Performance Continuity of the A-Train MODIS Observations: Welcome to the NPP VIIRS

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Introduction

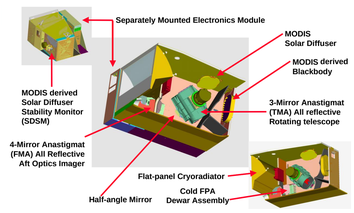
The Visible-Infrared Imaging Radiometer Suite (VIIRS) is a keystone instrument on the NPOESS Preparatory Project (NPP) satellite mission. The NPP satellite is fully populated with instruments at the Ball Aerospace Technology Corporation (Boulder, CO), where it will enter Observatory thermal vacuum testing in the Spring of 2011. The VIIRS is built by the Raytheon Corporation, and is the second-generation US moderate-resolution imaging radiometer, as the successor to the Moderate Resolution Imaging Spectroradiometer (MODIS) that is in space on NASA's Earth Observing System (EOS) Terra and Aqua spacecraft. MODIS, also built by the Raytheon Corporation, is a primary instrument on Aqua in the A-Train constellation. This poster introduces the attributes of the VIIRS instrument and highlights comparisons of the ground-test performance of VIIRS with the ground-test and on-orbit performance of MODIS Aqua.

General Instrument Characteristics and Data Products

VIIRS and MODIS Design Characteristics

	VIIRS	MODIS
Orbit	824 km, sun-synchronous, near-polar	705 km, sun-synchronous, near-polar
Scan Rate	33.6 rpm, cross-track	20.3 rpm, cross-track
Swath Dimensions	3000 km across track by 13 km along track at nadir	2330 km across track by 10 km along track at nadir
Size	1.3 m x 1.4 m x 0.9 m	1.0 m x 1.6 m x 1.0 m
Weight	263 kg	250 kg
Power	154 W	225 W
Data Rate	10.4 Mbps (peak)	11 Mbps (peak)
Quantization	12 bits	12 bits
Design Life	7 years	5 years

VIIRS Design



VIIRS on-board calibrator designs are based on MODIS heritage

VIIRS Data Products

Product Group	EDRs/Other Products	
Imagery	Imagery*	
Surface Temperatures	Sea Surface Temperature Ice Surface Temperature	Land Surface Temperature
Clouds	Cloud Base Height Cloud Cover/Layers Cloud Particle Size Cloud Optical Thickness	Cloud Top Height Cloud Top Pressure Cloud Top Temperature Cloud Mask**
Aerosols	Aerosol Optical Thickness	Aerosol Particle Size
Ocean Biosphere	Ocean Color/Chlorophyll	
Land Biosphere	Vegetation Index Vegetation Type	Albedo
Snow & Sea Ice	Snow Cover	Sea Ice Characterization
Fire	Fire Detection	
Other	Soil Moisture Net Heat Flux	Suspended Matter Geolocation**

* Key Performance Parameter (KPP)
** Intermediate Product (not an EDR)

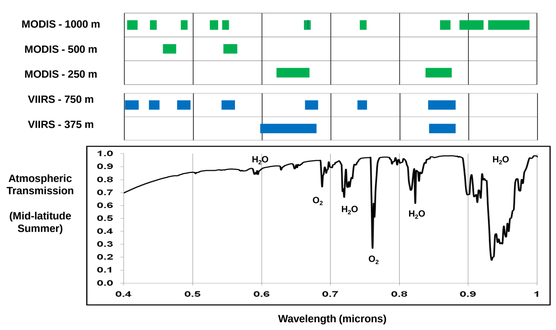
Comparison of VIIRS and MODIS Spectral Coverage

VIIRS has fewer bands (22) than does MODIS (36), but also carries 8 dual-gain bands. The VIIRS dual-gain bands can sense much higher radiance levels than corresponding MODIS bands. VIIRS does not have a fluorescence band for ocean color, and has fewer bands in the 0.4 to 1.0 μm spectral range than MODIS. The shortwave and midwave infrared band sets are similar within atmospheric window regions. The longwave band set for VIIRS does not include water vapor bands in the vicinity of 7 μm, nor CO_2 bands in the vicinity of 13 μm. VIIRS does not have any bands beyond 12.5 μm. Several VIIRS bands are spectrally broader than corresponding MODIS bands. The two instruments have similar spectral out of band characteristics. (See accompanying poster by Moeller *et al.* for details on performance of the spectral bands.) One of the VIIRS bands, the Day-Night band (DNB), provides broadband visible imagery at earth scene illumination levels ranging from quarter moon to full sun.

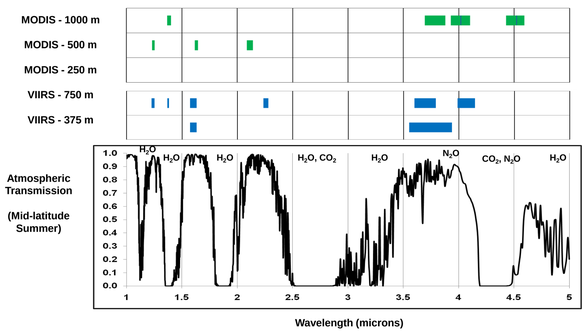
In the graphic to the right, VIIRS and MODIS bands are compared in 0.4 μm to 1 μm region. In the two graphics below VIIRS and MODIS bands are compared in the in 1 μm to 5 μm region (left) and in the 5 μm to 15 μm (right). Bands are grouped according to resolution at nadir.

VIIRS has 22 bands from 0.4 μm to 12.5 μm (8 dual gain). MODIS has 36 bands from 0.4 μm to 14.5 μm

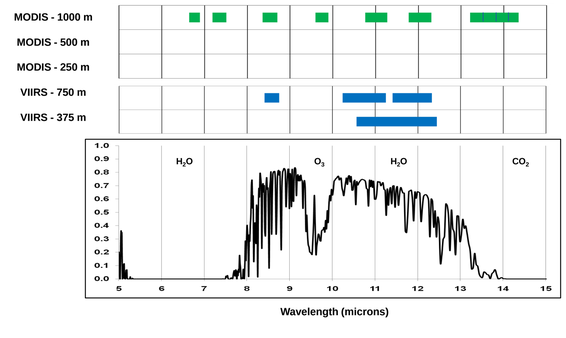
VIIRS and MODIS Spectral Coverage: 0.4 μm to 1.0 μm



VIIRS and MODIS Spectral Coverage: 1 μm to 5 μm

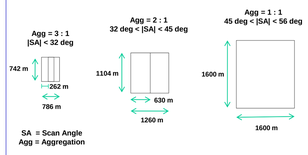


VIIRS and MODIS Spectral Coverage: 5 μm to 15 μm

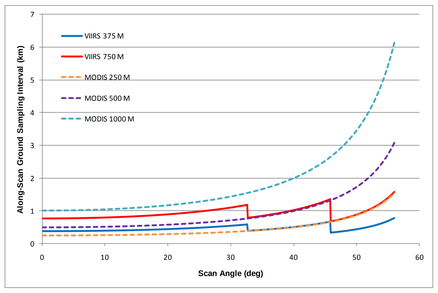


Comparison of VIIRS and MODIS Spatial Sampling

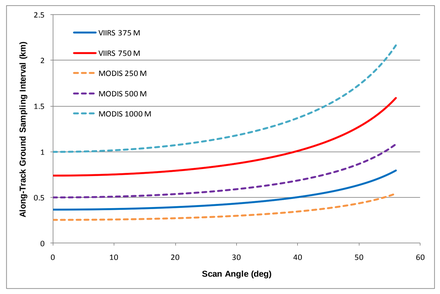
Ground sampling interval, the distance between successive pixel footprint centers on the ground, is shown for VIIRS and MODIS in the scan and track directions in the graphics to the right. VIIRS limits pixel growth in the scan direction via de-aggregation of sub-pixels as illustrated below.



VIIRS and MODIS Along-Scan Spatial Sampling



VIIRS and MODIS Along-Scan Spatial Sampling



VIIRS has 16 moderate resolution bands with 750 m footprint at nadir, 5 imaging resolution bands with 375 m footprint at nadir, and 1 DNB with 750 m footprint constant across scan. 3:1 aggregation used at nadir is reduced to limit footprint growth across scan. MODIS has 2 bands with 250 m footprint at nadir, 5 bands with 500 m footprint at nadir, 29 bands with 1000 m footprint at nadir.

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Comparison of VIIRS and MODIS Radiometric Performance

The correspondence between VIIRS and MODIS bands is shown in the table at the right. For each VIIRS band the spectral range and nadir Horizontal Spatial Resolution (HSR) are shown, followed by the corresponding MODIS band(s) and their spectral range and HSR. In some cases there are two MODIS bands that are close spectral matches but have different resolutions.

The comparison between VIIRS and MODIS Aqua signal-to-noise ratios (SNR) for reflective solar bands is shown in the plot below on the left. For each VIIRS band and a corresponding MODIS band four SNRs are plotted:

- MODIS Aqua SNR PL (pre-launch)
- MODIS Aqua SNR on-orbit
- VIIRS SNR PL (pre-launch)
- VIIRS SNR scaled to the MODIS resolution and reference radiance level

VIIRS SNR varies with aggregation zone. We have chosen to make the radiometric comparison in the near nadir region where VIIRS pixels are aggregated 3:1.

The comparison between VIIRS and MODIS Aqua Noise Equivalent Temperature Difference (NEdT) for thermal emissive bands is shown in the plot below on the right. The NEdT values are plotted in the same arrangement as described above for SNR.

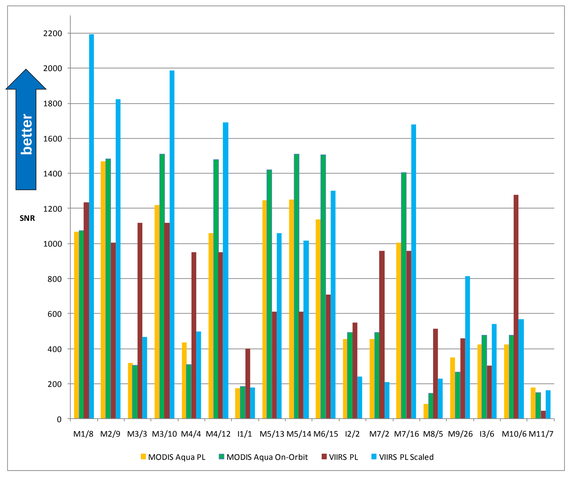
VIIRS SNR and NEdT are comparable or superior to MODIS SNR and NEdT when normalized to the same spatial scale and the same radiance level.

VIIRS and MODIS "Corresponding" Spectral Bands

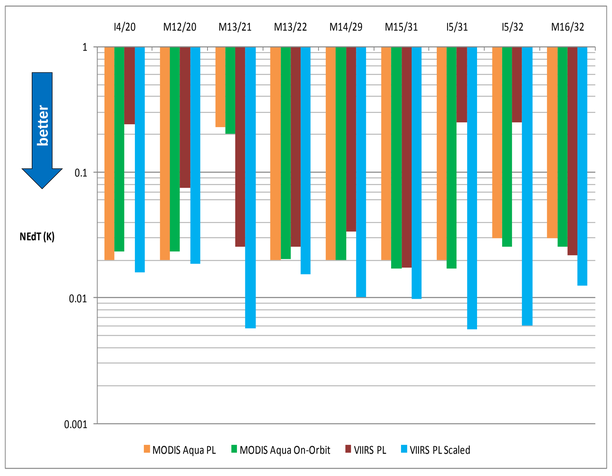
VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

● Dual-gain Band

Comparison of VIIRS and MODIS Aqua Reflected Solar Band SNR



Comparison of VIIRS and MODIS Aqua Thermal Emissive Band NEdT

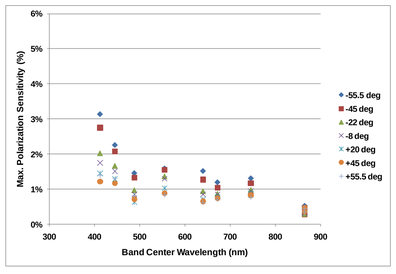


Horizontal Axis Band Pair Labeling: X/Y = (VIIRS Band X)/(MODIS Band Y)

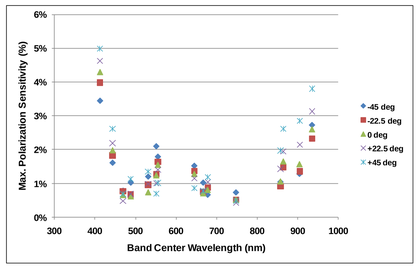
Comparison of VIIRS and MODIS Polarization Performance

Polarization sensitivity is a measure of the variation in sensor response to linearly polarized light as the plane of polarization is rotated through 180° with respect to the aperture. Polarization sensitivity is defined as the difference between the maximum and minimum response divided by the sum of the maximum and minimum response, *i.e.*, (Max Response - Min Response) / (Max Response + Min Response). VIIRS and MODIS Aqua polarization sensitivity *vs.* band center wavelength at a number of scan angles are shown in the far left and middle graphics below. VIIRS polarization sensitivity is generally lower than that of MODIS Aqua, less than 3% at scan angles up to 45°. MODIS Aqua polarization sensitivities are as high as 5% at 412 nm in this angular range. Polarization sensitivity depends more strongly on detector index in NPP VIIRS than in MODIS Aqua, as shown in the graphic on the far right.

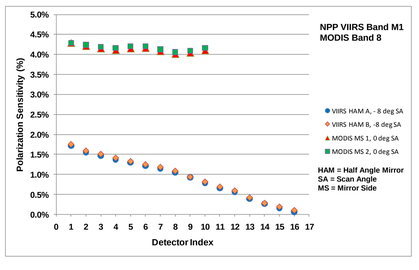
VIIRS VisNIR Polarization Sensitivity



MODIS Aqua VisNIR Polarization Sensitivity



Polarization Sensitivity *vs.* Detector Index



VIIRS polarization performance is generally better than that of MODIS. Unlike MODIS, NPP VIIRS polarization sensitivity varies strongly with field angle resulting in detector dependence. VIIRS pre-launch characterization provides high-quality, per-pixel characterization of polarization sensitivity and phase for use in data product processing.

Conclusions

VIIRS performance is comparable or superior to that of MODIS Aqua in corresponding bands in all key performance areas except crosstalk. NPP VIIRS has optical crosstalk in the VisNIR (0.8% average) that may impact Ocean Color/Chlorophyll and Aerosol data products. However, the second and subsequent VIIRS flight units will not have this level of optical crosstalk, due to improved spectral filters. In other key performance areas not addressed here, such as band-to-band registration, near-field response and stray light response, VIIRS performance compares favorably with that of MODIS Aqua. Overall, therefore, NPP VIIRS will provide excellent data continuity with the A-Train MODIS Aqua in regions of common spectral coverage.