NPOESS VIIRS on NPP: Reflective Radiometric Performance

Lushalan Liao, Northrop Grumman Aerospace System, Redondo Beach, CA

Introduction

The Visible/Infrared Imager/Radiometer Suite (VIIRS) is a key National Polar-orbiting Operational Environmental Satellite System (NPOESS) sensor. It will generate 21 Environmental Data Records (EDRs), including two EDRs with Key Performance Parameters (KPPs): sea surface temperature (SST) and imagery. Given the importance of the EDRs to be generated from VIIRS measurements, the integrity and quality of the VIIRS Sensor Data Record (SDR) are essential for NPOESS mission success. To ensure integrity and quality of radiometry, the VIIRS instrument for NPP has recently completed its environmental testing where the radiometric characteristics of the instrument were characterized. This poster will describe the reflective band radiometric performance of 11 reflective moderate resolution bands and 3 reflective imagery bands.

Methodology

The VIIRS instrument has an extremely stringent requirement on reflectance accuracy of 2% at typical radiance expected for each spectral band. Most of the reflective bands in the VisNir region are dual gain bands: high gain for data in the low radiance region and low gain for data in the high radiance region. The dual gain scheme allows for minimal quantization error while covering a large dynamic range. As a result, the dual gain bands have 2% uncertainty requirements at two radiance levels: one within high gain range the other in the low gain range. It is well known that the current available ground calibration source (SIS-100) is not capable of the 2% uncertainty over the desired dynamic range and spectral range. Thus, the calibration scheme for VIIRS reflective bands involves the use of our knowledge of Solar irradiance, a solar diffuser (SD) made of spectralon and a SD stability monitor (SDSM). Pre-launch, the SD bidirectional reflectance function (SDBRF) is carefully measured. Post-launch, SDBRF degradation is monitored by the SDSM, a ratioing radiometer. This calibration scheme is similar to what is employed for MODIS.

Figure 1 shows the error budget allocation for the various expected error sources. As can be seen, in order to satisfy the 2% uncertainty requirement, one must be able to extrapolate the radiance from the SD calibration point to the desired radiance very accurately. As can be seen from Figure 1, the majority of the error is caused by the uncertainty of the calibration scale set at the radiance level set by the solar irradiance after it reflects off SD.

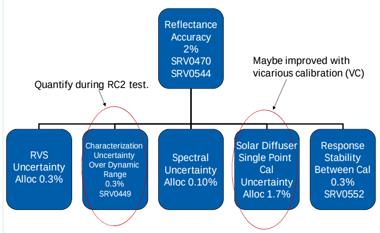

Figure 1. Reflective Band Radiometric Error Budget

In order to achieve the required characterization uncertainty of 0.3%, the ground calibration of VIIRS reflective bands uses the attenuator technique. In the attenuator technique, if one assumes polynomial calibration curve, one retrieves highly accurate coefficient ratios of all the power terms over the linear term. In the case of VIIRS, we use only second order polynomial to convert from counts (digitized photo-electrons) to radiance.

In order to achieve desired characterization uncertainty, both the sensor response and source output must be extremely stable between the time of data collection with attenuator out of the optical path to the time of the data collection with attenuator in the optical path. Any drift of greater than 0.1% will induce unacceptable uncertainty in the retrieved quadratic and offset coefficient ratios. Thus, while the attenuator technique is capable of highly accurate coefficient ratios, it places extremely stringent requirement on the short term stability of sensor response as well as source output.

In addition to the 2% uncertainty, VIIRS also has an uniformity requirement that guarantees minimal visual striping in imagery. The uniformity requirement states that when observing an uniform scene, each detector must retrieve a radiance that is within the noise equivalent radiance of the mean radiance.

This uniformity requirement imposes further constraint on the accuracy of the retrieved 2nd order coefficient ratio. In particular, at radiance levels far away from the SD point, the required retrieved radiance difference between detectors is often less than 0.1%. This places a constraint on differential detector drift between data collects that is not achievable with the instrument. As a result, once the 2nd order coefficient is set in stone with a particular calibration data set, we will suffer higher than desired non-uniformity unless further post processing is done. In summary, the attenuator technique has the following undesirable effects which we must minimize:

- Source drift and concurrent drift of detectors between in/out induces bias calibration error by incorrect 2nd order coefficient for all detectors.
- Differential detector drifts induces non-uniformity by promoting differential 2nd order coefficient error between detectors

The first effect is minimized by appropriate test design while the second effect is removed with post processing where we require the coefficient ratios must be such that the deviation from mean retrieved radiance is minimized while the calibration equation has a form that guarantees zero characterization uncertainty at SD in order to be consistent with the usage of SD on-orbit. Uncertainty analysis has shown that the proposed post-processing (bootstrap+) causes minor increases in characterization uncertainty. Figure 2. shows an example side by side comparison of characterization uncertainty for band M11.

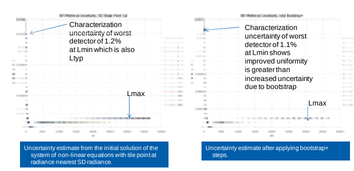

Figure 2. Example Uncertainty from band M11

In general, the form of the characterization uncertainty curve is a lopsided V curve with zero uncertainty at the SD point where we set the scale. Thus, for radiometric uncertainty at any point on the dynamic range, we simply RSS the characterization uncertainty at the desired radiance level with the other terms indicated in Figure 1.

Figure 3 shows the side by side uniformity results without and with post processing on uniformity for the same M11 band . Thus, we see that we can expect to see some striping in the imagery constructed from band M11 (due to differential error on 2nd order coefficient ratio induced by differential detector drift) with just the standard attenuator technique. On the other hand, striping will probably be not observable if one uses the 2nd order coefficient ratio produced with post processing as shown on the right hand side.

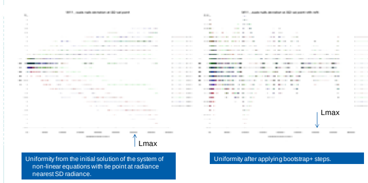

Figure 3. Example uniformity for band M11

Results

Table 1. shows the maximum characterization uncertainty reached within the dynamic range. Except for band M11, when we RSS with the other error sources shown in Figure 1, we expect to achieve 2% uncertainty at Ltyp. For M11, we see from Figure 2 that over the most of the dynamic range, we expect to achieve 2% total uncertainty and that it is only near the minimum radiance level that we expect to miss the 2% uncertainty requirement.

Band	Gain	Requirement (%)	Perf Est for Worst case Uncertainty
M1	High	0.3	<0.3
M1	Low	0.3	<0.3
M2	High	0.3	<0.3
M2	Low	0.3	<0.3
M3	High	0.3	<0.3
M3	Low	0.3	<0.3
M4	High	0.3	<0.3
M4	Low	0.3	<0.3
I1	N/A	0.3	0.67 (Lmin)
M5	High	0.3	<0.3
M5	Low	0.3	<0.3
M6	N/A	0.3	<0.3
M7	High	0.3	<0.3
M7	Low	0.3	0.4 (Lmin)
I2	N/A	0.3	<0.3
M8	N/A	0.3	<0.3
M9	N/A	0.3	1.1 (at Lmin)
M10	N/A	0.3	<0.3
I3	N/A	0.3	0.65 (Lmin))
M11	N/A	0.3	1.1(at Lmin and Ltyp)

Table 1. Characterization Uncertainty

Table 2. shows the expected uniformity performance after post processing as described previously. Most bands will have uniformity equal to sensor noise or better across the dynamic range with the exceptions of low gain states of M1, M2 and M3.

Band	Gain	Center Wavelength (nm)	Requirement (NedL)	Perf Est for Worst case Uncertainty
M1	High	412	1	Compliant
M1	Low		1	3
M2	High	445	1	Compliant
M2	Low		1	4.5
M3	High	488	1	Compliant
M3	Low		1	3
M4	High	555	1	Compliant
M4	Low		1	Compliant
I1	N/A	640	1	Compliant
M5	High	672	1	Compliant
M5	Low		1	Compliant
M6	N/A	746	1	Compliant
M7	High	865	1	Compliant
M7	Low		1	Compliant
I2	N/A	865	1	Compliant
M8	N/A	1240	1	Compliant
M9	N/A	1378	1	Compliant
M10	N/A	1610	1	Compliant
I3	N/A	1610	1	Compliant
M11	N/A	2250	1	Compliant

Table 2. Uniformity