NDE SNPP VIIRS
Green Vegetation Fraction (GVF)

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STAR/JPSS Enterprise Algorithms Workshop – NDE Implementation of J1 Products
NCWCP College Park, MD March 30-31, 2016

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- Lessons Learned
- Risks
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Team Members /Users

Team Members

- Marco Vargas (NOAA/STAR)
  Algorithm lead
- Zhangyan Jiang (STAR/AER)
  Algorithm Support
- Hanjun Ding (NOAA/OSPO)
  PAL
- Michael Ek (NOAA/NCEP)
  User readiness
- Weizhong Zheng (NOAA/NCEP)
  User readiness
- Yihua Wu (NOAA/NCEP)
  User readiness
- Walter Wolf (NOAA/STAR)
  AIT Team Lead

Users

- NWS/NCEP/EMC
- NASA SPoRT
- CLASS

VIIRS GVF Requirements Summary

Table 5.5.2 - Green Vegetation Fraction (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
a. Horizontal Cell Size	16 Km	4 Km (global), 1 Km (regional)
b. Vertical Reporting Interval	NS	NS
c. Mapping Uncertainty, 3 Sigma	4 Km	1 Km
d. Measurement Precision		
1. Global	15%	8 %
2. Regional	15%	8 %
e. Measurement Accuracy		
1. Global	12%	5%
2. Regional	12%	5%
f. Measurement Uncertainty		
1. Global	17%	10%
2. Regional	17%	10%
g. Refresh	24 Hours	24 Hours
		v2.5, 1/23/13
Notes:		

Source: Level 1 Requirements Supplement – Final Version: 2.10 June 25, 2014

SNPP VIIRS GVF Algorithm and Products

VIIRS GVF Algorithm

- The VIIRS GVF algorithm is a modified version of the Gutman and Ignatov's (1998) GVF algorithm
- The VIIRS GVF algorithm uses the VIIRS bands I1, I2 and M3 as input
- The VIIRS GVF is derived form EVI

The Green Vegetation Fraction

$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

The Enhanced Vegetation Index (TOC)

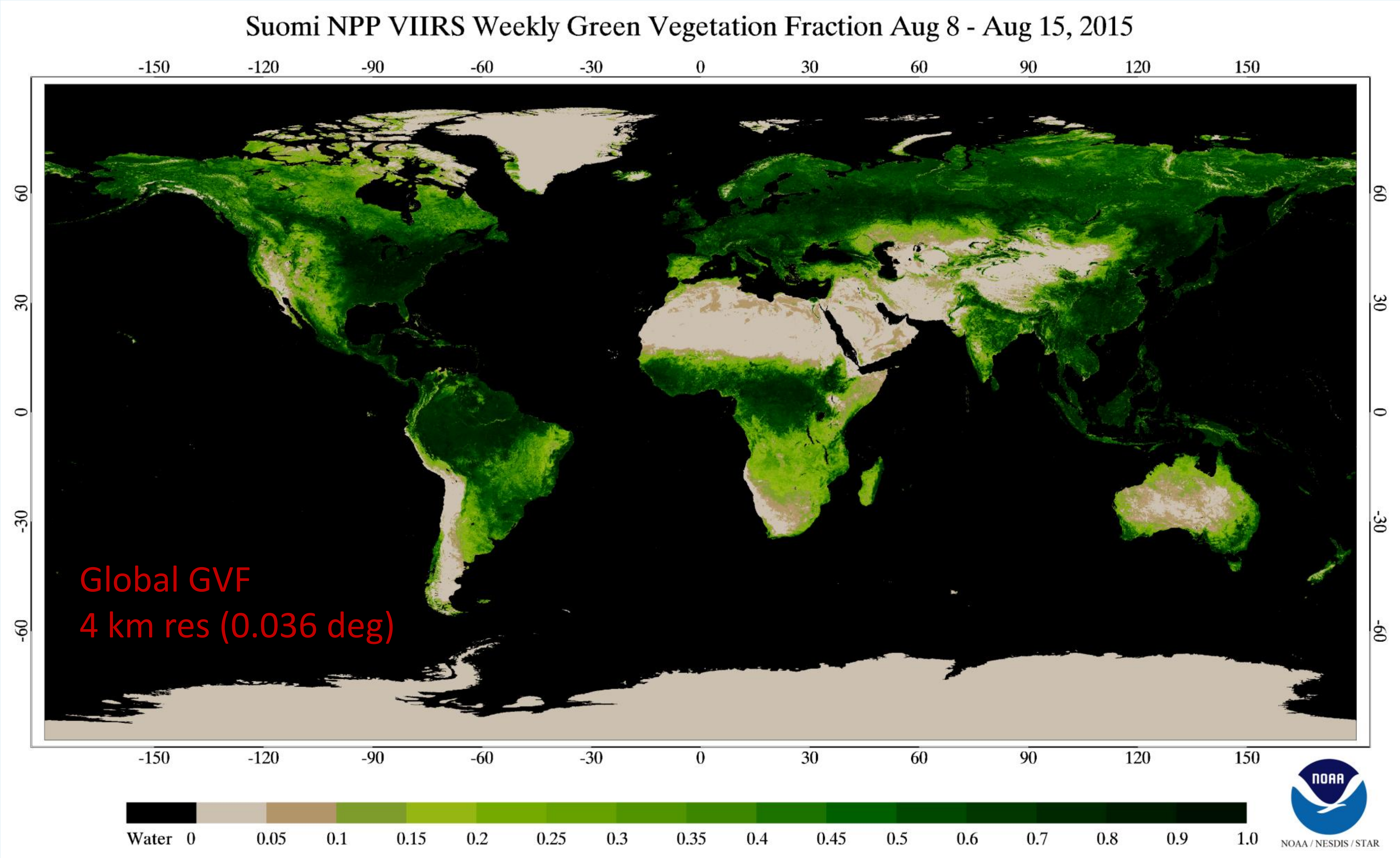
$$EVI = G \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \cdot \rho_{\mathrm{red}} - C_2 \cdot \rho_{\mathrm{blue}} + 1}$$

The SNPP VIIRS GVF system generates two products

1. *Weekly Global GVF at 4 km res*
2. *Weekly Regional GVF at 1 km res*
   (Lat 7.5°S to 90°N, Lon 130°E to 30°E)

- Weekly (updated daily) GVF products are generated in Lat/Lon projection
- Output File Format: NetCDF4
- The GVF product is available at NOAA/CLASS
- The NDE SNPP VIIRS GVF production system was declared operational by the NOAA SPSRB on 02/12/2015
- The user (NOAA/NCEP) wants a 1km resolution Global GVF product

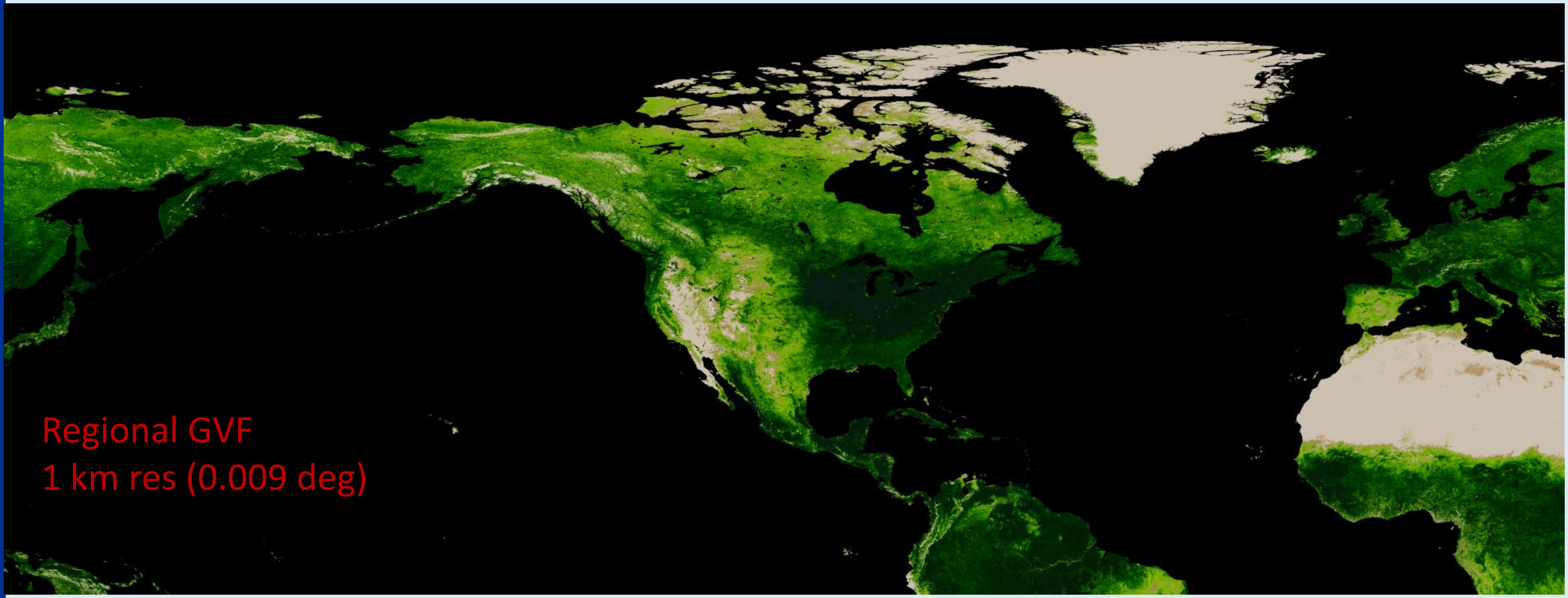
NDE SNPP VIIRS GVF
Current Operational Product



NDE SNPP VIIRS GVF
Current Operational Product

Regional GVF

Coverage: Lat 7.5°S to 90°N, Lon 130°E to 30°E

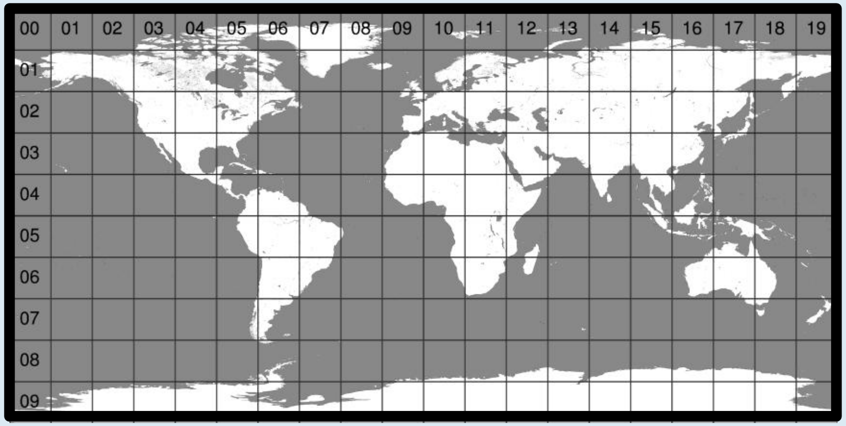


NDE VIIRS GVF Production System

SNPP VIIRS GVF Grid

- The VIIRS GVF grid is divided into square tiles to facilitate parallel computing (faster processing)
- The GVF grid is a set of 200 tiles that are 18 degrees square
- Each 18° x 18° tile has <u>6000 x 6000 grid cells</u> (0.003° pixels)
- The GVF grid provides global coverage in Lat/Lon projection

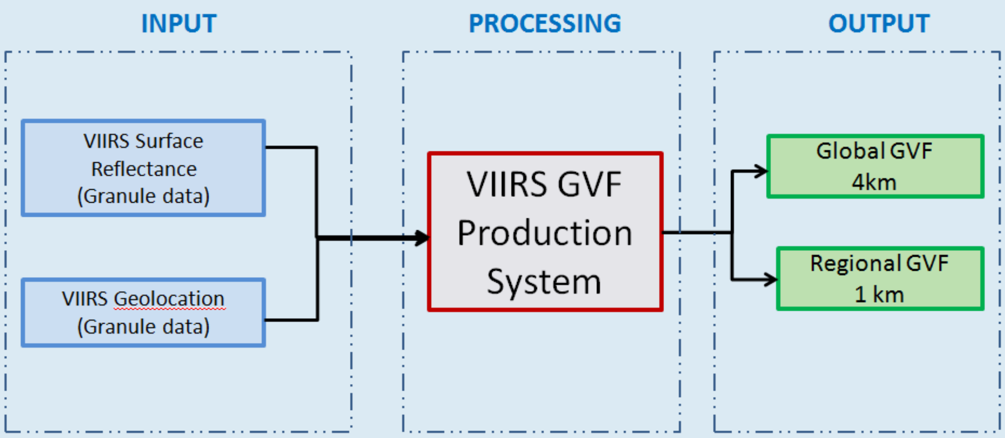
  at 0.003 deg res (0.333 km)

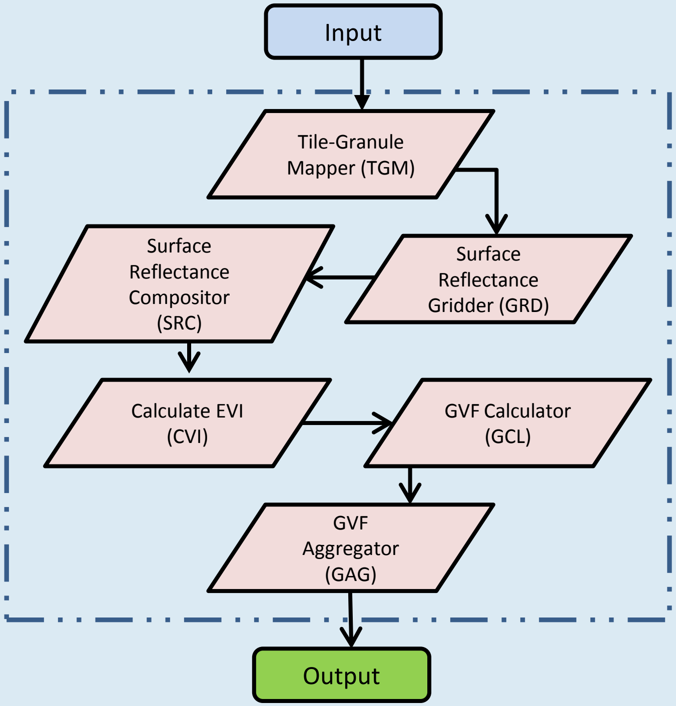


Product Aggregation

- The VIIRS GVF product is generated globally at 0.003° (0.333km)
- GVF is aggregated to 4km (0.036°) for the Global product
- GVF is aggregated to 1km (0.009°) for the Regional product (Lat 7.5°S to 90°N, Lon 130°E to 30°E)

NDE VIIRS GVF Production System High level process flow





The SNPP VIIRS GVF production system consists of 7 software units

1. Tile-Granule Mapper (TGM)
2. Surface reflectance gridder (GRD)
3. Surface reflectance compositor (SRC)
4. Calculate EVI (CVI)
5. Smooth EVI (SVI)
6. GVF calculator (GCL)
7. GVF aggregator (GAG)

GVF Useful Parameter for Biogeophysical Models

- GVF is an important parameter for the Noah land-surface model (LSM), which is coupled with the NOAA weather and climate models that are run at NCEP
- VIIRS GVF provides a better characterization of the surface in the Noah LSM compared to the current AVHRR GVF climatology. All operational NCEP models would benefit, e.g. better forecasts of near-surface winds, temperature, and humidity forecasts
- STAR Land Team members started a collaboration with NCEP EMC to demonstrate that using the new VIIRS GVF instead of the operationally used AVHRR GVF climatology in NCEP NWP models will improve the performance of NOAA’s operational environmental prediction suite

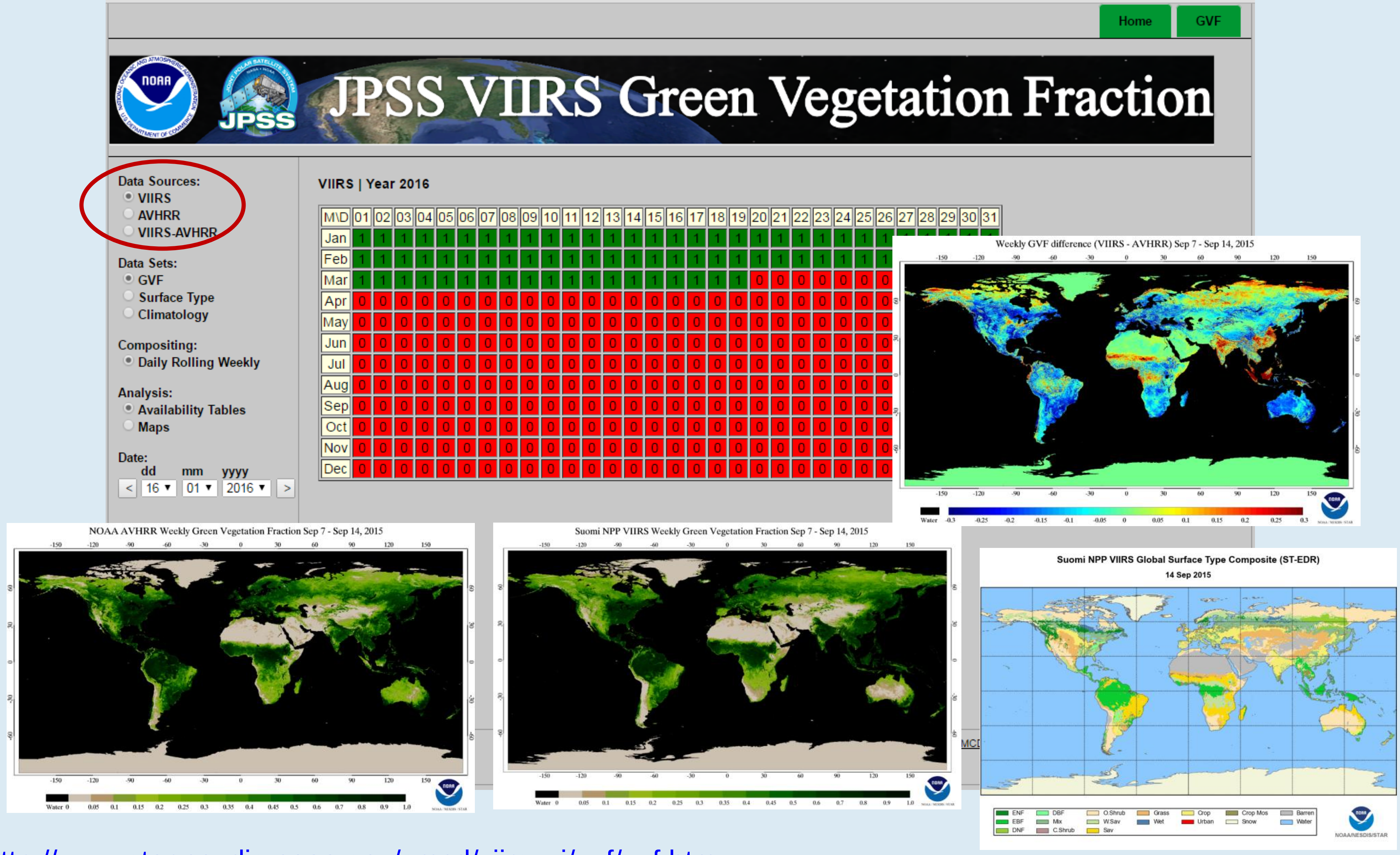
SNPP VIIRS GVF Validation

- GVF product maturity: Provisional
- The SNPP VIIRS GVF product was shown to meet the threshold performance attributes identified in the JPSS Level 1 Requirements Supplement
- SNPP VIIRS GVF pre-operational product was validated against Landsat derived GVF, and compared with AVHRR derived GVF
- Time series stability monitoring

Summary Table (APUs)

Attribute Analyzed	L1RD Threshold	VIIRS GVF
Measurement Accuracy		
1. Global	12%	7.9%
2. Regional	12%	6.5%
Measurement Precision		
1. Global	15%	10.9%
2. Regional	15%	12.6%
Measurement Uncertainty		
1. Global	17%	13.4%
2. Regional	17%	14.2%

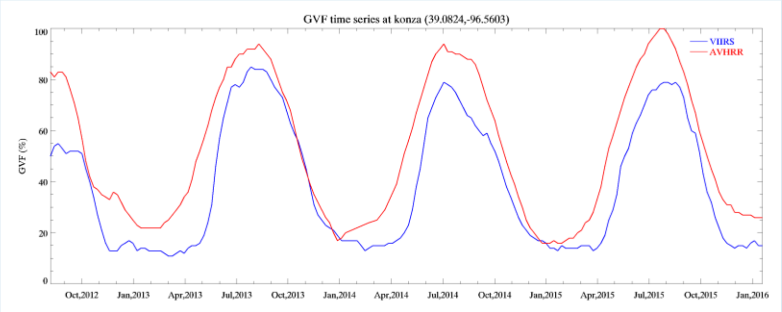
VIIRS GVF Product Validation



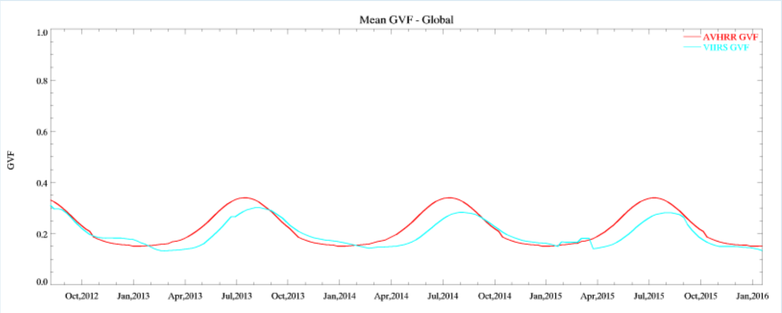
http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm

GVF Time Series and Correlative Analysis Between VIIRS and AVHR

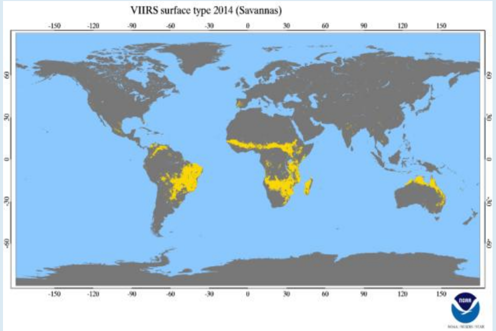
GVF Temporal Trajectories VIIRS vs. AVHRR Konza Validation Site

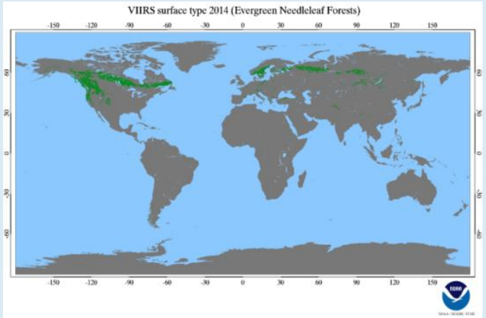


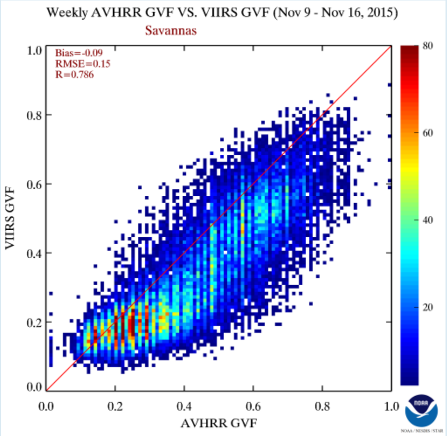
Global GVF Temporal Trajectories VIIRS vs. AVHRR

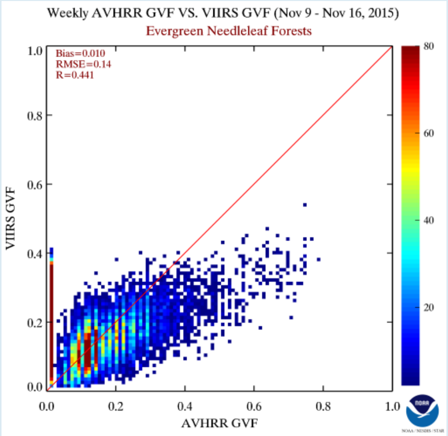


GVF Comparison by Surface Type VIIRS vs. AVHRR









Lessons Learned

- GVF Team members have a good understanding of the transition to operations process within NDE
- GVF product developers interacting closely with the algorithm integrators at NDE reduced the transition to operations time

Risks

- If the VIIRS input data to the GVF product system (and the VIIRS GVF record) are not reprocessed, then the quality of the GVF product will not be sufficient for global change science
- If SNPP fails before JPSS1 is operational, then there will be a gap in the GVF data record

Summary

– The NDE SNPP VIIRS GVF operational system is robust, the GVF product is stable and performing well
– STAR Land Team members are currently working with NCEP EMC to accelerate the use of the operational VIIRS GVF product in their land modeling suite

Recommendation

- Include VIIRS GVF product in the broad Enterprise Algorithm for Vegetation Products

Outstanding issues

- Reprocessing of the VIIRS input data record is necessary to incorporate all the refinements in sensor calibration (VIIRS instrument), and improvements to the upstream algorithms (SDR, VCM, SR, Aerosols)

For more information on SNPP VIIRS GVF

- http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm
- http://www.ospo.noaa.gov/Products
- http://www.star.nesdis.noaa.gov/jpss/
- http://viirsland.gsfc.nasa.gov/Products/GVF.html

References

- Gutman, G., and A. Ignatov (1998). The derivation of the green vegetation fraction from NOAA/AVHRR data for use in numerical weather prediction models. *Int. J. Remote Sensing* 19**,** 1533-1543.

SNPP/JPSS1 VIIRS Vegetation Index EDR Algorithm and Enterprise Algorithm for Vegetation Products

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Tomoaki Miura (University of Hawaii)

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  - Challenges
- Enterprise Algorithm Development
  - Current Operational Product
  - Development Strategy
    - Candidate Algorithms
  - Design/ High level process flow
  - Testing and Validation
  - Schedules and Milestones
- Risks
- Summary and Recommendations

Team Members /Users

Team Members

- Marco Vargas (NOAA/STAR) VI EDR algorithm lead
- Tomoaki Miura (University of Hawaii) VI EDR Cal/Val lead
- Ashley Griffin (ASRC Management Services Inc) Land JAM
- Michael Ek (NOAA/NCEP) User readiness
- Walter Wolf (NOAA/STAR) AIT Team Lead

Users

- NWS/NCEP
- USGS
- USDA

JPSS VI EDR Requirements Summary

Table 5.5.9 - Vegetation Indices (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
Vegetation Indices Applicable Conditions: 1. Clear, land (not ocean), daytime only		
a. Horizontal Cell Size	0.4 km	0.25 km
b. Mapping Uncertainty, 3 Sigma	4 km	1 km
c. Measurement Range		
1. $NDVI_{TOA}$	-1 to +1	NS
2. EVI (1)	-1 to +1	NS
3. $NDVI_{TOC}$	-1 to +1	NS
d. Measurement Accuracy - $NDVI_{TOA}$ (2)	0.05 NDVI units	0.03 NDVI units
e. Measurement Precision - $NDVI_{TOA}$ (2)	0.04 NDVI units	0.02 NDVI units
f. Measurement Accuracy - EVI (2)	0.05 EVI units	NS
g. Measurement Precision - EVI (2)	0.04 EVI units	NS
h. Measurement Accuracy - $NDVI_{TOC}$ (2)	0.05 NDVI units	NS
i. Measurement Precision - $NDVI_{TOC}$ (2)	0.04 NDVI units	NS
j. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	24 hrs.
		v2.8, 4/19/13

Notes:
1. EVI can produce faulty values over snow, ice, and residual clouds (EVI > 1).
2. Accuracy and precision performance will be verified and validated for an aggregated 4 km horizontal cell to provide for adequate comparability of performance across the scan.

Source: Level 1 Requirements Supplement – Final Version: 2.10 June 25, 2014

Introduction - Spectral Vegetation Indices

- Spectral Vegetation Indices (VIs) are optical measures of vegetation canopy “greenness”, a composite property of
  - Leaf chlorophyll
  - Leaf area
  - Canopy cover
  - Canopy architecture
- VIs are widely used in studies involving vegetation dynamics
  - Land surface phenology
  - Climate-vegetation interactions
- Vis can be used to produce estimates of
  - Leaf Area Index (LAI)
  - Fraction of Photosynthetically Active Radiation (fPAR)
  - Net Photosynthesis (PSN)
  - Annual Net Primary Production (NPP)
  - Green Vegetation Fraction (GVF)
- VI derived parameters are used as input to NWP models

IDPS Operational VI EDR Algorithm/Product

The IDPS Vegetation Index EDR consists of three vegetation indices:

1. Normalized Difference Vegetation Index ($NDVI^{TOA}$) from top-of-atmosphere (TOA) reflectances
2. Enhanced Vegetation Index (EVI^{TOC}) from top of canopy (TOC) reflectances.
3. Normalized Difference Vegetation Index ($*NDVI^{TOC}$) from top of canopy (TOC) reflectances

IDPS VI EDR Algorithm

$$NDVI^{TOA} = (\rho_{I2}^{TOA} - \rho_{I1}^{TOA}) / (\rho_{I2}^{TOA} + \rho_{I1}^{TOA})$$

$$EVI^{TOC} = (1+L) \cdot \frac{\rho_{I2}^{TOC} - \rho_{I1}^{TOC}}{\rho_{I2}^{TOC} + C_1 \cdot \rho_{I1}^{TOC} - C_2 \cdot \rho_{M3}^{TOC} + L}$$

$$^{*}NDVI^{TOC} = (\rho_{I2}^{TOC} - \rho_{I1}^{TOC}) / (\rho_{I2}^{TOC} + \rho_{I1}^{TOC})$$

ρ_{M3}^{TOC} Surface reflectance band M3 (488 nm)

ρ_{I1}^{TOC} Surface reflectance band I1 (640 nm)

ρ_{I2}^{TOC} Surface reflectance band I2 (865 nm)

ρ_{I1}^{TOA} Top of the atmosphere reflectance band I1 (640 nm)

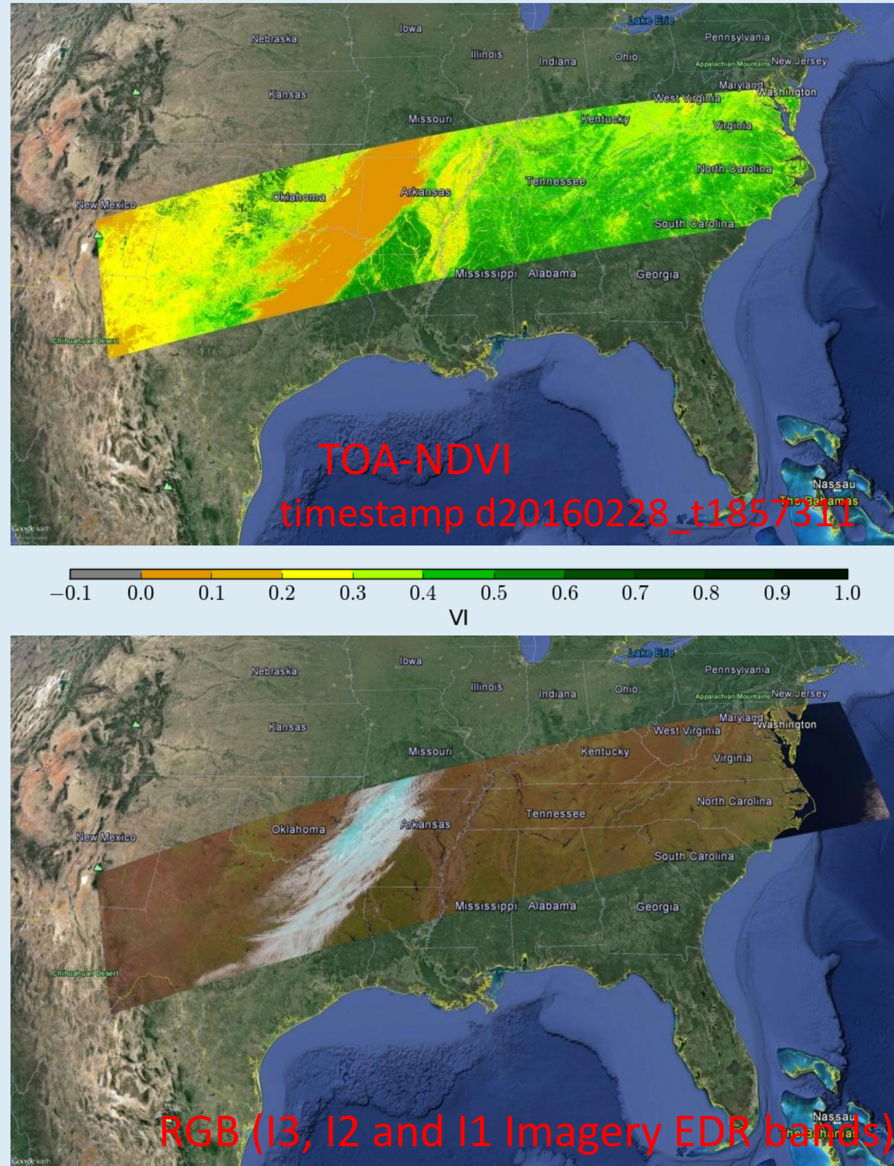
ρ_{I2}^{TOA} Top of the atmosphere reflectance band I2 (865 nm)

C_1, C_2 and *L* are constants

*New for JPSS1

Granulated IDPS VIIRS VI EDR Operational Product

- The VIIRS VI EDR operational product is generated as ~86 seconds granules at Imagery resolution (375m)
- VI EDR is produced over land only and during day time
- Format HDF5
- The granule file contains:
  - TOA NDVI
  - TOC EVI
  - *TOC NDVI
- Also included in the product are four quality flag (QF) layers on land/water mask, cloud confidence, aerosol loadings, and exclusion conditions
- Product available at NOAA CLASS http://www.class.ncdc.noaa.gov/



*New for JPSS1

IDPS VIIRS VI EDR Product Challenges

- The quality of the VIIRS VI EDR product is critically dependent on the quality of the cloud mask, geolocation and quality of the input bands (SDR and SR)
- Reprocessing of the VIIRS VI EDR is necessary to incorporate all the refinements in sensor calibration (VIIRS instrument), and improvements to the VI EDR Algorithm input datasets (SDR, VCM, SR, Aerosols)
- There is no VI EDR product reprocessing capability within the IDPS
- The IDPS Algorithm Change Process (ACP) is very complex

Advantages Of The IDPS Vegetation Index EDR Algorithm/Product

- The VI EDR provides complete daily global coverage at high spatial resolution (0.375km at nadir)
- The VI EDR algorithm is robust, globally-applicable, and requires no assumptions
- The VI EDR reached Validated maturity in 2014 and continues to meet the L1 product performance parameters
- The VI EDR is suitable for continuing the VI record that started with AVHRR and MODIS

Disadvantages Of The IDPS VI EDR (1/2)

SNPP operational Near Real Time (NRT) products were designed to meet the needs of the operational community, primarily the meteorological community (NWS NCEP), but

- VI EDR operational product is not gridded
- NWS NCEP NWP models require global gridded input data (granule format is not an option)
- Non-gridded, granulated products are difficult to handle (most users do not have the knowledge and skills to map, grid, composite, etc)
- Research community prefers global gridded products

Disadvantages Of The IDPS VI EDR (2/2)

- Land Essential Climate Variables (ECVs) are not being generated by the IDPS VIIRS VI EDR algorithm (e.g., LAI, and fPAR)
- EVI can produce unrealistic values for snow/ice and cloud contaminated pixels. This issue has been addressed by using EVI2 instead
- M3 band pixel size is incompatible with that of I1 and I2 bands (EVI uses the VIIRS bands I1, I2 and M3 as input). The M3 band pixel size (0.750km at nadir) is twice the size of the I1 and I2 bands (0.375km at nadir)
- Due to the adoption of a different gain factor from the heritage MODIS sensor, the dynamic range of the VIIRS EVI is systematically lower (~20%) than the MODIS EVI

STAR Enterprise Algorithms

JPSS VI EDR is a priority 4 product

- For JPSS Priority 3 and 4 products, JPSS STAR has been directed by NJO to:
  - Stop working on the NPOESS-heritage algorithms running in IDPS
  - Defer implementation of the algorithm change packages related to priority 3 and 4 products; only with exceptions with the changes that will impact the current operational users of those products
  - Continue work on enterprise science algorithms for all the JPSS Priority 3 and 4 EDR products

NJO Direction Letter on Deferring JPSS Priority 3&4 Products Implementation

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
Silver Spring, Maryland 20910
Joint Polar Satellite System Office

OCT 06 2014

Memorandum for: Distribution

From: Harry A. Cikanek III, Director

Subject: Deferral of Algorithm Integration Activities and Standards for Priority 3 and 4 Environmental Data Records and Termination of Listed NPOESS Heritage Algorithms

This memorandum provides programmatic guidance and direction to defer the algorithm integration and transition to operations for priority 3 and 4 algorithms until after Block 2.0 is successfully fielded. This memorandum also establishes expected standards for algorithm science verification scope of the Priority 3 and 4 Environmental Data Records (EDRs), effective through FY 2017 and directs the termination of further development on NPOESS heritage algorithms that are planned to be replaced by enterprise algorithms. The direction applies to scope allocated to the NASA JPSS Ground Project, the NESDIS Center for Satellite Applications and Research (STAR), and the JPSS Program System Engineering (PSE) team.

To ensure readiness of the critical data products, consistent with gap mitigation efforts, all Key Performance Parameter (KPP / Priority 1) data products for JPSS-1 must be ready for operational use the day following successful commissioning review and hand over of the JPSS-1 spacecraft for NOAA OSPO operations. Accordingly, updates and verification of the Priority 1 data products must be completed prior to the launch of JPSS-1. To allow adequate schedule and resources to accomplish this, the Ground Project and STAR will defer algorithm changes associated with Priority 3 and 4 EDRs performance until an appropriate interval (i.e., when most time- and cost-efficient) following IDPS Block 2.0 transition to operations (see Table 1). Reactive maintenance[1] of priority 3 and 4 EDRs shall be conducted to maintain current levels of product maturity and to avoid major impacts to operational users.

In conjunction with this deferral, my standard for the algorithm science performance requirements verification for Priority 3 and 4 EDRs will be continuity of performance represented by the current maturity of associated S-NPP EDRs. I will accept artifacts used to support S-NPP validated maturity declaration as applicable to JPSS-1 pre-launch science algorithm verification as appropriate. JPSS-1 Ground Segment pre-launch testing of these EDRs will be limited to ensuring continuity of the science and functional performance of the supporting algorithms within the new processing environments. Work involving required upgrades to algorithm science performance will continue to be performed by STAR in order to support integration activities after transition to Block 2.0 operations.

Please implement the following guidance:

STAR – Place highest priority on assuring KPP (Priority 1) data product algorithms are ready for operational use the day after commissioning JPSS-1. Stop all development work on the NPOESS-heritage data product algorithms identified to be discontinued in Table 1 below. Continue the algorithm

[1] Reactive maintenance refers to those activities, based on product trending and long-term monitoring, needed to maintain the current level of product maturity to ensure there is no degradation of product quality with time.

Table 1

Provide only reactive maintenance to NOAA enterprise algorithms within IDPS	Provide transitional reactive maintenance to NPOESS legacy algorithms within IDPS	Discontinue work and disposition IDPS code
Ozone Nadir Profile (OMPS)[6]	Active fires (VIIRS)[5]	Ocean Color (VIIRS)[4]
Total Column Ozone (OMPS)[6]	Aerosol Optical Thickness (VIIRS)[1]	
	Aerosol Particle Size Parameter (VIIRS)[1]	
	Cloud Base Height (VIIRS)[1]	
	Cloud Cover/Layers (VIIRS)[1]	
	Cloud Effective Particle Size (VIIRS)[1]	
	Cloud Optical Thickness (VIIRS)[1]	
	Cloud Mask (VIIRS)	
	Cloud Top Height (VIIRS)[1]	
	Cloud Top Pressure (VIIRS)[1]	
	Cloud Top Temperature (VIIRS)[1]	
	Ice Surface Temperature (VIIRS)[1]	
	Land Surface Temperature (VIIRS)[2]	
	Surface Type[2]	
	Quarterly Surface Type (VIIRS)[3]	
	Sea Ice Characterization (VIIRS)[1]	
	Snow Cover (VIIRS)[1]	
	Surface Albedo (VIIRS)[2]	
	Suspended Matter (VIIRS)[1]	
	Vegetation Index (VIIRS)[2]	

Notes:

1. Reactive maintenance will be maintained until the NOAA enterprise risk reduction cloud, cryosphere and aerosol algorithms are operationalized (planned spring 2016).

2. These products are not included in the enterprise risk reduction project and therefore these products are candidates for offline development by STAR. An implementation trade will be done as to where the algorithms will be processed.

3. CCR in work to propose removal of product requirement from L1RD and move into Level 3 requirements where STAR would provide this product as ancillary data.

4. The IDPS Ocean Color product will be replaced by the NOAA enterprise Ocean Color product and implemented in the NOAA/ESPC legacy system Okeanos on a best-effort basis.

5. The Active Fires algorithm is currently implemented in IDPS, but an Analysis of Alternatives is underway to determine the implementation for the new/updated algorithm.

6. Reactive maintenance should start following the implementation (in process) of the v8 algorithms.

Enterprise Algorithm Conversation Land: Vegetation Products (1/2)

Product	VIIRS	ABI	AVHRR	MODIS	Users of NOAA Product
TOA NDVI	O	F	O	—	NWS, USDA, USGS
TOC NDVI	R	—	—	O*	
EVI	O	—	—	O*	
EVI2	—	—	—	P*	
GVF	O	F	O	—	NWS/NCEP
LAI	—	—	—	O*	
fPAR	—	—	—	O*	
PSN	—	—	—	O*	
NPP	—	—	—	O*	

O – operational, F – future capability
R – Ready for operational implementation
*P – planned for production at NASA
*MODIS production at NASA

Enterprise Algorithm Conversation Land: Vegetation Products (2/2)

Path Forward for Enterprise Solution:

– Want all land products to use the same global grid and mapping tools
– NCEP's stated requirement is 1km resolution global gridded products
– LAI, FPAR, PSN, and NPP products are also needed (Users require composite products)
– A L3 suite of products for NDVI, TOC EVI, TOC NDVI and GVF are needed
– VIIRS GVF already in production at NDE
– GVF in NDE is a L3 product (calculates its own EVI)
– GOES-R has TOA NDVI and GVF, but Option 2 (not operational)
– TOA NDVI from AVHRR; VIIRS also has TOC EVI and TOC NDVI
– AVHRR has a Level 3 (L3) product; No official L3 product for VIIRS NDVI or EVI
– Want GOES-R GVF to be like VIIRS GVF; NDVI is the same for both
– Need to have follow on meetings for VIIRS and GOES-R algorithm path
– NDVI is an input to the Vegetation Health product, but it currently calculates NDVI separately from reflectance
– Need to align requirements across satellites, standardize the requirements
– Possible addition of Sentinel-3 data (gap filler)
– Move towards NDE and SPSRB
– Proposed solution is to develop a common vegetation products algorithm for TOA-NDVI, TOC-NDVI, GVF, EVI, EVI2, LAI, fPAR, PSN and NPP

Enterprise Algorithm for Vegetation Products

Acronym	Description	Purpose
TOA NDVI	Normalized Difference Vegetation Index, at the top of the atmosphere	Continuity with AVHRR heritage
TOC NDVI	Normalized Difference Vegetation Index, at the top of the canopy	Continuity with MODIS/AVHRR heritage, focused on surface values
EVI / *EVI2	Enhanced Vegetation Index	Continuity with MODIS heritage. Useful parameter for biogeophysical models and scientific interpretation. Complement the NDVI
GVF	Green Vegetation Fraction	Useful parameter for biogeophysical models and scientific interpretation
***LAI**	Leaf Area Index	Useful parameter for biogeophysical models and scientific interpretation
***fPAR**	Fraction of absorbed Photosynthetically Active Radiation	Useful parameter for biogeophysical models and scientific interpretation
***PSN**	Net Photosynthesis	Useful parameter for assessing the magnitude of CO_2 transport in the carbon cycle
***NPP**	Net Primary Production	Useful parameter for monitoring of crops and forests

*No L1 requirement to create these new products. The JPSS ATBD for Vegetation Index products describes that those products will be produced

JPSS ATBD for Vegetation Index

Effective Date: January 22, 2014
Revision A

GSFC JPSS CMO
July 17, 2014
Released

Joint Polar Satellite System (JPSS) Ground Project
Code 474
474-00039

Joint Polar Satellite System (JPSS) VIIRS Vegetation Index (VVI) Algorithm Theoretical Basis Document

For Public Release

The information provided herein does not contain technical data as defined in the International Traffic in Arms Regulations (ITAR) 22 CFC 120.10. This document has been approved For Public Release.

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

ABSTRACT

The Visible/Infrared Imager/Radiometer Suite (VIIRS) Vegetation Index (VVI) is one of more than two dozen environmental data records (EDRs) explicitly required as products to be derived from the VIIRS sensor slated to fly onboard the National Polar-orbiting Operational Environmental Satellite System (NPOESS), which is scheduled for launch in the late 2000's. The requirements for the VIIRS EDRs are described in detail in the VIIRS Sensor Requirements Document (SRD). These requirements form the foundation from which both the algorithms and the sensor are designed and built. A revised version of the SRD was released in November 1999, detailing a set of new requirements targeted toward the NPOESS Preparatory Project (NPP), a National Aeronautics and Space Administration (NASA) endeavor to build upon the Moderate Resolution Imaging Spectroradiometer (MODIS) heritage beginning in 2005. Based upon the sum of these requirements, the VVI is currently proposed to consist of a suite of four vegetation indices. Two other suites of related products will be produced for added value: the VVI Secondary Products (VVI2P) and the VVI Tertiary Products (VVI3P). Individual algorithms within the suites will be referred to by their traditional names, e.g., NDVI, LAI.

The VVI will contain the following products at the imagery resolution pixel level: the Normalized Difference Vegetation Index (NDVI)—both top-of-canopy (TOC) and top-of-atmosphere (TOA)—for continuity with the Advanced Very High Resolution Radiometer (AVHRR) heritage; the Enhanced Vegetation Index (EVI), for continuity with the MODIS heritage; and a placeholder for an Advanced Vegetation Index (AVI), which exhibits an optimal combination of sensitivity to vegetative processes and insensitivity to non-vegetative effects. The VVI2P will contain leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FPAR) at the moderate resolution pixel level. The VVI3P will contain net primary production (NPP) and net photosynthesis (PSN), as useful inputs to biophysical and climate models, on a global 1-km grid. Additionally, a Gridded Weekly Vegetation Index (GWVI), compositing the NDVI from nadir-adjusted surface reflectances to remove the effects of clouds and bi-directional reflectance variations, will be produced in VIIRS post-processing each day from a preceding eight-day window.

Enterprise Algorithm for Vegetation Products Development Strategy (1/2)

– Develop the Enterprise Algorithm for Vegetation Products to generate: TOA-NDVI, TOC-NDVI, GVF, EVI, EVI2*, LAI*, fPAR*, PSN* and NPP*
– Global gridded products in Lat/Lon projection
– Spatial resolution: 1 km (0.009 degree)
– Temporal resolution: daily, weekly updated daily, bi-weekly updated daily
– VIIRS GVF Algorithm is already running at NDE
– Output File Format: NetCDF4

*No L1 requirement to create these new products

Enterprise Algorithm for Vegetation Products Development Strategy (2/2)

- Currently the granulated VI EDR is not used as input to other IDPS generated products
- Daily gridded product (not granulated product) will be produced and provided
- In this scenario, we would not need the granule level VI EDR products
- There is no need to unplug the VI EDR software from the IDPS and plug it into the FRAMEWORK
- Input data to the Enterprise Algorithm for VI are: SR, SDR, GEO, AOT, VCM, ST
- The Enterprise Algorithm for Vegetation Products will have the capability to ingest data from JPSS, GOES-R, and other non-NOAA missions like Sentinel-3 and Himawari

2-phased Development Strategy

- Implement a 2-phased approach for the development of the Enterprise Algorithm for Vegetation Products

➢ Phase 1

Products to be implemented in this phase:

TOC EVI, TOC EVI2, TOC NDVI, TOA NDVI, GVF

➢ Phase 2

Products to be implemented in this phase:

LAI, fPAR, NPP, PSN

Phase - 1 Enterprise Algorithms for Vegetation Products

The Normalized Difference Vegetation Index (TOA and TOC)

$$NDVI = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{red}}}$$

The Enhanced Vegetation Index (TOC)

$$EVI = 2.5 \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \cdot \rho_{\mathrm{red}} - C_2 \cdot \rho_{\mathrm{blue}} + 1}$$

The 2-band EVI (no Blue band)

$$EVI2 = 2.5 \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + 2.4\rho_{\mathrm{red}} + 1}$$

The Green Vegetation Fraction

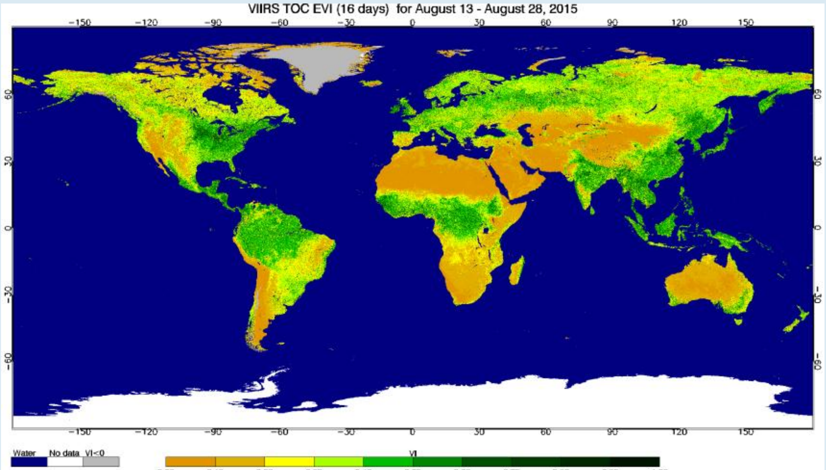
$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

Global Gridded Vegetation Products

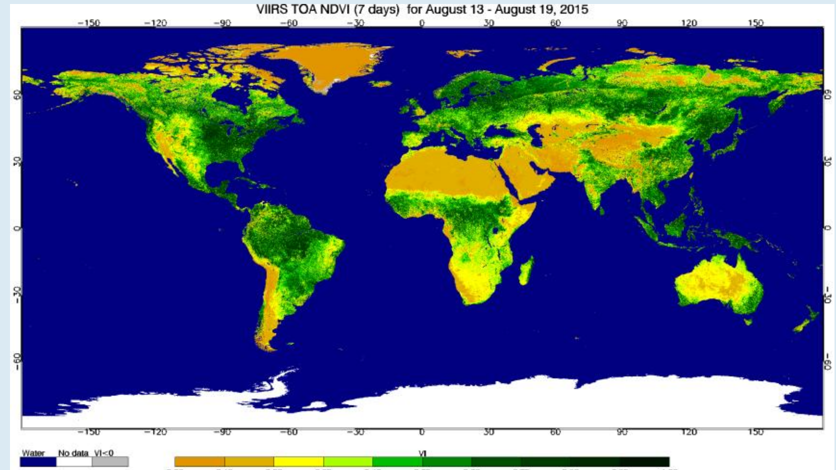
- Projection: Geographic Lat/Lon
- Spatial resolution: 0.009 degree (1 km @ nadir)
- Temporal resolution: daily, weekly updated daily, bi-weekly updated daily
- Format: tiled in NetCDF4 (and GRIB2 for NCEP)
- Quality Flags: Land/Water, Coastal, Clouds, Aerosols, Snow/Ice, etc
- Additional Scientific Data Layers: Gridded, composited surface reflectance and observation geometry for use in science/advanced data analysis
- File Naming Convention: follow NDE standards
- Metadata: follow NDE standards

Sample Global Gridded VIIRS Vegetation Products (Phase 1)

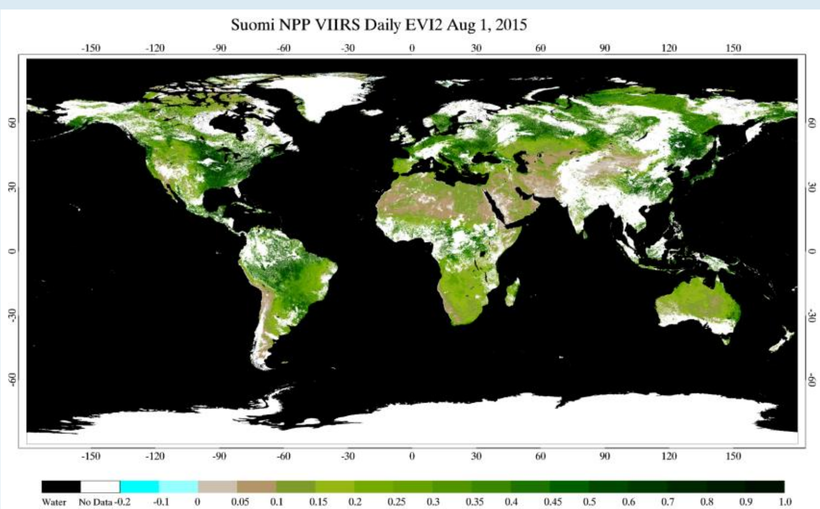
16-day TOC EVI August 13-28, 2015



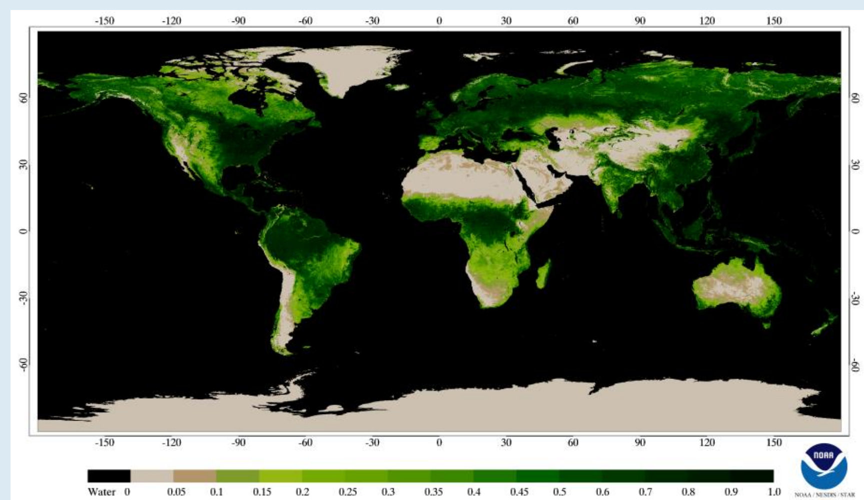
7-day TOA NDVI August 13-19, 2015



Daily TOC EVI2 August 01, 2015



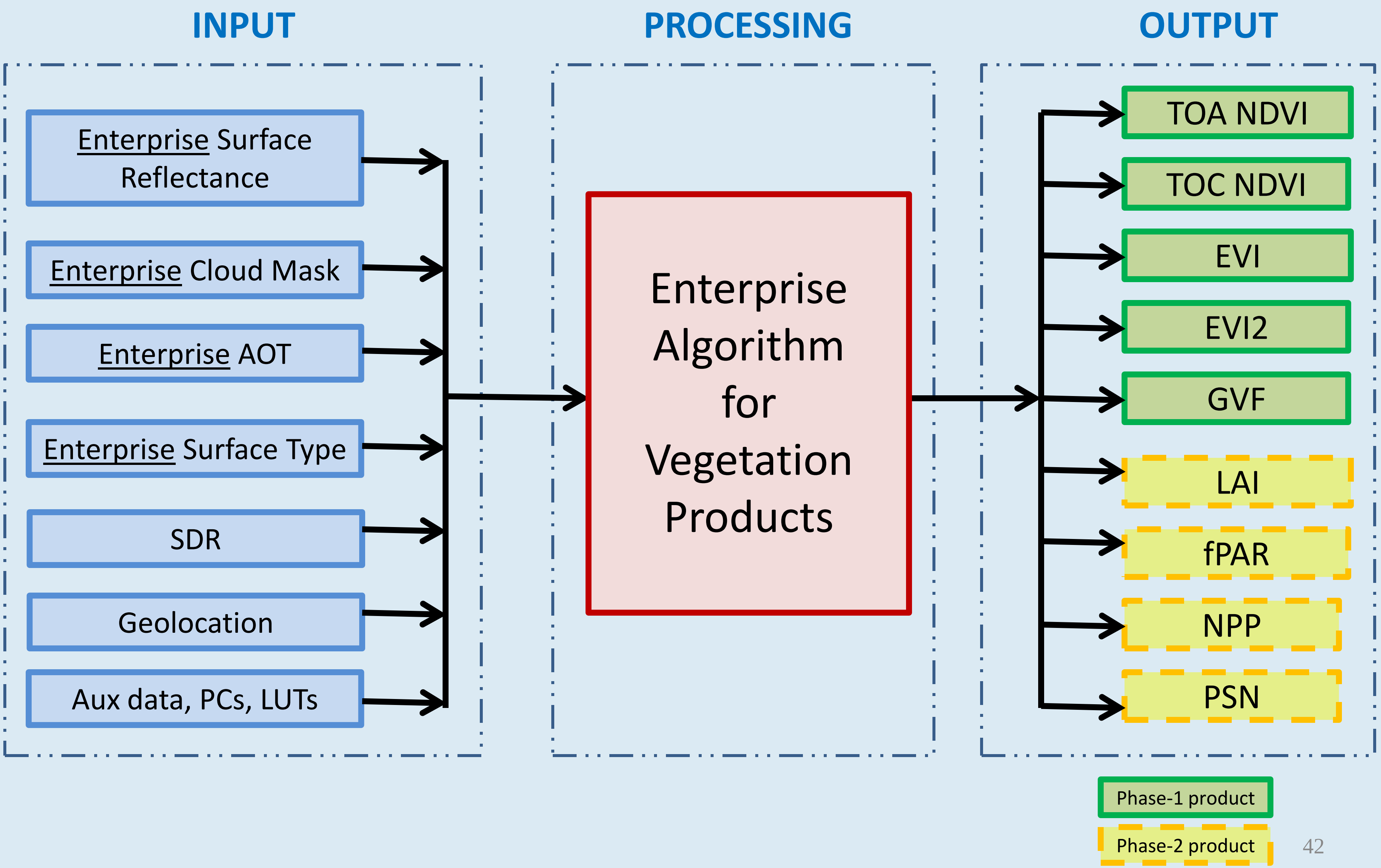
Weekly GVF August 7-13, 2015



Phase - 2 Enterprise Algorithms for Vegetation Products

Phase - 2 Vegetation Products	Retrieval Strategy
Leaf Area Index (LAI): a measure of the amount of one-sided leaf area per unit ground area in a pixel	Following the MODIS heritage, the VIIRS **LAI** and **FPAR** products will be derived from a lookup table (LUT) based on three-dimensional canopy modeling combined with measurements of reflectance, surface type and viewing geometry
Fraction of Photosynthetically Active Radiation (fPAR): a measure of absorbed photosynthetically-active radiation (PAR) by vegetation	
(Daily) Net Photosynthesis (PSN): net carbon exchange over 1 day (photosynthesis – respiration)	$PSN = \varepsilon \cdot VI \cdot PAR$ **PAR** is the incident photosynthetically active radiation and ***ε*** is the light use efficiency
(Annual) Net Primary Production (NPP): the net flux of carbon from the atmosphere into green plants per unit time, i.e., the amount of vegetable matter produced (net primary production) per year	$NPP = \sum_{annual} PSN$ **NPP** is the time integral of **PSN** over a single year (will therefore be reported annually on a global 1-km grid)

Vegetation Index Production System
High level process flow



Algorithm & Product Validation (1/5)

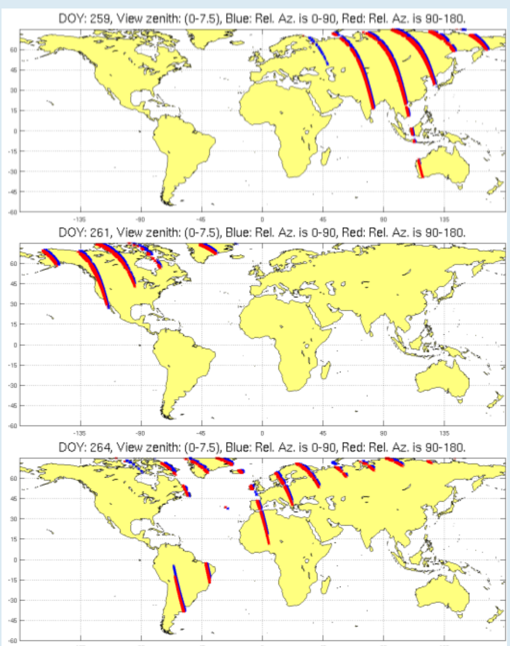
- Adhere to the JPSS Product Maturity standards
- Build on the current VIIRS VI Team's validation efforts and develop new protocols
  - Global cross-/inter-comparisons with products from other sensor data (e.g., MODIS)
  - Evaluation over AERONET sites
  - Time series validation over *in situ* network sites (e.g., FLUXNET)
  - STAR JPSS VI Monitor
- Adopt CEOS Land Product Validation (LPV) protocols

Algorithm & Product Validation (2/5) Global Cross-/Inter-Comparison

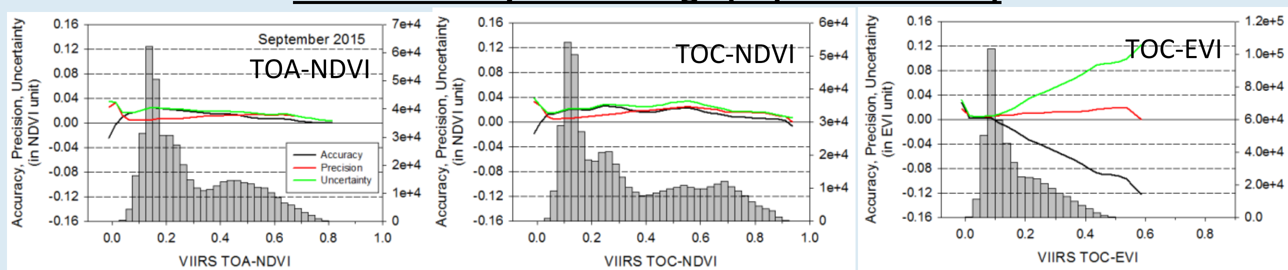
- Coincident observations of VIIRS with other sensors (e.g., MODIS) over overlapped orbital tracks throughout the globe will be used to obtain APUs of VIIRS VI products
- The protocol is applicable to Phase 1 and, upon adjustments, Phase 2 products

(Vargas et al., 2013, JGR)

VIIRS-MODIS overlapped orbital tracks (VZ < 7.5°) (Red = forward scattering geometry; Blue = backward scattering geometry)



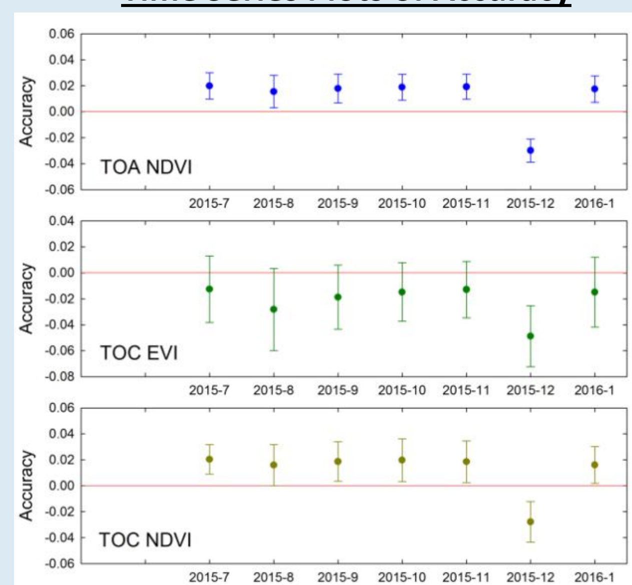
APU Across Dynamic Range (September 2015)



Global APU Estimates (2014 - 2015)

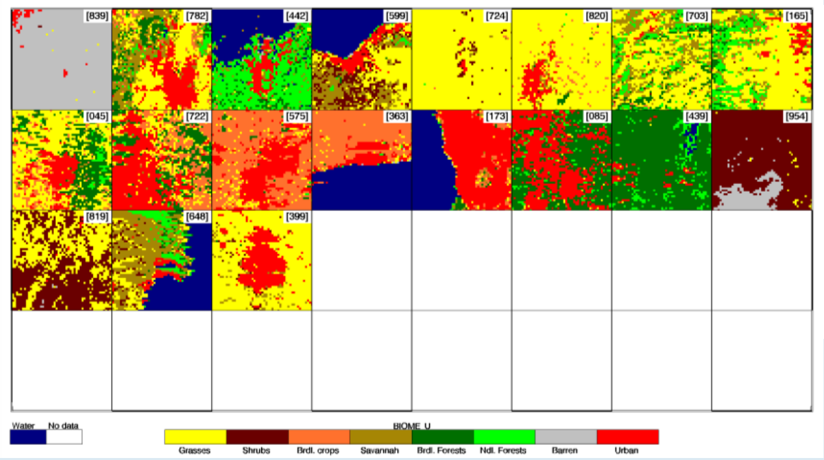
Attribute	L1RDS Threshold (VI units)	Validation Results
TOA NDVI Accuracy	0.05	0.005
TOA NDVI Precision	0.04	0.017
TOA NDVI Uncertainty	0.06	0.020
TOC EVI Accuracy	0.05	0.037
TOC EVI Precision	0.04	0.011
TOC EVI Uncertainty	0.06	0.039
TOC NDVI Accuracy	0.05	0.007
TOC NDVI Precision	0.04	0.023
TOC NDVI Uncertainty	0.06	0.025

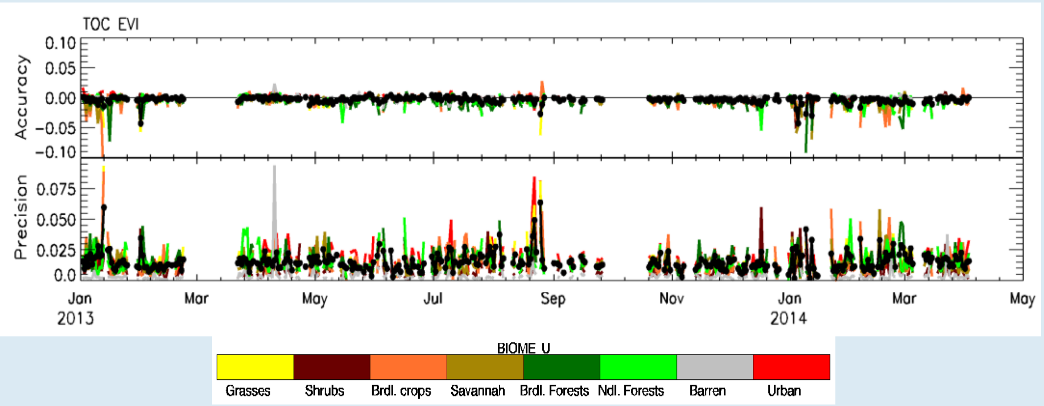
Time Series Plots of Accuracy

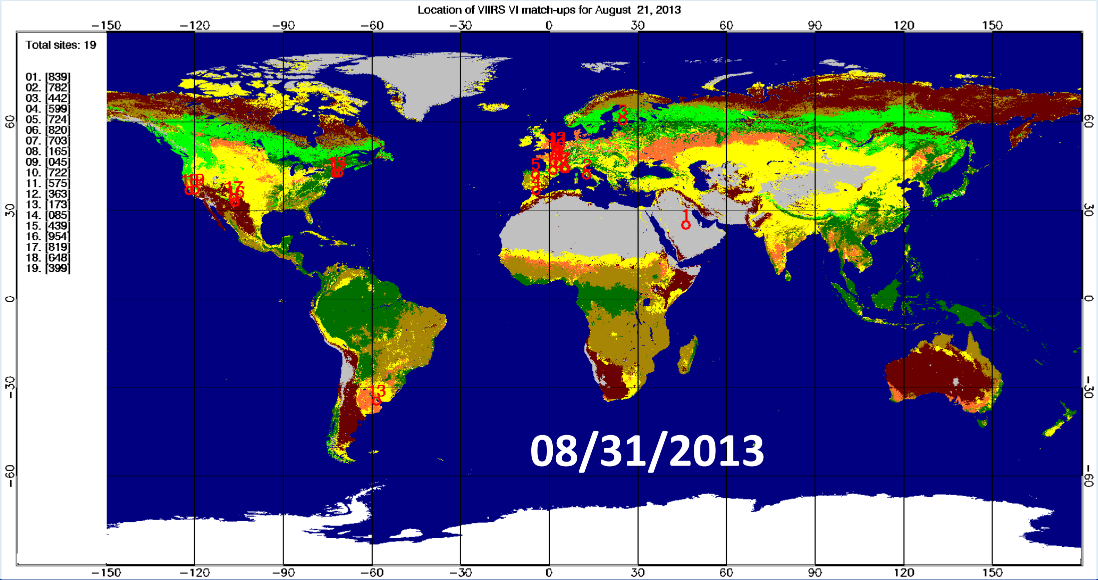


Algorithm & Product Validation (3/5)
Evaluation Over AERONET Sites

– Globally-distributed match-up sites, covering different surface types and including urban areas, can be used to evaluate accuracy of atmospherically-corrected, TOC VIs. The protocol is applicable to Phase 1 products







Global APUs
(Jan 1, 2013 – Mar 31, 2014)

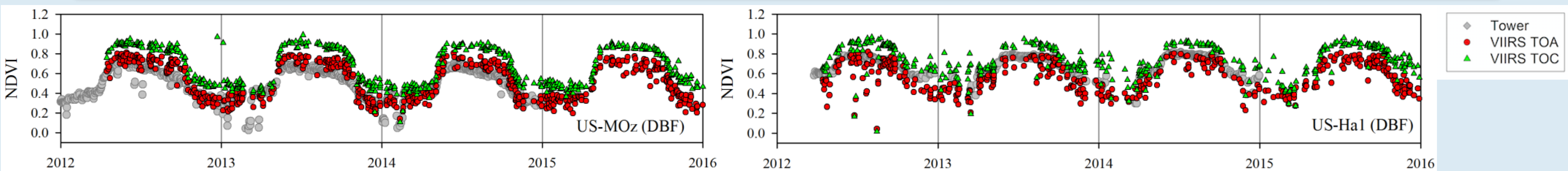
	TOC EVI	TOC NDVI
A	0.004	0.009
P	0.015	0.035
U	0.016	0.038

(Shabanov et al., 2015, RSE)

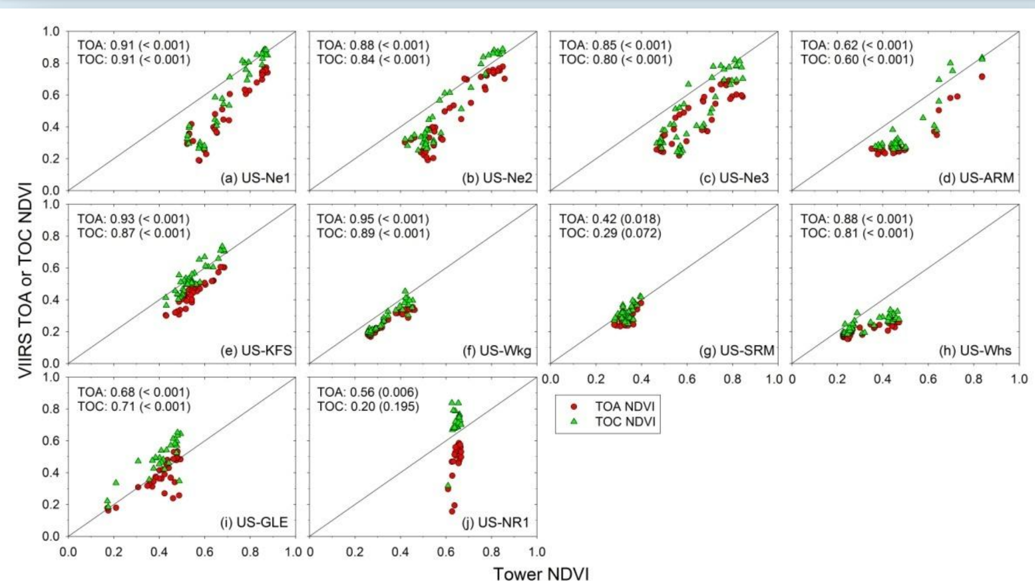
Algorithm & Product Validation (4/5)
Time Series Validation Using *In Situ* Networks

– High-quality time series measurements obtained through *in situ* tower networks will be used in time series validation of Phases 1 & 2 products (e.g., variables from FLUXNET: tower VIs, NPP, GPP, NEE) (Wang et al., 2016, *in review*)

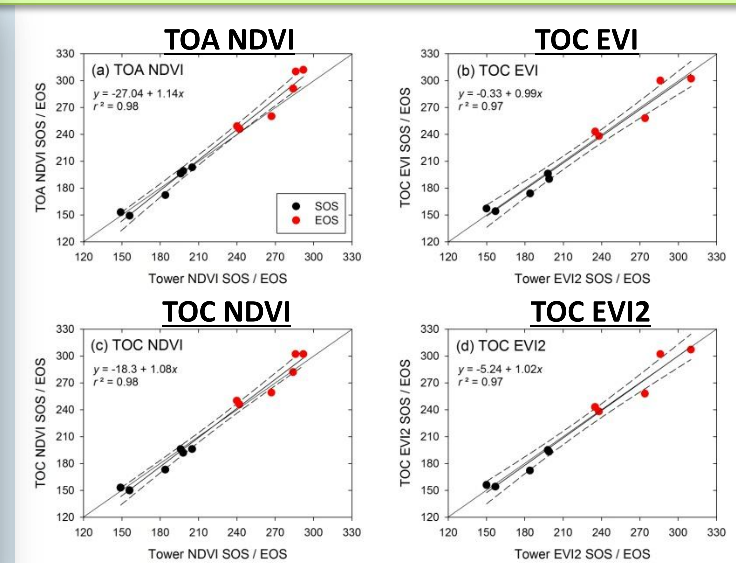
Inter-Comparison of VIIRS vs. Tower NDVI Temporal Trends



Correlative Analysis between VIIRS and Tower VI Data



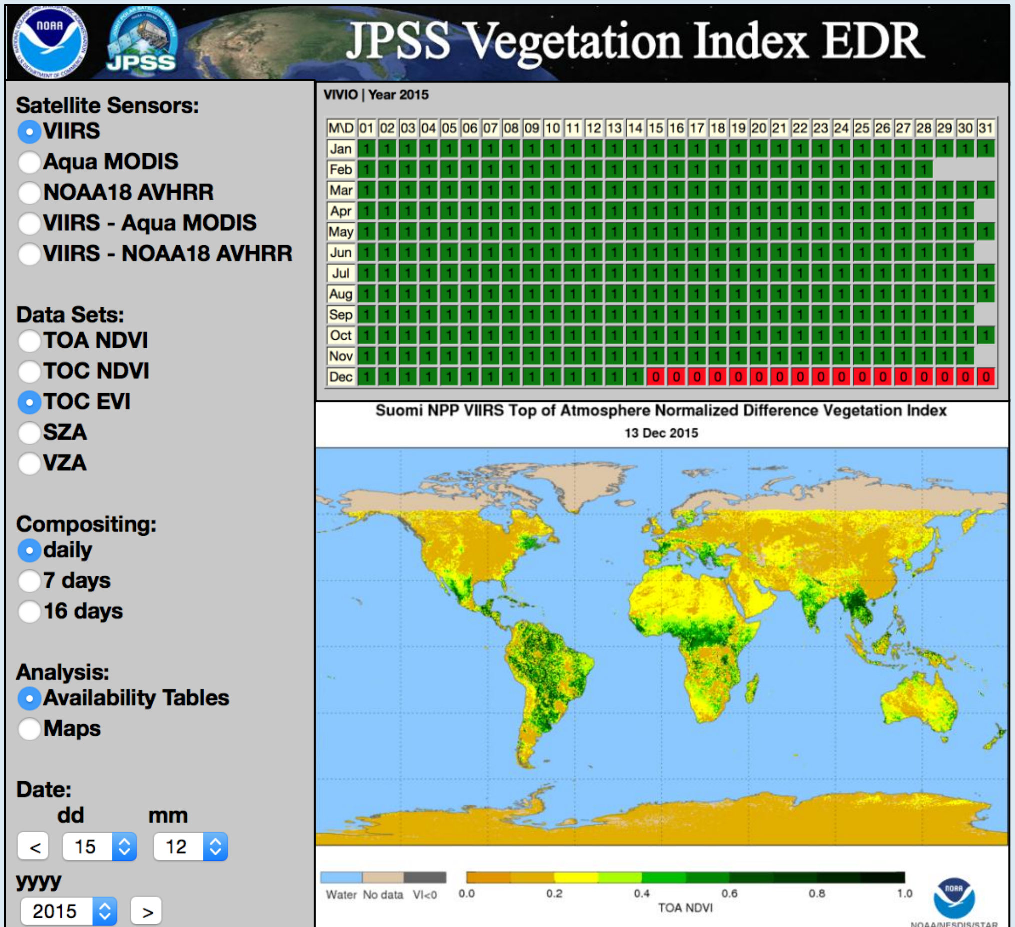
Cross-Comparison of "Start-of-Season" Phenological Metrics Derived from VIIRS and Tower VI Temporal Profiles



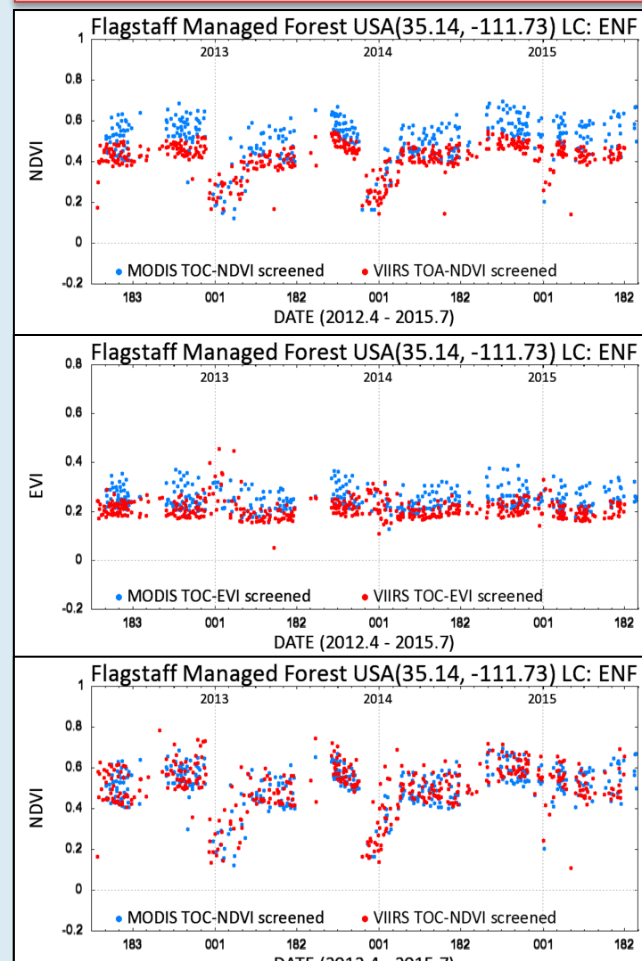
Algorithm & Product Validation (5/5)
STAR JPSS VI Monitor

– Daily, global composites will be generated for Phases 1 and 2 products, which can be used for quality assessment of the products from the system

Global Mosaic Viewer

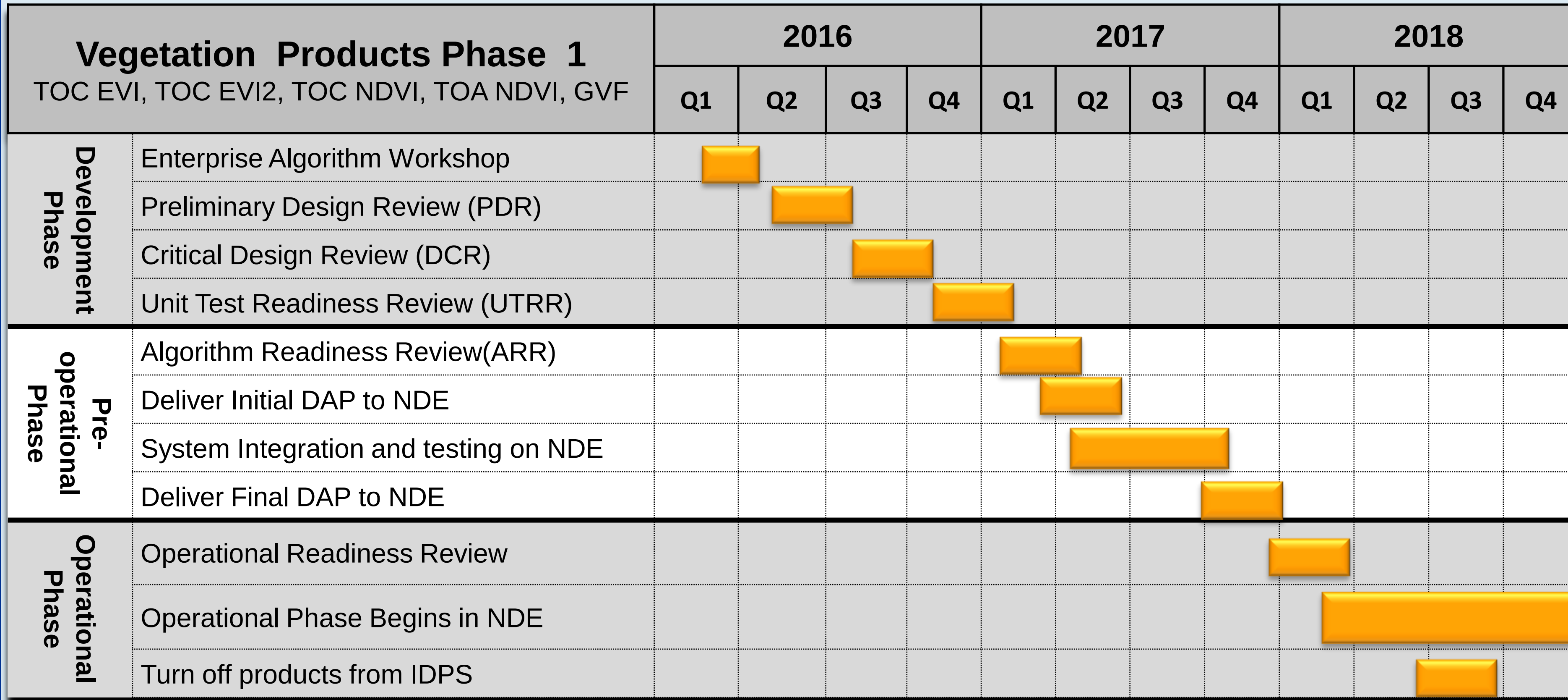


Temporal Profile Viewer



Vegetation Products Development

Phase 1 – Schedule and Milestones



Vegetation Products Development

Phase 2 – Schedule and Milestones

Vegetation Products Phase 2 Products: LAI, fPAR, NPP, PSN		2017				2018				2019			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Development Phase	Algorithms selected		■										
	Preliminary Design Review (PDR)			■									
	Critical Design Review (DCR)				■								
	Unit Test Readiness Review (UTRR)					■							
Pre-operational Phase	Algorithm Readiness Review(ARR)						■						
	Deliver Initial DAP to NDE						■	■					
	System Integration and testing on NDE							■	■				
	Deliver Final DAP to NDE									■			
Operational Phase	Operational Readiness Review									■	■		
	Operational Phase Begins in NDE										■	■	■

Risks

– If the L1 requirements are not changed on time to add the new vegetation products, then there will be a delay in the development and transition to operations of the new vegetation products
– If the VIIRS input data to the Enterprise Algorithm for Vegetation Products (SDR, SR, VCM, AOT) are not reprocessed, then the quality of the vegetation products will not be sufficient for global change science
– If NDE is not ready to implement all the P3 and P4 algorithms, then there will be a schedule impact
– If SNPP fails before JPSS1 is operational, then there will be a gap in the vegetation data record

Summary

Recommendation:

– Develop a 2-phased Enterprise Algorithm for Vegetation Products

Benefits of the Enterprise Algorithm

- Reduce redundant software development
- Generate consistent science for data assimilation, fused products, enhanced products, and climate records
- Require maintenance of a fewer algorithms and systems within operations
- Bring continuity of NOAA products between current and future NOAA operational satellites

Outstanding issues

- Requirement changes to L1RD/L1RDS, Multi Mission System Specification (MMSS) and Data Product Specification (DPS)
- Reprocessing of the VIIRS input data record is necessary to incorporate all the refinements in sensor calibration (VIIRS instrument), and improvements to the upstream algorithms (SDR, VCM, SR, Aerosols)

For more information on VIIRS Vegetation Index EDR

- STAR JPSS

http://www.star.nesdis.noaa.gov/jpss/EDRs/products_VegIndex.php

http://www.star.nesdis.noaa.gov/smcd/viirs_vi/Monitor.htm

http://www.star.nesdis.noaa.gov/jpss/

- NOAA JPSS

http://www.jpss.noaa.gov/

- NOAA CLASS

http://www.nsof.class.noaa.gov/

- NASA

http://viirsland.gsfc.nasa.gov/Products/VIEDR.html

Questions?