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Using VIIRS to Provide Data Continuity with MODIS

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Abstract – Comparisons are made between the key properties of the MODIS and VIIRS sensors.

I. INTRODUCTION

Long-term continuity of the data series being initiated by the MODIS (MODerate Resolution Imaging Spectroradiometer) on NASA's Terra mission will be obtained using the VIIRS (Visible Infrared Imaging Radiometer Suite) flying on the converged National Polar-Orbiting Environmental Satellite System (NPOESS) and on the NPOESS Preparatory Project (NPP). The data series include critical parameters such as cloud and aerosol properties, vegetation index, land use and land cover, ocean chlorophyll and sea surface temperature.

VIIRS is being designed and built by Raytheon for the Integrated Program Office (IPO), the DoD, NOAA and NASA consortium that is responsible for NPOESS. In addition to meeting the requirements for operational environmental monitoring, VIIRS will meet the needs of the global change research community through the use of state-of-the-art algorithms and calibration and characterization activities.

II. SPECTRAL BANDS

VIIRS covers the spectral range from 0.4 to 12 μ in 22 spectral bands. Spatial resolution ranges from 341 to 742 meters at nadir. Unlike MODIS, the VIIRS is designed to minimize pixel growth over the ground track using a pixel aggregation approach. The ground swath is 3,000 km, permitting global daily coverage.

The reduction in the number of spectral bands from 36 to 22 results primarily from the elimination of MODIS bands used in atmospheric sounding, precipitable water, and ocean fluorescence. Additional capability is provided through the use of dual gains in 7 bands.

A more complete description of VIIRS is given in presentations by Welsch et al. (A Next-Generation Operational Sensor for NPOESS: The VIIRS (Visible Infrared Imaging Radiometer Suite)) in the Instrumentation and Future Technologies session.

In the Vis/NIR region, the 16 MODIS bands have been replaced by 9 VIIRS bands. See Table 1. MODIS bands 17-19 that are used to measure precipitable water, bands 13 high and 14 that are used to measure ocean chlorophyll fluorescence, and band 11 that is used in ocean color

Table 1 Vis/NIR Bands Compared

VIIRS			MODIS		
Band Name	Band Ctr	Band Width	Band #	Band Ctr	Band Width
M1*	412 nm	20 nm	8	412 nm	15 nm
M2*	445 nm	18 nm	9	443 nm	10 nm
M3*	488 nm	20 nm	10	488 nm	10 nm
			3	469 nm	20 nm
M4*	555 nm	20 nm	12	551 nm	10 nm
			4	555 nm	20 nm
I1	645 nm	50 nm	1	645 nm	50 nm
M5*	672 nm	20 nm	13	667 nm	10 nm
M6	751 nm	15 nm	15	748 nm	10 nm
M7*	865 nm	39 nm	16	870 nm	15 nm
I2	865 nm	39 nm	2	859 nm	36 nm

* Dual gain

measurements are not matched in VIIRS. But 6 of the 7 moderate resolution (or radiometric) bands have dual gains, which permits their use over both land and ocean. Thus bands M3 and M4 are part of the essential set of ocean color bands and they fulfill the role of MODIS bands 3 and 4, the 500-meter land imaging bands. VIIRS imaging bands I1 and I2 provide the functionality of the high-resolution MODIS bands 1 and 2. Spatial resolution of the VIIRS and MODIS bands are compared in Table 4.

In the short-wave and mid-wave infrared (SWIR/MWIR) 11 MODIS bands have been replaced by 8 VIIRS bands. See Table 2. One of them, I3 duplicates the wavelength of M10 but with higher spatial resolution and lower radiometric accuracy so that effectively only 7 VIIRS bands provide unique spectral information. The reduction in the number of bands is met through the dropping MODIS bands 24, 25, 27 and 28, which are used for atmospheric sounding. On NPP and NPOESS, the sounding EDRs are assigned to the Cross-track Infrared Sounder (CrIS). Additionally, MODIS band 22 at 3.96m is replaced by VIIRS band M12, the analog of MODIS band 20 at 3.75μ. The combination of bands at 3.75μ and 4.05μ are similar to the MODIS approach to MWIR sea surface temperature retrieval. Dual gain capability of M13 allows VIIRS to match the role of MODIS band 21 for fires.

In the long wave infrared (LWIR) region 8 MODIS bands are replaced by 4 VIIRS bands. See Table 3. The primary difference is due to the absence of sounding bands (MODIS 31-36 (13.2-14.1μ) on VIIRS since that capability is met by CrIS. Additionally, the ozone band (MODIS band 30 at 9.58μ) is not needed since that data is available from a variety of other sources. The SST bands on VIIRS are significantly broader than those on MODIS.

Table 2 SWIR/MWIR Bands Compared

VIIRS			MODIS		
Band Name	Band Ctr	Band Width	Band #	Band Ctr	Band Width
M8	1.24 μ	0.020 μ	5	1.24 μ	0.020 μ
M9	1.378 μ	0.015 μ	26	1.375 μ	0.030 μ
M10	1.61 μ	0.06 μ	6	1.64 μ	0.02 μ
I3	1.61 μ	0.06 μ	NA		
M11	2.25 μ	0.05 μ	7	2.13 μ	0.05 μ
M12	3.70 μ	0.18 μ	20	3.75 μ	0.18 μ
I4	3.74 μ	0.38 μ	NA		
M13*	4.05 μ	0.16 μ	21	3.96 μ	.06 μ
			23	4.05 μ	0.06 μ

* Dual gain

Table 3 LWIR Bands Compared

VIIRS			MODIS		
Band Name	Band Ctr	Band Width	Band #	Band Ctr	Band Width
M14	8.55 μ	0.3 μ	29	8.55 μ	0.3 μ
M15	10.8 μ	1.0 μ	31	11.03 μ	0.5 μ
M16	12.0 μ	1.0 μ	32	12.02 μ	0.5 μ
I5	11.5 μ	1.9 μ			

III. SPATIAL AND GEOMETRIC PROPERTIES

Table 4 shows that the intrinsic spatial resolution of VIIRS at nadir is generally better than that of MODIS.

Table 4 Spatial Resolutions Compared

VIIRS		MODIS	
Band Name	GSD (m) Nadir	Band #	GSD (m) Nadir
M1	742	8	1,000
M2	742	9	1,000
M3	742	10	1,000
		3	500
M4	742	12	1,000
		4	500
I1	371	1	250
M5	742	13	1,000
M6	742	15	1,000
M7	742	16	1,000
I2	371	2	250
M8	742	5	500
M9	742	26	1,000
M10	742	6	500
I3	371		
M11	742	7	500
M12	742	20	1,000
I4	371		
M13	742	21	1,000
	742	23	1,000
M14	742	29	1,000
M15	742	31	1,000
M16	742	32	1,000
I5	371		

VIIRS uses a pixel aggregation scheme based on a very small instantaneous field of view (262m x742m at nadir for the moderate resolution bands), resulting in less integration drag than found in MODIS. See Table 4.

The pixel aggregation reduces the pixel growth such that at edge of scan (1,500 km from nadir) the 742 m pixels will be 1.6 km x 1.6 km. MODIS 1 km nadir pixels grow to 2 km by 6 km at edge of scan (1,150 km from nadir).

Both MODIS and VIIRS data can be geolocated to ±200 m (3σ) with post processing. Band-to-band co-registration is better than 0.2 pixels.

IV. RADIOMETRIC PROPERTIES

Signal to noise is generally comparable between MODIS and VIIRS. Table 5 shows the specification for VIIRS and MODIS at nadir. VIIRS values reflect the aggregation of 3 pixels. Note that no adjustment has been made for differing pixel sizes.

Radiometric resolution is also similar, with both sensors transmitting 12-bit digitization and using similar values for maximum radiances. On-board calibration is nearly identical, with both sensors utilizing a single black body source, a solar diffuser and a solar diffuser stability monitor. The extensive on-board Spectral Radiometer and Calibration Assembly (SRCA) found on MODIS is not on VIIRS.

V. CONCLUSION

Other design features of interest include the use of a rotating telescope in place of the large MODIS paddle-wheel scan mirror, a greatly reduced parts count, and all reflective fore-, relay- and aft-optics.

Table 5 Signal to Noise

VIIRS				MODIS	
Band Ctr	**Gain**	L_{typ} T_{typ}	**SNR**	L_{typ} T_{typ}	**SNR**
412	High	45	764	45	880
	Low	200	1781		
445	High	40	977	42	838
	Low	56	2456		
488	High	32	1067	32	803
	Low	52	3050	35	243
555	High	21	932	21	750
	Low	29	3275	29	228
645	Single	22	335	22	129
672	High	10	645	10	914
	Low	22	3346		
751	Single	10	557	10	600
865	High	6	864	6	517
	Low	25	3714	25	201
865	Single	25	435	25	201
1.24	Single	5	228	5	74
1.378	Single	6	257	6	150
1.61	Single	7	867	7	270
1.61	Single	7	149		
2.25	Single	0	26	1	111
3.74	Single	270	146	300	470
3.74	Single	270	46		
4.05	High	300	894	300	364
	Low	380	1035		
8.55	Single	270	1628	300	1066
10.8	Single	300	2233	300	1362
12.1	Single	300	2428	300	1475
11.45	Single	210	91.7		

VIIRS represents the first step in converting EOS-era state-of-the art research sensors into operational sensors that can serve the needs of both the operational and research communities. It is a significant step forward in NASA's plans to maintain needed systematic measurements and to fulfill its role to inject technology into the NPOESS at appropriate times.