Implementation of a Polarization Correction for the Cross-track Infrared Sounder (CrIS) Sensor

Joe K. Taylor[1], Henry E. Revercomb[1], David C. Tobin[1], Robert O. Knuteson[1], Michelle L. Feltz[1], Graeme Martin[1], Yong Chen[2], Flavio Iturbide[2]
1. Space Science and Engineering Center, University of Wisconsin-Madison, USA
2. NOAA Center for Satellite Applications and Research, College Park, Maryland, USA

ITSC-XXII
Saint-Sauveur, Québec, Canada

Introduction

- Incident radiance is partially polarized by reflection from the scene select mirror (SSM); there is a small degree of polarization in the IR for uncoated gold mirrors
- The CrIS sensor utilizes a "barrel-roll" scene select mirror that rotates about an axis that is 45° from the mirror normal, preserving the angle of incidence at the mirror and optical axis for all calibration and scene views.
- However, the orientation of the polarization axis of the scene select mirror changes with scene mirror rotation
- When coupled with the polarization sensitivity of the sensor, this produces a radiometric modulation of the detected signal that is dependent on the rotation angle of the scene select mirror and creates a calibration error
- The SSM and sensor effectively act as a polarizer and analyzer pair
- Total signal intensity generated for an arbitrary, unpolarized scene or calibration radiance observed at a scene selection mirror angle δ and a sensor polarization axis at an angle α:

$$\begin{aligned} C_\delta = & \frac{L_\delta}{2} r_p \left[t_{\max} \cos^2(\delta-\alpha) + t_{\min} \sin^2(\delta-\alpha) \right] \\ & + \frac{L_\delta}{2} r_s \left[t_{\max} \sin^2(\delta-\alpha) + t_{\min} \cos^2(\delta-\alpha) \right] \\ & + \frac{B_{SSM}}{2} \varepsilon_p \left[t_{\max} \cos^2(\delta-\alpha) + t_{\min} \sin^2(\delta-\alpha) \right] \\ & + \frac{B_{SSM}}{2} \varepsilon_s \left[t_{\max} \sin^2(\delta-\alpha) + t_{\min} \cos^2(\delta-\alpha) \right] \\ & + C_{inst}. \end{aligned}$$

- Which can be simplified to:

$$C_\delta = \left(L_\delta - B_{SSM}\right) rt + B_{SSM} t + \left(L_\delta - B_{SSM}\right) p_r p_t rt \cos 2(\delta-\alpha) + C_{inst}$$

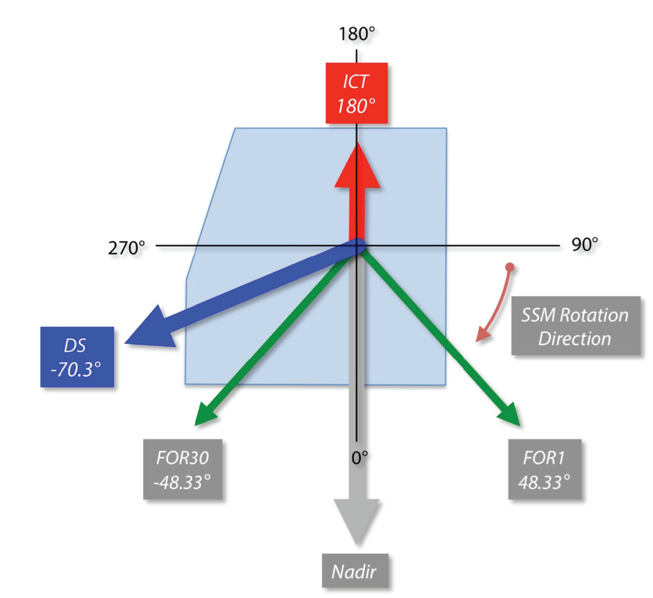
- The polarization induced calibration error (E_p) can be derived by substituting the expression above into the complex calibration equation:

$$E_p \cong p_r p_t \left\{ \begin{array}{l} L_S \cos 2(\delta_S-\alpha) - L_H \frac{L_S - L_C}{L_H - L_C} \cos 2(\delta_H-\alpha) - L_C \frac{L_H - L_S}{L_H - L_C} \cos 2(\delta_C-\alpha) \\ -B_{SSM} \left[\cos 2(\delta_S-\alpha) - \frac{L_S - L_C}{L_H - L_C} \cos 2(\delta_H-\alpha) - \frac{L_H - L_S}{L_H - L_C} \cos 2(\delta_C-\alpha) \right] \end{array} \right\}$$

Pitch Maneuver

- Both SNPP and NOAA-20 completed a pitch maneuver (2012-02-20, 2018-01-31, respectively). During the maneuver all CrIS cross-track (ES) and deep space cal (DS) FORs and FOVs viewed deep space
- This represents the only existing end-to-end measurements that can be used to derive the polarization parameters for CrIS
- The raw and calibrated signals from the pitch maneuver show clear polarization effects and are very well represented by the theoretical model
- α, the effective polarizer angle of the sensor, has band dependence (aft-optic dichroics) and a small FOV dependence (slightly different optical paths through the sensor).
- $p_r p_t$, the combined polarization of the SSM (p_r) and sensor (p_t), is wavenumber dependent, and has a small FOV dependence
- The effective polarization angle (δ) of the scene mirror is FOV dependent
- Due to optical coating differences between SNPP and NOAA-20, they have slightly different polarization parameters

CrIS Scan Angle Geometry Assumptions
Nadir selected as 0° reference for polarization



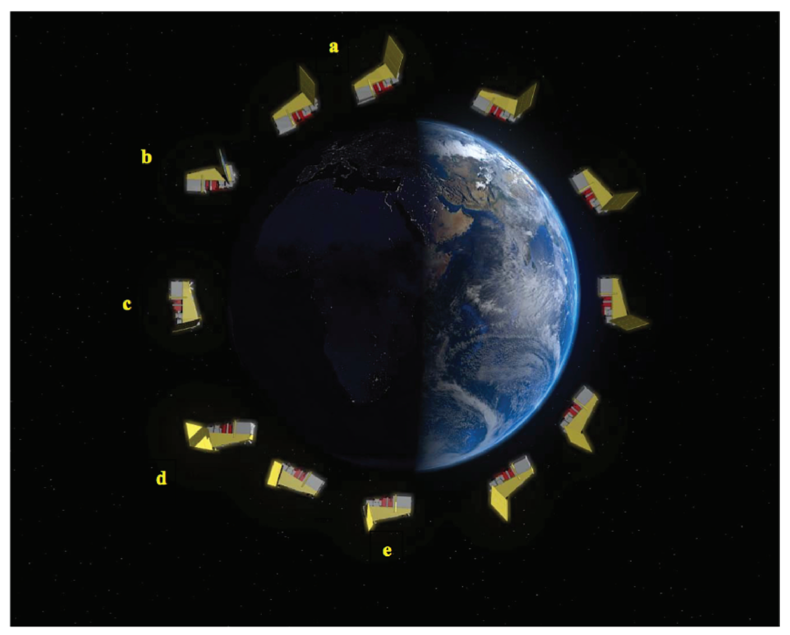
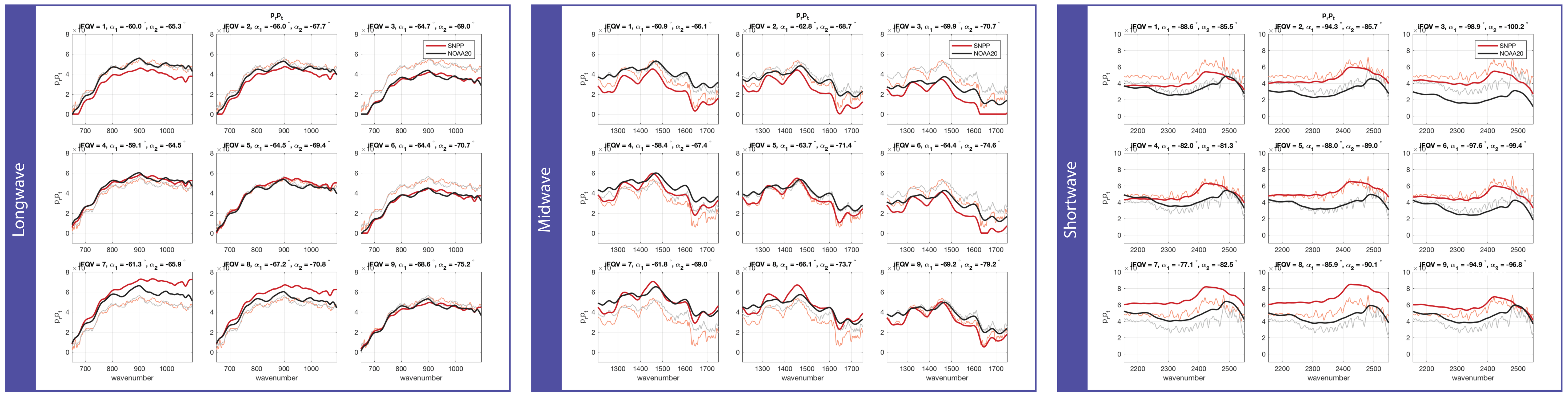


Figure 8. The SNPP spacecraft pitch-over maneuver enabling VIIRS to scan deep space.

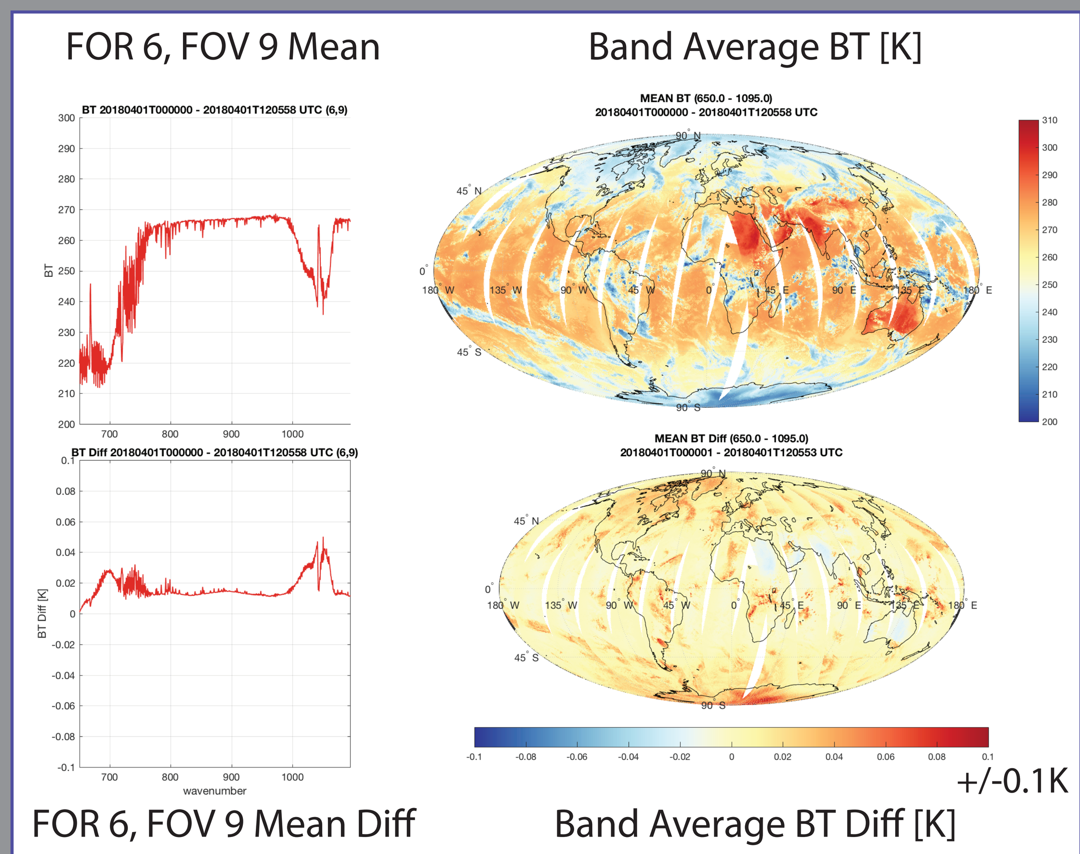
J. Butler: "An overview of Suomi NPP VIIRS calibration maneuvers"

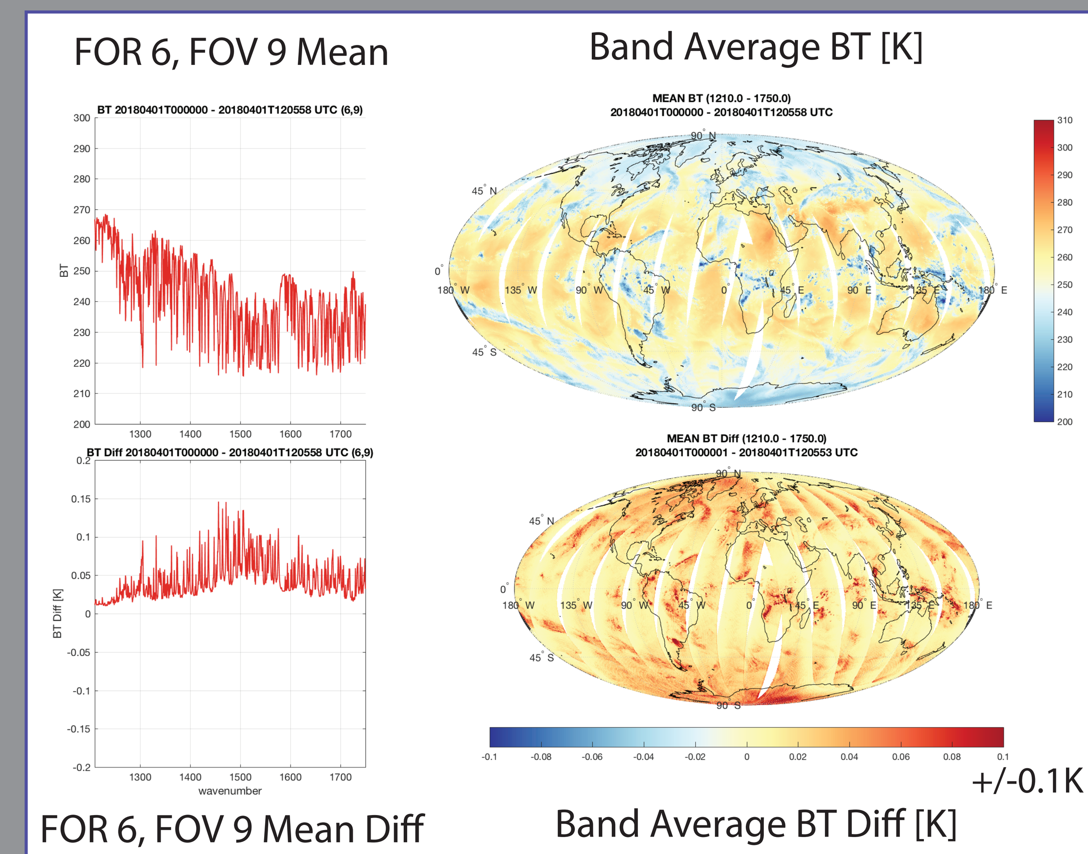
Polarization Parameters Derived from the Pitch Maneuver

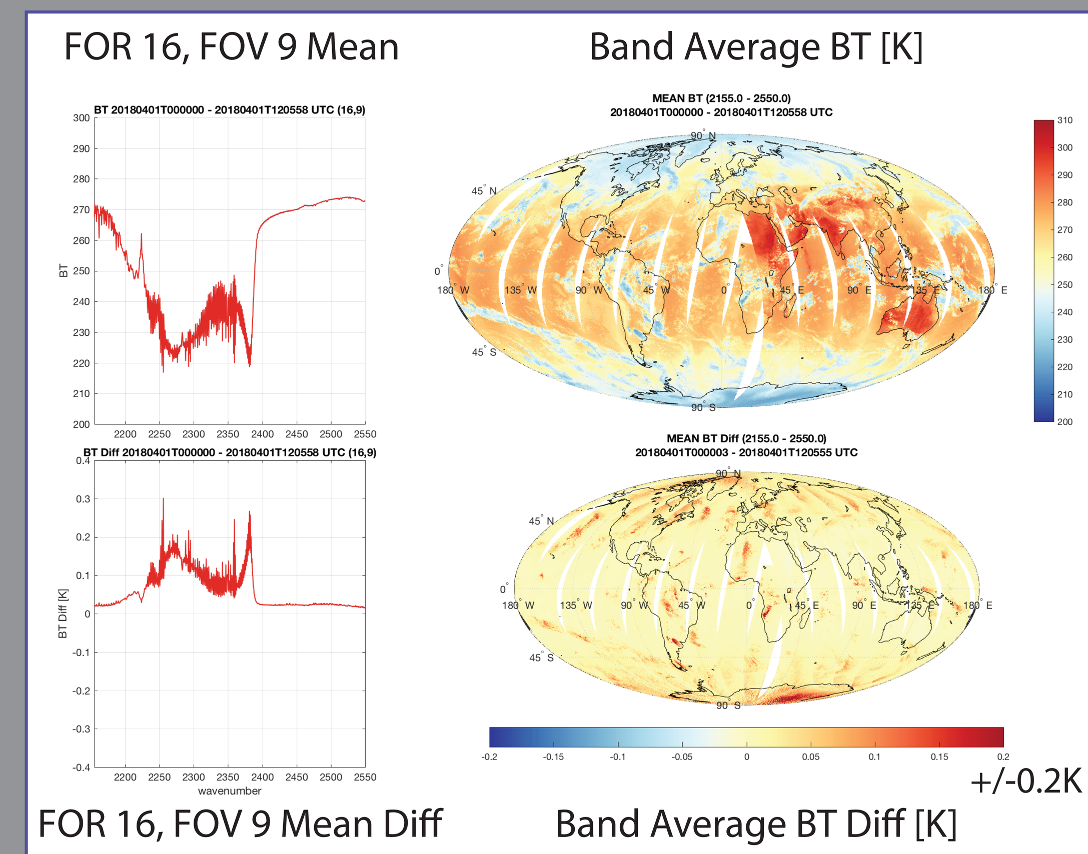


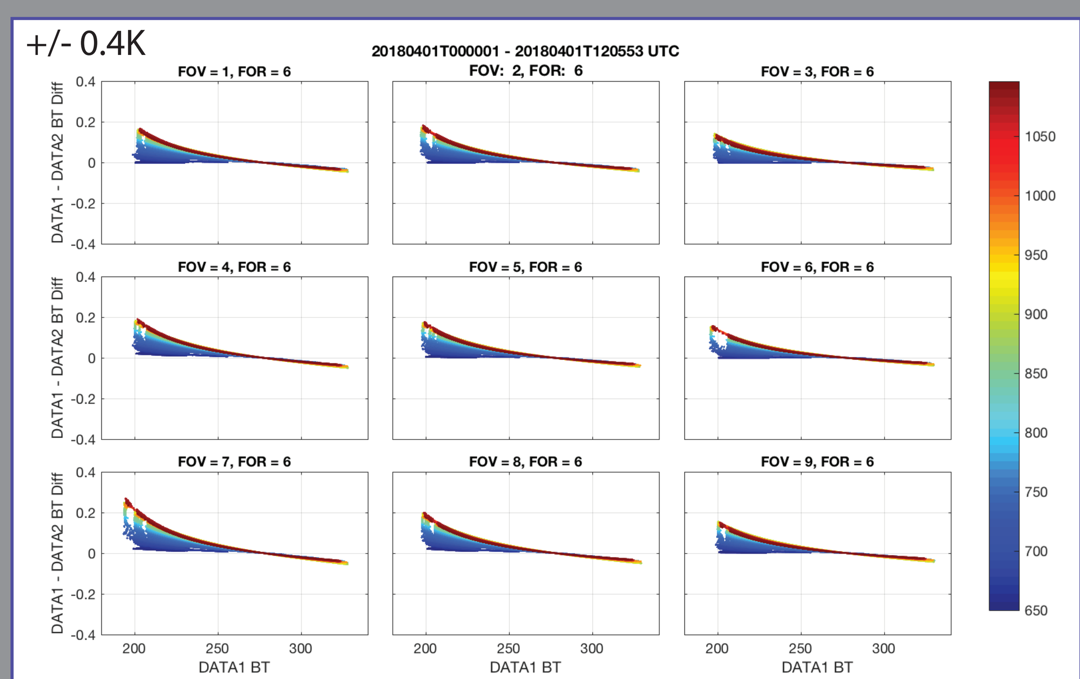
light lines: fit to all FOV average with no filtering or smoothing

Sample Polarization Correction Results, NOAA20

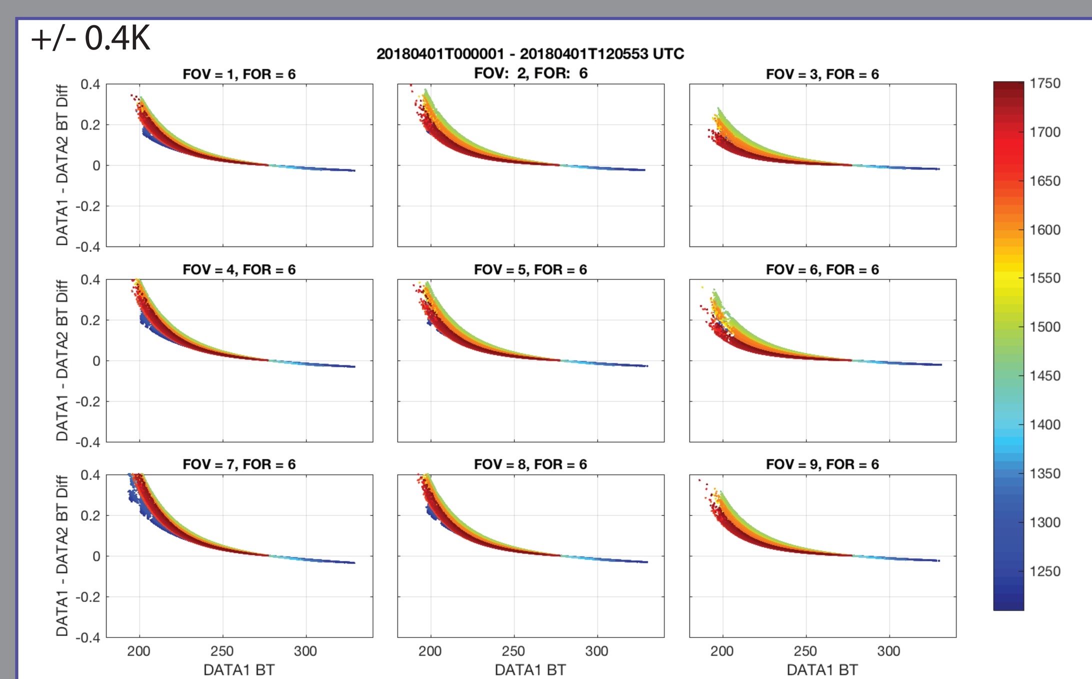




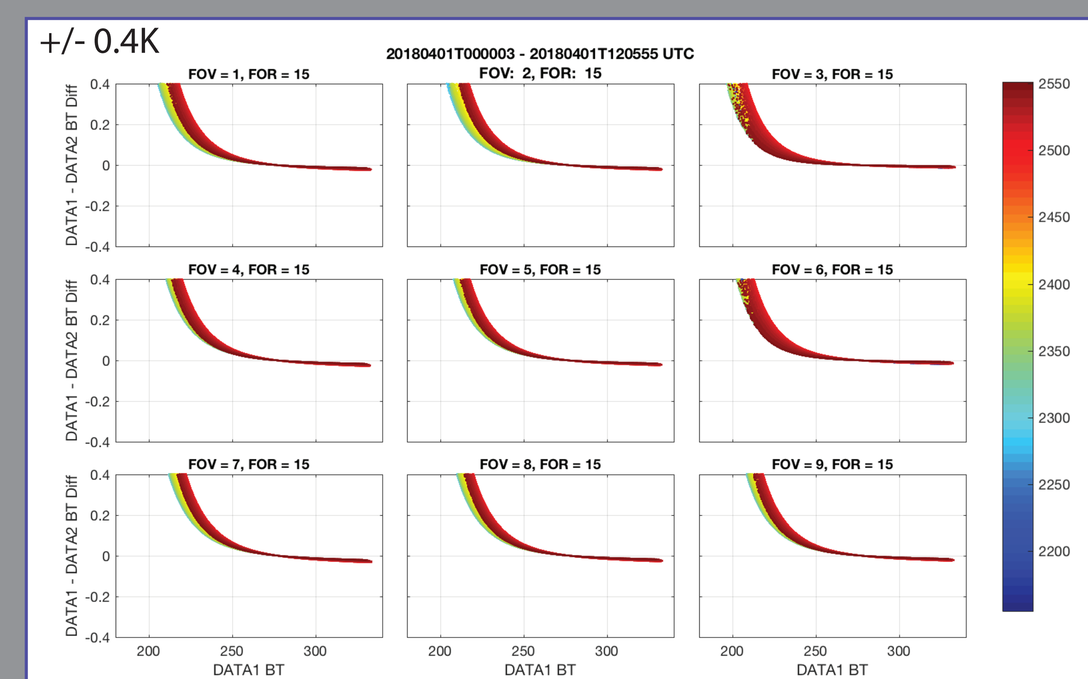




LW correction peaks near FOR 6. FOR 6 shown above for all FOVs

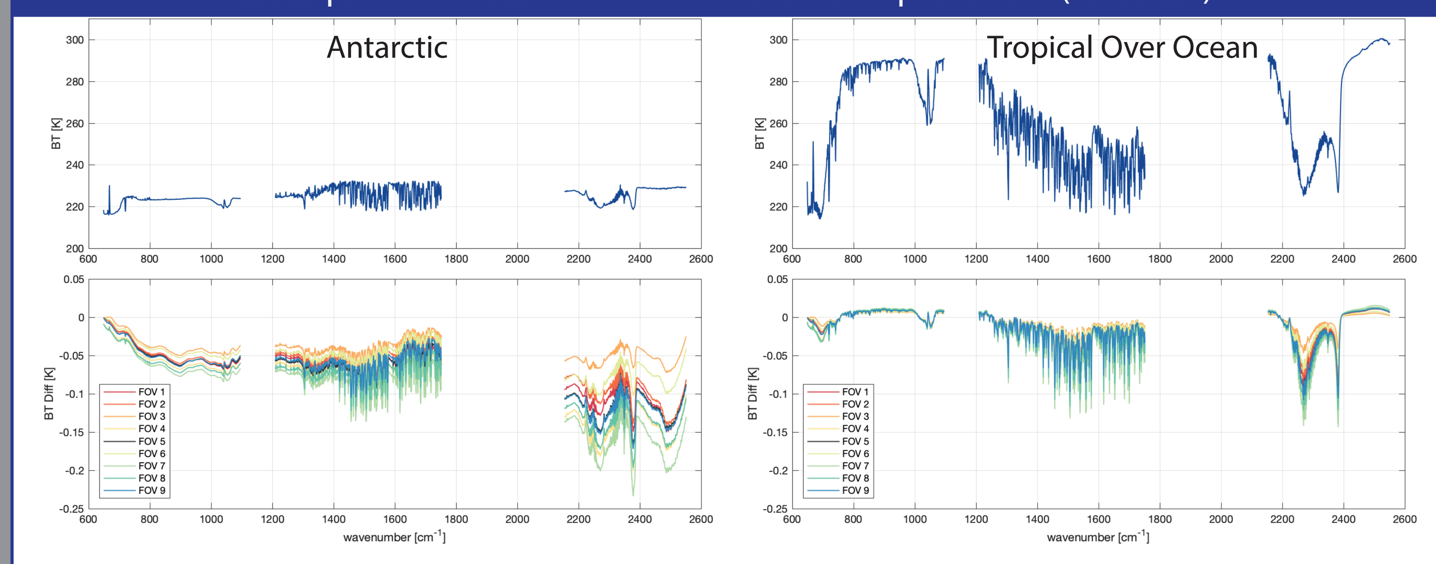


MW correction peaks near FOR 6. FOR 6 shown above for all FOVs



SW correction peaks near FOR 15. FOR 15 shown above for all FOVs

Example of Polarization Correction FOV Dependence (NOAA20)



- Polarization correction is not included in the current NASA L1b or NOAA SDR products, but will be implemented in the next releases of both the NASA and NOAA processing
- Polarization correction parameters were derived independently for SNPP and NOAA-20 using pitch maneuver data
- The correction in the LW and MW bands is relatively small; the largest correction (expressed in BT) is in the SW band for cold scenes and short wavelengths
- The SNPP correction is slightly larger than the correction for NOAA-20
- Polarization correction of both CrIS sensors results in better agreement between the two sensors (using AIRS or IASI as the intermediate reference)
- Polarization correction reduces CrIS inter-FOV variability for NOAA-20 and SNPP
- Polarization correction improves the symmetry of the CrIS observations with respect to nadir

joe.taylor@ssec.wisc.edu, Space Science and Engineering Center, University of Wisconsin-Madison, 1225 West Dayton Street, Madison WI 53706 USA