NPOESS VIIRS on NPP : Image Quality and Pointing Performance

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VIIRS Instrument

The Visible/Infrared Imager/Radiometer Suite (VIIRS) is a key National Polar-orbiting Operational Environmental Satellite System (NPOESS) sensor. It will generate 22 Environmental Data Records (EDRs), including two Key Performance Parameters (KPPs): sea surface temperature (SST) and imagery. The instrument spatial performance contributes directly to two KPPs : Imagery nadir horizontal resolution and SST horizontal cell size. In addition, the spatial performance also directly contributes to mapping uncertainty for all 22 EDRs.

In terms of footprint, VIIRS data can be divided into three distinct groups: moderate (M) resolution, imagery resolution (I) and Day and Night Band (DNB) resolution. We will only concentrate on M-band and I-band spatial characteristics. M-band footprints are approximately twice as large as I-bands. At nadir, I-band footprints are slightly less than 400 meters. Because VIIRS detectors have constant angular filed of view (FOV), the footprint of each detector grows as the scan angle moves from nadir. In the scan direction, constant sampling time also results in growing scan FOV as function of scan angle. To minimize the variation in scan direction ground foot print, there are three aggregation zones in the scan direction. This is shown in Figure 1.

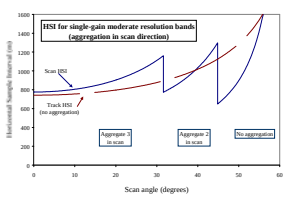

Figure 1. VIIRS Aggregation Zones

Most spatial characteristics such as line spread function (LSF), modulation transfer function (MTF), and horizontal sampling resolution (HSR) are measured in the no aggregation zone and the nadir performance (3-aggregate zone) is derived by analysis from the unaggregated LSF.

VIIRS LSF

LSF is the response of the instrument to a line source. Due to its design, VIIRS has two line spread functions, one in the track direction and one in the scan direction. The LSF in the track direction is the convolution of the detector perimeter and optical blur. Hence, it resembles a top-hat. The LSF in the scan direction is additional convolved with the scan drag and hence resembles a blurred triangle. Figure 2 shows the model-based construction of LSF and representative results for band I1.

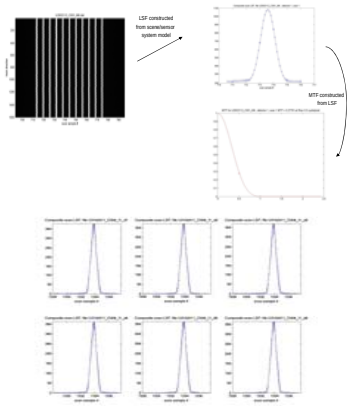

Figure 2. LSF construction and Results

Majority of image quality parameters are derived from LSF, including HSR and MTF. Full width at half maximum (FWHM) of a LSF is a measure of the 'goodness of focus'. Ideally for a remote sensing camera, the focal plane array is placed at the focus and the 'best' focus is achieved for objects located at infinity. Due to a coefficient of thermal expansion (CTE) mismatch between the coating of the VIIRS primary mirror and the substrate, VIIRS optical focus position changes as function of temperature. Figure 3 shows the focus curve for the middle detector for band I1.

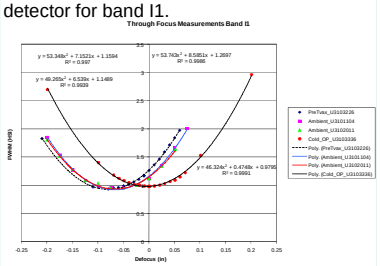

Figure 3. Temperature Dependence of Defocus Curve

Thus, we see that image quality parameters for I-bands will vary as function of temperature with worst performance for VisNir I-bands occurring at hot temperatures. The temperature range shown in Figure 3 ranged from -40ºC to 20ºC which is much larger than the expected on-orbit operating range of approximately -20ºC to -1ºC. Thus, we expect the LSF FWHM to vary much less than the approximately 25% that is shown. We do not expect thermal variation to impact M-band significantly because the thermal variation in optical blur is a much smaller fraction of the detector size. Figure 4 shows the derived HSR at nadir for I-bands. Due to aggregation by 3, we do not expect thermal variation to impact nadir HSR significantly. As can be seen from Figure 4, VIIRS will easily meet the KPP imagery nadir horizontal resolution requirement of 400 meters across the entire operating temperature range.

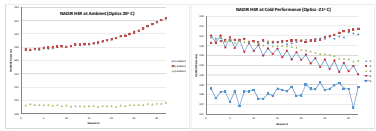

Figure 4. I-band nadir HSR

Table 1. shows the worst case edge of scan (EOS) HSR. As can be seen that only I1 and I2 will significantly exceed the desired 800 meters.

Band	I1	I2	I3	I4	I5
EOS HSR	750 - 950 meters	750 - 950 meters	700-800 meters	710-800 meters	700-780 meters

Table 1. EOS HSR Performance

Figure 5. shows the two worst non-compliant MTF bands. With the exception at nyquist frequency, it is expected that VIIRS will come very close to meeting M-band MTF requirements, as shown in Table 2.

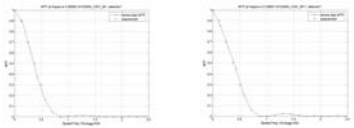

Figure 5. MTF performance M1and M11 at nominal plateau

Spatial Freq (1/2-samples)	Specification	Worst Performance	Worst Band
0	1	1	N/A
0.25	0.9	0.87	M11
0.5	0.7	0.69	M1
0.75	0.5	0.46	M1
1	0.3	0.25	M1

Table 2. MTF Performance

VIIRS Pointing and Geolocation

In addition to image quality characteristics discussed previously, VIIRS contribute to the mapping accuracy requirement of every EDR through its pointing knowledge. The VIIRS geolocation algorithm uses encoder data from the scan motors for both the rotating telescope (RTA) and the half angle mirror (HAM) to accurately calculate the line of sight (LOS) vector for each scan data sample. The mapping accuracy requirements are 400 meters at nadir and 1500 meters at EOS. Such accuracy is not achievable without on orbit training with ground control points. Figure 6 shows the current error budget from geolocation knowledge. It is clear that static uncertainty alone will exceed the total mapping uncertainty allocation unless majority of it is removed. It is expected that 95% of the bias will be removed with ground control point matching technique develop by the MODIS team.

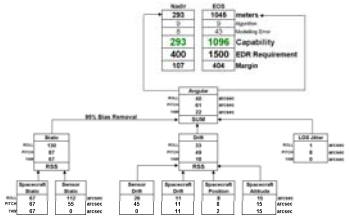

Figure 6. Pointing Knowledge and Geolocation Performance

Plans for On-Orbit Verification

On orbit, VIIRS geolocation validation will employ similar training algorithm as was implemented for MODIS. We will employ the same model-based technique in our image-quality validation activities that was employed to analyze the test data. See references (1) through (3) for details.

References

1. Robert E. Wolfe, Masahiro Nishihama, Albert J. Fleig, James J. Kuyper, David P. Roy, James C. Storey and Fred S. Patt, "Achieving sub-pixel geolocation accuracy in support of MODIS land Science", Remote Sensing of Environment, 83, 31-49
2. Lushalan Liao, "Model based performance evaluation of VIIRS spatial performance", Calcon 2008.
3. Lushalan Liao, Stephen Mills, Frank De Luccia and Bruce Guenther, "NPOESS/NPP VIIRS SDR calibration and validation plan", AMS 2010 General Meeting