Early Performance Predictions of Imagery, Cloud Mask, and Fire Mask Data Products for the NPOESS Preparatory Project VIIRS Sensor

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The VIIRS flight sensor for the NPOESS Preparatory Project (NPP) is now undergoing its final pre-launch characterization and calibration. The NPOESS Integrated Program Office (IPO) Data Products Division (NDPD) has generated the performance assessments for the Imagery Environmental Data Record (EDR), Cloud Mask, and Fire Mask of the Visible/Infrared Imaging Radiometer Suite (VIIRS). The Cloud and Fire Masks are not EDRs, but will be delivered products available to users. The Imagery EDR is a Key Performance Parameter of the NPOESS program.

The EDR Assessments were developed by the NDPD in consultation with subject matter experts from government labs and universities to collect and track algorithm development status and expected performance against contractual specifications and applicability to user missions.

This poster summarizes the Imagery, Cloud Mask, and Fire Mask assessments and provides an overview of these NPP data products. For each algorithm, the current best estimate, performance drivers, watch items, and mitigation strategies are presented.

The NPP EDR Assessments are used to capture and communicate algorithm issues and expected performance to the Program stakeholders and will be updated as sensor testing and algorithm development continue.

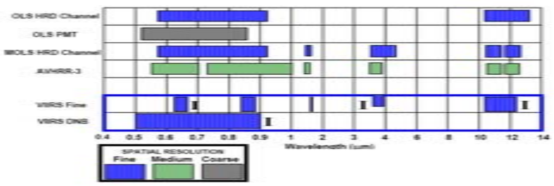
The VIIRS Fire Mask provides information on fire location, and the Cloud Mask provides information on cloud and cloud shadow location, presence of heavy aerosol, and cloud phase. We predict that the VIIRS Imagery and Cloud Mask products will approach equivalent quality as is currently obtained with the MODIS products. Due to sensor limitations, the fire mask will not achieve MODIS performance.

Imagery

Algorithm Overview

The NPP Imagery Data Products consist of the Environmental Data Record (EDR) and the Application Related Products (ARPs). The Imagery EDR is defined as two products: a two-dimensional array of locally averaged absolute in-band radiances at the top of the atmosphere measured in the direction of the viewing sensor; and the corresponding array of Equivalent Black Body Temperatures if the band is primarily emissive, or the corresponding array Top-Of-the Atmosphere (TOA) reflectances if the band is primarily reflective during daytime. The Imagery EDR applications, or ARPs, are based on NPOESS data, but are not NPOESS products. The ARPs include:

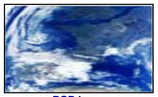
(1) Manually Generated Cloud Data are estimates of cloud cover and cloud type generated by a human analyst viewing the unprocessed and/or processed imagery, e.g., by data fusion, spatial rescaling, image enhancement, etc.
(2) Cloud cover is defined as the fraction of a given area on the Earth's surface for which a locally normal line segment extending between two given altitudes intersects a detectable cloud.
(3) Cloud Type are identifiable from the imagery products and include: Altocumulus, Altostratus, Cirrocumulus, Cirrocumulus (standing lenticular), Cirrostratus, Cirrus, Cumulonimbus, Cumulus, Towering Cumulus, Stratocumulus, Stratocumulus (standing lenticular), Stratus, Obscured/not cloudy, and Clear.



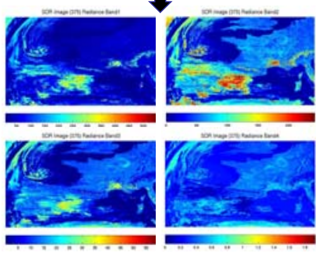
The VIIRS SDR TOA radiances, reflectance and brightness temperatures for all I-Bands, six M-Bands, and DNB

Predicted Performance

NGST estimates that nearly all Imagery attributes will meet specification. Radiometric performance of the imagery bands exceeds uncertainty specifications with margin for performance of Imagery Application-Related Products (ARPs). The performance quality is directly related to sensor characterization and calibration post launch. The impact of FM1 astigmatism on spatial resolution at extreme edge of scan is problematic and needs to be characterized. Verification is not possible pre-launch due to lack of quantitative truth data. Image banding and striping is expected at a level similar to previous missions (e.g., MODIS) and will need to be mitigated post-launch.



RGB Image



VIIRS I-Band Radiance for I1-I4 Test Scene: 2003081.1300

Imagery EDR Specification

EDR/Attribute	Appendix D Specification
Visible and Infrared Imagery Spectral Bands	
1. Visible Daytime/Nighttime Band (DNB)	0.50 - 0.90 mic, Nominal
2. I1 Band (Daytime Visible)	0.60 - 0.68 mic, Nominal
3. I2 Band (Imagery Application Enhancement)	0.8455 - 0.8845 mic, Nominal
4. I3 Band (Imagery Application Enhancement)	1.58 - 1.64 mic, Nominal
5. I4 Band (MWIR)	3.55 - 3.93 mic, Nominal
6. I5 Band (LWIR)	10.5 - 12.4 mic, Nominal
Horizontal Spatial Resolution (HSR)	
1. Nadir, Bands I1, I2, I3, I4, and I5	0.4 km
2. Edge of Swath, Bands I1, I2, I3, I4, and I5	0.8 km
3. DNB, Worst Case	0.8 km
Horizontal Reporting Interval	Imagery HSR
Horizontal Coverage	Global
Measurement Range	
1. DNB (Day and Night)	3E-5 - 200 W/(m^2 sr)
2. I1 Band (Daytime Only)	5.0 - 718 W/(m2 sr mic)
3. I2 Band (Daytime Only)	12.4 - 291W/(m2 sr mic)
4. I3 Band (Daytime Only)	1.5 - 47.2 W/(m2 sr mic)
5. I4 Band (Day and Night)	210 K - 353 K
6. I5 Band (Day and Night)	190 K 340 K
Measurement Uncertainty	Derived
Measurement Uncertainty, 3 Sigma	
1. Nadir, Visible and IR Imaging Bands on VIIRS Native Swath	0.4 km
2. Edge of Swath, Visible and IR Imaging Bands on VIIRS Native Swath	1.5 km
Maximum Local Average Revisit Time	
1. Visible and Infrared Imaging Bands	6.0 hrs
Maximum Local Refresh, Visible and Infrared Imaging Bands	6.0 hrs (TBR)
Fraction of revisit times less than a specified value, Visible and Infrared Imaging Bands	At any location at least 75% of the revisit times shall be 6 (TBR) hours or less
Latency	NPP - 140 min NPOESS - 28min
Revisit time exclusion if there is not an NPOESS spacecraft in each of the 2 nominal orbits.	

Imagery ARP Specification

ARP Attribute	Appendix D Specification
Cloud Cover	
Horizontal Cell Size [VIIRS Guarantee]	3 time HSF (1.2 km at Nadir)
Horizontal Reporting Interval [VIIRS Guarantee]	Horizontal Cell Size
Measurement Range [VIIRS Guarantee]	0 - 1, 0.1 Increments
Measurement Uncertainty [VIIRS Guarantee]	0.1
Cloud Type	
Horizontal Cell Size [VIIRS Guarantee]	3 time HSF (1.2 km at Nadir)
Horizontal Reporting Interval [VIIRS Guarantee]	Horizontal Cell Size
Measurement Range [VIIRS Guarantee]	14 Cloud Types
Probability of Correct Typing [VIIRS Guarantee]	85%
Ice Edge Location	
Horizontal Coverage [VIIRS Guarantee]	North of 36 deg North Latitude, South of 50 deg South Latitude for Sea Ice
Measurement Range [VIIRS Guarantee]	Any Latitude, Longitude Within Horizontal Coverage
Measurement Uncertainty	
1. Clear, Nadir [VIIRS Guarantee]	0.4 km
2. Clear, Worst Case [VIIRS Guarantee]	1.0 km
Degraded Clear Measurement Condition, Worst Case: Thermal Contrast 1K (TBR) to 2.2K Between Ice and Open Water [VIIRS Degradation]	2.0 km (TBR during EMD)
Excluded Clear Measurement Conditions: [VIIRS Limitation]	
1. Thermal Contrast < 1 K (TBR) Between Ice and Open Water	
2. Aerosol Optical Thickness > 1.0	
Ice Concentration	
Horizontal Coverage [VIIRS Guarantee]	North of 36 deg North Latitude, South of 50 deg South Latitude for Sea Ice
Measurement Range [VIIRS Guarantee]	0 - 1 HCS Area, 0.1 Increments
Measurement Uncertainty [VIIRS Guarantee]	0.1

VIIRS Cloud Mask IP

Algorithm Overview

The VIIRS Cloud Mask Intermediate Product algorithm performs cloud detection at both the imagery and moderate resolutions. The cloud detection involves a series of thresholding and ratioing tests using solar reflectances. It also involves thresholding and differencing tests using thermal Brightness Temperatures. The threshold values for various tests depend upon the dominant regional classification, or surface type, of the pixel to be tested.

The binary cloud mask product classifies pixels as Confidently Clear, Probably Clear, Probably Cloudy, and Confident Cloudy.

The cloud phase analysis designates opaque cirrus, cirrus, mixed phase, water cloud, overlap, partly cloudy, and clear at the pixel-level. Additional pixel level information includes the presence of heavy aerosol and cloud shadow.

VIIRS Bands used in VCM Processing

VIIRS Band	Wavelength (µm)	Equivalent MODIS Band
M1	0.412	0.412
M5	0.672	0.667
M7	0.865	0.869
M9	1.378	1.375
M12	3.7	3.75
M13	4.05	4.05
X	X	6.7
M14	8.55	8.55
M15	10.7625	11.03
M16	12.0125	12.02
X	X	13.7
X	X	13.9
X	X	14.2

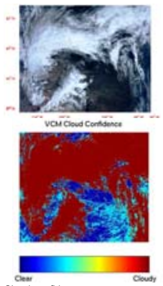
No VIIRS Equivalent

VIIRS Tests vs. Processing Paths

		Day					Night				
Type Cloud Test	Bands Used	Snow/Ice	Water	Land	Desert	Coast	Snow/Ice	Water	Land	Desert	Coast
Cirrus Detection	Ref M9	X	X	X	X	X					
Cirrus Detection	BTM15-BTM16		X	X	X	X		X	X	X	X
IR Threshold	BTM15						X	X	X	X	X
High Cloud	BTM12-BTM16						X		X	X	X
IR Temp Diff	BTM14-BTM15 & BTM15-BTM16		X					X			
Temp Diff	BTM15-BTM12	X	X	X	X	X	X	X	X	X	X
Temp Diff	BTM12-BTM13	X	X	X							
Vis Refl	RM5			X		X					
Vis Refl	RM1				X						
Vis Ratio	RM7/RM5		X	X							
Vis Refl	RM7		X								

Predicted Performance

All NGST and Government analyses indicate good performance for cloud detection and cloud phase and all pixel-level products are expected to meet performance needs. There are no important sensitivities to the FM1 cross-talk issues. The lack of a 6.7 µm water vapor band and CO2 atmospheric bands (design decision during sensor source selection) may reduce performance compared to MODIS in N. Hemisphere snow covered areas but has not been quantified. Performance in the terminator will be challenging and needs to be validated. Global testing and validation is necessary to fully characterize performance and CALIPSO/CloudSat data will provide useful comparisons. Lessons learned from MODIS Collection 6, now under development, will be used to enhance performance where necessary, as the global albedo and emissivity map incorporation greatly enhanced MODIS performance.



Cloud confidence generated by the VIIRS Test Scene: MOD2001.164.1800

VIIRS Active Fires ARP

Algorithm Overview

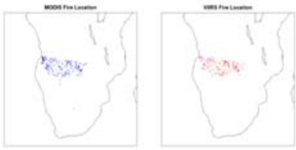
The current implementation of the VIIRS Active Fires ARP includes a "sparse array" fire product consisting of the LAT/LON of fire locations.

Predicted Performance

For NPP, the Program will generate and deliver a "sparse array" fire product. Due to saturation in the M15 (10.76 micron) band and the limitation of the Dozier algorithm for the retrieval of the sub-pixel temperature and area of the fire, the NPOESS specification will not be met.

Active Fire ARP Specification

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size (HCS)	
1. At Nadir	0.75 km
2. Worst Case	1.6 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. Sub-pixel Average Temperature of Active Fire	800 K - 1200 K
2. Sub-pixel Area of Active fire	From 1000 m^2 to 50 m Times Ground Sample Distance in Scan Direction
Measurement Uncertainty	
1. Sub-pixel Average Temperature of Active Fire	50 K
2. Sub-pixel Area of Active Fire when computed for total area of contiguous fires	30%
Mapping Uncertainty, 3 Sigma	1.5 km
Maximum Local Average Revisit Time	6 hrs
Latency	NPP - 140 min NPOESS - 28 min
Exclude Measurement Condition	
Aerosol Optical Thickness > 1.0	



Chain Test Result for VIIRS Active Fire ARP - Comparison of MODIS and VIIRS Fire Pixel location for granule 2003194_0905

The IPO is investigating alternative approaches to generate and provide a fire product to meet the fire community needs. This includes developing and evaluating an active fire algorithm suitable for the VIIRS instrument, based on the instrument specifications and pre-launch instrument performance results, developing and testing code which would be used to generate a VIIRS product and preparing for running the code on real VIIRS data.

Image Source:
http://rapidfire.sci.gsfc.nasa.gov/gallery/?2008321-1116/California.A2008321.1930.1km.jpg
2008/321 - 11/16 at 19 :30 UTC
Fires in southern California

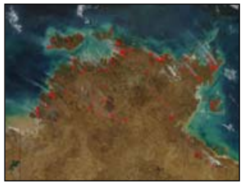


Image Source:
http://rapidfire.sci.gsfc.nasa.gov/gallery/?2008230-0817/Australia.A2008230.0440.1km.jpg
2008/230 - 08/17 at 04 :40 UTC
Fires in northern Australia