Evaluation of early NOAA-20 VIIRS RSB radiometric performance using intercomparison with Aqua MODIS

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ABSTRACT

The radiometric performance of the reflective solar bands (RSBs) of NOAA-20 VIIRS, recently launched on 18 November 2017, is evaluated through an intercomparison with Aqua MODIS. The analysis adapts a "nadir-only" refinement of the simultaneous nadir overpass (SNO) to generate comparison time series for assessment of the on-orbit calibration of NOAA-20 VIIRS RSBs using the official sensor data records (SDRs). The comparison result reveals an unstable and varying early radiometric performance upward of 5%. SNPP VIIRS, the precursor VIIRS, is also used to generate a comparison time series against Aqua MODIS. The result shows that NOAA-20 VIIRS RSBs have a 2 to 8% radiometric deficit relative to SNPP VIIRS RSBs.

Key Words: VIIRS, MODIS, RSB, Inter-sensor comparison, Intercalibration, SNO, NOAA-20, SNPP, JPSS-1, J1, Aqua.

1. INTRODUCTION

The follow-up Visible Infrared Imaging Radiometer Suite (VIIRS), housed in the NOAA-20 satellite, formerly known as JPSS-1 satellite, was launched on 18 November 2017. The NOAA-20 VIIRS is first of the four follow-ups after the precursor VIIRS in the Suomi-NPP satellite that was launched 7 years prior on 11 October 2011. The sensor data records (SDRs) of the NOAA-20 VIIRS, generated by the institutional processing system the Interface Data Processing System (IDPS), are available through the NOAA CLASS system (https://www.bou.class.nasa.gov).

In this preliminary examination, we assess the radiometric performance of the NOAA-20 VIIRS reflective solar bands (RSBs) via an inter-sensor comparison with Aqua MODIS. We follow the procedure of Chu et al. [1-3] carried out for SNPP VIIRS versus Aqua MODIS in a "nadir-only" refinement of the simultaneous nadir overpass (SNO) analysis in which the concurrently observed scenes are analyzed only for a small nadir-centered subscene area. The refined approach eliminates confounding issues associated with large angles and extended scene areas, such as the responses-versus-scan angle (RVS) effect, thus focusing the radiometric evaluation to that of the performance of the on-orbit RSB calibration. As Aqua MODIS RSBs has been shown to be radiometrically stable within 1% over its multi-year performance [1-3], the comparison time series of NOAA-20 VIIRS versus Aqua MODIS over the short period of past nine months will provide sufficiently clarity of the NOAA-20 VIIRS RSB performance. The Collection 6 release of Aqua MODIS [4,5] is used in this analysis.

SNPP VIIRS is also compared with Aqua MODIS, and the result is used to compare with that of NOAA-20 VIIRS versus Aqua MODIS. Specifically, there are two calibrated SDR versions for SNPP VIIRS RSBs that are used – the official version by the IDPS and an independent version by the NOAA Ocean Color (OC) Team [6-9] – thus generating two comparison sets of SNPP VIIRS versus Aqua MODIS. The OC SDRs of SNPP VIIRS RSBs had been shown to achieve significant improvement over the IDPS version [1-3] and generate the correct science result [10,11]. One of the primary improvements achieved in the OC version is the mitigation of the worsening bias due to an inherent calibration

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error using the solar diffuser (SD) [7-9,12]. In the past nine month period, the cumulative effect of the multi-year drift prior to 2018 can lead to significant bias of few percent in the comparison result.

2. PROCEDURE AND ANALYSIS

The radiometric performance of VIIRS RSBs is tested against the matching spectral Aqua MODIS RSBs. The spectrally matching RSBs of SNPP VIIRS and Aqua MODIS are listed in Table 1 along with some key specifications, which should serve as specifications for NOAA-20 RSBs as well. We utilizes also the Aqua MODIS imaging bands B1–B5 primarily because of their wider dynamic range allowing for better comparisons. These MODIS imaging bands have finer spatial resolution at 0.25 or 0.50 km, but the aggregated 1-km resolution data will be used instead. The smaller dynamic range of many moderate-resolution MODIS bands severely limits the utility of the comparison due to detector saturation. The VIIRS spatial resolution is 750-m for moderate bands and 375-m for imagery bands.

Table 1. The specifications for SNPP VIIRS and Aqua MODIS RSBs used in the inter-sensor comparison. Lmax and spectral radiance have units of W/m^2-μm-sr.

	SNPP VIIRS					Aqua MODIS				
	Band	Spectral Range (nm)	Center λ (nm)	Spatial Resolution (m)	Lmax	Band	Spectral Range (nm)	Center λ (nm)	Spatial Resolution (m)	Lmax
VIS	M1	402 - 422	410	750	615	8	405 - 420	412	1000	269
	M2	436 - 454	443	750	687	9	438 - 448	443	1000	190
	M3	478 - 498	486	750	702	3	459 - 479	469	500	591
						10	483 - 493	488	1000	140
	M4	545 - 565	551	750	667	12	546 - 556	551	1000	88
						4	545 - 565	555	500	532
	M5	662 - 682	671	750	651	1	620 - 670	645	250	512
						13	662 - 672	667	1000	42
						14	673 - 683	678	1000	42
NIR	M6	739 - 754	745	750	41	15	743 - 753	748	1000	35
	M7	846 - 885	862	750	349	2	841 - 876	859	250	240
						16	862 - 877	869	1000	25
SWIR	M8	1230 - 1250	1238	750	165	5	1230 - 1250	1240	500	123

The basics of the "nadir-only" SNO have been fully described [1-3] and only the final selection criteria are presented below. An area of 36×36 km^2 centered on each matched nadir is used for comparison. The "nadir-only" condition achieved through the use of a small area which averts various angle-dependent impacts such as the response versus scan-angle (RVS) effect, terrain and the bidirectional reflectance distribution function (BRDF) of the scene. Within each SNO event, the homogeneity filter at 4.5% is applied to all pixels and the sample size is set at 500 matching pixel pairs. Each pixel-based radiometric ratio is computed as the radiance of VIIRS over Aqua MODIS. The population average and standard deviation of all qualified pixel-based ratios represent the ratio and the error bar (precision) of the SNO event. The threshold of the precision for each SNO event is set at 2%.

Three sets of intersensor comparison are generated. The first is NOAA-20 VIIRS versus Aqua MODIS for the direct assessment of NOAA-20 VIIRS RSB performance relative to Aqua MODIS, with the latter presumed to be stable for the past nine months. The second is the OC SDR version of SNPP VIIRS versus Aqua MODIS, and this comparison result is presumed to be the most reliable set among the three. Finally, the third set is the IDPS version of the SDRs of SNPP VIIRS versus Aqua MODIS, which provides another helpful comparison reference.

3. RESULTS

In all figures, Aqua MODIS serves as the common reference for all VIIRS comparisons. Each radiometric ratio point represents the radiance of VIIRS over Aqua MODIS per qualified SNO event. The NOAA-20 VIIRS-based time series are shown in red diamonds, the OC-based SNPP VIIRS time series are shown in green squares, and the IDPS-based SNPP VIIRS time series are shown in blue stars. The solid green line represents the mean of the OC-based time series of SNPP VIIRS and the two dashed green lines mark 2% above and below that mean. The OC-based times series of SNPP VIIRS versus Aqua MODIS are presumed to be reliable as the OC SDRs have been rigorously examined and tested on all three levels: calibration [4-9], radiometric examination [1-3], and science product performance [10,11].

3.1 NOAA-20 VIIRS M1–M4

In all four cases shown in Fig. 1, the NOAA-20 VIIRS radiance shows numerous significant shifts and overall instability. Although not shown in Fig. 1b, the NOAA-20 VIIRS M2 time series also has early large shift but it has been filtered out due to the poorer signal quality of Aqua MODIS B9. Around mid-April 2018, all four NOAA-20 time series appear to have stabilized for the ensuing two months, and thus we evaluate the bias against the SNPP VIIRS OC result base on that two-month period. The biases for the first four NOAA-20 VIIRS RSBs are -4%, -2%, -4% and -8%.

It is worth noting that the two SNPP VIIR versions of the SDRs (green squares and blue stars) exhibit significant differences of 2% or more. For SNPP VIIRS RSBs, as the IDPS SDRs have not been mitigated for the worsening calibration error, their overall deviation has drifted beyond 2%.

The multi-set comparison result confirms also numerous interesting features due to Aqua MODIS. For example, similar strong seasonal fluctuation can be seen in Fig. 1c for all three comparison time series, thus pointing to Aqua MODIS as the source of the deviation that was already seen in previous studies [1-3].

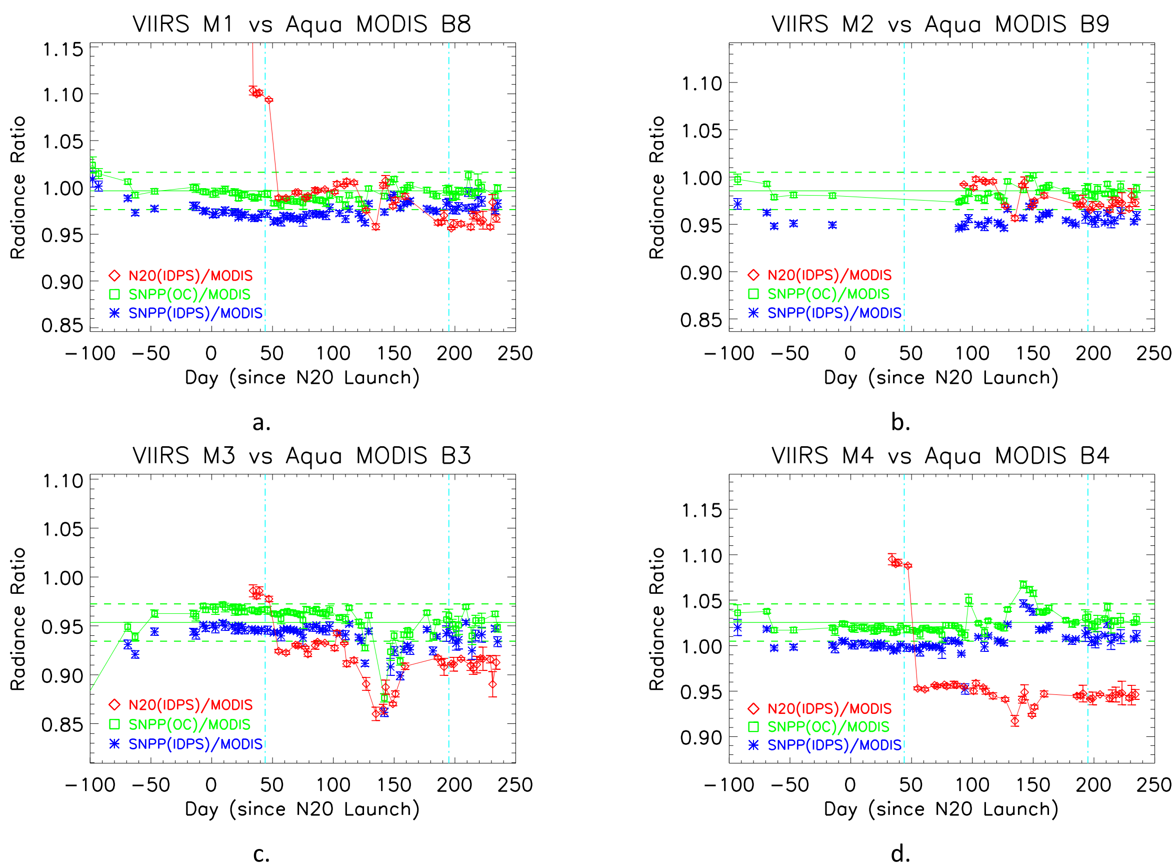


Figure 1. The inter-sensor comparison result for VIIRS M1–M4 against Aqua MODIS bands from late September 2017 to early July 2018.

3.2 NOAA-20 VIIRS M5, M7 and M8

In Fig. 2a, NOAA-20 VIIRS M5-based time series (red diamonds) is shown to be biased -6% relative to SNPP VIIRS M5 (green squares). For M7 in Fig. 2b, NOAA-20 VIIRS result is -3% relative to SNPP VIIRS M7. For M8 in Fig. 2c, NOAA-20 VIIRS result is -3% lower relative to SNPP VIIRS M8. The VIIRS M6 versus Aqua MODIS B15 is not shown because the comparison lacks sufficient outcomes due to constant Aqua MODIS B15 saturation over the polar scenes.

The VIIRS M7 result in Fig. 2b shows a surprising difference between the two versions of SNPP VIIRS SDRs, which was not present prior to 2017 [1]. This difference signals some additional issue that has emerged within the past two years.

Finally, the VIIRS M8 versus Aqua MODIS B5 comparison time series in Fig. 2c shows a very telling result. Given that VIIRS M8 and Aqua MODIS have effectively the same spectral coverage (see Table 1), the comparison ratio will follow along ratio=1.0 flat line provided that the calibration for both respective sensors has been correctly done. The OC version of the SNPP VIIRS M8 versus Aqua MODIS B5 (green squares) indeed shows a consistent flat line around 1.0, thus supporting that both OC SDR of SNPP VIIRS and Aqua MODIS C6 are very well calibrated. On the other hand, the IDPS version of the SNPP VIIRS M8 versus Aqua MODIS (blue stars) demonstrates some bias or drift of about 1% over the past nine months, signaling some systematic error in the IDPS version of the calibration of SNPP VIIRS M8. Finally, the result of the comparison of this particular band pair convincingly shows that the IDPS calibration of NOAA-20 VIIRS indeed has a significant discrepancy, in this case about -3% for NOAA-20 VIIRS M8.

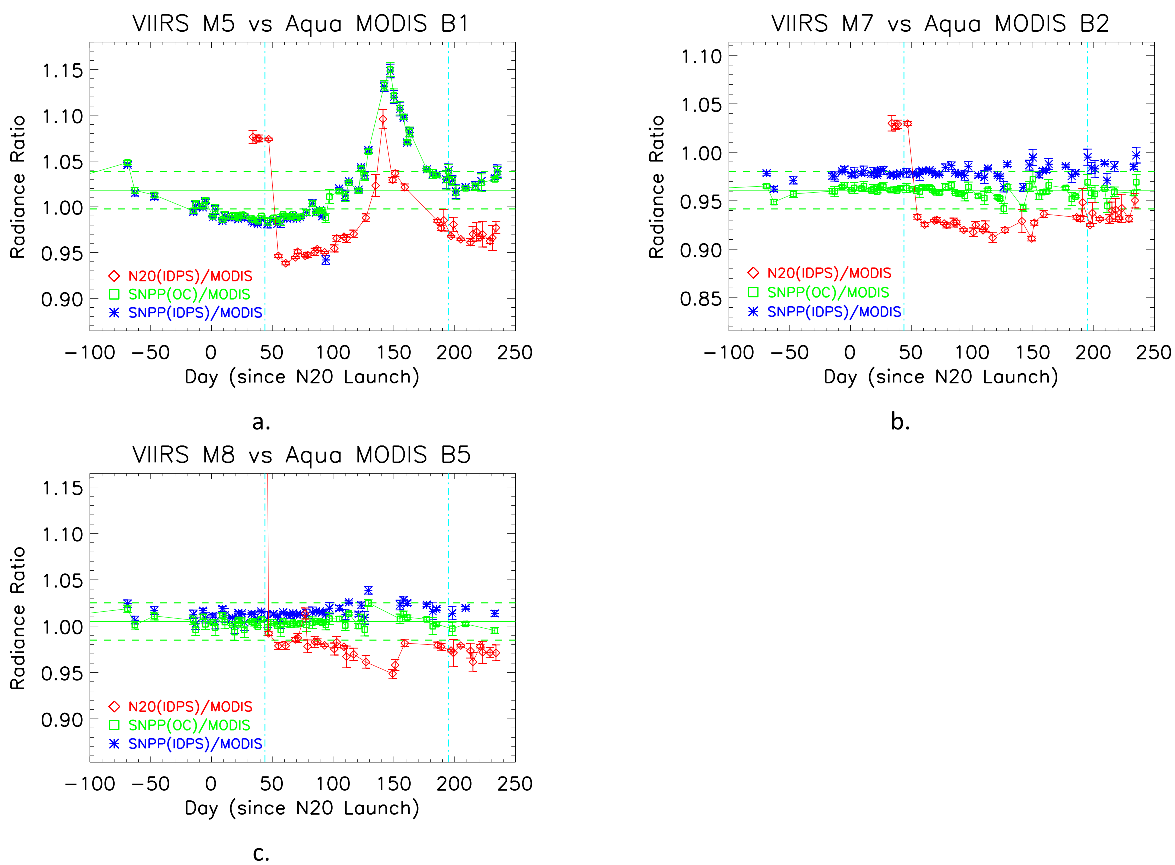
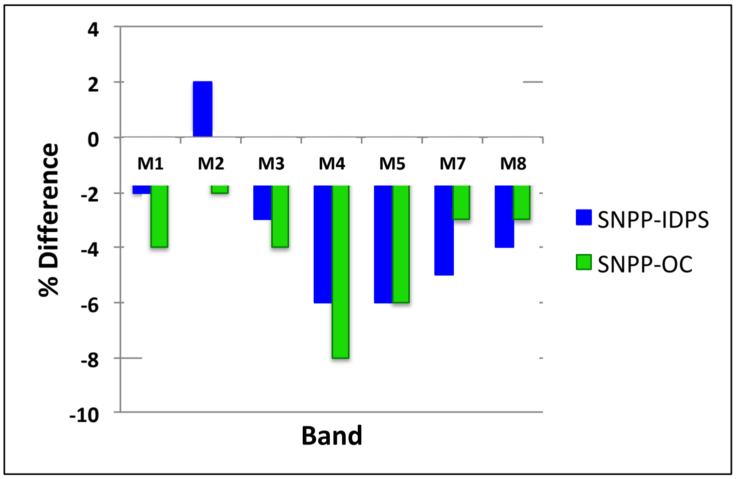


Figure 2. The inter-sensor comparison result for VIIRS M5, M7 and M8 against Aqua MODIS bands from late September 2017 to early July 2018.

3.3 Result Summary

A summary of the differences for VIIRS RSBs between NOAA-20 and SNPP for the most recent two-month period is shown below in Table 2.

Table 2. Summary of the radiometric discrepancy of NOAA-20 VIIRS RSBs relative to SNPP VIIRS.



5. SUMMARY

We have conducted a performance evaluation of the IDPS SDRs of the NOAA-20 VIIRS RSBs referencing to Aqua MODIS. The "nadir-only" SNO analysis quantified the recent bias of NOAA-20 VIIRS RSBs, in comparison to the OC version of the calibrated SNPP VIIRS RSBs, to range from -2 to -8%. The significant radiometric deficit as well as the overall instability demonstrates the need for the continual improvement of the RSB calibration for the official IDPS version of the SDRs of NOAA-20 VIIRS.

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