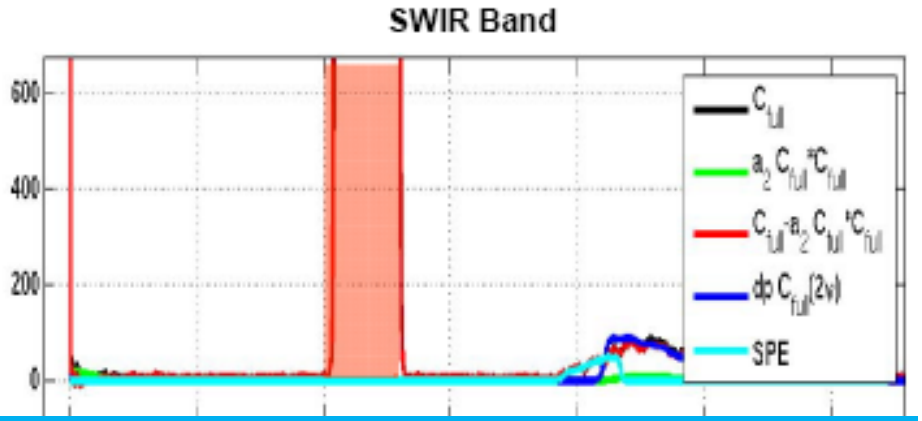
$$IGM_{ideal} = (1 + 2a_2V)IGM_{measure} + a_2 * IGM_{measure}\text{^}2 + V\text{^}2 + V_{ideal} + \ldots$$

$$SPC_{ideal} = (1 + 2a_2V)SPC_{measure} + a_2 * SPC_{measure} @ SPC_{measure}$$

$$(1 + 2a_2V)SPC_{measure} + a_2 * SPC_{measure} @ SPC_{measure} = 0$$

$$a_2 = a_2'/(1 - 2Va_2'), a_2' = -SPC_{measure} / SPC_{measure} @ SPC_{measure}$$

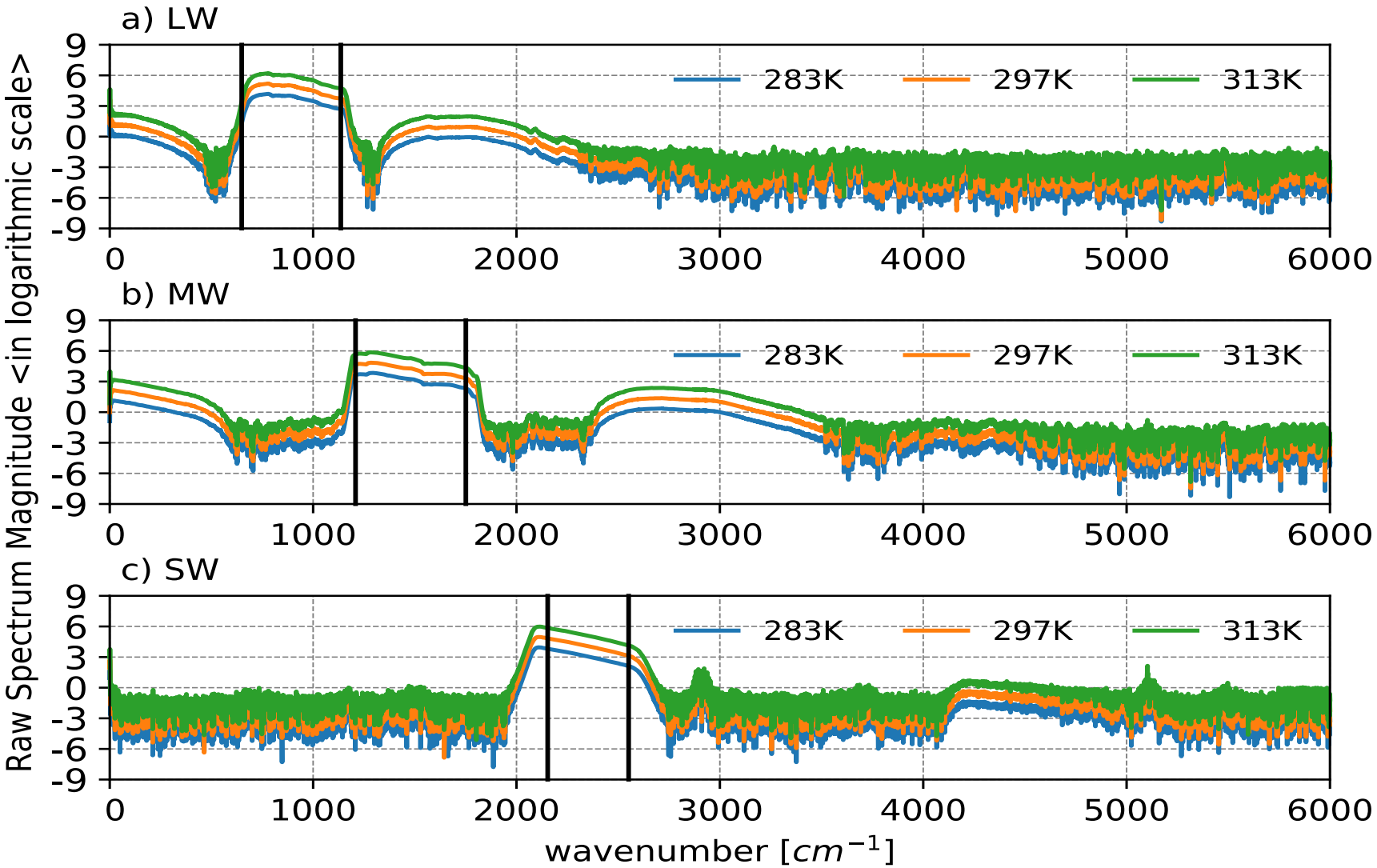




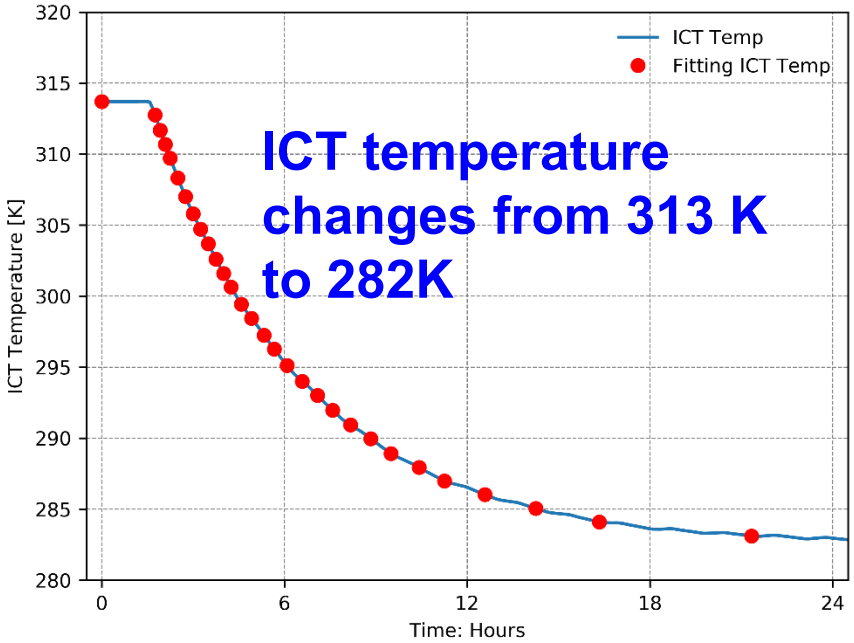
$$IGM_{ideal} + V_{ideal} = (IGM_{measure} + V) + a_2 * (IGM_{measure} + V)\text{^}2 + \ldots.$$

$$SPC_{ideal} = (1 + 2a_2V)SPC_m$$

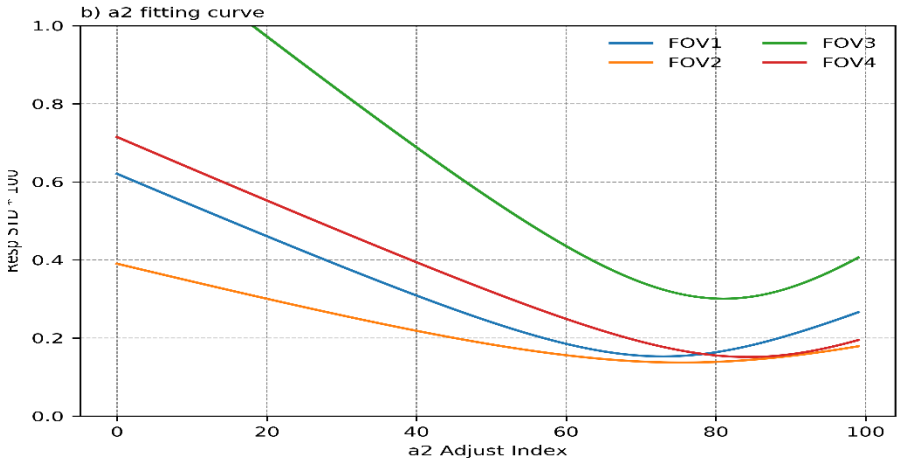
Method: Nonlinearity Correction



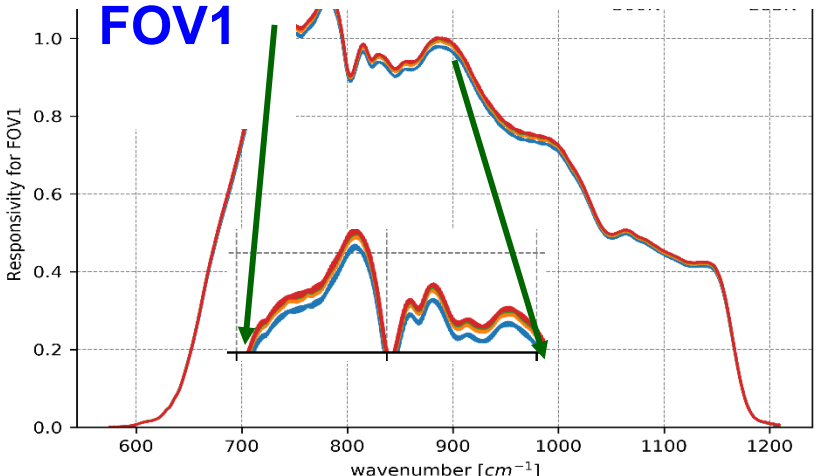
Method deriving a2 from On-Orbit ICT with Variable Temperature



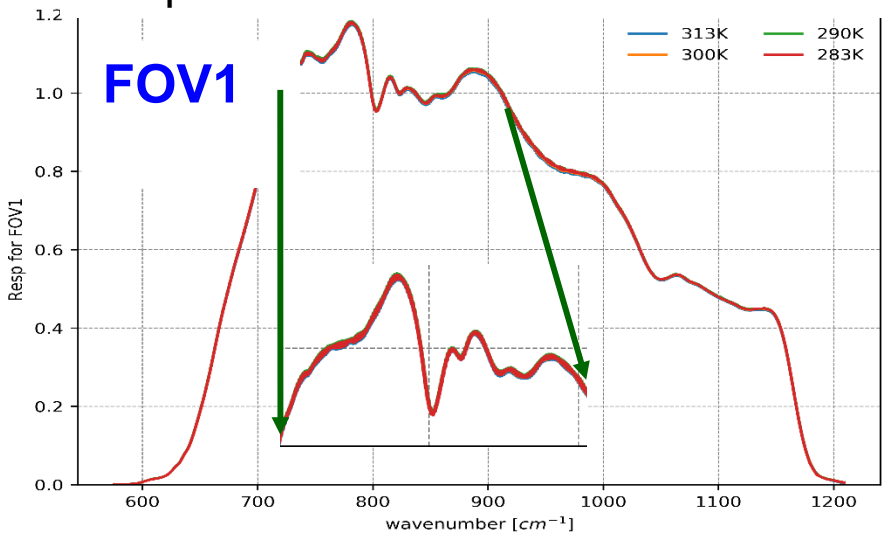
a2 fitting to minimize the responsivity Diff



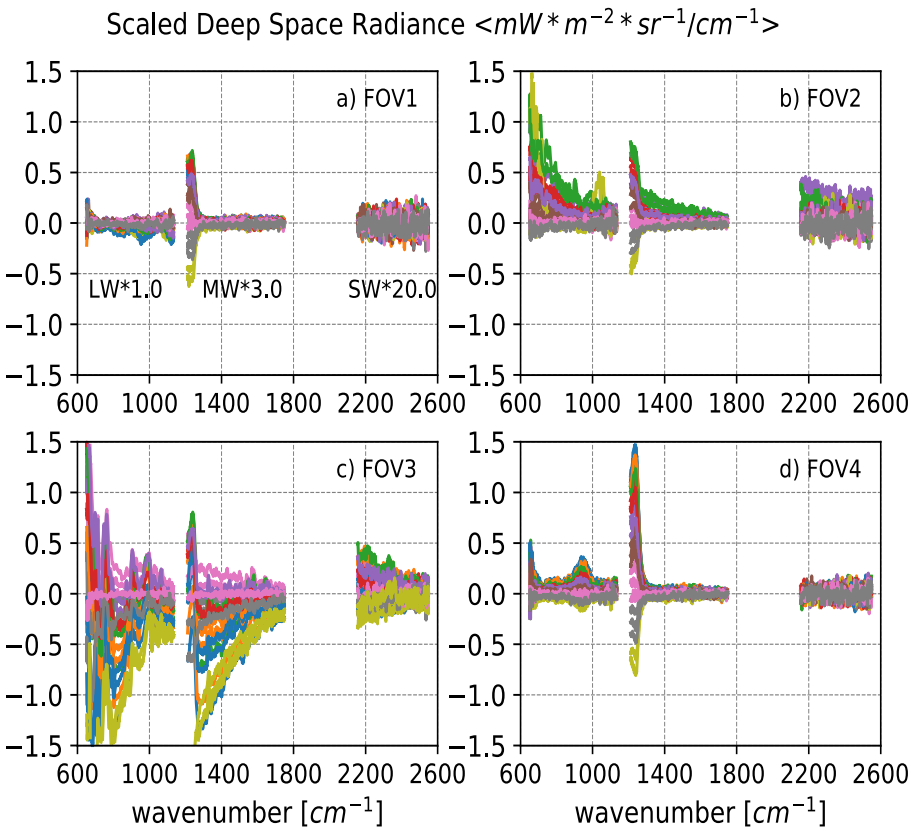
Responsivities variation due to nonlinearity

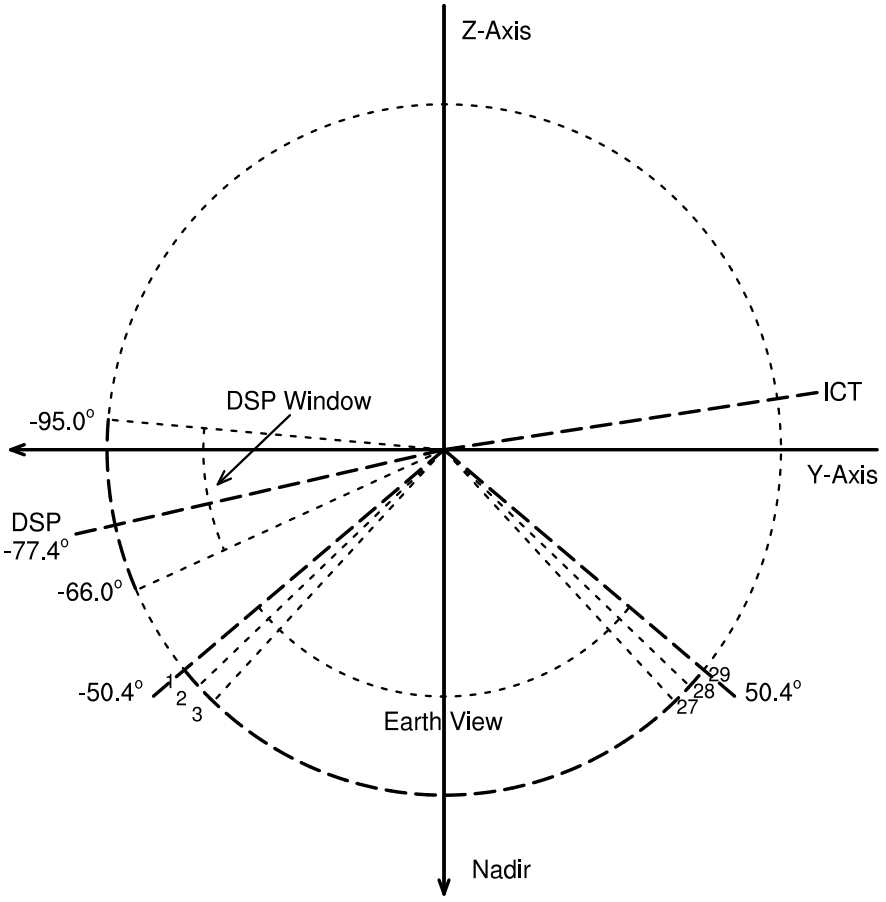


Responsivities after NL Correction



Method: Polarization Correction

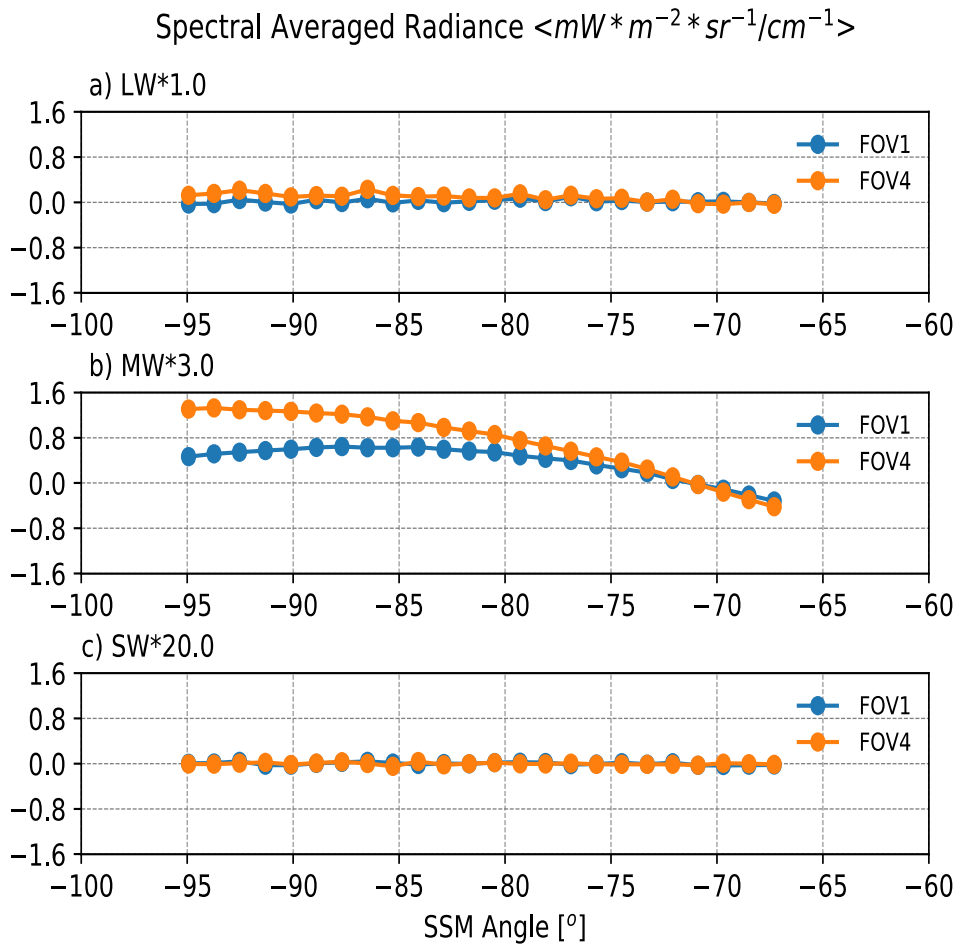


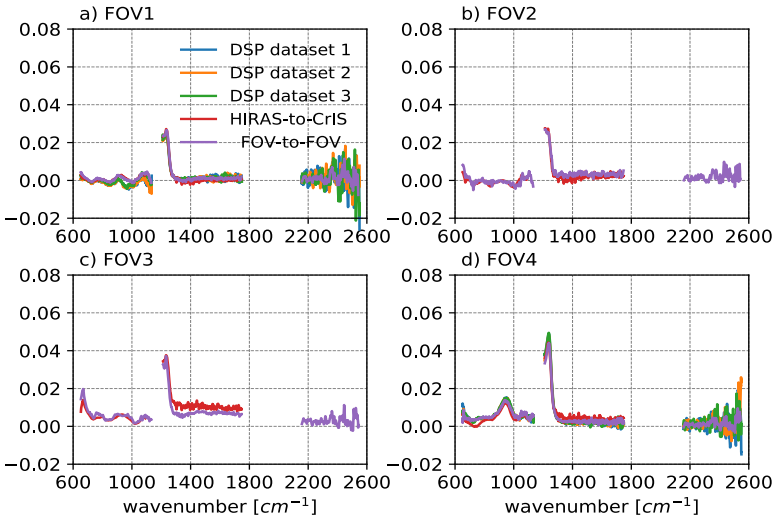


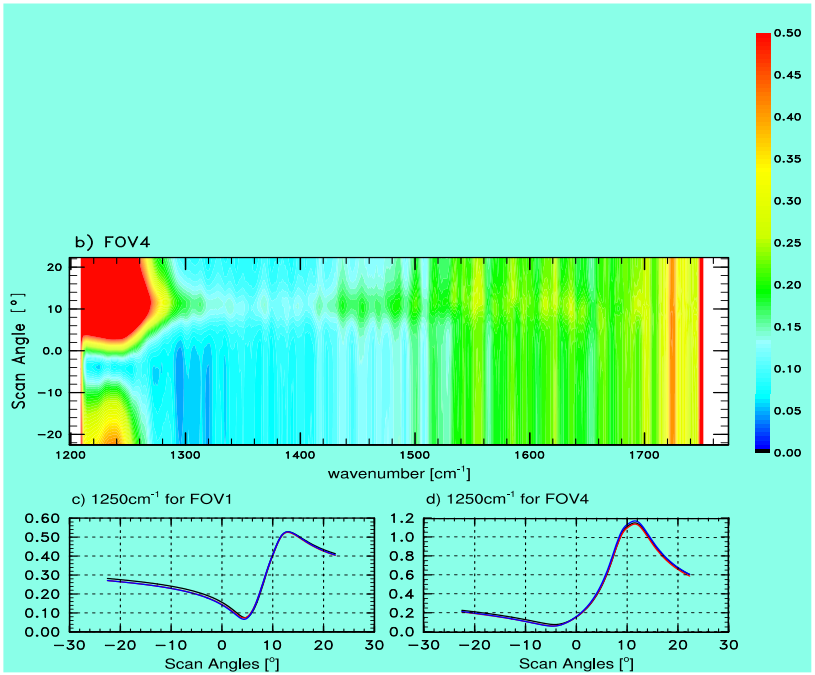
The radiance spectra when the FOVs view DSP at different SSM scan angles, calibrated without the polarization corrections. Different colors represent radiance spectra at different SSM scan angles.

$$E_p = L_{\delta,ES} - L_{ES} = p_r p_t \frac{(L_{ES} - B_{SSM})[\cos(2(\delta_{ES} - \alpha)) - \cos(2(\delta_{DS} - \alpha))]}{1 + p_r p_t \cos(2(\delta_{DS} - \alpha))}$$

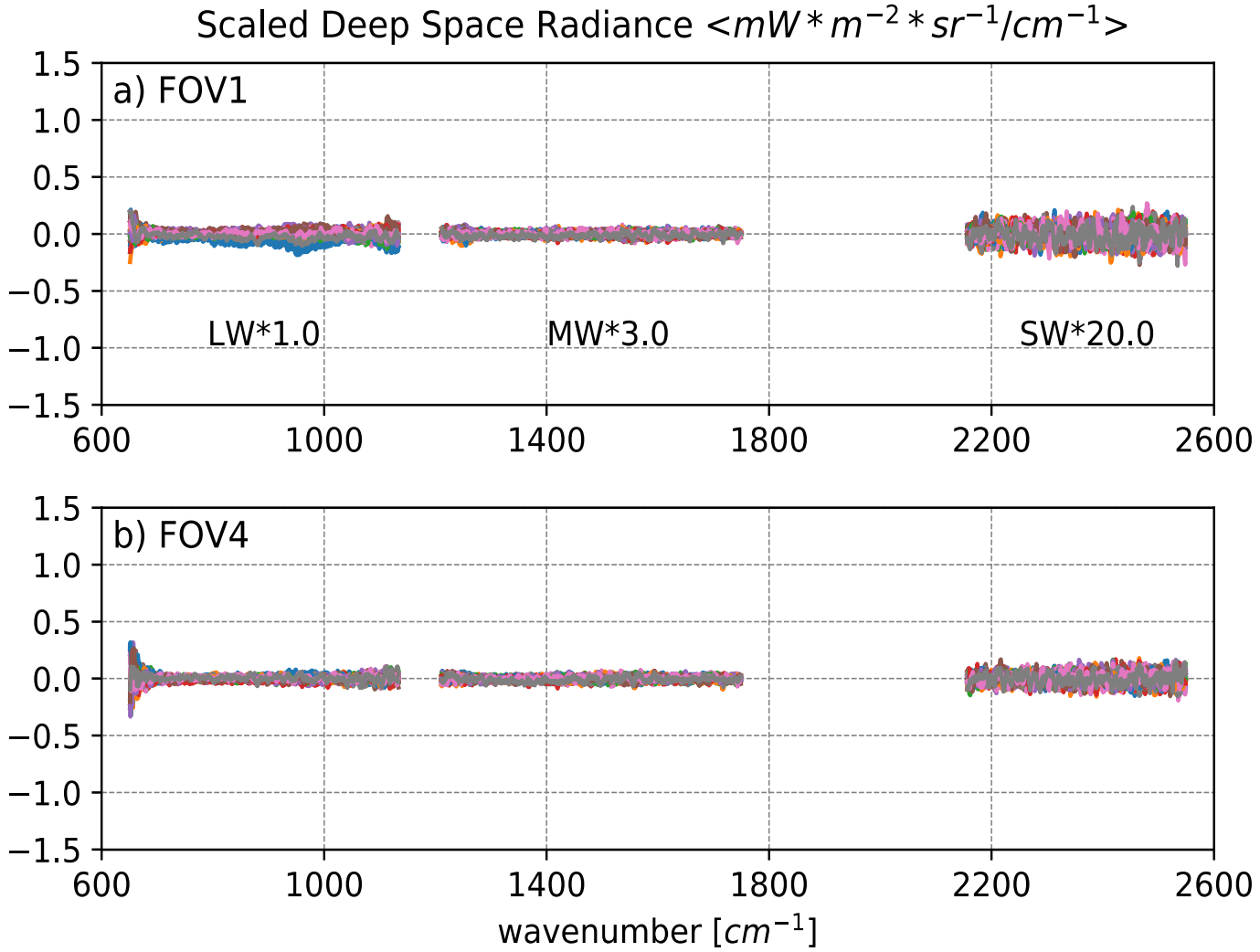
Method: Polarization Correction







Method: Polarization Correction



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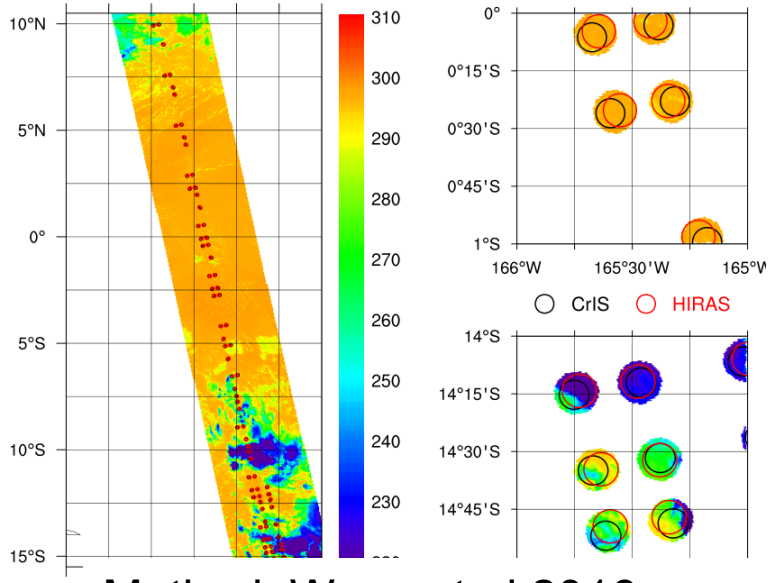
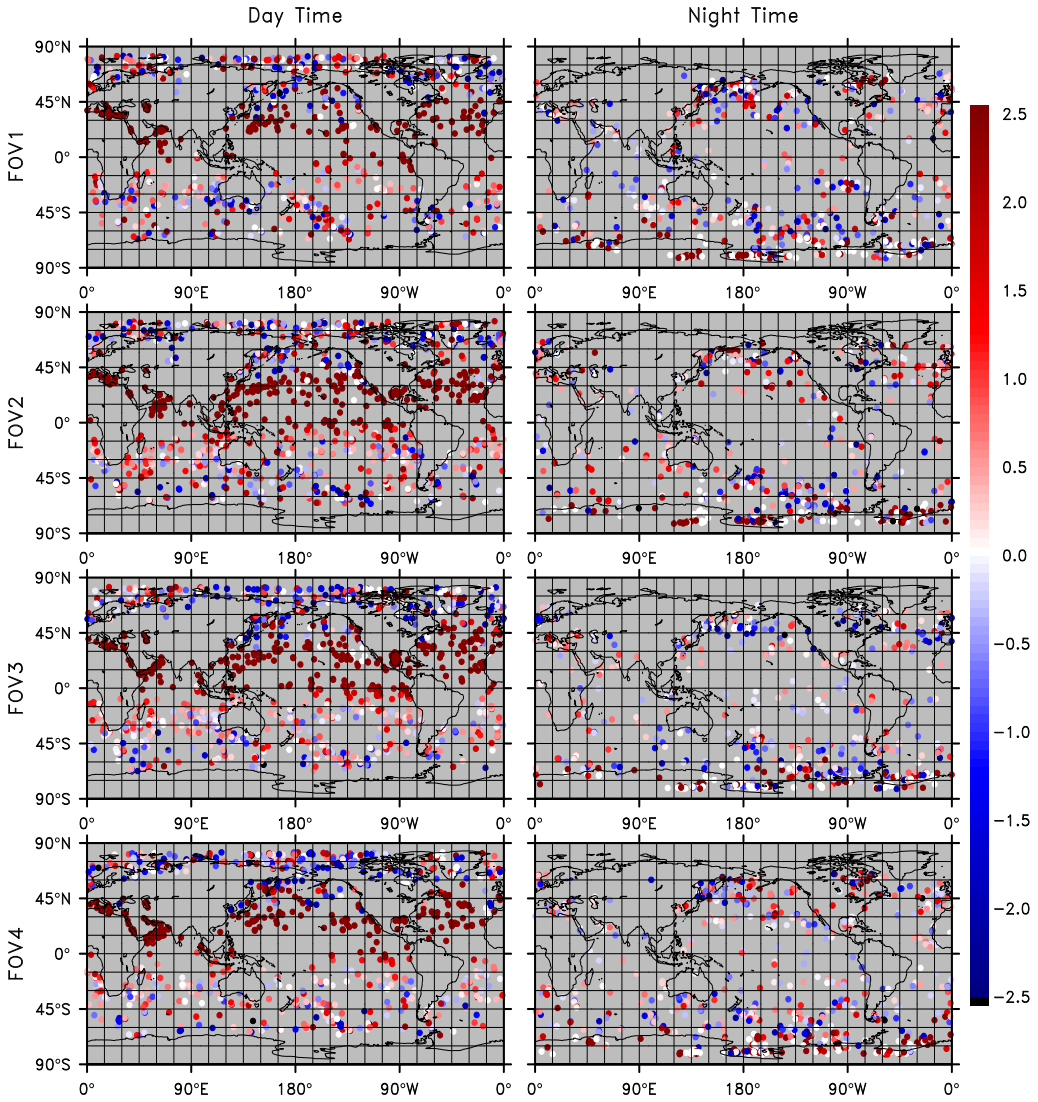
Validation: Method for SNO Paring

SNO Pairing Method

- Time Constrains:
  10 minutes
- Air Path Constrains
  FOR 14-17 for CrIS
  FOR 14-16 for HIRAS.
- Distance constrains
  5 km (Great circle)
- Scene uniformity
  VIIRS & MERSI: std < 0.2K

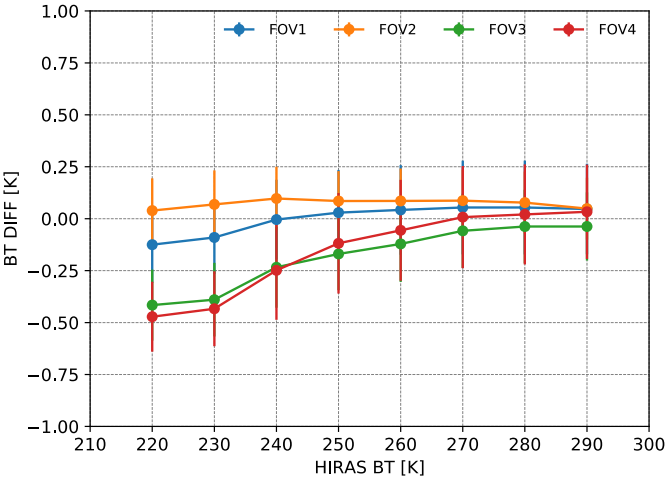


Method: Wang et al 2016

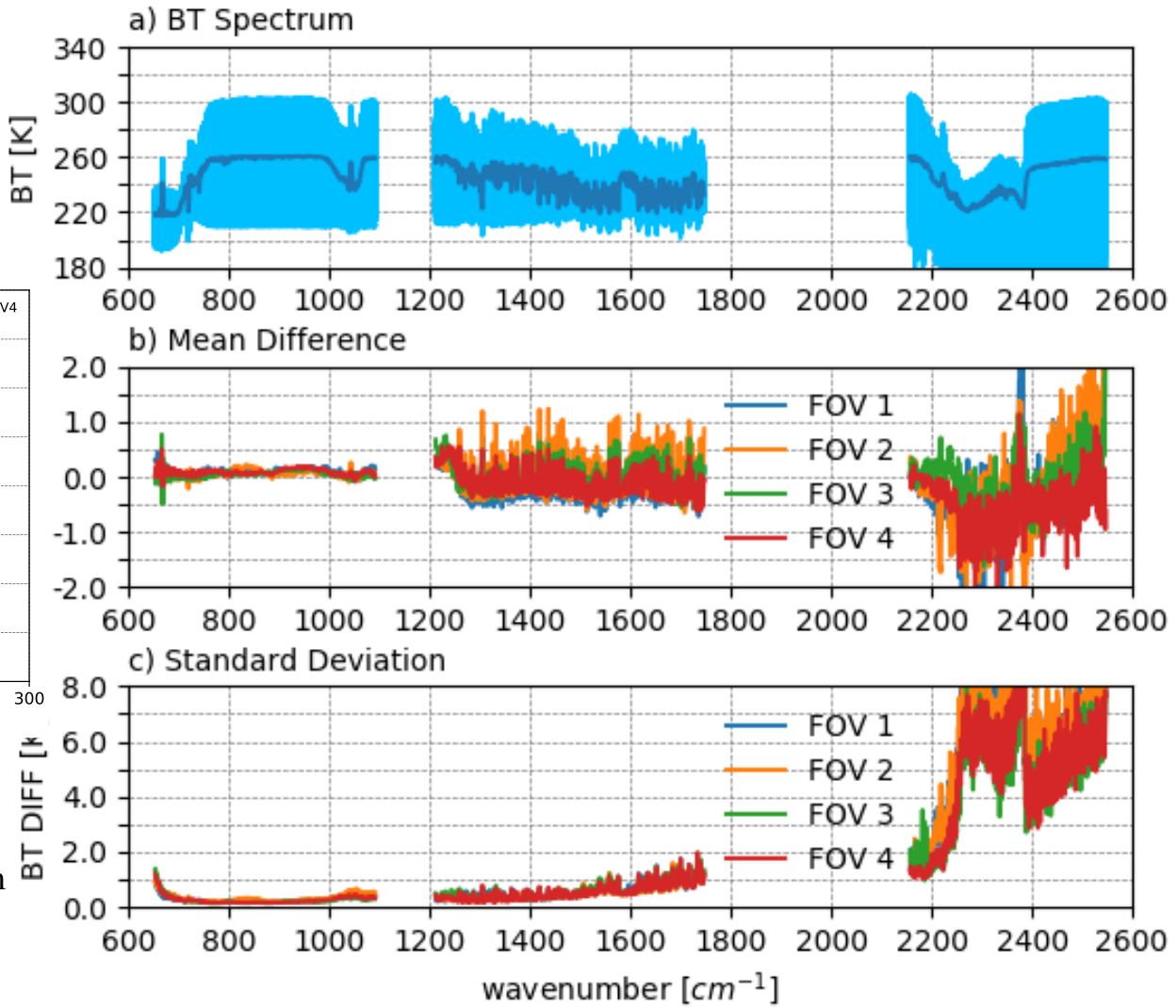


Samples are uniform in scene temperature

Validation: Radiometric based on SNO



The window channel BT (averaged over 980cm^{-1} to 1020cm^{-1}) difference between HIRAS and CrIS varying with scene temperatures, indicated by the HIRAS BT.

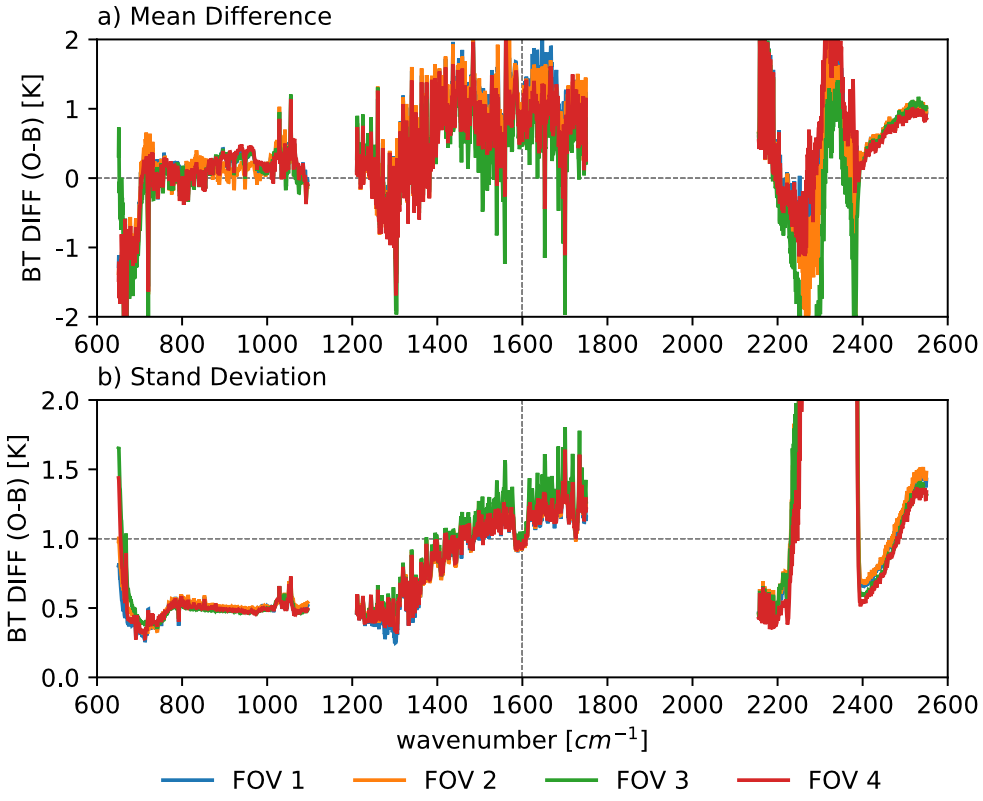


Validation: Compare with Simulation

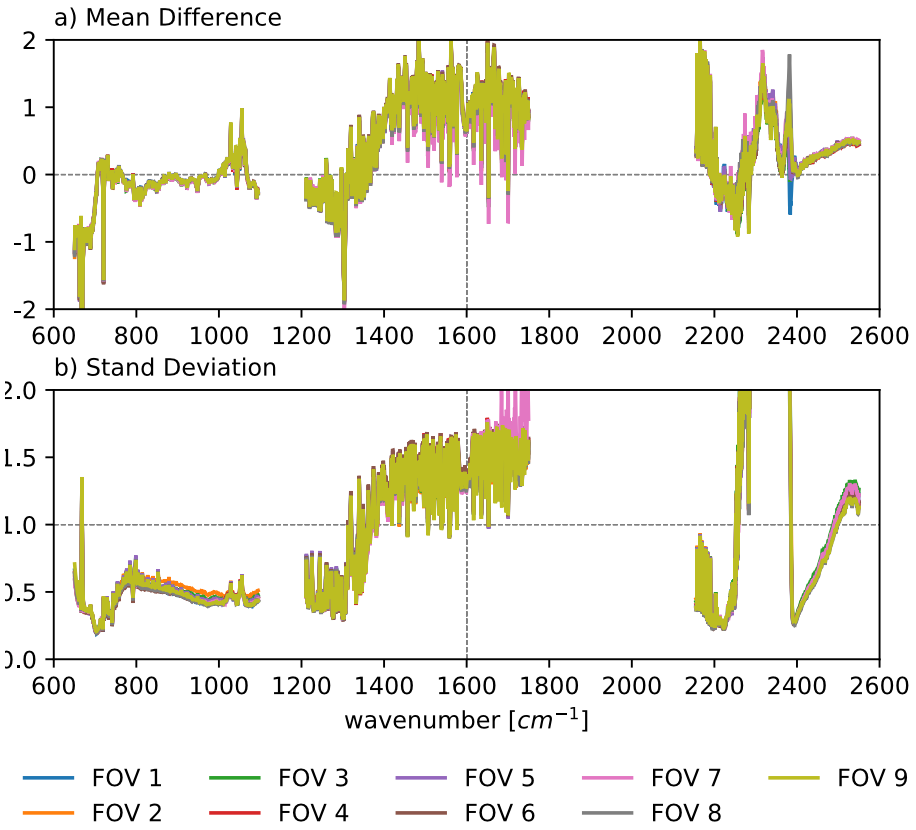
Model: RTTOV 10 **2018.04.26-04.29**

Input: ERA-Interim **Clear FOVS over Low Latitude Ocean**

HIRAS/FY3D



CrIS/NPP



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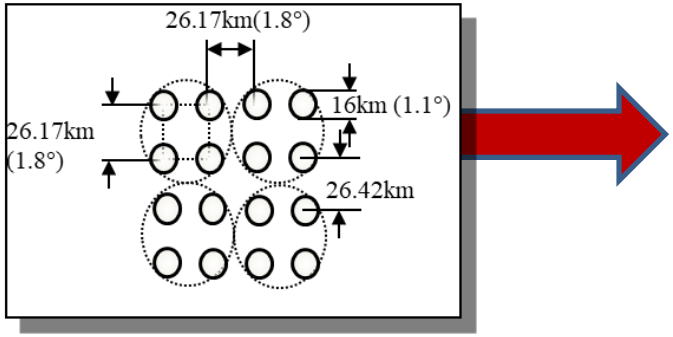
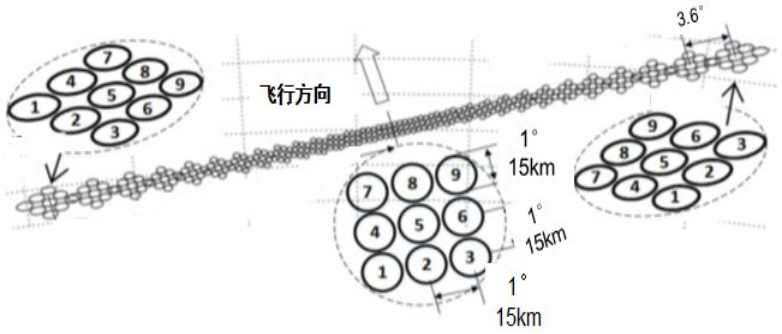
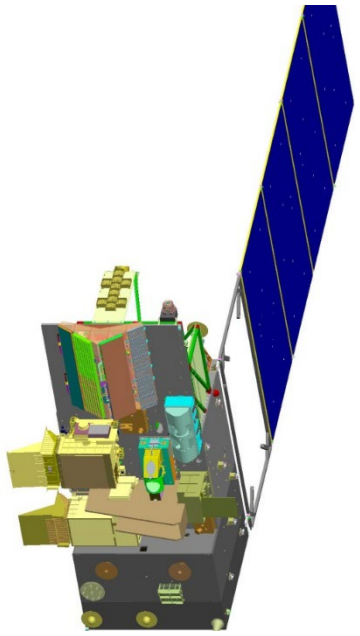
HIRAS Improvement from FY-3D to FY-3E Early Morning orbit

FY-3D



FY-3E





Band	Spectral Range (cm^{-1})	Spectral Resolution (cm^{-1})	Sensitivity (NEΔT@280K)			Num of Channels
			FY-3D	FY-3E		
LWIR	650～1136 （15.38μm～8.8 μm）	0.625	0.15(Expectation) 0.4K(Requirement)	650 ～667 cm^{-1}	0.8K	778
				667～689 cm^{-1}	0.4K	
				689～1000 cm^{-1}	0.2K	
				1000～1136 cm^{-1}	0.4K	
MWIR1	1210～1750 （8.26μm～5.71 μm）	1.25	0.1(Expectation) 0.7K(Requirement)	1210～1538 cm^{-1}	0.2K	433
				1538～1750 cm^{-1}	0.3K	
MWIR2	2155～2550 （4.64μm～3.92 μm）	2.5	0.3(Expectation) 1.2K(Requirement)	2155～2300 cm^{-1}	0.3	159
				2300～2550 cm^{-1}	0.5	

The Status of FY-3E Development

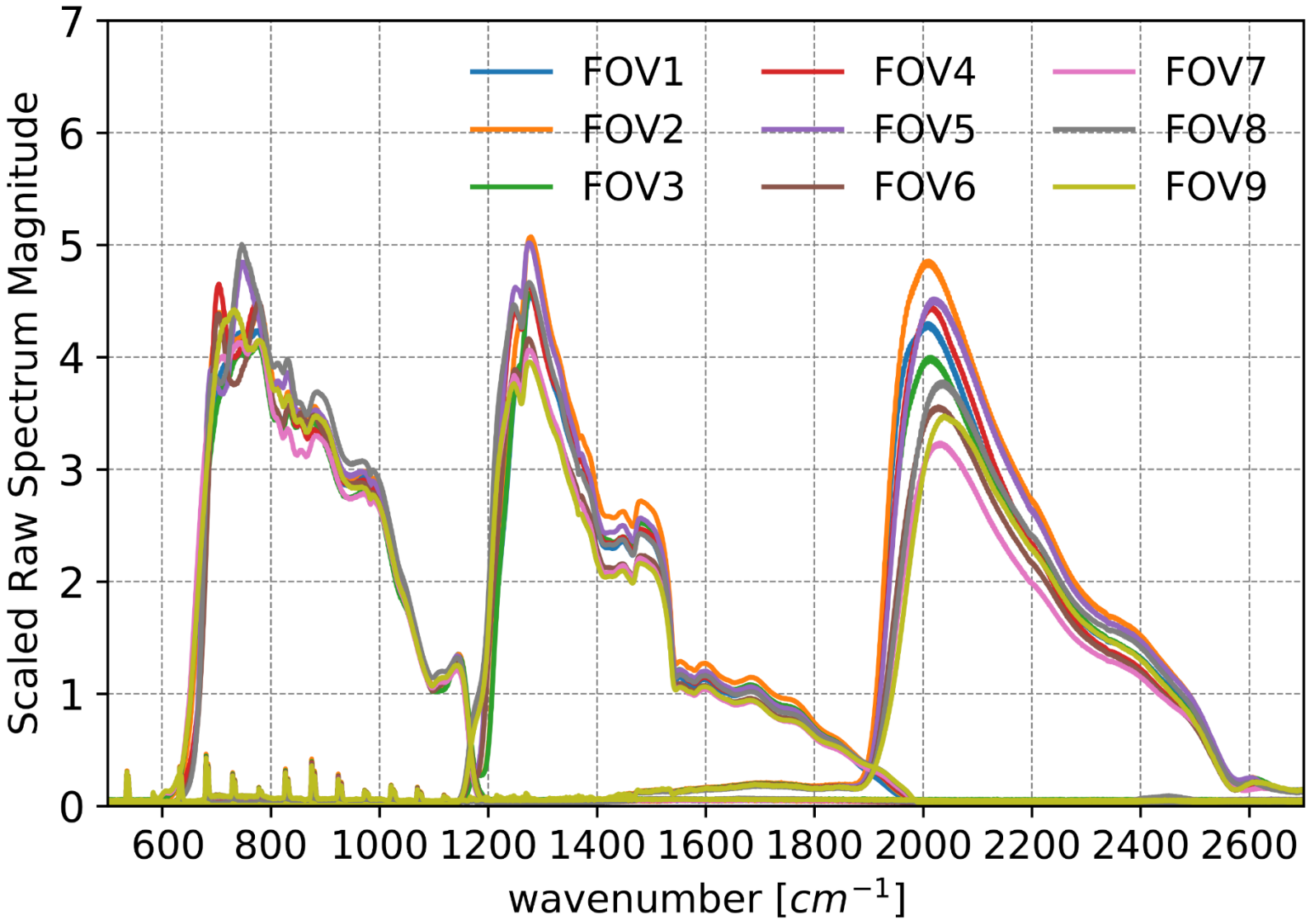
Till Sep 2019:

- Engineering protype
- TVAC Experiment, preliminary results will be shown later

From Jan 2019:

- Produce the flight module for the space-segment
- TVAC Experiment

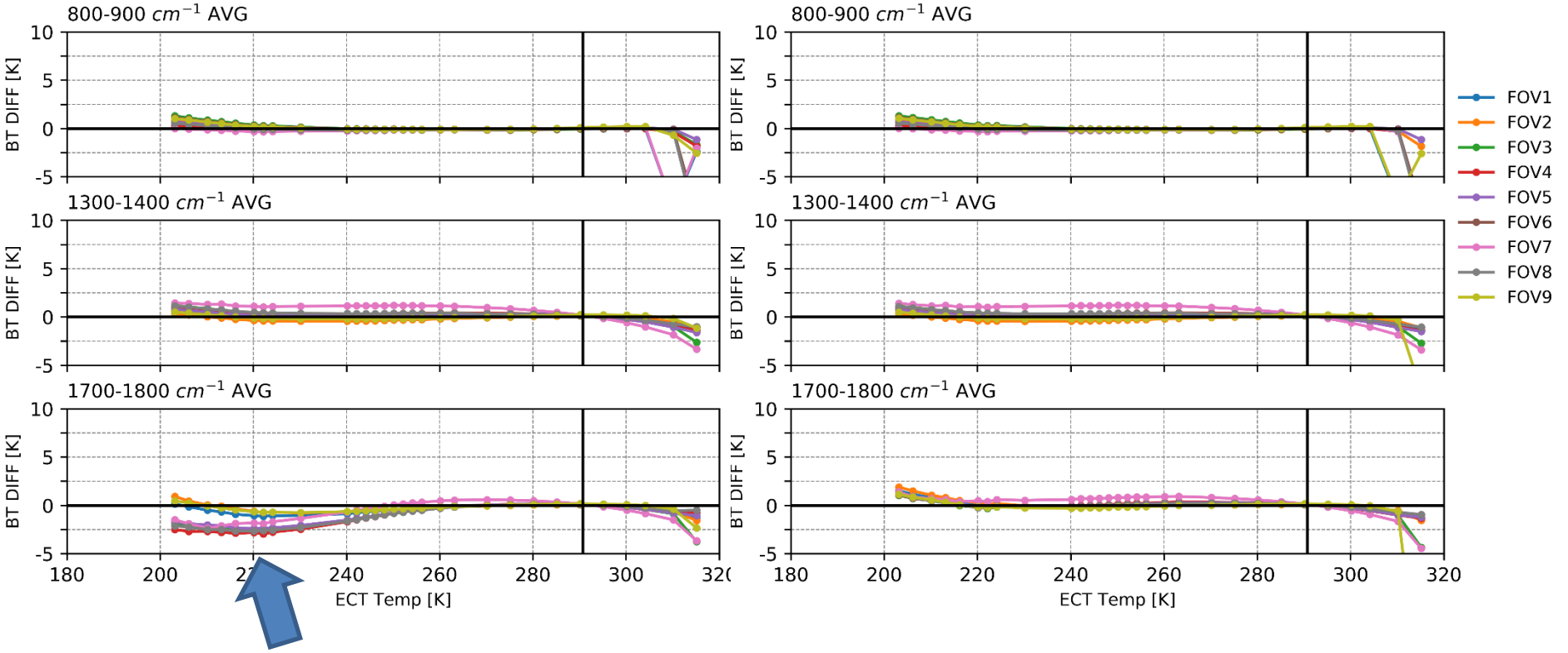
FY-3E HIRAS Spectral Range



Radiometric Accuracy

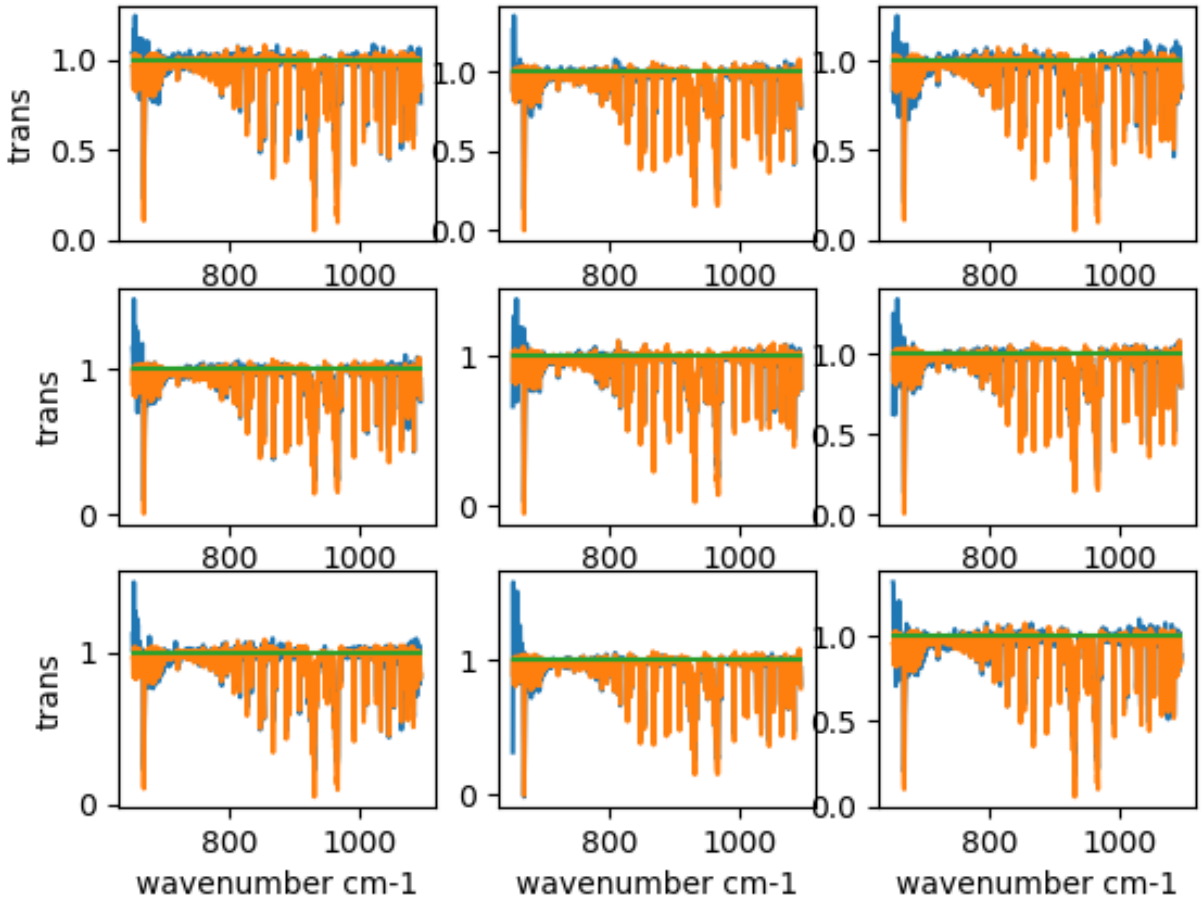
DIR0

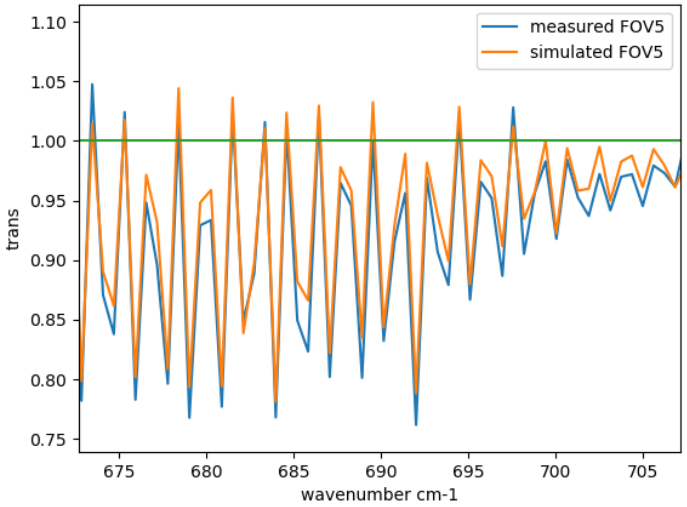
DIR1

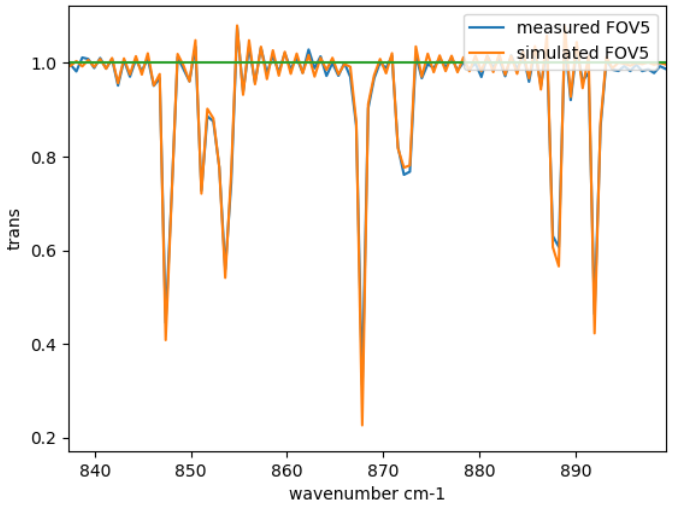


In the extended Spectral Region,
In investigation

OBS/LBL Transmittance







Summary

- The nonlinearity correction coefficients are derived by minimizing the spread of the responsivity functions derived from the measurements of the internal calibration target with varying temperatures.
- The polarization correction coefficients are derived from the cold space observations and the routine Earth scene measurements
- Compared to CrIS, the radiometric differences are about 0.3 K and 0.7 K for the LW and MW bands, respectively, and 0.5 K for the CO absorption and window regions in the SW band.
- The consistency of the radiometric calibration among the four FOVs is estimated to be within 0.2 K for most of the spectral domain. The consistency is different within scene temperatures.

Thank you for your attendance!!