Advancements in DCC Calibration:

VIS/NIR ATBD Update, Empirical BRDFs for SWIR wavelengths, and Future Directions

Raj Bhatt, Dave Doelling, Prathana Khakurel, Conor Haney, Arun Gopalan, Ben Scarino

CERES Imager and Geostationary Calibration Group
NASA Langley Research Center

GSICS VIS/NIR Subgroup Meeting
May 9, 2024

Key assumptions of DCC-IT calibration method

- **DCC-IT inter-calibration technique relies on a large ensemble of tropical DCC pixels identified using similar thresholds for reference LEO and target GEO sensors**
- **DCC-IT does not require simultaneous and ray-matched observations between GEO and LEO for inter-calibration**
  - *Agencies do not need to acquire real-time VIIRS data for calibrating GEOs*
  - *DCC response over a specific GEO domain is stable and characterized using the reference VIIRS instrument*

Revised DCC-IT Calibration ATBD: *key improvements*

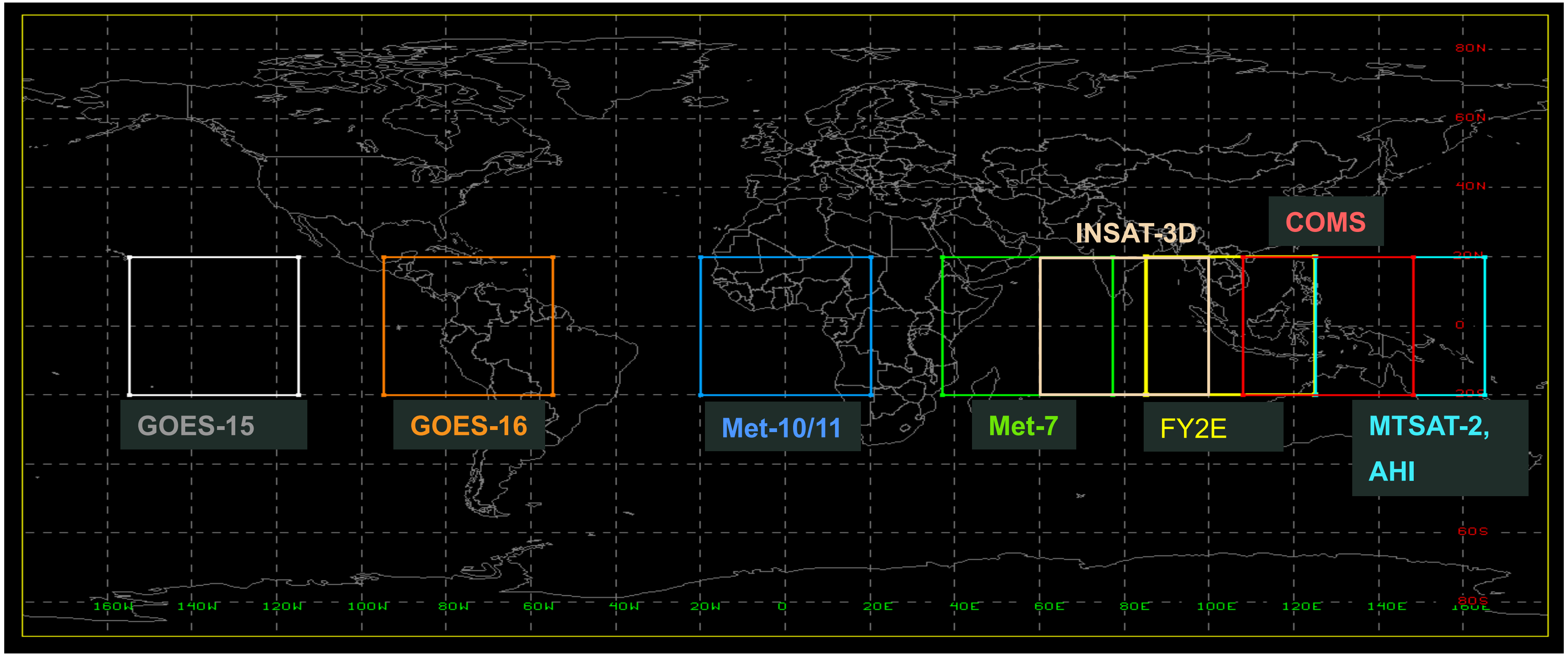
- *Extends the methodology to all spectral channels between 0.4-1.0 µm*
- *Uses the most recent and well-calibrated NOAA-20 VIIRS sensor as a reference instrument for DCC characterization*
- *IR BT threshold normalization between GEO and VIIRS for consistent DCC sampling and response*
- *Seasonal corrections of GEO monthly DCC response*
- *Spectral corrections using NASA Langley's robust online SBAF computation tool*
- *PDF bin optimization*

- ***Link for preliminary draft of ATBD***
- ***http://gsics.atmos.umd.edu/pub/Development/20210909/DCC_ATBD_2021a.pdf***

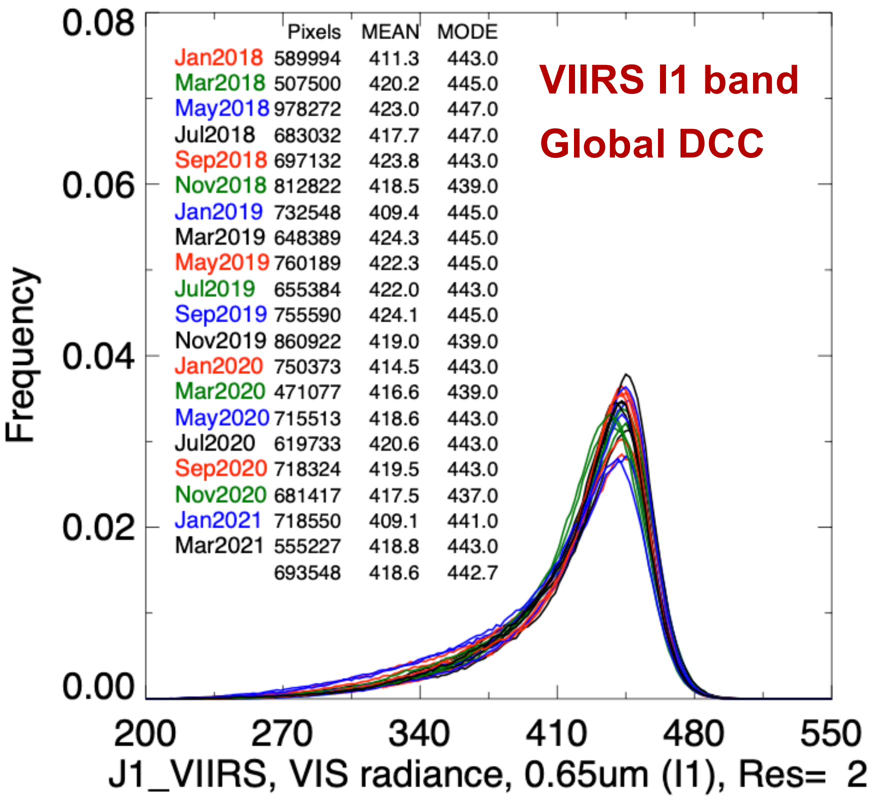
VIS/NIR DCC Calibration ATBD Update

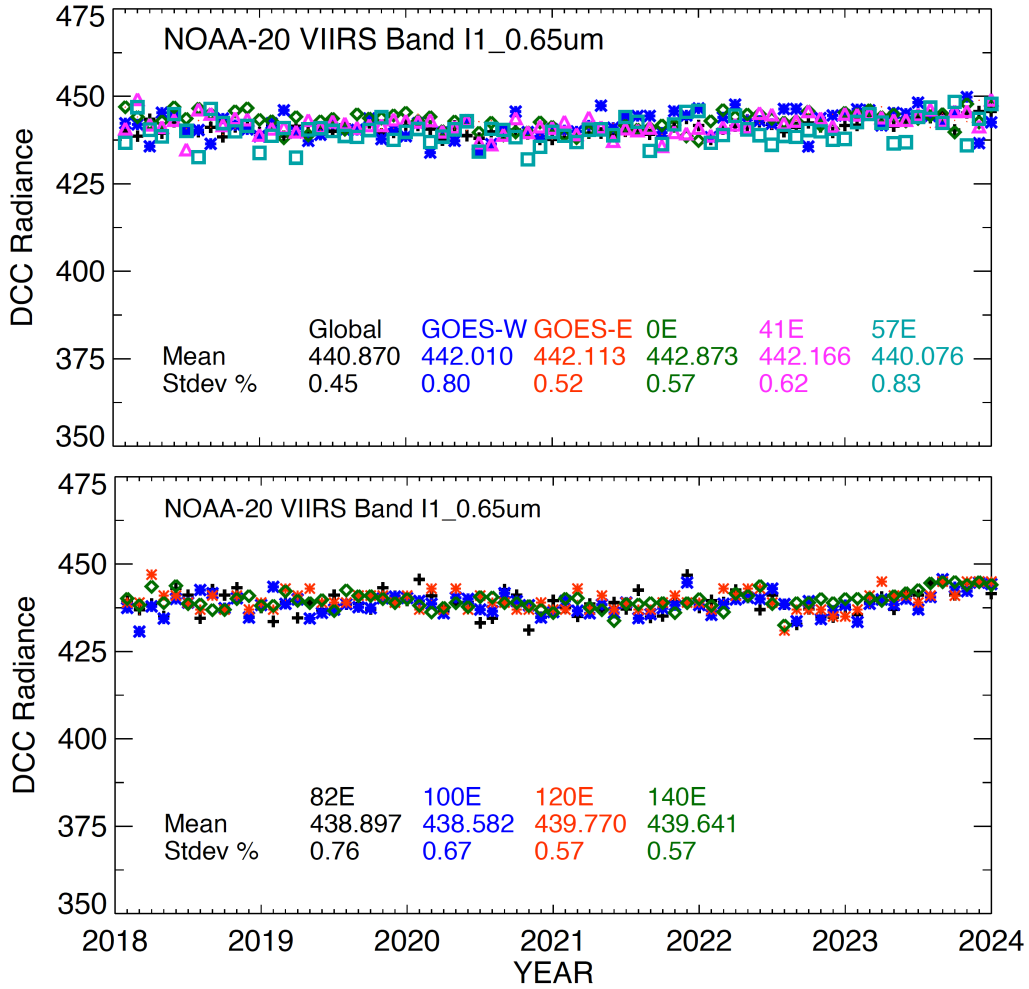
- DCC characterization updated with extended NOAA-20 VIIRS C2.1 record (2018-2023)
- Reference DCC mode radiances are derived for the global tropical region along with nine geostationary satellite domains
- Associated 1-sigma uncertainties computed for each GEO domain based on temporal standard deviation

GEO Imagers DCC Identification Domains



±20° Lat/Lon from the GEO sub-satellite point

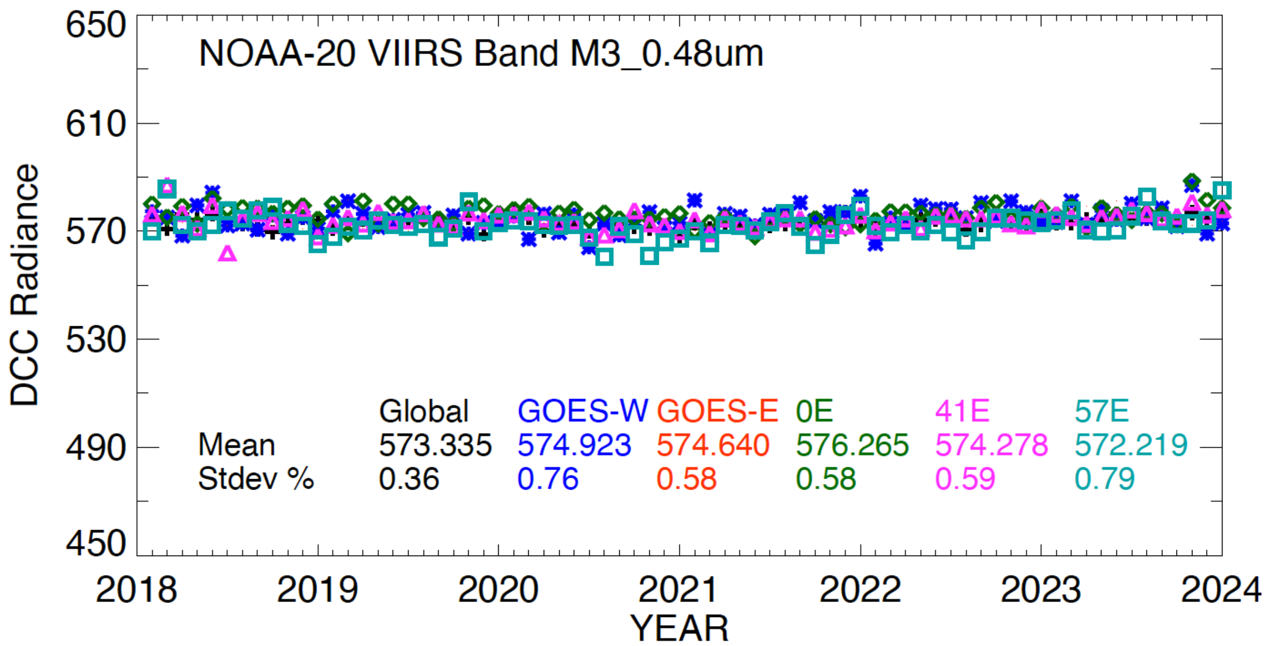


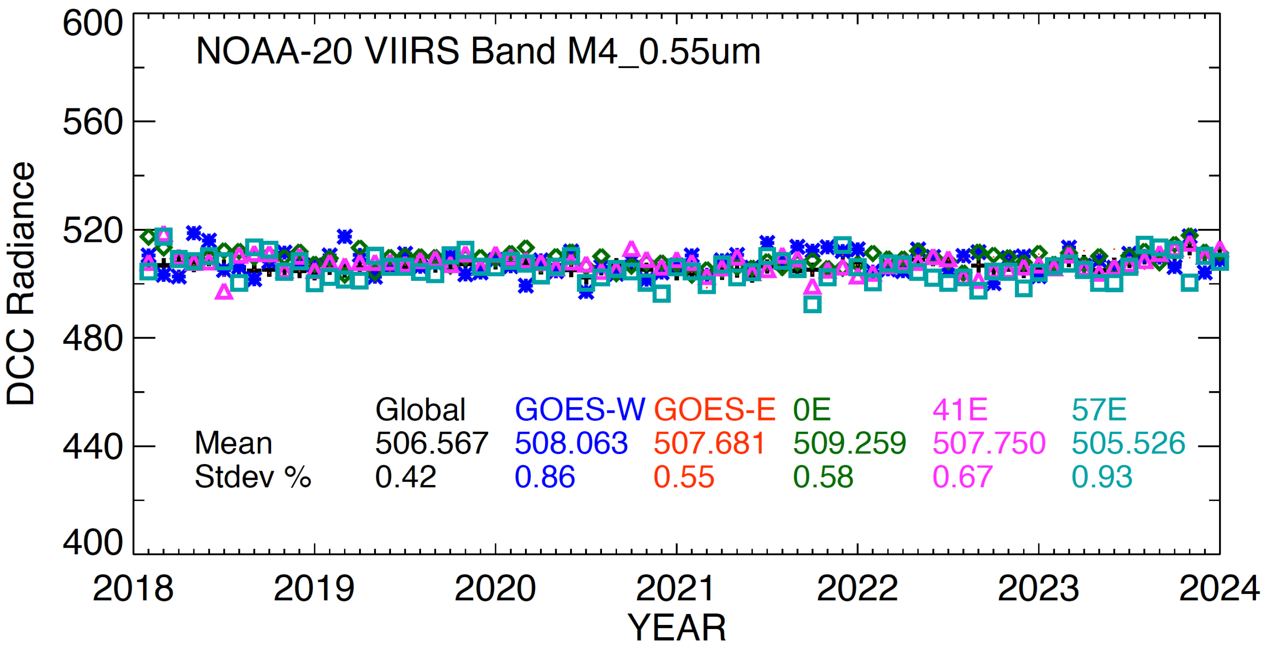


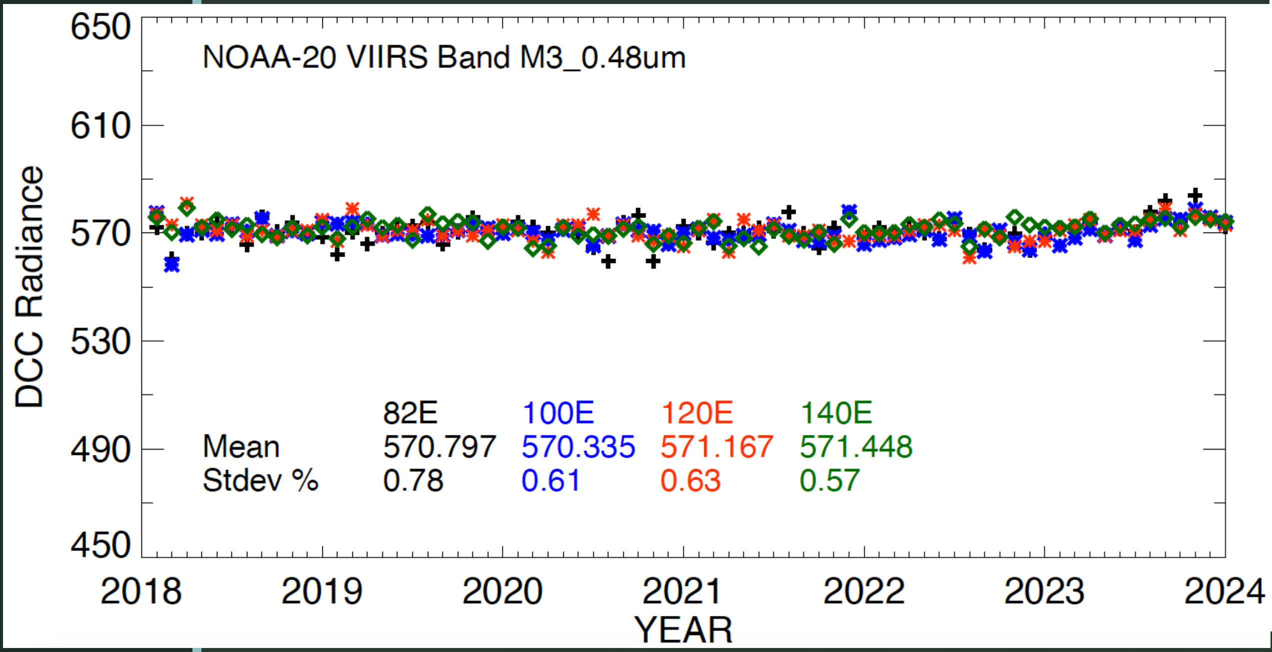
This study uses NOAA-20 VIIRS L1B Collection 2.1 products from NASA Land SIPS

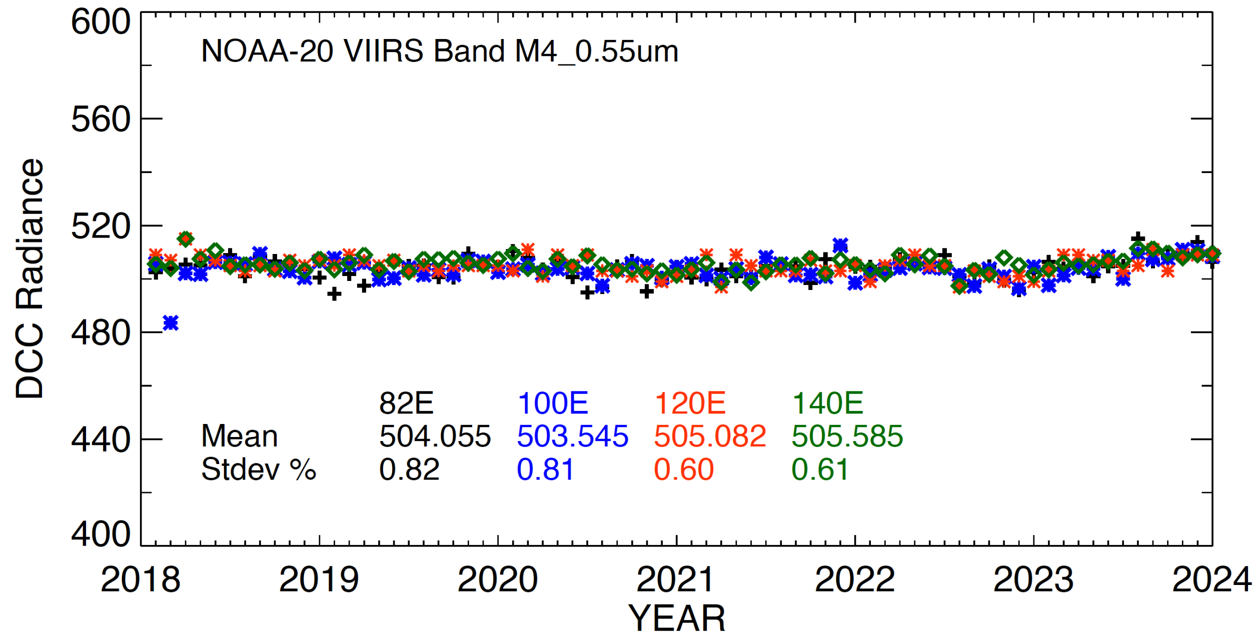
- ***Regional variation of DCC mode is <1%***
  - ***brightest over 0°E longitude***

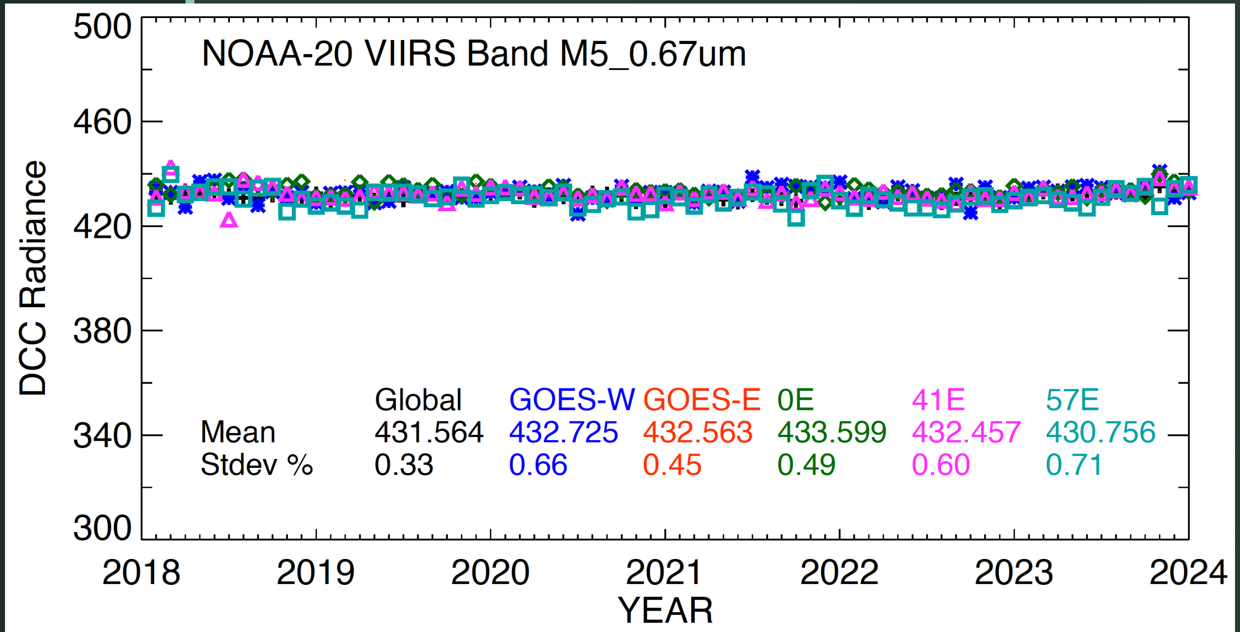
DCC reference mode radiances based on NOAA-20 VIIRS

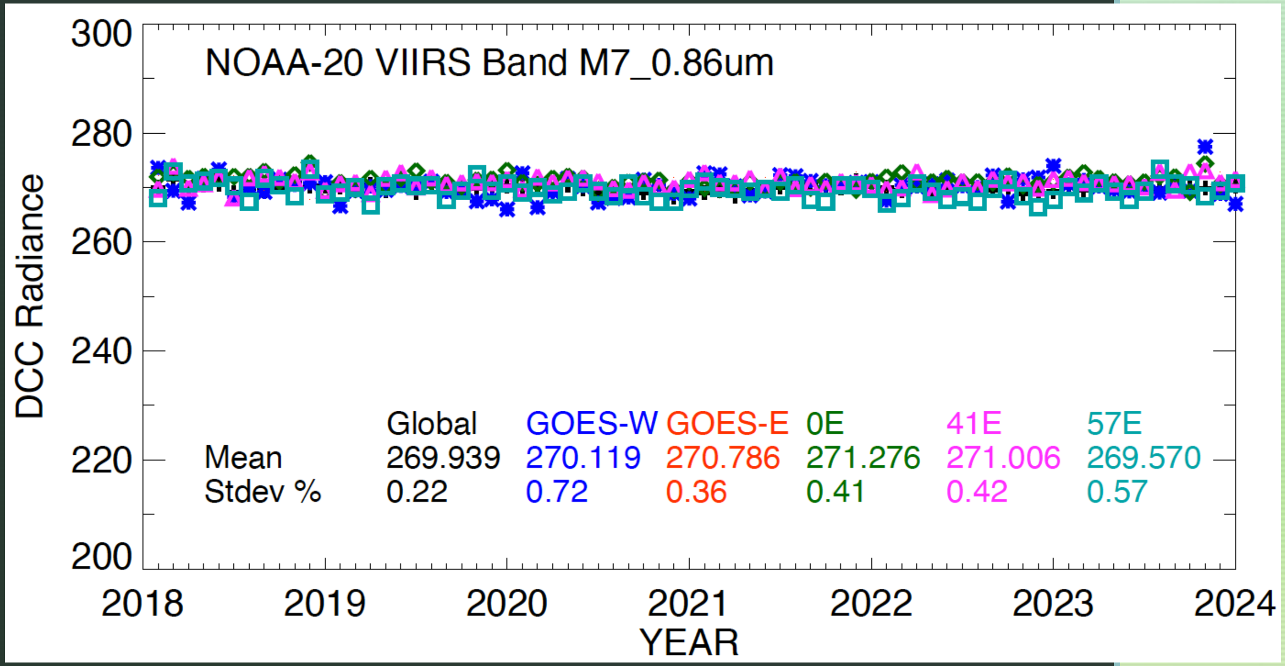


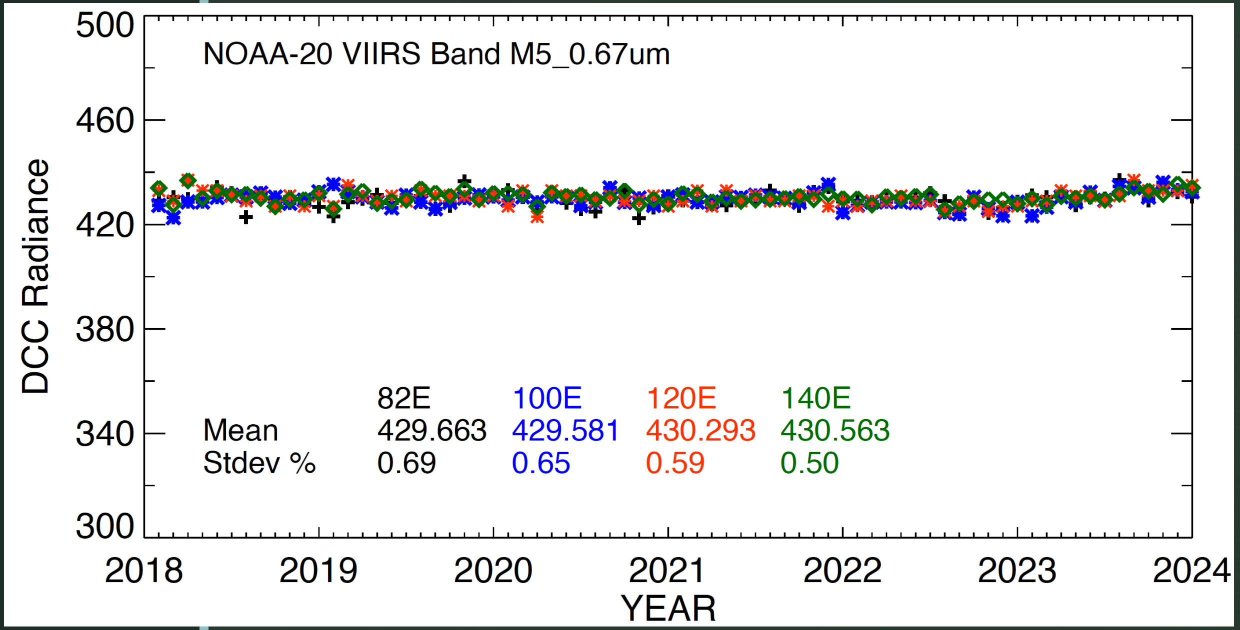


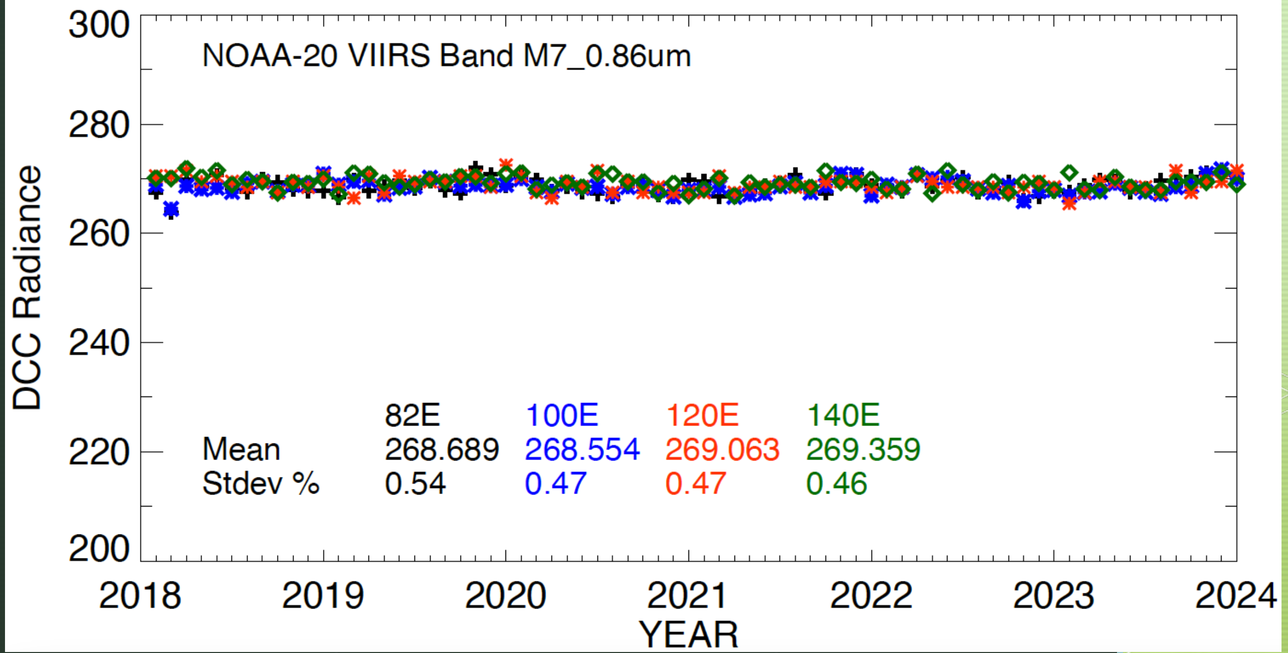





NOAA-20 VIIRS Band M5_0.67um
DCC Radiance
YEAR
Global GOES-W GOES-E 0E 41E 57E
Mean 431.564 432.725 432.563 433.599 432.457 430.756
Stdev % 0.33 0.66 0.45 0.49 0.60 0.71


NOAA-20 VIIRS Band M7_0.86um
DCC Radiance
YEAR
Global GOES-W GOES-E 0E 41E 57E
Mean 269.939 270.119 270.786 271.276 271.006 269.570
Stdev % 0.22 0.72 0.36 0.41 0.42 0.57


NOAA-20 VIIRS Band M5_0.67um
DCC Radiance
YEAR
82E 100E 120E 140E
Mean 429.663 429.581 430.293 430.563
Stdev % 0.69 0.65 0.59 0.50


NOAA-20 VIIRS Band M7_0.86um
DCC Radiance
YEAR
82E 100E 120E 140E
Mean 268.689 268.554 269.063 269.359
Stdev % 0.54 0.47 0.47 0.46

Reference DCC Mode Radiances ($L_{VIIRS,Mode}$) and associated 1-sigma natural variability for GEO domains

NOAA-20 VIIRS based reference DCC radiance for GEO domains (based on 6 years of observation)										
Band	Global	GOES-W	GOES-E	0E	41E	57E	82E	100E	120E	140E
M3_0.48um	573.3351	574.9233	574.6403	576.2651	574.2777	572.2185	570.7969	570.3353	571.1668	571.4476
M4_0.55um	506.5673	508.0633	507.6811	509.2591	507.7496	505.5262	504.0547	503.5453	505.0821	505.5847
M5_0.67um	431.5638	432.725	432.5629	433.5989	432.4566	430.7561	429.6634	429.581	430.2929	430.5628
M7_0.86um	269.9388	270.1186	270.786	271.2761	271.0064	269.5704	268.6892	268.5538	269.0626	269.359
I1_0.65um	440.8696	442.01	442.1128	442.8726	442.1656	440.0756	438.8965	438.5818	439.7704	439.6406

1-sigma uncertainty based on temporal standard deviation										
Band	Global	GOES-W	GOES-E	0E	41E	57E	82E	100E	120E	140E
M3_0.48um	0.3637	0.7558	0.5785	0.5831	0.5929	0.794	0.7836	0.6073	0.6275	0.5741
M4_0.55um	0.4176	0.8564	0.5478	0.58	0.6677	0.9278	0.8236	0.8099	0.6038	0.6054
M5_0.67um	0.3279	0.6629	0.4508	0.4931	0.5984	0.7141	0.6869	0.652	0.5897	0.4961
M7_0.86um	0.2249	0.7181	0.3585	0.4066	0.4163	0.5678	0.5403	0.4653	0.4671	0.4566
I1_0.65um	0.4518	0.7954	0.5226	0.5667	0.6159	0.8342	0.7639	0.6653	0.5689	0.5736

- *Units of these mode radiances are* ***$Wm^{-2}\mu m^{-1}sr^{-1}$***

$$L_{GEO,Mode,reference} = SBAF \times L_{VIIRS,Mode} \ (Wm^{-2}\mu m^{-1}sr^{-1})$$

Future work

DCC reference data in a netCDF file

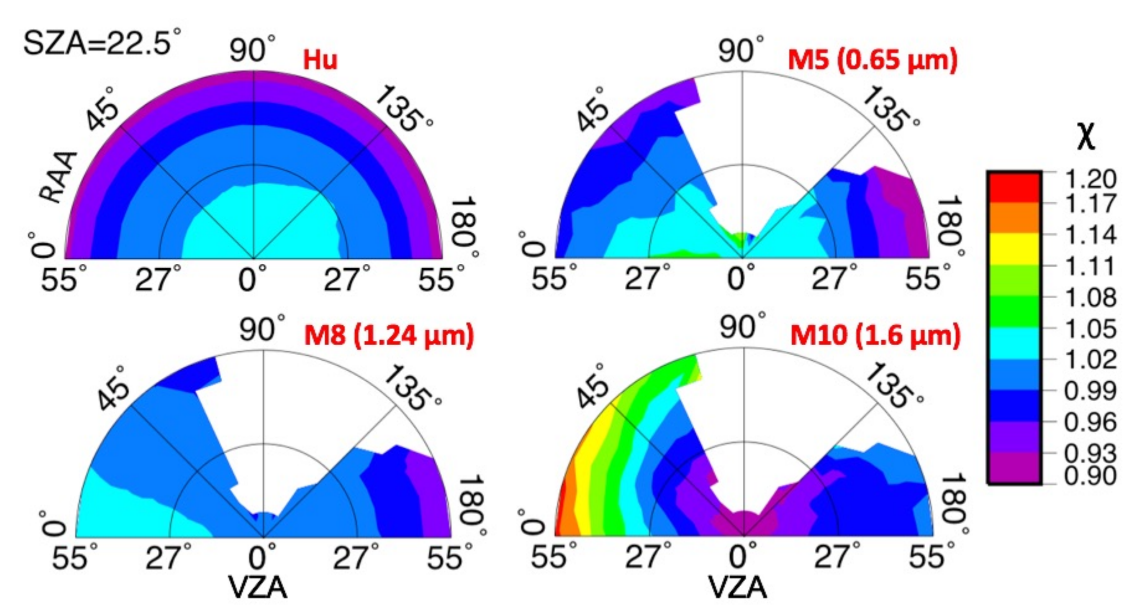
DCC ATBD completion (Fall 2024)

DCC ATBD paper for reflective solar wavelengths

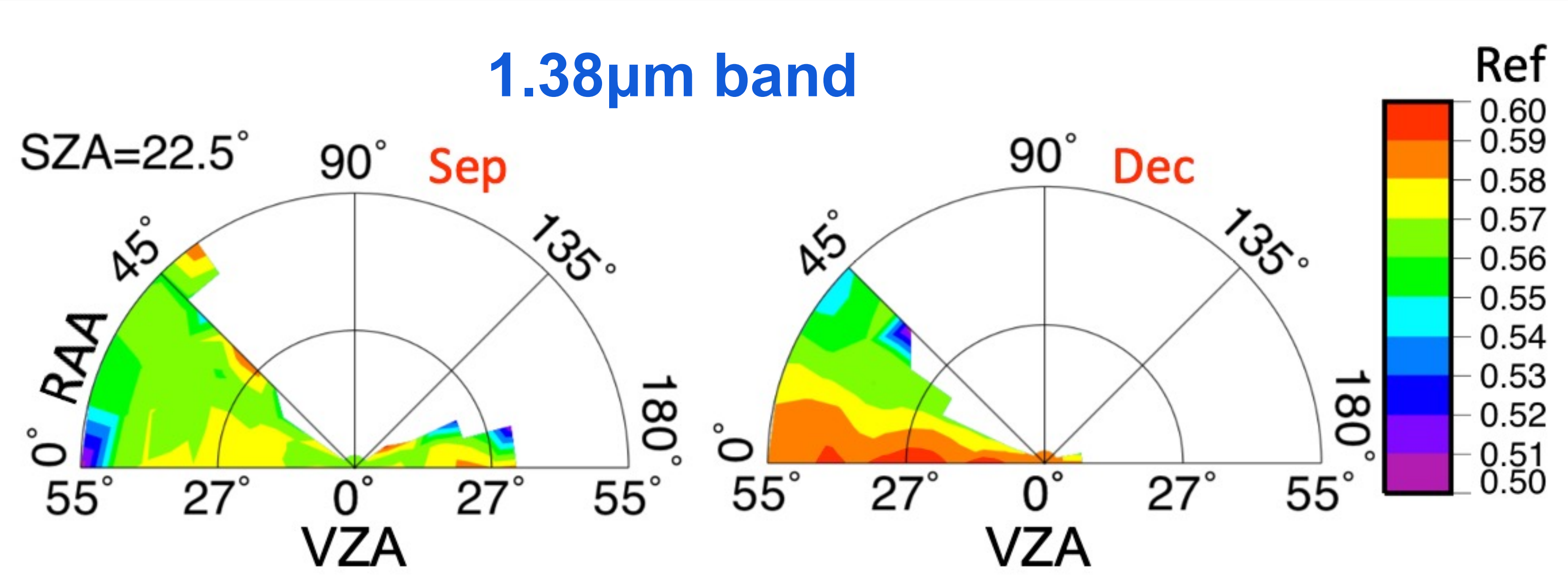
Part 1: Algorithm Formulation for VIS/NIR and Results with an example GEO

Part 2: Validation of VIS/NIR algorithm (Agency wide implementation, results, and analysis)

Need for DCC BRDFs for SWIR bands



- VIS-NIR BRDFs are similar and covered by Hu-model
- At SWIR wavelengths,
  - DCC are more absorptive
  - SNR is low
  - Greater sensitivity with BT threshold
  - BRDF is seasonal and wavelength dependent
- Proper seasonal characterization of DCC allows the extension of DCC method to calibrate SWIR channels
- Monthly DCC BRDFs are proposed for SWIR bands

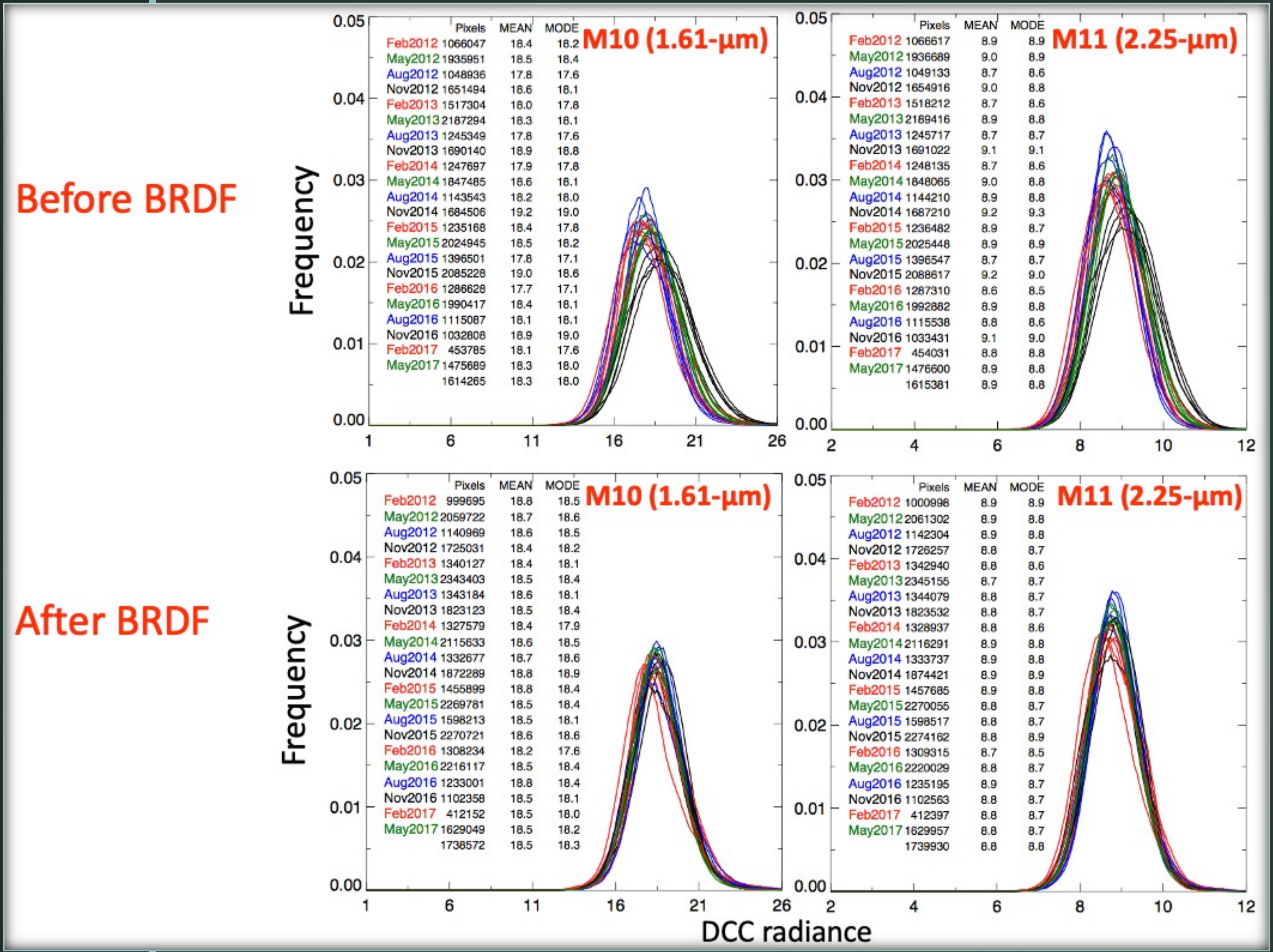


DCC BRDF formulation

- BRDFs are constructed using the SNPP-VIIRS DCC samples from 2012-2023
- Pixel-level DCC reflectance values are partitioned into angular bins
  - Angular discretization:
    - VZA and SZA range from 0-60° with a 5° step size
    - RAA varies from 0-180° at 10° intervals
- For each SZA bin, mean TOA reflectance and standard deviation values are recorded
- SWIR band BRDFs are unique and wavelength-dependent

$$BRF = \frac{BRDF(22.5, 32.5, 145.0)}{BRDF(SZA, VZA, RAA, MONTH)}$$

$$\rho_{corrected} = \rho_{observed} * BRF$$

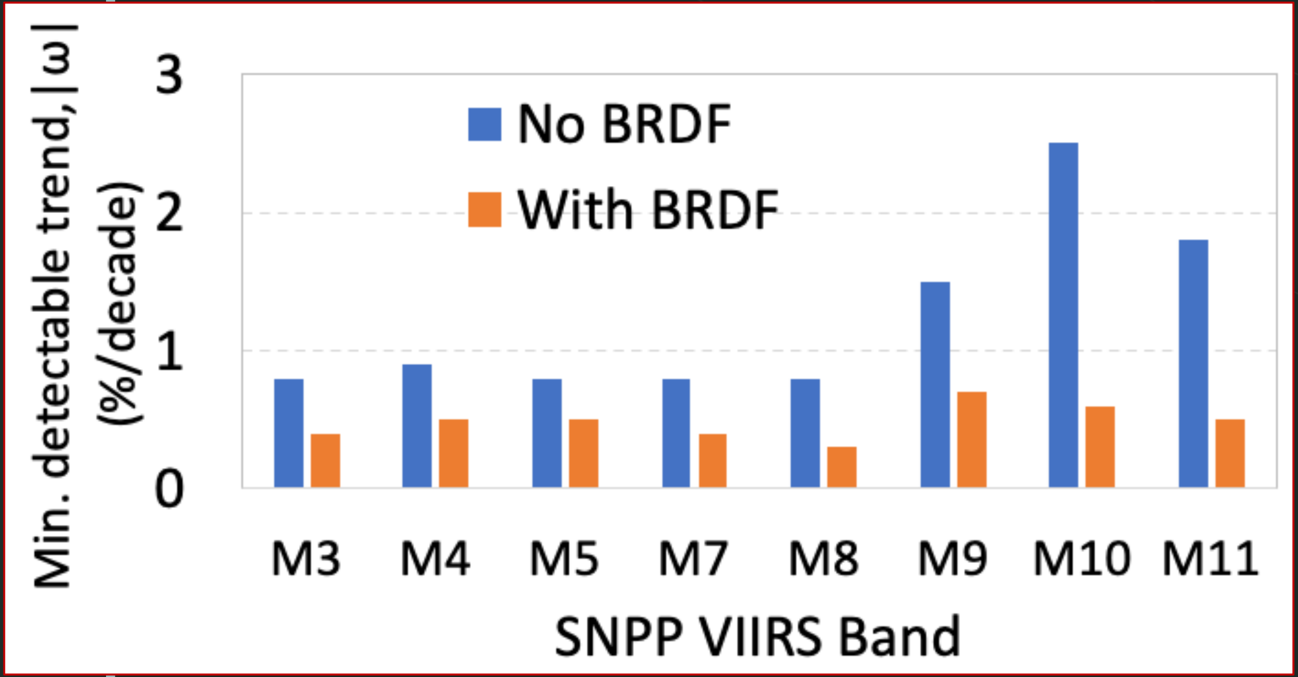


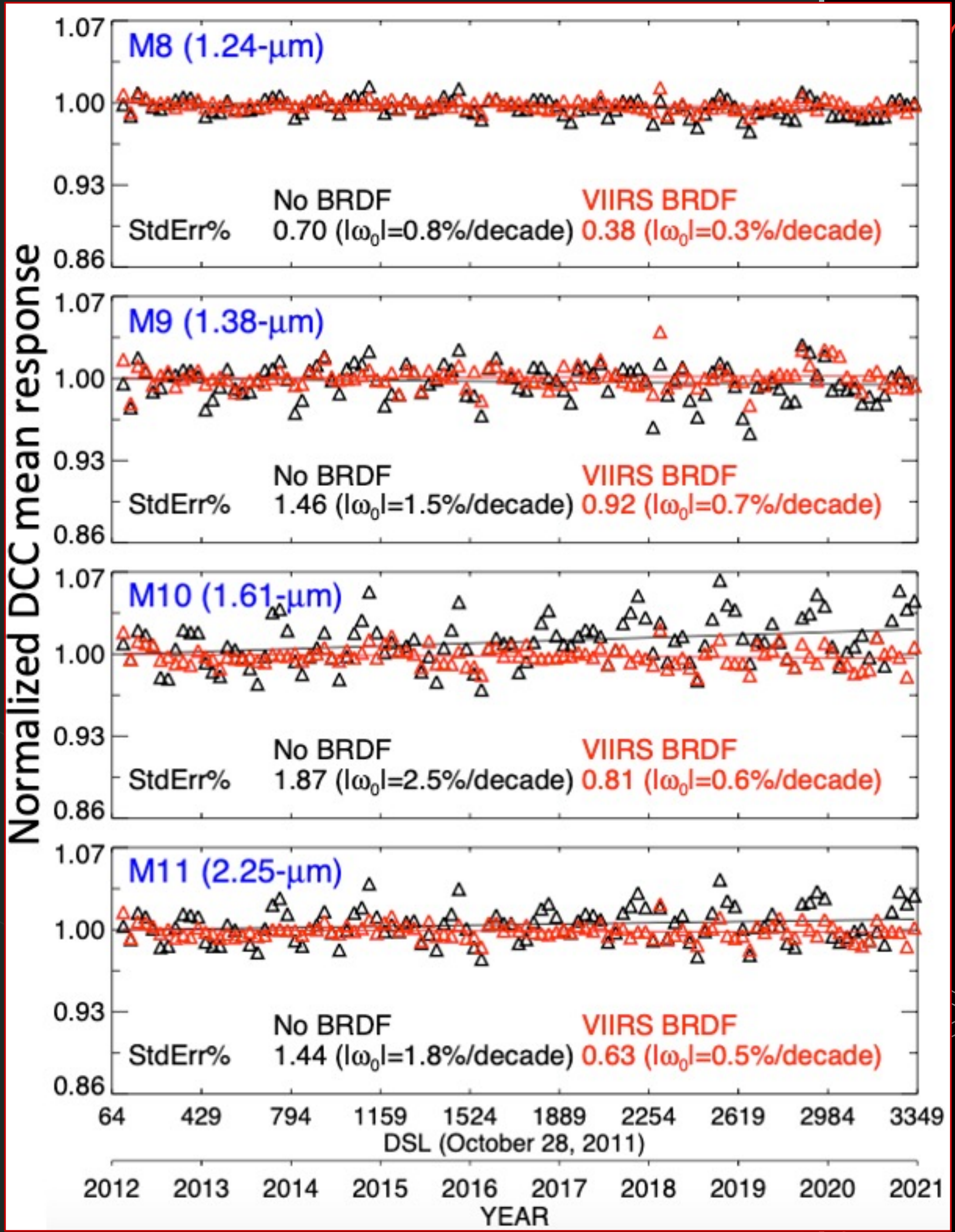
Before and After BRDF Normalization

- *After BRDF normalization, the monthly PDFs exhibit consistent shapes, signifying seasonal variance is mitigated in the SWIR bands DCC response*

Effectiveness of DCC BRDFs

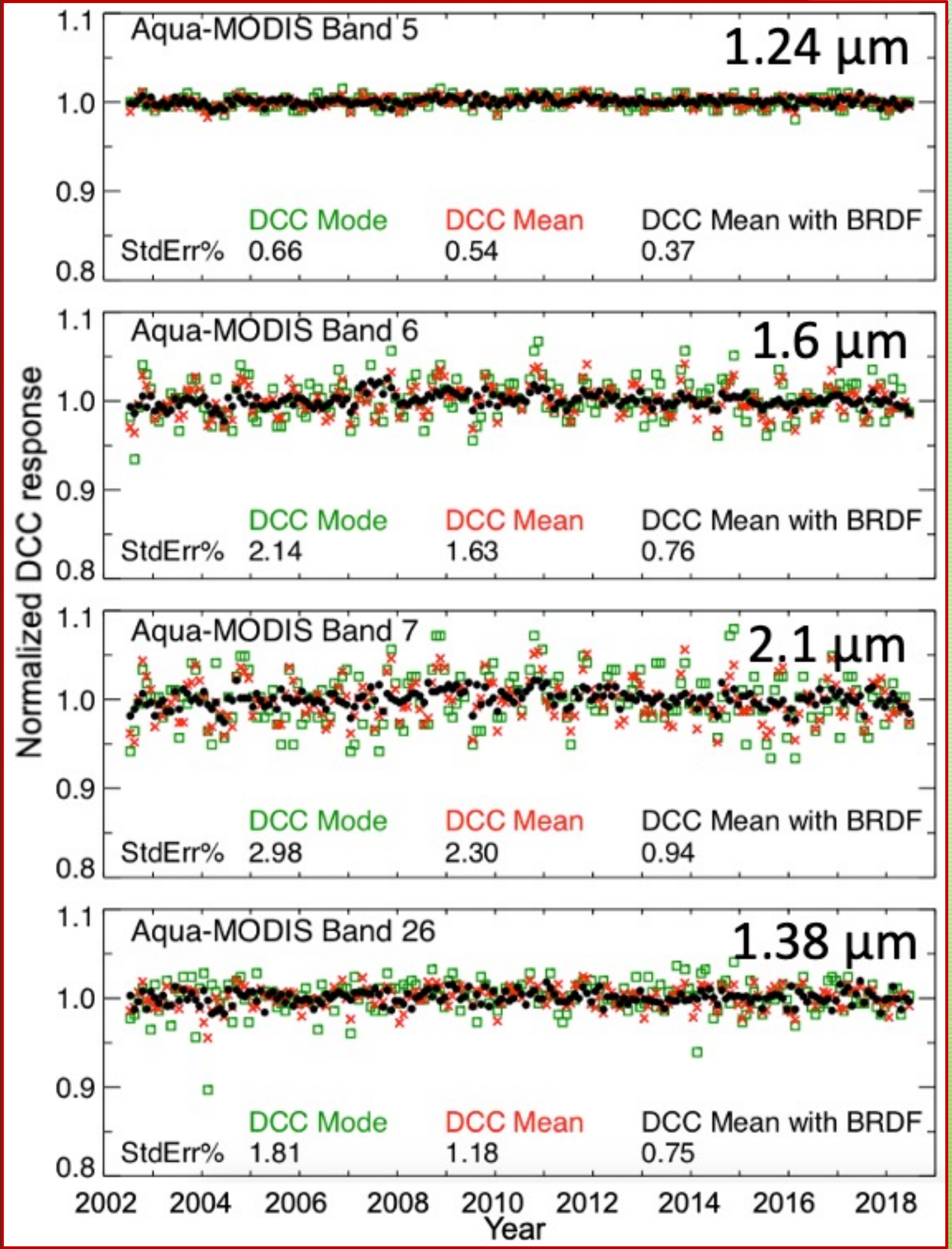
- Improved BRDF models reduce the SWIR band DCC temporal variability by up to 65%
- Monthly mean DCC response is more stable than mode for SWIR bands
- DCC method can detect a sensor trend of <1%/decade in all reflective solar bands of VIIRS instrument at a significance level of α=0.05



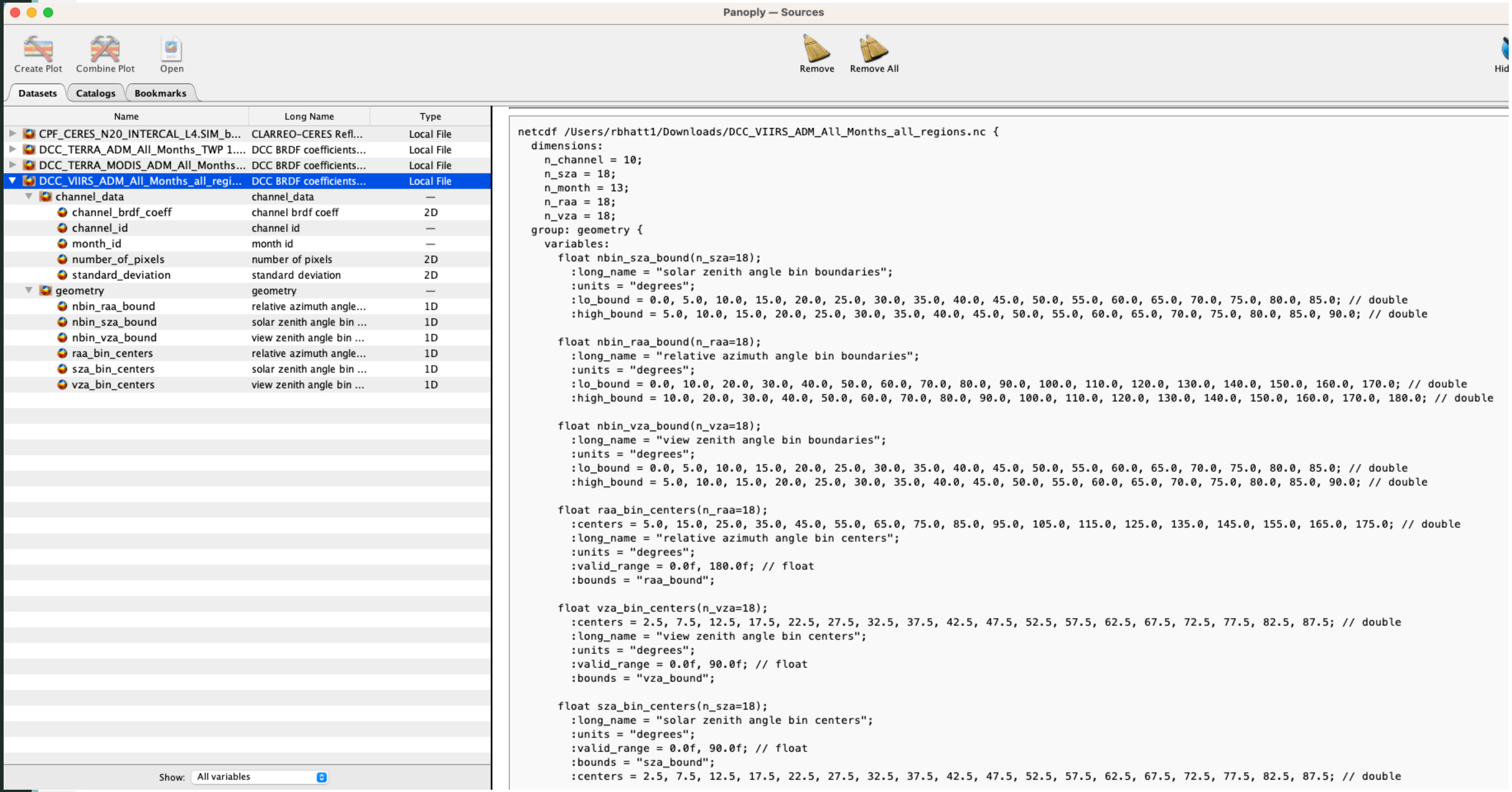


Effectiveness of improved DCC BRDFs (contd.)

- SNPP VIIRS-based BRDF models are applicable to Aqua-MODIS bands too
- MODIS band 7 (2.1 µm) is spectrally different than its counterpart band (M11) in VIIRS
  - MODIS band 7 DCC BRDF is derived using a similar method (described earlier) but utilizing MODIS data



DCC SWIR band BRDF data



Future Direction

- The CERES IGCG is presently focused on preparing a SWIR band BRDF netCDF file for MODIS and VIIRS. This file will be released to the GSICS community for evaluation.
- Publish SWIR band DCC intercalibration methodology and validation

Questions, comments, discussion?