GEO-LEO thermal emissive bands comparison method with applications to SNPP vs N20 VIIRS and GOES-16 vs GOES-17 ABI

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SNPP and N20 VIIRS thermal emissive bands calibration comparison using the GEO-LEO double difference method

- Introduction
- Methodology and data processing
  - ABI and VIIRS spectral bands
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  - Data processing
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  - ABI and VIIRS comparison
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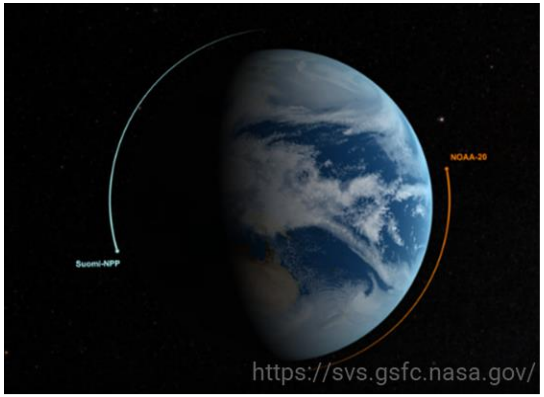
- Application to GOES16-GOES-17 ABI comparison
- Summary

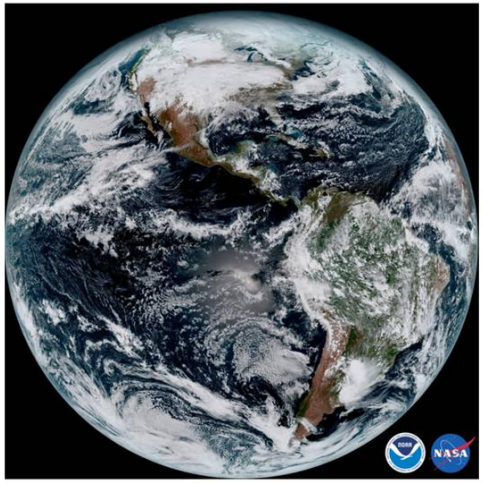
Background

SNPP: Launched on October 28, 2011, Low Earth orbit (LEO)
N20: Launched on November 18 2017 and in the same orbit as SNPP.



VIIRS:
--14 reflective bands covering 0.4-2.2 µm and 7 thermal emissive bands (TEB) covering 3.7-12 µm.
--The spatial resolution at nadir is 750m for the 16 moderate resolution radiometric bands (M bands) and 375 m for the 5 imaging bands (I bands).

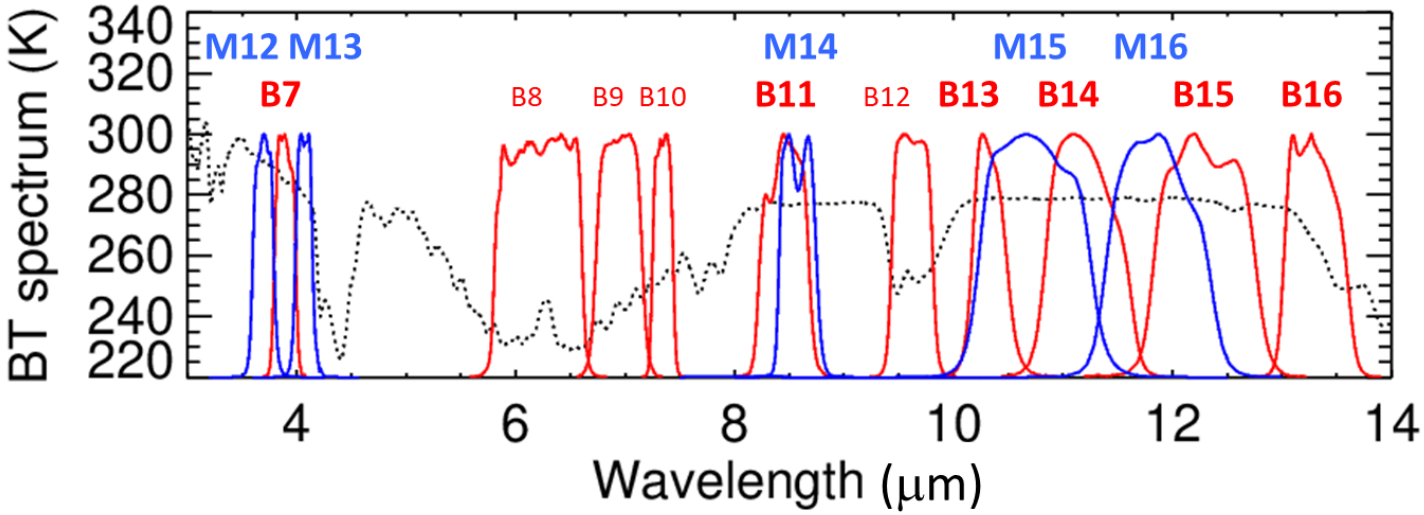
GOES16: Launched on November 19, 2016; reached the GOES East position (longitude of 75.2° West) by December 11, 2017; declared fully operational on December 18, 2017.
GOES17: Launched on March 1, 2018; became operational as GOES-West (longitude of 137.2° West) on February 12, 2019 .



ABI:
--16 spectral bands at the visible, near-infrared (IR), and IR wavelengths.
-- Bands 7 to 16 are infrared channels covering the 3.9 to 13.3 µm range.
-- The spatial resolutions are 2 km in their full-disk image products.
-- ABI produces full-disk Earth images every 10 minutes

ABI and VIIRS spectral bands

The MODTRAN-modeled BT spectrum for a typical ocean site (black dotted line) and the SRF for GOES17 ABI thermal bands (red) and SNPP VIIRS (blue).



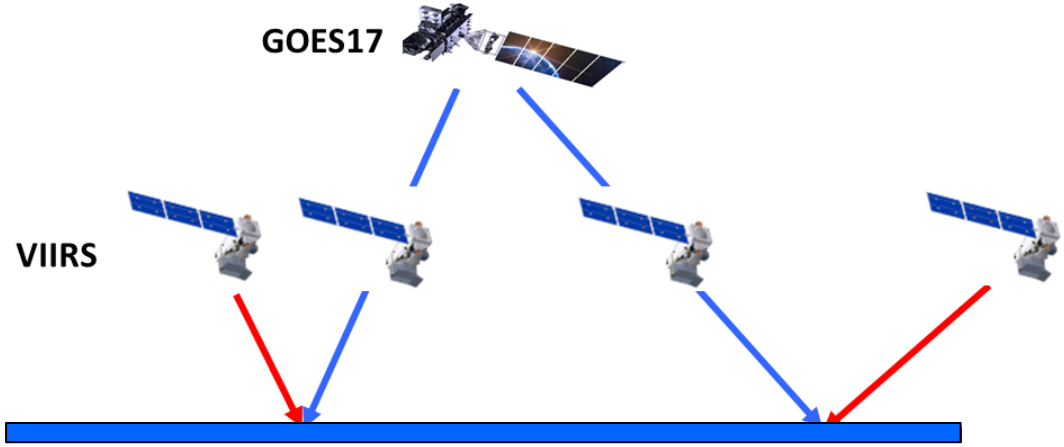
ABI/VIIRS Band	B7/M12	B7/M13	B11/M14	B13/M15	B14/M15	B14/M16	B15/M16
VIIRS center wavelength (μm)	3.70	4.05	8.55	10.76	10.76	12.01	12.01
ABI center wavelength (μm)	3.90	3.90	8.44	10.35	11.20	11.20	12.30

- The comparison in this paper includes the effect of slight spectral difference between SNPP/VIIRS and N20/VIIRS. This effect can be adjusted using MODTRAN modeling over typical scene.
- The comparison focus on VIIRS M bands, and the method can be extended to I bands

View angle matching

- For TEB, the instrument view zenith angle affects the measurements. The comparison uses the measurements with same view zenith angle up to 60º within up to 1º difference.
- The Ray-matching and quasi-ray-matching are used in the ABI-VIIRS comparison.

Illustration of the ray-matching (red rays) and quasi-ray-matching (red-blue rays) method.

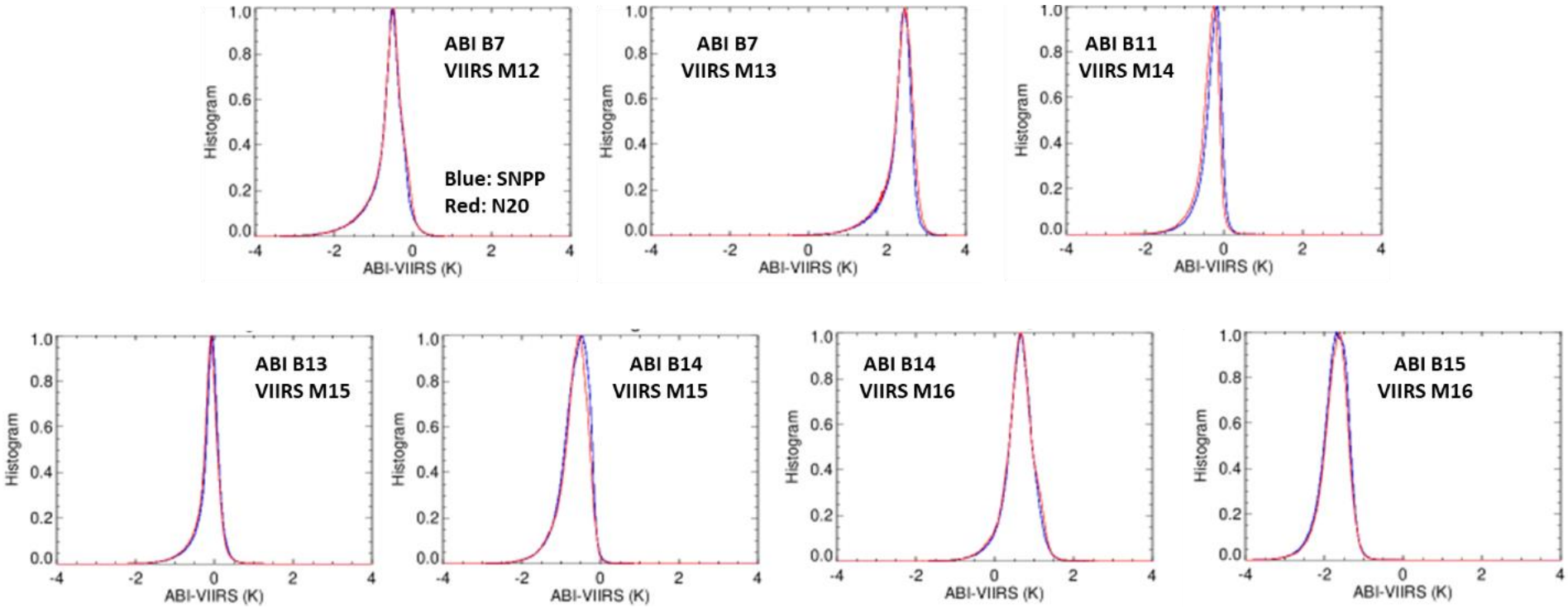


Ray-matching: same view angle and close to zero azimuth angle difference.
Quasi-ray-matching: same view angle with large azimuth angle difference.

Data processing
VIIRS-ABI-VIIRS comparison

- GOES17/ABI full disk image.
- Ocean site along equator with G17 view angle up to 60º
- The data collected for comparison start on February 2019.
- The VIIRS TEB pixels are resampled to ABI pixel. ABI-VIIRS pixel-to-pixel comparison are analyzed separately.
- For the direct comparison, an entire year (2020) comparison data are analyzed.
- For the trending all the monthly results from February 2019 to June 2022 are analyzed.
- ABI L2+ Binary Cloud Mask (BCM) product and VIIRS L2 BCM products. In this work, BCM filtered clear sky measurement data are used for both VIIRS and ABI measurements.
- To enhance the comparison accuracy for TEB, only nighttime observations are used.
- ABI full disk image is produced for every 10 minutes and the VIIRS granule with the nearest observation time is selected for the comparison. The maximum observation time difference is 5 minutes.

ABI-VIIRS comparison



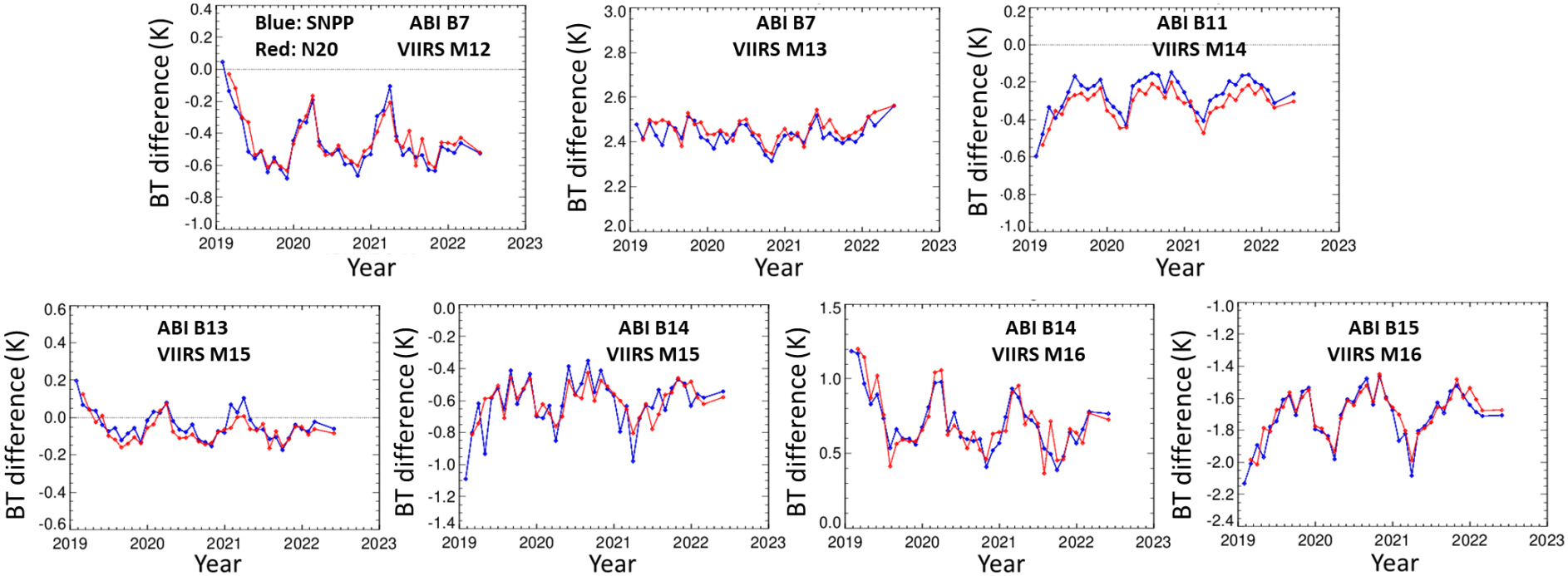
The direct pixel-to-pixel and simultaneous GOES17/ABI-VIIRS comparison results for the matching band pairs over the ocean site for the year 2020. The blue curves define the histograms for the comparison with SNPP VIIRS, while the red curves represent the histograms for the comparison with N20 VIIRS.

Double difference

The table lists the ABI-VIIRS difference for SNPP and N20 and derived the difference between SNPP/VIIRS and N20/VIIRS for selected matching bands for year 2020. The large differences between ABI-VIIRS are due to the spectral mismatching and this effect can be basically canceled using the double difference for SNPP/VIIRS and N20/VIIRS comparison.

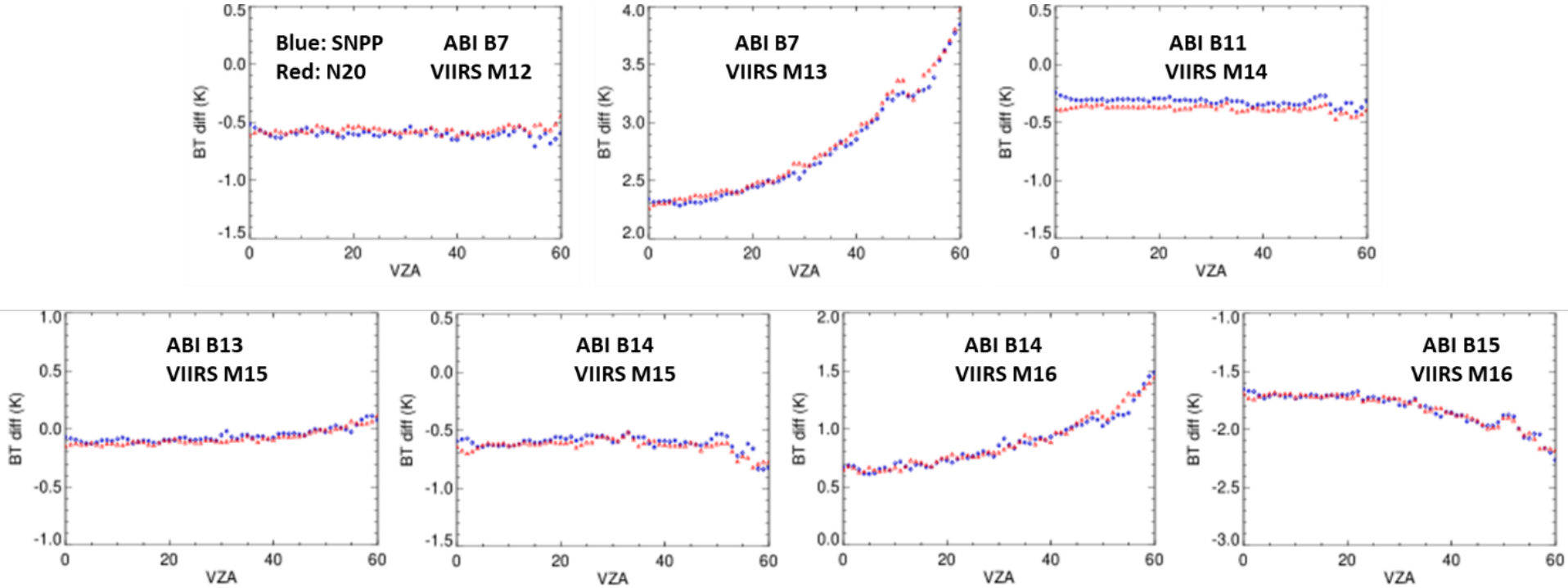
ABI/VIIRS Band	B7/M12	B7/M13	B11/M14	B13/M15	B14/M15	B14/M16	B15/M16
G17/ABI-SNPP/VIIRS (K)	-0.510	2.422	-0.234	-0.059	-0.558	0.666	-1.668
G17/ABI-N20/VIIRS (K)	-0.501	2.439	-0.301	-0.086	-0.579	0.666	-1.671
SNPP/VIIRS-N20/VIIRS (K)	-0.009	-0.017	0.067	0.027	0.021	0.000	0.003

ABI-VIIRS difference trending



The trending of direct pixel-to-pixel and simultaneous GOES17/ABI-VIIRS comparison results for the matching band pairs. Each symbol is a processed difference over one month. Blue is for GOES17/ABI-SNPP/VIIRS comparison and red is for GOES17/ABI-N20/VIIRS comparison.

View angle effect

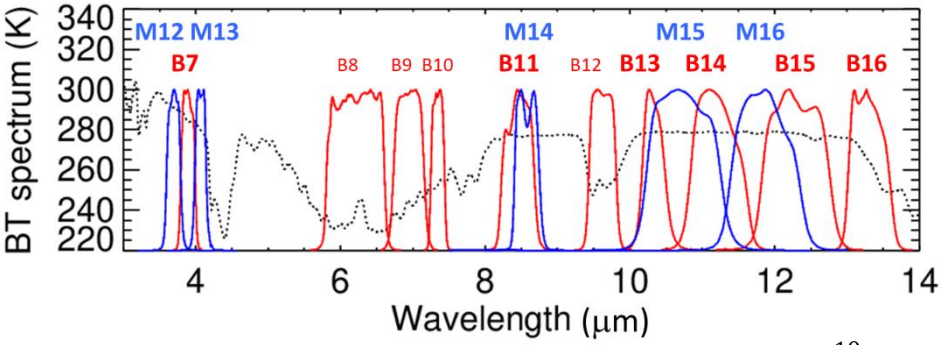


- BT difference as function of ABI and VIIRS VZA.

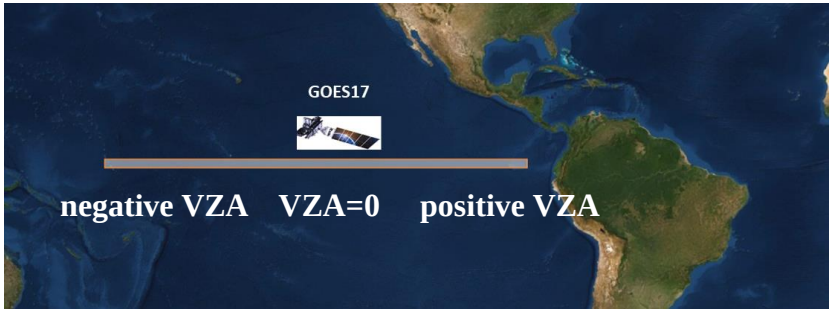
  Blue: GOES17/ABI-SNPP/VIIRS

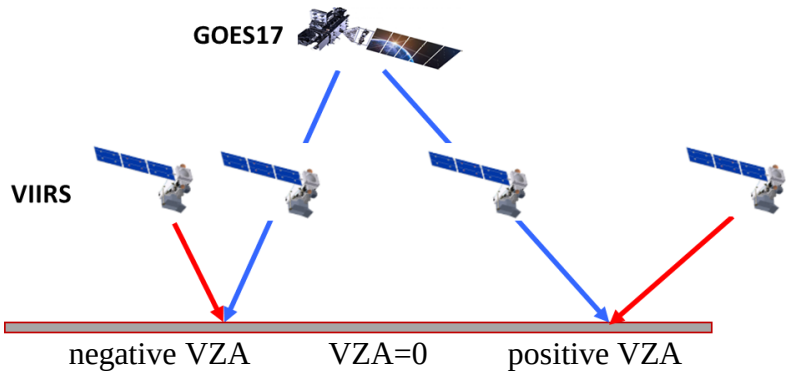
  Red: GOES17/ABI-N20/VIIRS

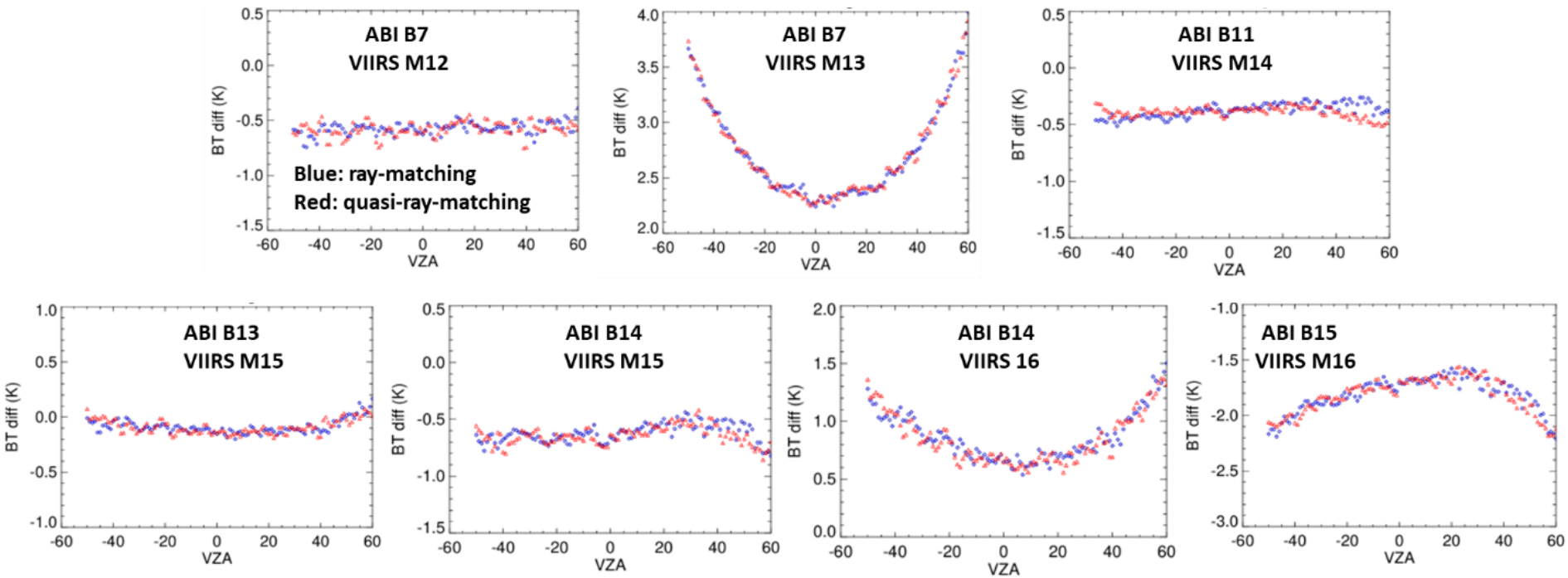
- The large view angle dependency is due to large spectral difference between ABI and VIIRS



Ray-matching vs quasi-ray-matching



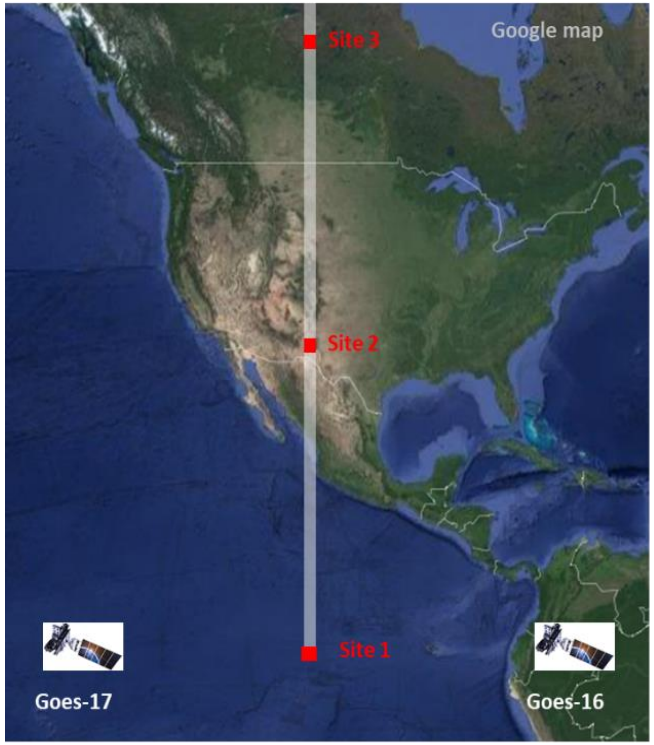


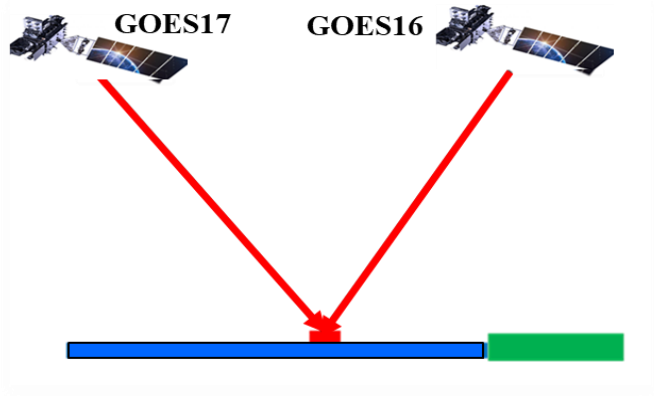


The difference between GOES17/ABI-N20/VIIRS as function of ABI and VIIRS VZA.

Application to GOES16-GOES-17 ABI comparison

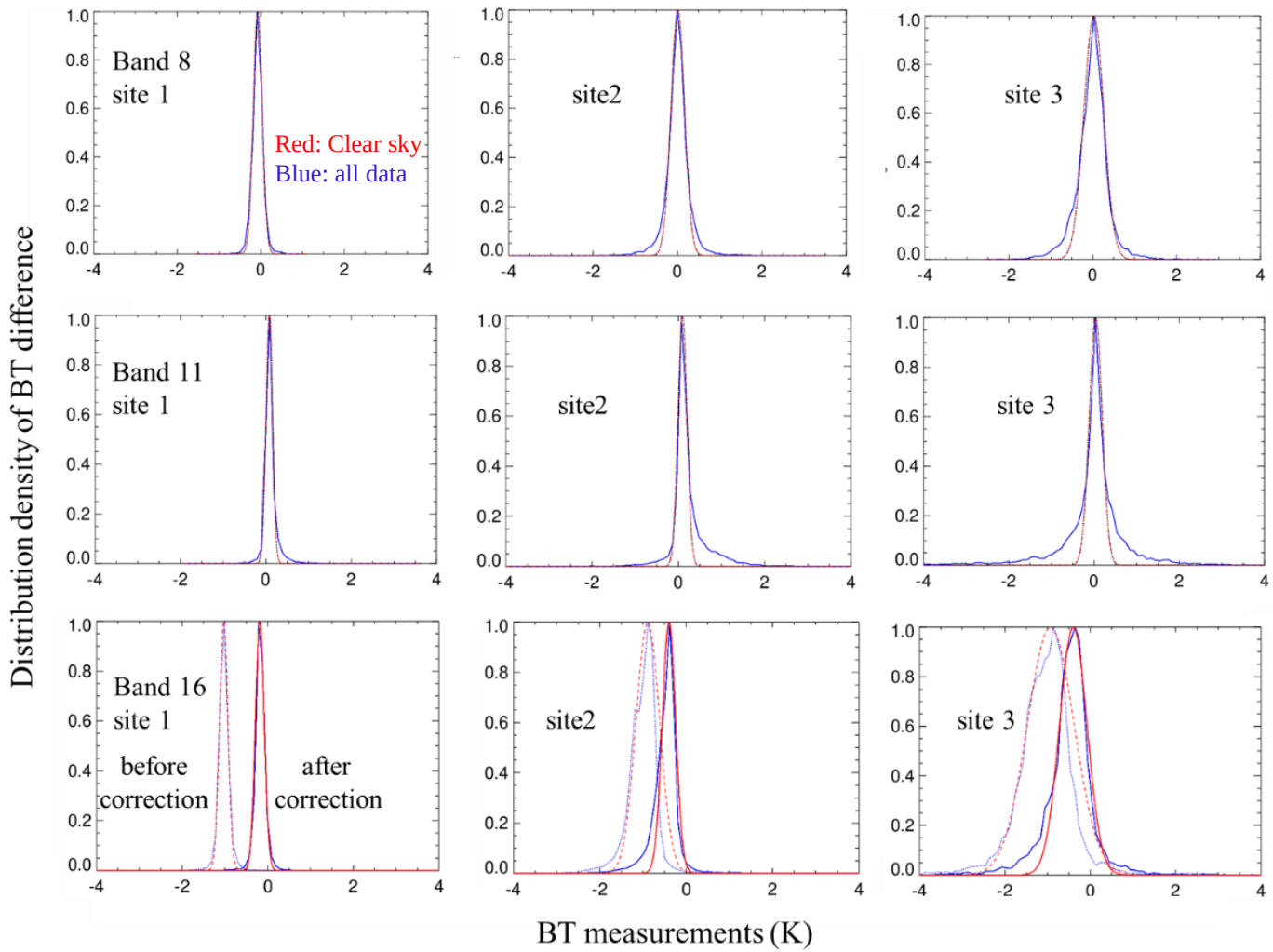
- The quasi-ray-matching method is applied. The gray strip indicates the area in the middle of the G16 and G17 locations. Both the G16 and G17 ABI view the area with the same view angle.
- All nighttime G16 and G17 ABI full disk images (every 10 minutes) simultaneous measurements in entire year 2020 are used
- G16 and G17 ABI L2+ Binary Cloud Mask (BCM) are used for clear sky filtering.





Site	Scene	Latitude (degree)		Longitude (degree)	
1	Ocean	1.0 South	1.0 North	107.2 West	105.2 West
2	Desert	31.5 North	33.5 North		
3	Mixed Forest	55.5 North	57.5 North		

Application to GOES16-GOES-17 ABI comparison



- Distribution of BT difference between GOES-17 and GES-16 ABI bands 8 and 11 for the three sites using all-data and clear sky measurements.
- The data are the pixel-to-pixel difference in night of entire year 2020. Blue markers: all-data; red markers: clear sky.
- For band 16, the correction of spectral difference using MODTRAN modeling over typical scene is applied

Application to GOES16-GOES-17 ABI comparison

- BT difference between GOES-17 and GOES-16 ABI TEB for the three sites using clear sky measurements.
- Bands 9 and 16 have relatively larger spectral difference effect on the difference, the correction of spectral difference using MODTRAN modeling over typical scene is applied (the value in parentheses). The others band spectral difference is small.
- Band 7, affected by stray light (reference below), needs special considerations, and is not included.

Band	Site 1 (ocean)		Site 2 (desert)		Site 3 (mixed forest)	
	Diff (K)	Unc (K)	Diff (K)	Unc (K)	Diff (K)	Unc (K)
8	-0.07	0.11	0.01	0.16	0.03	0.24
9	0.28 (-0.01)	0.11	0.30 (0.01)	0.16	0.22 (-0.07)	0.26
10	-0.04	0.09	0.01	0.15	-0.07	0.21
11	0.08	0.08	0.10	0.10	0.04	0.15
12	-0.03	0.09	0.10	0.11	0.05	0.15
13	-0.05	0.08	0.10	0.11	0.04	0.16
14	-0.05	0.07	-0.02	0.15	-0.21	0.18
15	0.02	0.08	0.10	0.13	-0.04	0.17
16	-1.03 (0.17)	0.10	-0.91 (0.41)	0.27	-0.96 (0.40)	0.51

Reference: Shao, X., et. al, Journal of Applied Remote Sensing, 15(1) (2021)

Summary

- GOES-R ABI provides good reference for inter-sensor comparison for GEO and LEO sensors.
- Ray-matching and quasi-ray-matching methods are presented for GEO-LEO comparison. Both methods are applied to the ABI-VIIRS TEB comparison, while the quasi-ray-matching is applied to GOES16 and GOES17 ABI TEB comparison

- The SNPP/VIIRS and N20/VIIRS TEB were compared using double difference with GOES17/ABI as a reference.
- SNPP/VIIRS and N20/VIIRS TEB comparison over ocean shows an excellent consistent measurements within less than 0.1K. The SNPP-N20 difference is up to 0.2K for in the monthly trending.

- The ocean, desert, and mixed forest scene are used for GOES16 and GOES17 ABI TEB comparison. The spectral difference effect on the difference has been corrected for bands 9 and 16.
- The difference between GOES16 and GOES17 ABI TEB is up to 0.3K, except band 16. The difference for band 16 is up to 0.4K