Early Performance Predictions of Land and Snow/Ice Environmental Data Records 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 Land Environmental Data Records (EDRs) of the Visible/Infrared Imaging Radiometer Suite (VIIRS). The VIIRS Land EDRs include the Land Surface Temperature (LST), Vegetation Index (VI), Surface Albedo, Surface Type (ST), Ice Surface Temperature (IST), Sea Ice Characterization (SIC), and Snow Cover. The VIIRS Land Surface Reflectance product is an Intermediate Product (IP) and is included with the EDRs because of its importance in generating downstream Land products.

The EDR Assessments were developed by the NDPD and NPP Government Customers to collect and track algorithm development status and expected performance against contractual specifications and applicability to user missions.

This poster summarizes the land assessments and provides an overview of the NPP land data products and the predicted performance for each EDR.

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.

Early predictions are that the VIIRS land products will perform at an equivalent quality as is currently obtained with the MODIS land products since the spectral, spatial, and radiometric characteristics of the VIIRS and MODIS are equivalent.

Surface Albedo

Algorithm Overview

Surface albedo is the total amount of solar radiation in the 0.4 to 4.0 micron band reflected by the Earth's surface into an upward hemisphere (sky dome), including both diffuse and direct components, divided by the total amount incident from this hemisphere, including both direct and diffuse components. The VIIRS Surface Albedo product is produced during daytime only and under clear conditions only.

The VIIRS Surface Albedo algorithm is composed of two sub-algorithms, the dark pixel sub-algorithm (DPSA) and the bright pixel sub-algorithm (BPSA). The DPSA is based on the MODIS approach, and is used for all dark surfaces, including most vegetation and water and the BPSA is a regression approach, and is used for all bright surfaces, including snow, desert, and many instances of bare soil.

Predicted Performance

VIIRS FM1 sensor performance issues (VisNIR cross-talk, gain-switch noise) not expected to be problems for this product, but this has yet to be demonstrated.

The MODIS Bidirectional Reflectance Distribution Function (BRDF) kernels is the default option for this product. However, multiple BRDF kernels will be evaluated during Cal/Val if NPOESS specification of performance is not met. The MODIS single-model paradigms for this product is used as a back-up.

High fidelity VIIRS FM1 proxy data for likely on-orbit sensor not yet run through code for this product.

The community desires narrow band albedo which is not presently distributed.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Reporting Interval	
1. Edge of Swath	1.6 km
2. Nadir	0.75 km
Horizontal Cell Size	4 km (TBR)
Horizontal Coverage	Global
Measurement Range	0 - 1.0 Units of Albedo
Measurement Accuracy	0.03 Units of Albedo
Measurement Precision	0.02 Units of Albedo
Long Term Stability	0.01 Units of Albedo
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	24 hrs, Daytime and Clear Only
Latency	NPP - 150 min.
	NPOESS - 28 min.
Degraded Measurement Conditions:	
1. Measurement Accuracy If Solar Zenith Angle 65 to 85 deg	0.04 Units of Albedo
2. Measurement Precision If Solar Zenith Angle 65 to 85 deg	0.04 Units of Albedo
3. Over Ocean, the ratio of the Rayleigh-corrected radiance of Band M2 to Band M4 is greater than or equal to 0.95 (TBR).	0.1 Units of Albedo (TBR)
4. Regions containing sea ice	0.3 Units of Albedo (TBR)
Excluded Measurement Conditions:	
1. Solar Zenith Angle > 85 deg	
2. Aerosol Optical Thickness > 1.0	
3. With scattering error greater than what would exist at a point 6 milliradians away from the VIIRS Bright	

Land Surface Temperature

Algorithm Overview

Land surface temperature is defined as the skin temperature of the uppermost layer of the land surface. The VIIRS LST EDR is retrieved on all land pixels under all conditions except for "confidently cloudy" categorized by the cloud mask. This EDR also provides temperature measurements for inland (navigable waters) and coastal water regions, and snow-covered land ice surfaces.

The VIIRS dual split window day/night LST algorithm establishes one equation to each International Geosphere-Biosphere Programme (IGBP) surface type by using 4 Moderate Resolution VIIRS brightness temperatures at 10.8, 12, 3.75, and 4.005 mm (M12, M13, M15, and M16), and a solar zenith angle correction during the daytime. In sun glint regions, the fullback split window algorithm is employed
using only M15 and M16.

Predicted Performance

The Land Surface Temperature algorithm performs adequately against synthetic truth surface temperature, however, there is a concern among the science community that additional testing of algorithm land cover classifications with an independent, validated land surface emissivity product needs to be performed.

Measurement Accuracy has been met with synthetic test data.

Measurement Precision specification of 0.5K is considered unattainable given current state of available land emissivity models.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Nadir	0.75 km
2. Edge of Swath	1.3 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	213 K - 343 K
Measurement Accuracy	2.4 K
Measurement Precision	0.5 K
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	6 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Clear Measurement Precision Degradation Condition: Satellite Zenith Angle greater than 40 degrees	1.5 K (TBR)
Excluded Measurement Condition:	
1. Aerosol Optical Thickness > 1.0	
2. Thin cirrus as indicated by Cloud Mask Think Cirrus Flag	
3. Fire as indicated by Cloud Mask Fire Flag	

Surface Type

Algorithm Overview

At the global scale, the VIIRS Surface Type algorithm will exploit the VIIRS spectral and temporal information to separate the 17 IGBP surface types. The Surface Type EDR algorithm, itself, is very simple. It consists of extracting:

1. Surface type according to the Quarterly Surface Types IP, snow mask and fire masks,
2. Computing the Green Vegetation Fraction, which uses the internally computed Vegetation Index.

The VIIRS Surface Type algorithm executes (1) Over Land, (2) under Daytime (3) and Cloud Free Conditions.

Predicted Performance

The Surface Type algorithm performs well against test data and test results indicate the NPOESS System can deliver Surface Type to specified parameters.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	1 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. Vegetation/Surface Type	17 Types
2. Vegetation Cover	0 - 100 %
Measurement Accuracy (Vegetation Cover)	20%
Measurement Precision (Vegetation Cover)	10%
Correct Typing Probability (Vegetation /Surface Type)	70%
Mapping Uncertainty, 3 Sigma	1.5 km
Max Time Between Local EDR Updates	24 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Excluded Measurement Condition: Aerosol Optical Thickness > 1.0	

Vegetation Index

Algorithm Overview

The VIIRS Vegetative Index EDR produces a top-of-atmosphere (TOA) Normalized Difference Vegetation Index (NDVI) and a top-of-canopy (TOC) Enhanced Vegetation Index. The TOA NDVI calculation uses the traditional NDVI formulation with TOA reflectance inputs. To develop the NDVI data product, the algorithm will combine inputs from reflectances acquired by the VIIRS 375 m resolution bands in the red part of the visible range (I1; 600 – 680 nm) and in the near infrared (I2; 845 – 885 nm). The TOC Enhanced Vegetation Index is computed utilizing a combination of 375 m resolution bands 640 nm and 865 nm (I1 and I2) and one 750 m resolution band, M3 (478 - 498 nm).

Predicted Performance

Expected VIIRS FM1 sensor performance issues with cross-talk has small impact on Vegetation Index.

NPP System can deliver Top of Atmosphere Vegetation Index to specification, however, the Top of Canopy Enhanced Vegetation Index may not meet NPOESS specification due to Aerosol Optical Thickness uncertainties.

Expect some degradation from MODIS product to VIIRS product due to larger I1 band width compared to MODIS B1.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Edge of Swath	0.8 km
2. Nadir	0.375 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. NDVI Units	-1 to +1
2. EVI Units	-1 to +1
Measurement Accuracy	0.016 NDVI Units
Measurement Precision	0.02 NDVI Units
Long Term Stability	0.01 NDVI Units
Mapping Uncertainty, 3 Sigma	
1. Nadir	0.4 km
2. Edge of Swath	1.5 km
Max Local Average Revisit Time	24 hrs, Daytime Only
Measurement Uncertainty for EVI	0.11 Units of EVI
Long Term Stability	0.01 NDVI Units
Latency	NPP - 140 min.
	NPOESS - 28 min.
Measurement Degradation Conditions:	
1. EVI Measurement Uncertainty if Solar Zenith Angle 65 to 85 deg	0.2 EVI Units
Measurement Exclusion Conditions:	
1. Solar Zenith Angle > 85 deg, for both NDVI and EVI	
2. Aerosol Optical Thickness > 1.0, for EVI	

Land Surface Reflectance IP

Algorithm Overview

The surface reflectance IP is the key product for the many land products including vegetation index EDR, surface albedo EDR and IP and surface type EDR and IP. It depends on the active fire mask, the cloud mask IP, the aerosol optical thickness IP, the aerosol model IP, and ingests water vapor data from NCEP or NOGAPS, column ozone from NCEP or OMPS, surface pressure from NCEP or NOGAPS.

This algorithm is based currently on a Lambertian approximation of the surface reflectance and therefore works on a pixel-by-pixel basis. For each pixel, an atmospheric correction is applied to the top of the atmosphere reflectance. The surface reflectance is then inferred from the part of the top of the atmosphere signal due to the Lambertian surface.

Predicted Performance

The NGST System Specification does not have a specific requirement for the Surface Reflectance IP. However, derived requirements on Surface Reflectance can be inferred from EDRs that depend on it which are the Surface Albedo EDR and the Vegetation Index EDR. The NPOESS IPO and Land Subject Matter Experts are currently assessing the performance of the Land Surface Reflectance IP and it's impact on dependent EDRs.

Ice Surface Temperature

Algorithm Overview

The VIIRS Ice Surface Temperature processing algorithm derives surface temperatures in 750 m resolution over snow-covered sea ice pixels as indicated by VIIRS Ice Concentration IP under all conditions, except for confidently cloudy. The VIIRS algorithm is a regression technique and employs a two-band split-window water vapor correction method using brightness temperatures from two 750 m resolution bands in the LWIR, 10.76 and 12.01 microns (M15 and M16).

Predicted Performance

The Ice Surface Temperature algorithm is sensitive to errors in the Ice concentration IP and the VIIRS Cloud Mask IP. These errors remain to be fully assessed.

Current performance assessment shows that there is good correlation between the VIIRS and MODIS Ice Surface Temperature results, with small bias explained by using VIIRS IST algorithm regression coefficients trained on VIIRS synthetic data with brightness temperatures obtained from MODIS data.

Expect IST EDR performance to improve when the regression coefficients are retrained using newly developed global synthetic data specifically constructed for training and testing the IST and LST algorithms.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size (HCS)	
1. Nadir	0.8 km
2. Worst Case	1.6 km
Horizontal Reporting Interval	1.0 km
Horizontal Coverage	Ice-covered Oceans
Measurement Range	213 K - 275 K
Measurement Uncertainty at Horizontal Reporting Interval	0.5 K
Mapping Uncertainty, Nadir, 3 Sigma	0.4 km
Maximum Local Average Revisit Time	24 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Measurement Exclusion Condition:	
1. Aerosol Optical Thickness > 1.0	
2. Inland waters	
3. Coastal waters	
4. Thin cirrus as indicated by Cloud Mask Thin Cirrus Flag	

Sea Ice Characterization

Algorithm Overview

The VIIRS Sea Ice Characterization EDR provides ice age information. Sea Ice Age is defined as the time that has passed since the formation of the surface layer of an ice covered region of the ocean. The categories of Sea Ice Age are (1) Ice-free, (2) New/Young, and (3) All Other Ice.

Predicted Performance

Sea Ice Concentration is expected to perform as well as the MODIS Sea Ice product.

Sea Ice Age specified performance for Probability of Correct Typing (New/Young and All Other Ice) requires algorithm enhancements to phenomenology models.

Government assessment shows algorithm cross-talk exists between ice concentration and ice characterization calculations due to similar reflectance and radiometric characteristics of pixels with low-concentration ice and pixels with new/young ice.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size (Ice Age)	
1. Clear	2.4 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Oceans
Measurement Range	
1. Ice Age Classes, Clear	Ice-free, New/Young ice, All other ice
Probability of Correct Typing (Ice Age)	
1. Ice-free	70%
2. New/Young	70%
3. All other ice	70%
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	24 hrs
Latency	NPP - 150 min.
	NPOESS - 8 hr
Degraded Clear Measurement Condition for Probability of Correct Typing: [VIIRS Degradation]	
1. Thermal Contrast 1.5 K (TBR) to 2.2 K Between Ice and Open Water	60% (TBR)
2. Snow Fall 6 cm to 10 cm (TBR)	60% (TBR)
Excluded Clear Measurement Condition for Probability of Correct Typing:	
Thermal Contrast < 1.5 K (TBR) Between Ice and Open Water	
Snow Fall > 10 cm (TBR)	
Aerosol Optical Thickness > 1.0	
Sun Glint	

Snow Cover

Algorithm Overview

The VIIRS Snow Cover EDR provides the horizontal extent of snow cover. Additionally Snow Fraction and Binary Snow/No Snow products will be produced. The algorithm will execute under Confidently Clear, probably clear, and probably cloudy conditions.

Predicted Performance

The VIIRS Snow Cover/Depth algorithm is expected to behave similarly to the MODIS Level2 product, however, the MODIS product includes sub-pixel snow fractional coverage and the VIIRS EDR does not provide this data.

The total probability of correct typing for all tests is predicted to meet the VIIRS system specification requirement of 95% for the VIIRS snow cover binary map EDR.

The VIIRS snow fraction algorithm performance tests indicate that the snow fraction algorithm does not meet the 10% snow fraction uncertainty requirement.

EDR Specification Table

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Nadir	0.8 km
2.Edge of Swath	1.6 km
Horizontal Reporting Interval	HCS
Snow Depth Ranges	Snow/No Snow
Horizontal Coverage	Land
Measurement Range	0 - 100% of HCS
Measurement Uncertainty	10% of HCS (Snow/No Snow)
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	24 hrs Daytime Only
Binary HCS	
1. Nadir	0.4 km
2. Edge Of Swath	0.8 km
Long Term Stability	10%
Latency	NPP - 140 min.
	NPOESS - 28 min.
Binary Map- Measurement Range	Snow/No Snow
Binary Map- Probability of Correct Typing	90%
Measurement Uncertainty Degradation If Solar Zenith Angle 70 to 85 deg	40% of HCS (Snow/No Snow)
Measurement Exclusions:	
1. Snow Fraction Measurement Exclusion Condition: Horizontal Cell Contains Forest Canopy	
2. Binary Map Probability of Correct Typing Exclusion Condition: Snow Fraction 0.2 to 0.7 or Solar Zenith Angle > 60 deg	
3. All Measurements If Aerosol Optical Thickness > 1.0	
4. All Measurements If Solar Zenith Angle > 85 deg	