Deep convective cloud calibration sensitivity studies in support of radiometrically scaling GEO imagers with VIIRS

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Motivation

- PDF statistics for DCC-IT are used to monitor instrument stability and transfer calibration between sensors
  - Mode, mean, median, and inflection point

- In order to test which DCC-IT PDF statistic is most suited to radiometrically scale HIM8 AHI B3 to NPP-VIIRS I01, HIM8 radiances are inter-calibrated with VIIRS via DCC ray-matching
  - DCC ray-matched VIIRS and HIM8 30-km radiance pairs are linearly regressed to compute the gain from observed HIM8 counts
  - Optimal DCC-IT PDF statistic is the one that most closely matches the relative ratio between the VIIRS and HIM8 radiances

- DCC identification criteria sensitivity studies are performed to determine the optimal PDF statistics
  - Brightness Temperature (BT)
  - Spatial homogeneity

Data

- NPP-VIIRS
  - NASA L1B Collection 2 subset retrieved from Atmospheric Science Data Center Distributed Active Archive Center (ASDC DAAC)
  - 6-minute granules
  - Band I01 (0.64μm), natively at 375-m, averaged and subsampled to 1.5-km
  - Bands M03, M04, M05, and M07, natively at 750-m, subsampled to 1.5-km
    - Band M15 used for 10.763μm DCC IR brightness temperature (BT) criteria (also subsampled to 1.5-km)

- Himawari-8 AHI
  - Retrieved from the Man computer Interactive Data Access System (McIDAS) from the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison
  - 10-minute imagery
  - Band 3 (0.64μm), natively at 0.5-km subsampled to 2-km
  - Bands 1, 2, and 4 subsampled to 2-km
    - Band 14 (11.2μm) used for DCC IR BT criteria, natively at 2-km

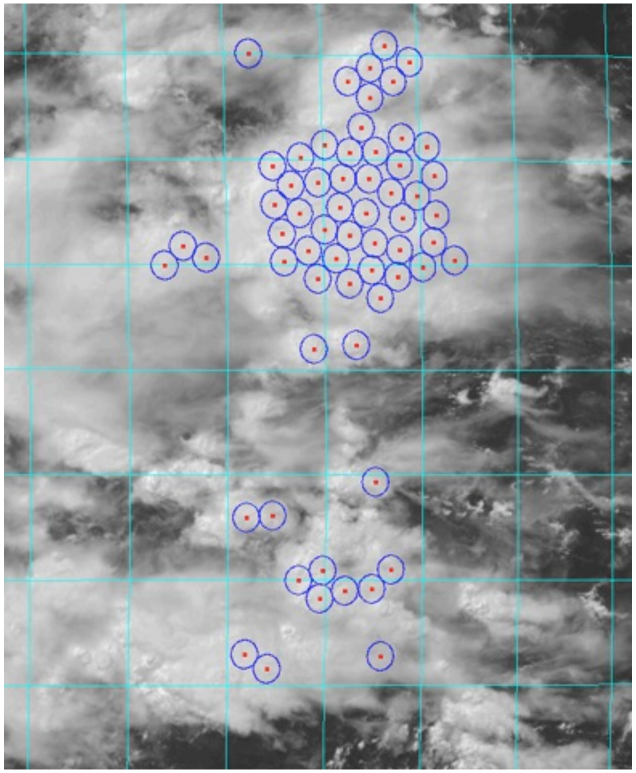
DCC Ray-matching

• Follows the DCC Ray-matching approach of:

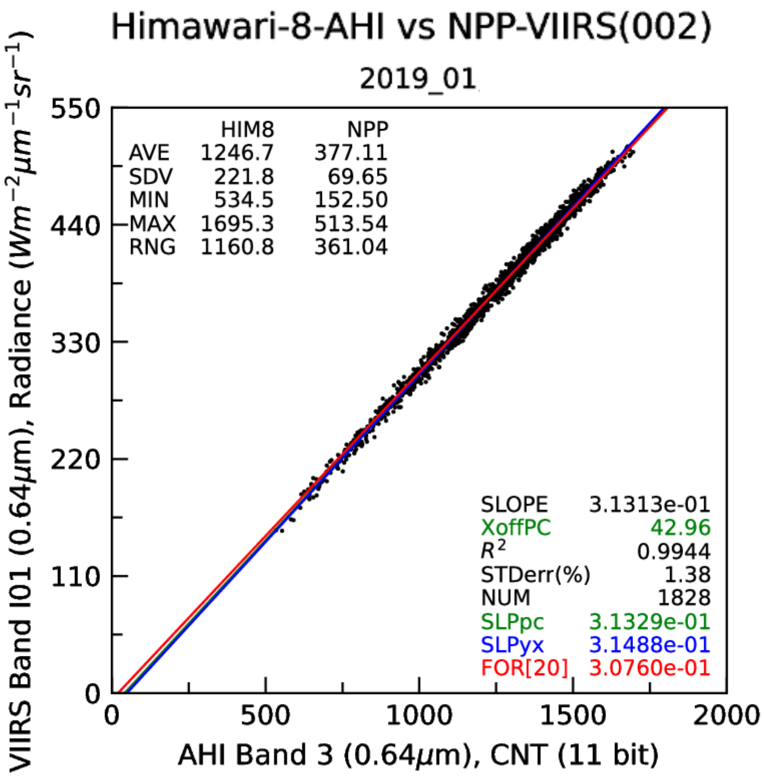
Doelling, D. R., C. O. Haney, B. R. Scarino, A. Gopalan, and R. Bhatt, 2016: Improvements to the Geostationary Visible Imager Ray-Matching Calibration Algorithm for CERES Edition 4. J. Atmos. Oceanic Technol., 33, 2679-2698, https://doi.org/10.1175/JTECH-D-16-0113.1.

- VIIRS data and HIM8 AHI data are aggregated to ~30km
- DCC ray-matching criteria are listed in the table to the right

Parameter	Ray-matching Criteria
VZA	<40°
SZA	<40°
RAA	10°<RAA<170°
BT (11μm)	<220K
VIS_{hom}	<0.2
IR_{hom}	<7.5K
ΔGMT	<5 minutes
ΔVZA	<15°
ΔSZA	<5°
ΔRAZ	<15°
ΔSCAT	<15°
Footprint	30-km
latitude	-20°<lat<20°
longitude	100°<lon<180°



Gain Calculation



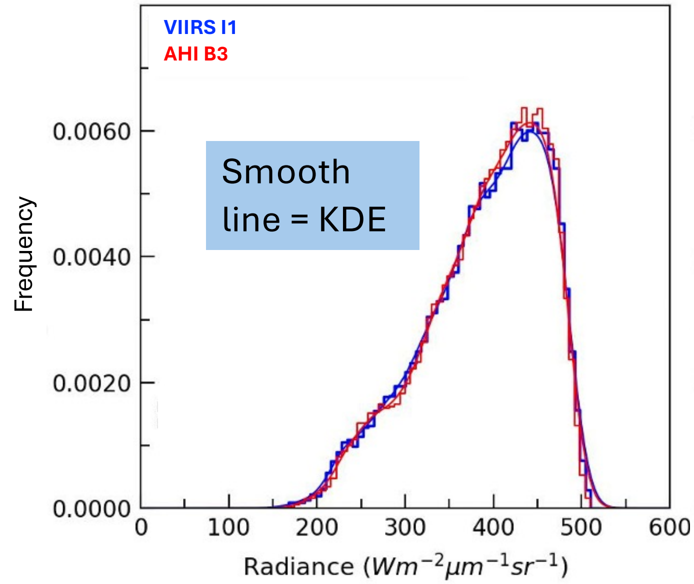
The gain calculated here can be used to convert a HIM8 count into a radiance, using the regression forced through the published visible space count of 20

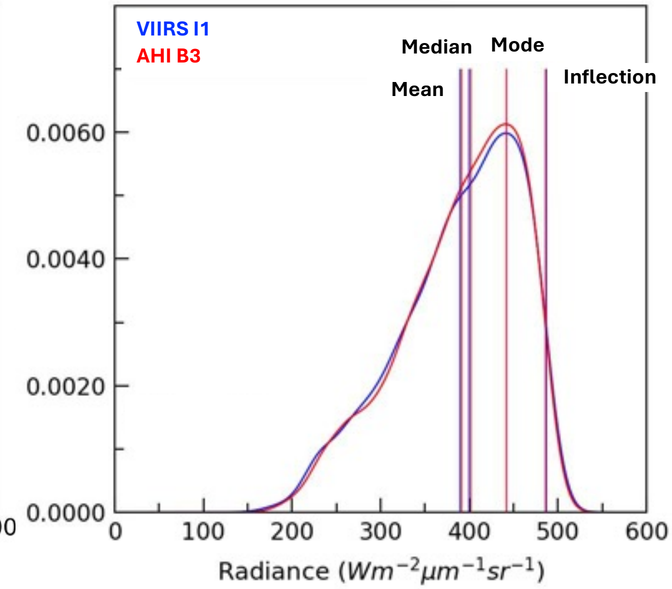
$$Rad_{VIIRS} \bullet SBAF_{VIIRS\text{->}GEO} = (Cnt_{HIM8} - Cnt_{offset}) \bullet gain \bullet [\cos(SZA_{VIIRS})/\cos(SZA_{HIM8})]$$

Apply the gain as follows to the HIM8 count to obtain radiance: $\mathrm{Rad_{HIM8}} = \mathrm{gain} \times (\mathrm{Cnt_{HIM8}} - \mathrm{Cnt_{offset}})$

Kernel Density Estimation(KDE) & PDF Statistics

To overcome the bin discretization, this study utilizes a kernel density estimation (KDE) from the gaussian_kde function from SciPy





- **Mean** = average of the pixel radiances
- **Median** = radiance where half of the pixels are a lesser radiance and half of the pixels are higher radiance
- **Mode** = radiance with the greatest frequency
- **Inflection point** = radiance where the curvature sign changes (only after the mode and before 10%*max frequency)

We can test how well all the dataset statistics compare by seeing what the relative calibration ratio for each statistic is between VIIRS and HIM8

Datasets Used for Comparison

Three datasets are used for this study:

- Ray-matched 30-km DCC cells
- 1-km data contained within the 30-km DCC cell
- Time-matched DCC-IT 1-km data is using the operational DCC-IT method, but only using the VIIRS granules and HIM8 images where a ray-matched 30-km footprint exists and has met the DCC ray-matching criteria

Parameter	Ray-matched 30-km Dataset	Ray-matched 1-km	Image-matched DCC-IT Dataset
VZA	<40°		<40°
SZA	<40°		<40°
RAA	10°<RAA<170°		10°<RAA<170°
BT (11µm)	<205K		<205K
VIS_{hom}	<0.2		<0.03
IR_{hom}	<7.5K		<1K
ΔGMT	<5 minutes	*Valid if 1-kmpixel is within 30-km dataset	<5 minutes
ΔVZA	<15°		
ΔSZA	<5°		
ΔRAZ	<15°		
ΔSCAT	<15°		
Footprint	30-km		1-km
latitude	-20°<lat<20°		±20°
longitude	100°<lon<180°		100°<lon<180°

Comparison of PDF Statistics across datasets

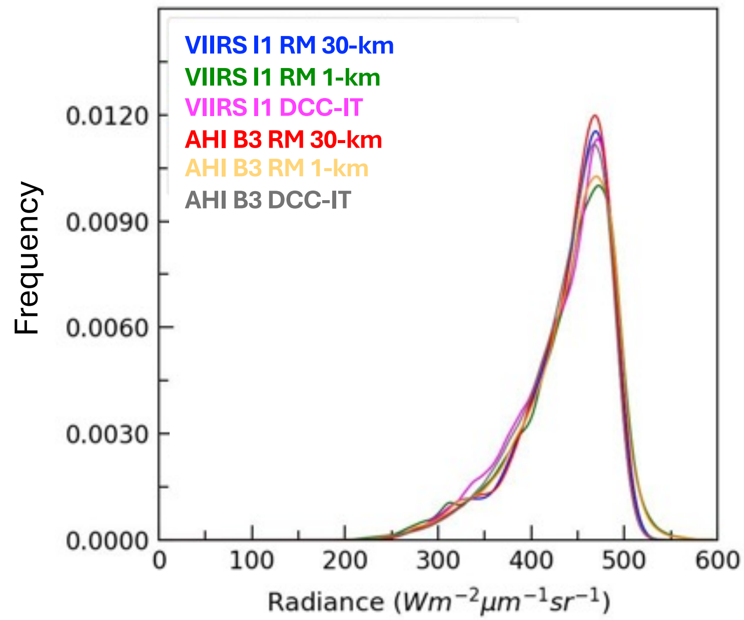
- $\Delta RAD_{normalized} = [(Rad_{HIM8} - Rad_{VIIRS}) / Rad_{VIIRS}]*100\%$
  where Rad_{HIM8} and RAD_{VIIRS} is from the same dataset and PDF statistic

- Ray-matched 30-km PDF statistics are all within 0.25%, as would be expected

- 1-km ray-matched PDF statistics are all within 0.2% except for KDE mode

- However for operational 1-km only the median and inflection points are within 0.2%

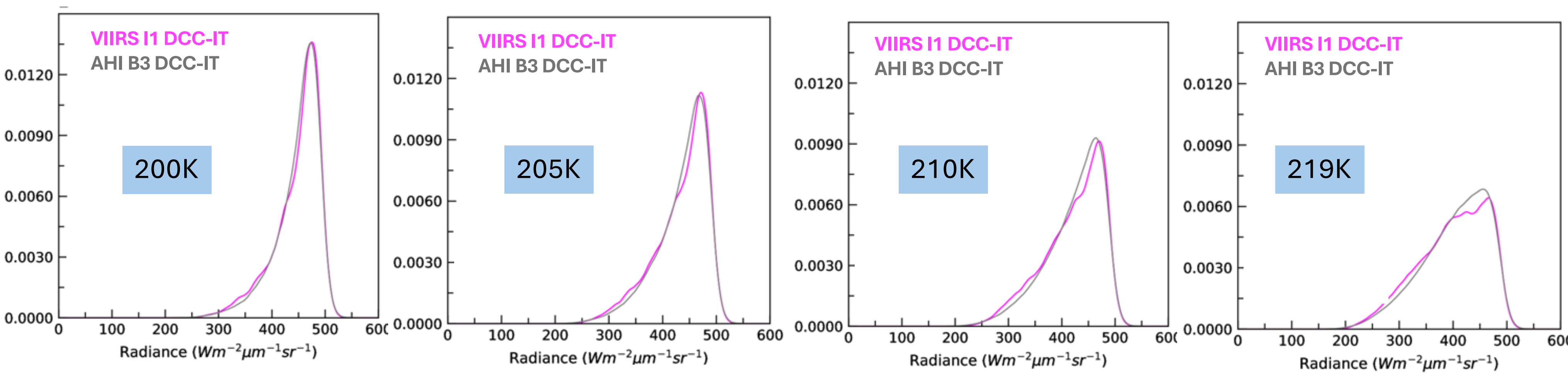
- Overall the median and inflection appear to be the most robust PDF statistics for inter-calibrating HIM8 and VIIRS



NUM	MIN	MAX	MEDIAN	MEAN	MODE	KDEMODE	INFLPT
431	248.87	496.91	452.714	438.652	471.000	469.162	492.946
190071	158.20	665.39	451.168	438.670	471.000	472.135	495.324
587739	212.10	553.88	446.869	433.991	471.000	471.541	490.568
431	262.45	496.76	452.152	439.383	471.000	468.568	491.757
96975	170.06	650.48	451.251	439.397	471.000	469.757	495.919
3081726	183.29	675.57	447.600	436.109	465.000	467.378	490.568

Dataset ΔHIM8-VIIRS (%)	Median	Mean	Mode PDF	Mode KDE	Inflect point
Ray-matched-30km	**-0.12**	**+0.17**	**0.00**	**-0.13**	**-0.22**
Ray-matched-1km	**+0.02**	**+0.17**	**0.00**	-0.50	**+0.12**
Time-matched 1km	**+0.16**	+0.49	-1.27	-0.88	**+0.00**

Comparison of PDF Statistics with BT thresholds, 0.65µm



BT	Median%	Mean%	Mode%	Inflct %
200	**-0.12**	+0.31	-0.50	+0.48
205	**+0.16**	+0.49	-0.88	**+0.00**
210	+0.73	+0.80	-1.27	**-0.12**
219	+1.44	+1.15	-2.04	**-0.12**

Comparison of PDF Statistics with BT thresholds

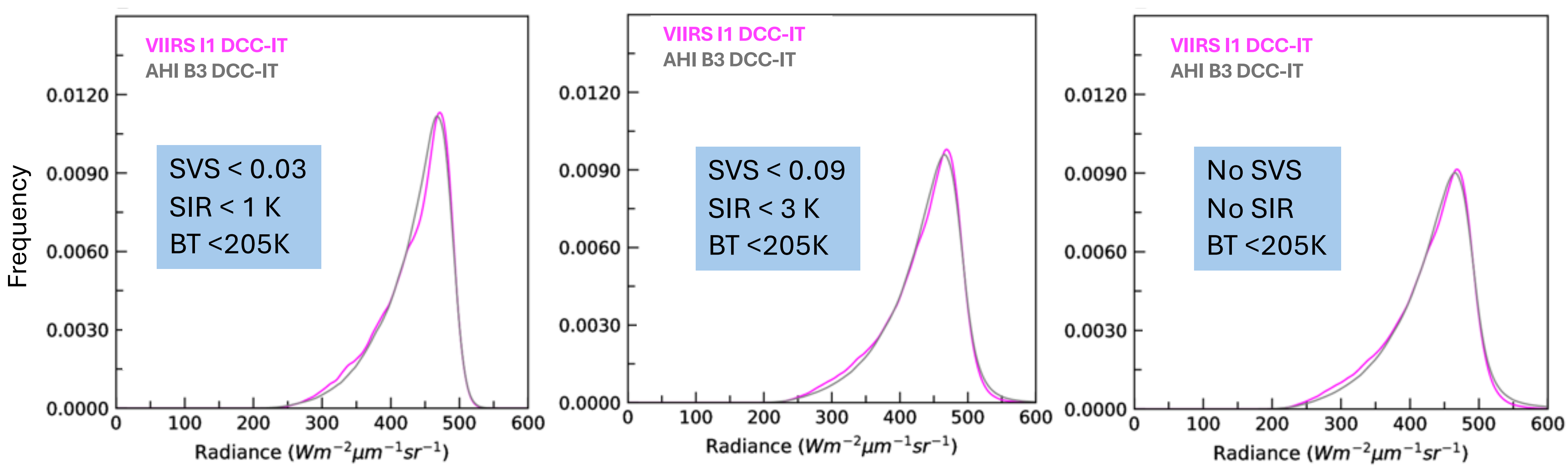
BT=200K	Median%	Mean%	Mode%	Inflct%
M3	+0.39	+0.78	**+0.00**	**+0.12**
M4	**+0.04**	+0.46	-0.55	**-0.13**
I01	**-0.12**	+0.31	-0.50	+0.48
M5	**-0.05**	+0.46	-0.49	+0.71
M7	**+0.17**	+0.68	+0.27	-0.40

BT=210K	Median%	Mean%	Mode%	Inflct%
M3	+1.52	+1.44	-0.76	**-0.12**
M4	+1.07	+1.07	-1.11	**+0.13**
I01	+0.73	+0.80	-1.27	**-0.12**
M5	+0.72	+0.87	-1.12	**+0.12**
M7	+1.10	+1.23	-0.41	+0.40

BT=205K	Median%	Mean%	Mode%	Inflct%
M3	+0.39	+0.78	**+0.00**	**+0.12**
M4	+0.44	+0.70	-0.42	**+0.13**
I01	**+0.16**	+0.49	-0.88	**+0.00**
M5	**+0.22**	+0.60	-0.87	**+0.12**
M7	+0.48	+0.89	**-0.14**	**+0.13**

BT=219K	Median%	Mean%	Mode%	Inflct%
M3	+2.35	+1.93	-1.40	-0.36
M4	+1.86	+1.53	-1.96	-0.80
I01	+1.44	+1.15	-2.04	**-0.12**
M5	+1.35	+1.16	-2.26	**+0.00**
M7	+1.90	+1.60	-0.83	+0.40

Comparison of PDF Statistics with homogeneity, 0.65µm



SVS	SIR	Median%	Mean%	Mode%	Inflct%
0.03	1	**+0.16**	+0.49	-0.88	**+0.00**
0.09	3	+0.30	+0.86	-0.63	**-0.24**
None	None	+0.69	+1.47	-0.64	**-0.12**

Comparison of PDF Statistics with homogeneity

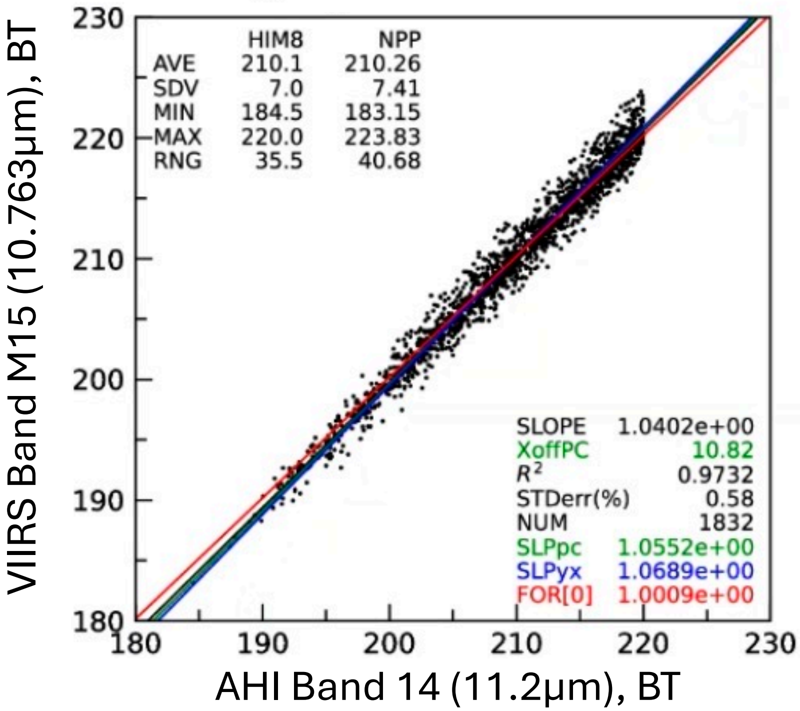
SIR=1K SVS=0.03	Median%	Mean%	Mode%	Inflct%
M3	+0.84	+1.05	**-0.25**	**+0.00**
M4	+0.44	+0.70	-0.42	**+0.13**
I01	**+0.16**	+0.49	-0.88	**+0.00**
M5	**+0.22**	+0.60	-0.87	**+0.12**
M7	+0.48	+0.89	**-0.14**	**+0.13**

SIR=No SVS=No	Median%	Mean%	Mode%	Inflct%
M3	+1.39	+2.23	**-0.13**	**+0.12**
M4	+0.95	+1.83	-0.70	**+0.13**
I01	+0.69	+1.47	-0.64	**-0.12**
M5	+0.74	+1.66	-0.50	**+0.12**
M7	+1.08	+2.09	**-0.14**	+0.40

SIR=3K SVS=0.09	Median%	Mean%	Mode%	Inflct%
M3	+0.98	+1.54	**-0.13**	**+0.12**
M4	+0.55	+1.17	-0.56	+0.27
I01	+0.30	+0.86	-0.63	**-0.24**
M5	+0.36	+1.03	-0.62	**+0.12**
M7	+0.83	+1.41	-0.28	**+0.13**

HIM8 and VIIRS BT Difference

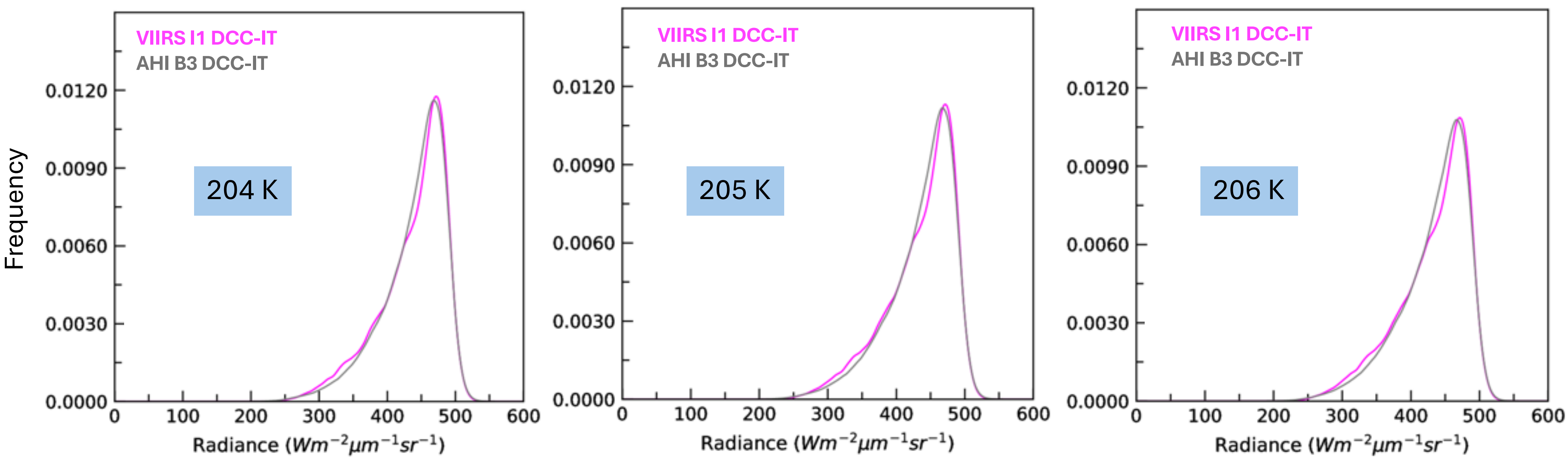
- HIM8 BT may need to be adjusted to make sure it is equivalent to VIIRS



VIIRS BT	BT Fit	HIM8 BT
205K	PC	205.10K
	Force	204.82K

standard error of the fit = 0.58% = ~1 K

Comparison of PDF Statistics ΔBT, 0.65µm



HIM8 BT	Median%	Mean%	Mode%	Inflct%
204	**+0.10**	+0.48	-0.63	**-0.12**
205	**+0.16**	+0.49	-0.88	**+0.00**
206	**+0.24**	+0.52	-0.88	**+0.00**

Summary and Future Work

- PDF statistical comparisons were made between Himawari-8 AHI and NPP-VIIRS for three datasets:
    - DCC ray-matched 30-km cells
    - 1-km pixels within the DCC ray-matched 30-km cells
    - Image-matched DCC-IT 1-km cells in images that contained AHI/VIIRS 30-km footprints

- The median and inflection point PDF statistics appear to be the most robust statistics for inter-calibrating using DCC in the VIS

- For 11µm BT threshold sensitivity testing for 0.65µm, the median provided calibration ratios within 0.21% for BT ≤ 205K, while the inflection point provided calibration ratios within 0.12% for BT ≥ 205K
    - Across all channels, median worked well for 200K, while inflection point worked well for 205 K and 210 K

- For the homogeneity factor sensitivity testing, the median provided calibration ratios within 0.22% for strict factors, while the inflection point gave calibration ratios within 0.25% for all homogeneity factors
    - Across all channels, inflection point performed best in nearly all cases

- Future work involves performing this analysis for other channel-pairs for AHI and VIIRS in the SWIR