JPSS1 and SNPP VIIRS Vegetation Index Products and Algorithm Development

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Outline

- Overview
  - Team Members, Product Requirements, Accomplishments
- Algorithm Evaluation
  - Algorithm Description, Validation
- JPSS1 Cal/Val Plan
- Enterprise Vegetation Index Algorithm
- NASA SNPP VIIRS Vegetation Index Products
- Future Plans
- Summary

VI EDR Team Members

- Marco Vargas (NOAA/STAR) STAR VI EDR algorithm lead
- Tomoaki Miura (University of Hawaii) VI Cal/Val lead
- Anna Kato (University of Hawaii) Product monitoring and algorithm validation
- Mahany Lindquist (University of Hawaii) Product monitoring and algorithm validation
- Leslie Belsma (Aerospace) Land JAM
- Michael Ek (NOAA/NCEP) User readiness
- Walter Wolf (NOAA/STAR) AI&T Team Lead

JPSS VI EDR Product Requirements

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

VI EDR Accomplishments

- Validated Stage 1 Maturity approved by AERB in April 2015
- JPSS1 Algorithm Development (J1 Upper)

  - Completed the development of TOC NDVI

  - CCR-15-2382 approved by AERB in July 2015
- Delivered JPSS1 Cal/Val plan
- Started planning for Vegetation Index Enterprise Algorithm
- Started LTM activities
- New publication

Shabanov, N., M. Vargas, T. Miura, A. Sei, and A. Danial (2015), Evaluation of the performance of Suomi NPP VIIRS top of canopy vegetation indices over AERONET sites, Remote Sensing of Environment pp. 29-44, doi:10.1016/j.rse.2015.02.004.

SNPP/JPSS Vegetation Index EDR

- The 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. New for JPSS1 (J1 "Upper") Normalized Difference Vegetation Index ($NDVI^{TOC}$) from top of canopy (TOC) reflectances
- These indices are produced at the VIIRS image channel resolution (375 m at nadir) over land in granule style (swath form)
- File format: HDF5

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)

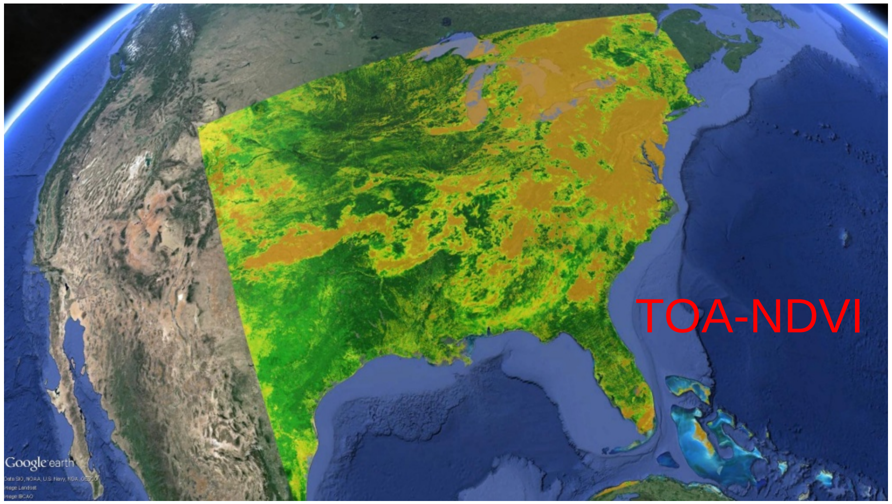
ρ_{I2}^{TOC} Surface reflectance band I2 (865 nm)

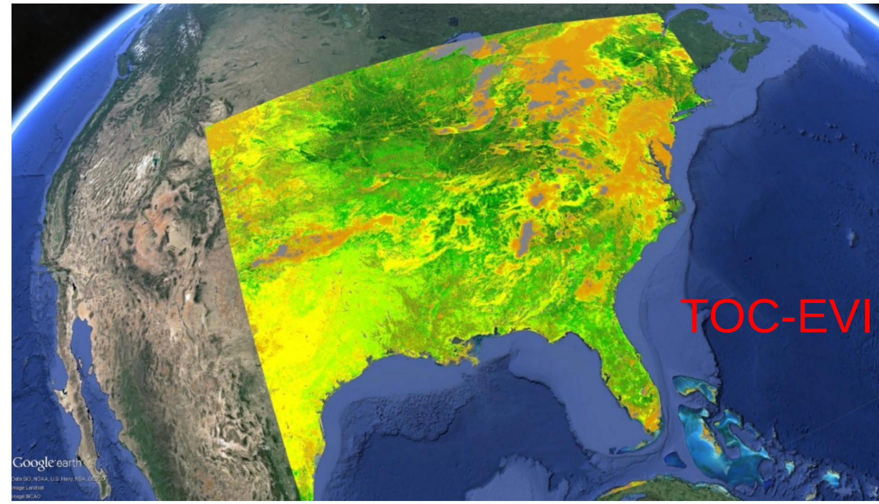
ρ_{I1}^{TOA} Top of the atmosphere reflectance band I1 (640 nm)

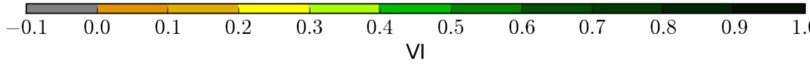
ρ_{I2}^{TOA} Top of the atmosphere reflectance band I2 (865 nm)

C_1, C_2 and L are constants

VI-EDR August 10, 2015







5 merged SNPP VIIRS VIVIO Granules

timestamp d20150810_t1844472
timestamp d20150810_t1846126
timestamp d20150810_t1847380
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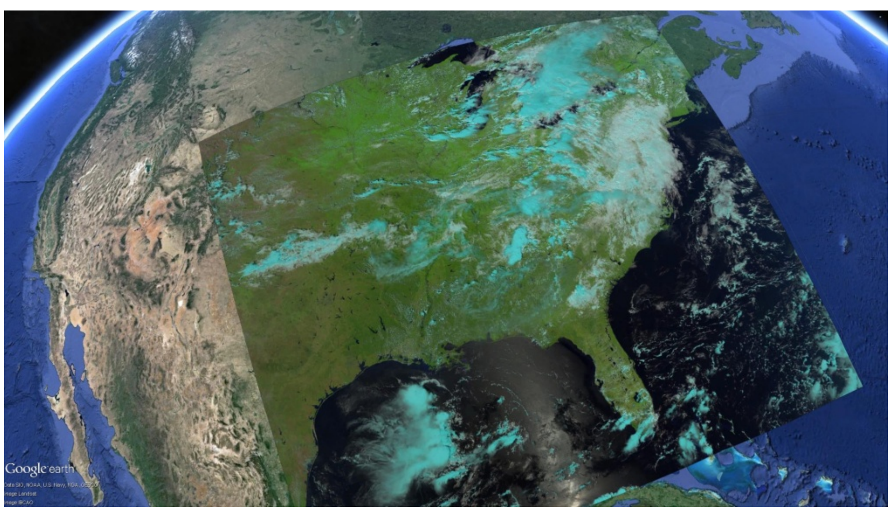
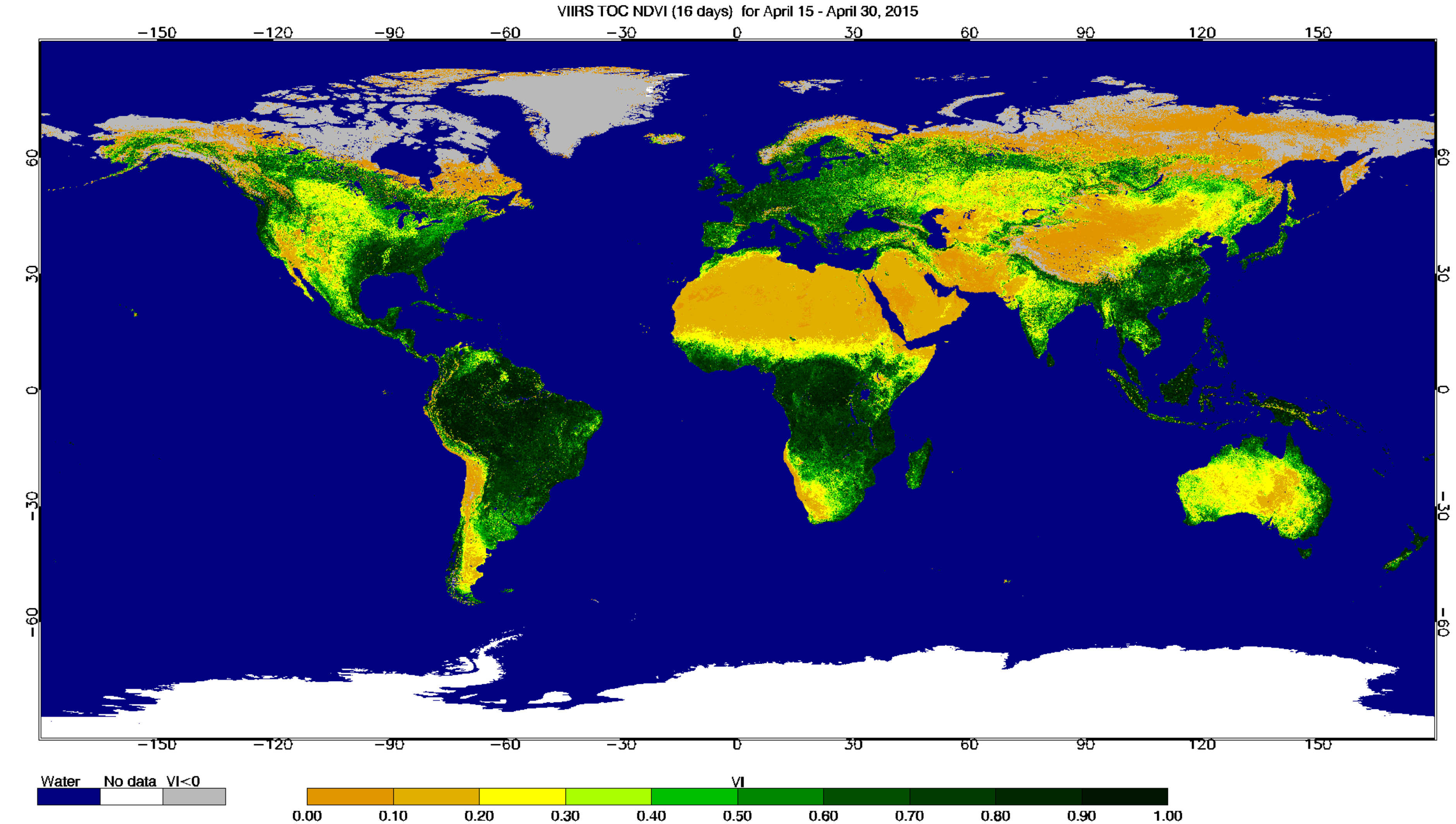
timestamp d20150810_t1850288



RGB (I1, I2 and I3 Imagery EDR bands)

TOC-NDVI
16-day composite



SNPP VIIRS Vegetation Index EDR Current Status

SNPP VI EDR Maturity: Validated Stage 1

Validation activities

1) Global comparisons with Aqua MODIS
2) Evaluation over AERONET sites
3) Time series validation over FLUXNET sites

Instrument/product quality

- High radiometric quality, meeting the L1RDS requirements

VI algorithm issues

- Unrealistic EVI for snow/ice or cloud-contaminated pixels

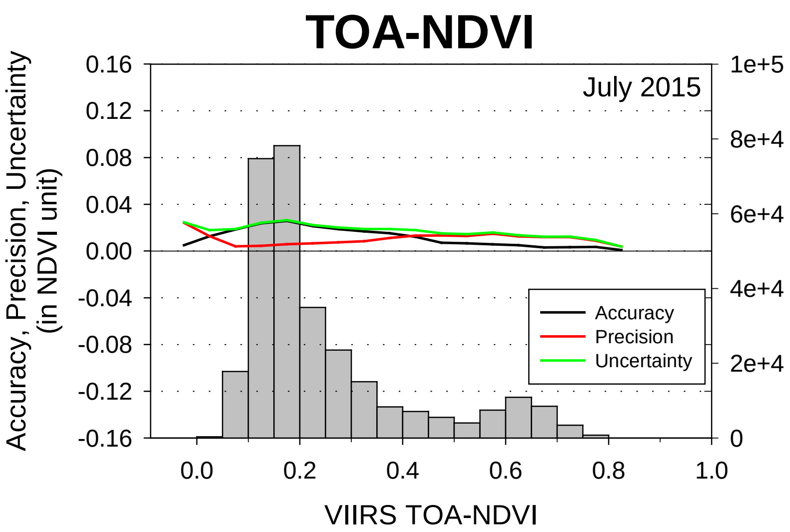
Long Term Monitoring (LTM)

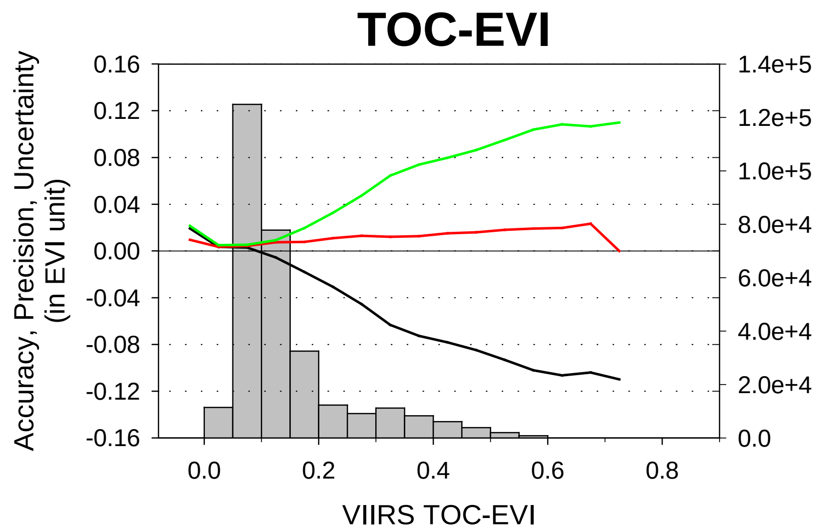
- Ongoing

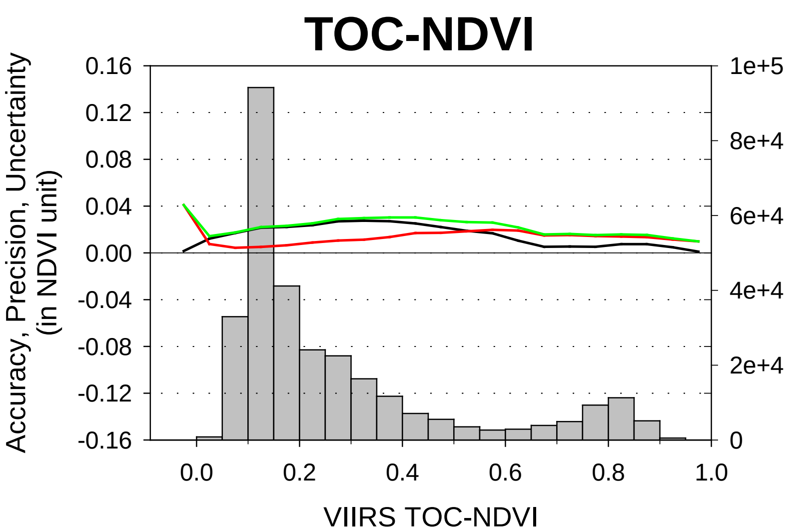
Global APU Estimates (2014 - 2015)

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

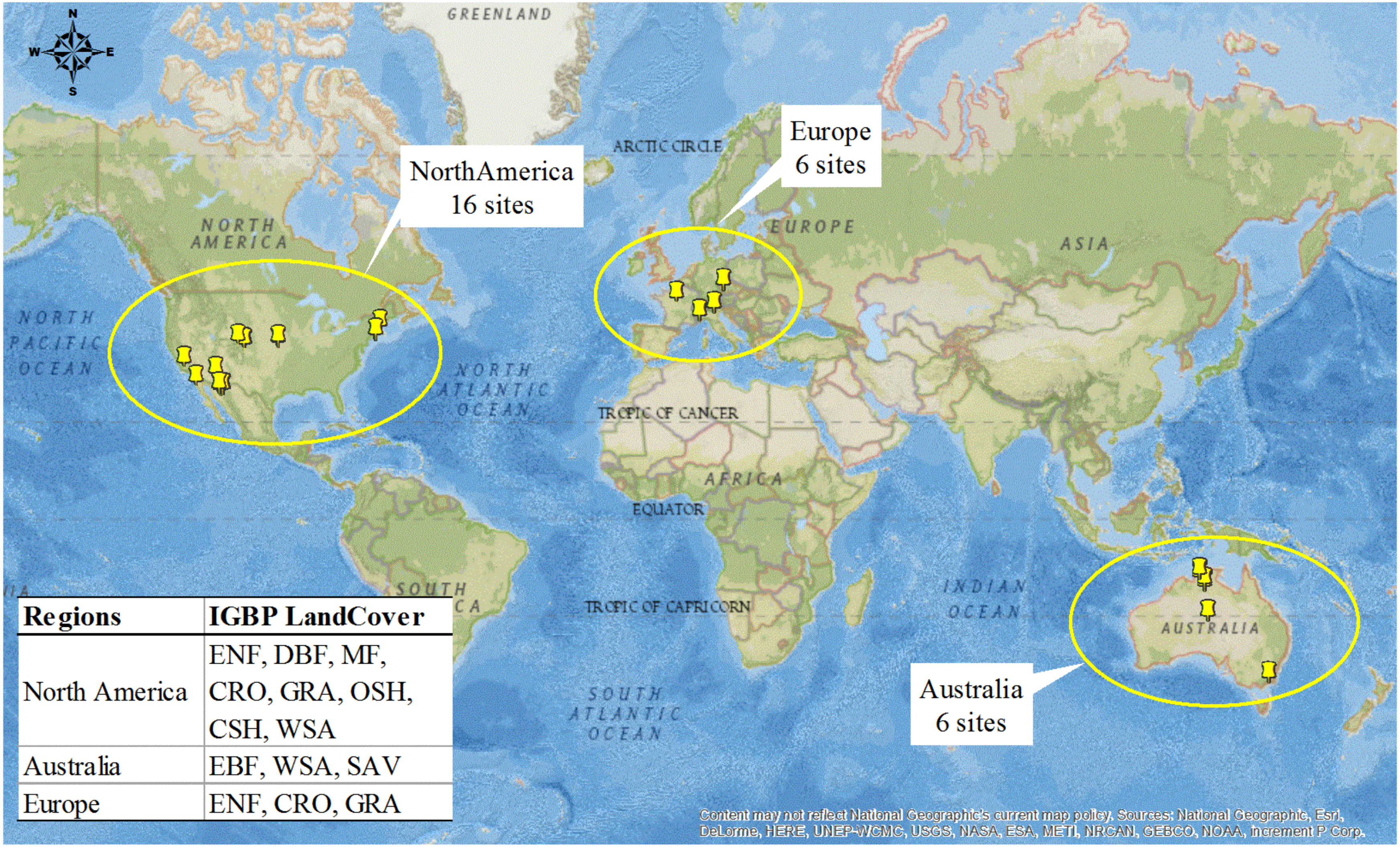
VIIRS Veg. Index EDR Global APU (Aqua MODIS as Reference) July 2015







VIIRS Vegetation Index EDR Temporal Profile Evaluation



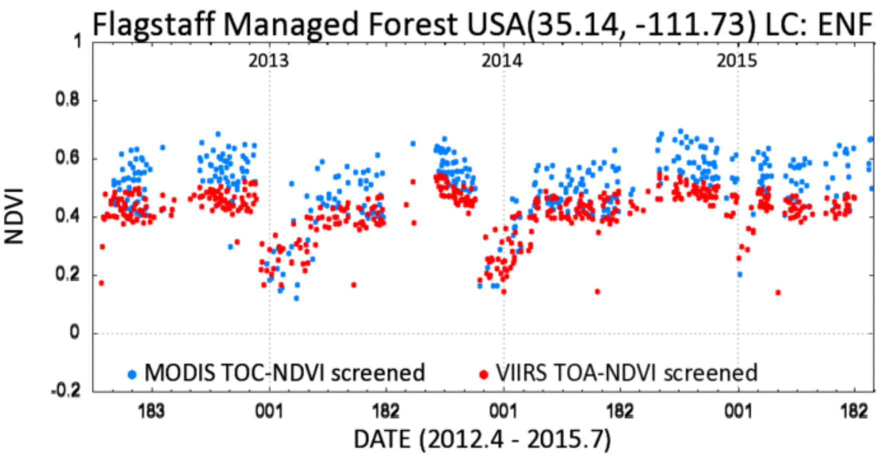
Regions	IGBP LandCover
North America	ENF, DBF, MF, CRO, GRA, OSH, CSH, WSA
Australia	EBF, WSA, SAV
Europe	ENF, CRO, GRA

Validation sites

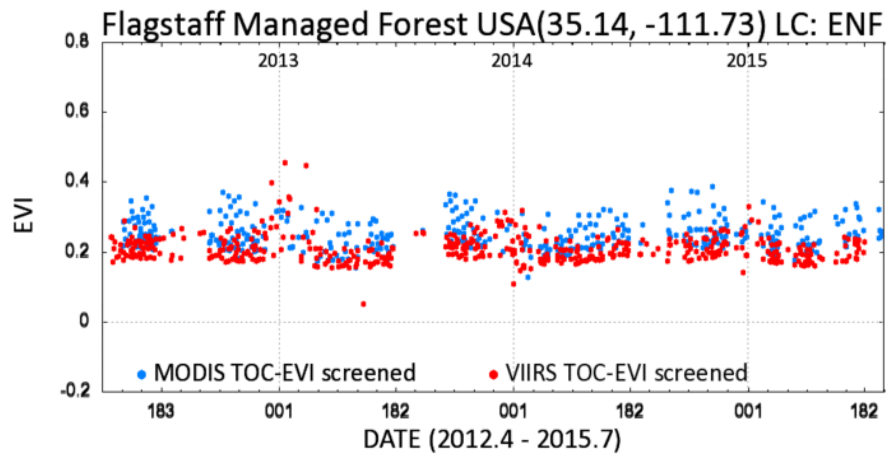
VIIRS Vegetation Index EDR Temporal Profile Evaluation

Red – VIIRS, Blue - MODIS

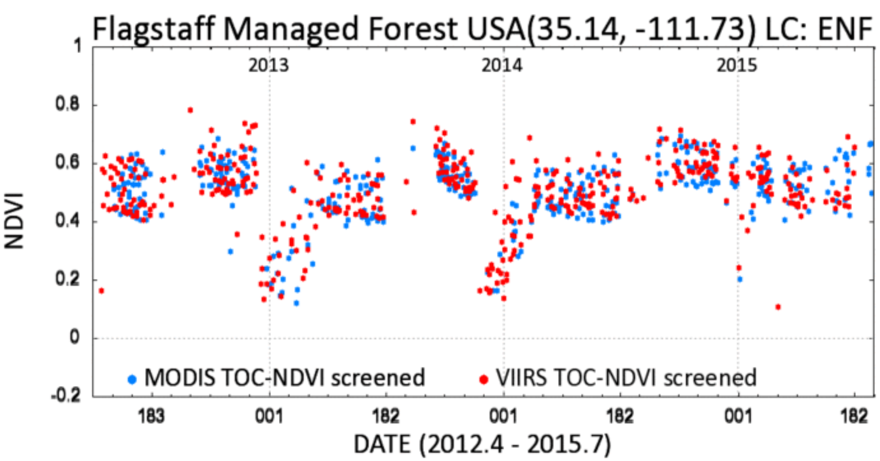
TOA NDVI



TOC EVI

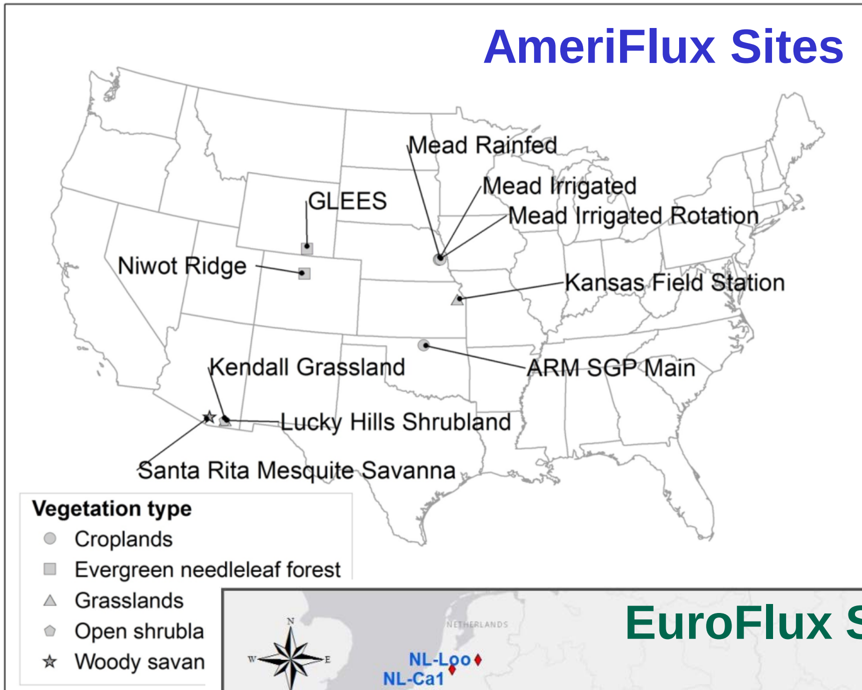


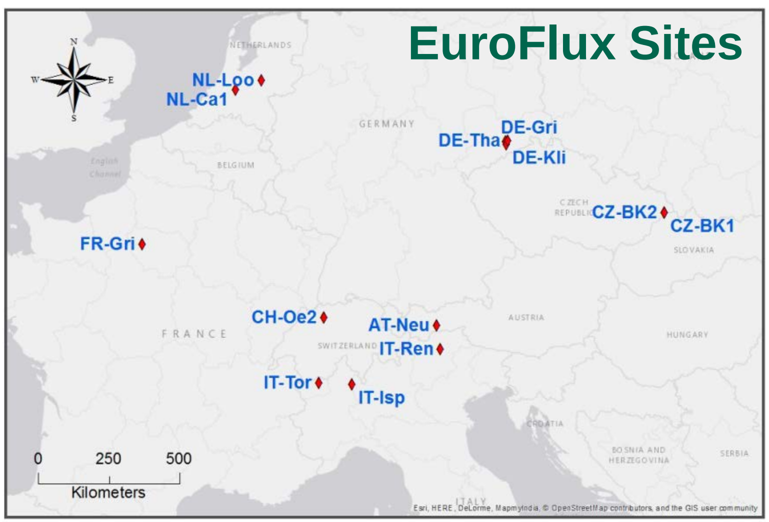
TOC NDVI



- VIIRS temporal profiles show matching seasonal changes with those of MODIS over CONUS, Europe, & Australia, e.g.,
  - Timing & length of peak growing period
  - Multiple growing periods
  - Interannual variations in seasonal changes
- VIIRS daily time series show secondary variations associated with variable Sun/view geometries among observations.

VIIRS Veg. Index Validation Using FLUXNET Radiation Flux Data

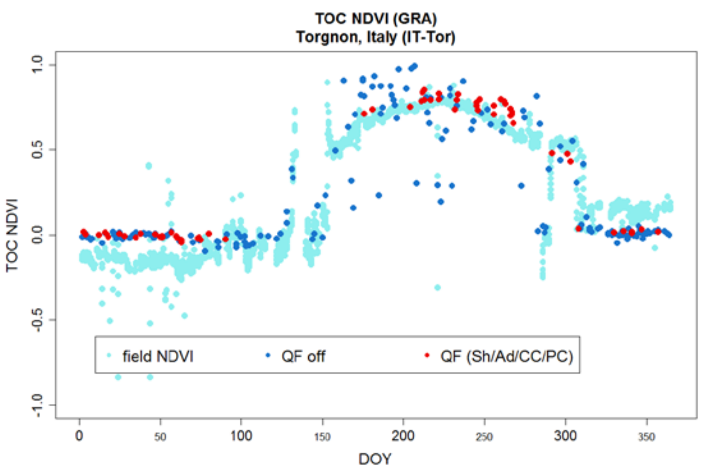


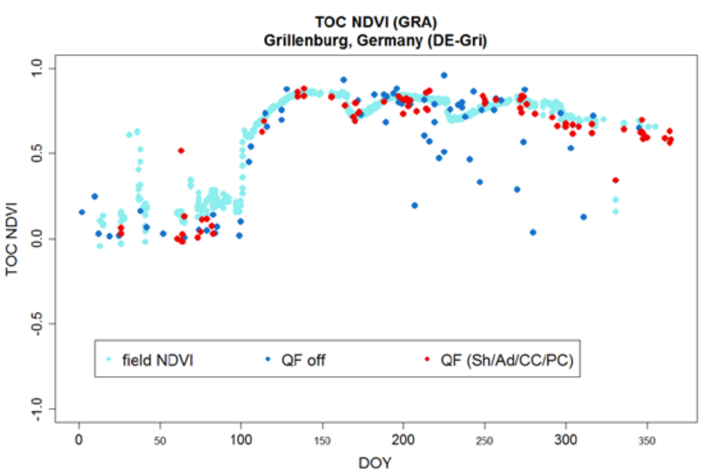


- FLUXNET sites
  - Spatial extent and homogeneity comparable to VIIRS pixels
  - Continuous PAR & global radiation measurements available
- High-temporal resolution NDVI and EVI2 (2-band EVI) time series
  - Computed from PAR & global radiation data (Wilson & Meyers 2007)
  - Cloudy observations removed (using precipitation and incoming global radiation data)

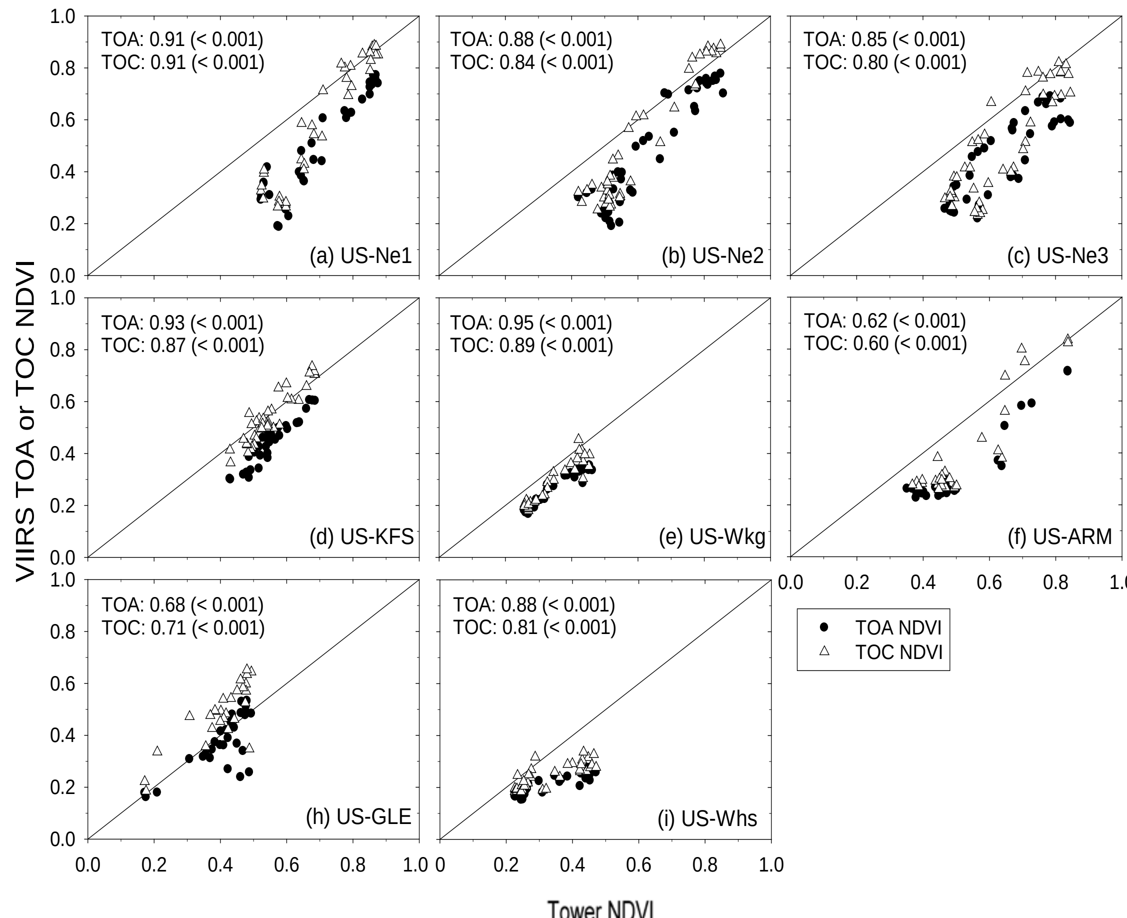
VIIRS Veg. Index Validation Using FLUXNET Radiation Flux Data

TOC NDVI: Sample Time Series
- *EuroFlux* -





VIIRS vs. Tower NDVI Cross-plots
- *AmeriFlux* -



JPSS1 VI EDR Cal/Val Plan

- **JPSS1 VI EDR will be validated by cross-comparisons with:**
  (1) data and products from other sensors (S-NPP VIIRS, MODIS, Landsat 8)
  (2) in situ data from observation networks (AERONET, FLUXNET)
  (3) independently-obtained climate datasets and analysis of process model results (FLUXNET)
- **APUs will be calculated periodically and plotted in time series to assure long-term consistency of the JPSS1 VI EDR**
- **Anticipated data needs for future validation**
  - MODIS, SNPP, FLUXNET, AERONET
- **VI EDR Cal/Val Tools**
  - VDDT, Time Series Analysis Tool, APU Tool, VIIRS Matchup Tool, VI Monitor, VI Phenological Metrics Tool, VI Cross-Comparison Tool
- **Schedule and Milestones** (based on availability of JPSS1 VIIRS VI products no later than March 2017)
  - Beta: October 2017 (VIIRS SDR Beta + 3 months)
  - Provisional: April 2018 (Beta + 6 months)
  - Validated: April 2019 (Provisional + 12 months)

NESDIS Enterprise Algorithms & NESDIS Ground Enterprise Architecture System (GEARS)

- NESDIS embarked in the Strengthening NESDIS initiative to reduce the cost of development, implementation, transition to operations, maintenance and sustainment of the NESDIS ground system
- NESDIS is transitioning to the Ground Enterprise Architecture System (GEARS)
- A new organization, the Office of Satellite Ground Services (OSGS), will consolidate the development and sustainment of all NESDIS ground systems

NESDIS Enterprise Algorithms

Definition: An Enterprise Algorithm is defined as an algorithm that uses the same scientific methodology and software base to create the same product from differing input data (satellite, in-situ or ancillary)

Motivation:

- Brings continuity of NOAA products between current and future NOAA operational satellites
- Cost effective processing for NOAA products
- Maintenance of fewer algorithms and systems within operations

Benefits: One set of algorithms will:

- Satisfy differing program requirements (latency, accuracy, resolution, etc)
- Reduce redundant software development and O&M costs
- Consistent science for data assimilation; fused products; enhanced products; and climate records

STAR Enterprise Algorithms

- **<u>VI EDR is a priority 4 product</u>**
- 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

Enterprise Algorithm Assessment VI and GVF Products

Product	VIIRS	ABI	GOES	AVHRR	MODIS	Users
VI (NDVI, EVI)	O	F		O	O*	NWS
GVF	O	F				NWS

O – operational, F – future capability, *MODIS production at NASA

Path Forward for Enterprise Solution:

- 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
- GVF in NDE is a L3 product. Calculates its own EVI, same formula as JPSS EVI.
- A L3 suite of products for NDVI, TOC EVI, TOC NDVI and GVF are needed (GVF already in production)
- Need to align requirements across satellites, standardize the requirements
- LAI and FPAR products are also needed. (Users require composite products)
- GOES-R has NDVI and GVF but Option 2 and not operational
- 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
- Want all land products to use the same Grid and mapping tools. NCEP's stated requirement is 1km global grid
- Move towards NDE and SPSRB (Not use the IDPS deliveries and processes)
- Enterprise NDVI should be TOC NDVI
- NDVI is used for Vegetation Health product but it currently calculates NDVI separately from reflectance
- Possible addition of Sentinel-3 data (gap filler)

NASA SNPP VIIRS Vegetation Products

- NASA has funded a Science Team to produce Earth System Data Records From Suomi NPP (funded by NASA ROSES-13)
- NASA SNPP VI Team is generating Vegetation Index products from SNPP VIIRS extending the EOS-MODIS VI record
- NASA SNPP VIIRS VI Products: NDVI, EVI, EVI2 (Level 3 products for MODIS continuity at all resolutions)
- NASA is reprocessing the entire VIIRS SDR record
- NASA SNPP VIIRS VI products scheduled for archiving and distribution at the Land Processes Distributed Active Archive Center (LP DAAC) starting in April 2016
- STAR VI EDR Team Members Vargas and Miura have met with Kamel Didan (PI for the NASA VIIRS VI product suite) to coordinate efforts to make a successful Algorithm/Product suite for both science (NASA) and operations/applications (NASA/NOAA)

Future Plans

- Support JPSS1 Pre-launch and Post-launch Cal/Val activities
- Continue LTM, anomaly resolution, and reactive maintenance of the SNPP Vegetation index EDR
- Develop Level 3 Vegetation Index products
- Support the STAR/JPSS Enterprise Algorithm development effort

Summary

- The SNPP VIIRS Vegetation Index EDR operational product is stable and performing well
- VI Team ready to support JPSS1 pre-launch activities
- The SNPP VI EDR LTM phase is ongoing
- The JPSS1 VIIRS VI EDR algorithm development has been completed
- JPSS1 Cal/Val plan developed
- Vegetation Index Enterprise Algorithm in planning stage

For more information on VIIRS Vegetation Index EDR

- STAR JPSS

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

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

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

- NOAA JPSS

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

- NOAA CLASS

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

- NASA

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

JPSS1 and SNPP VIIRS
Green Vegetation Fraction (GVF)

Marco Vargas[1], Zhangyan Jiang[2]

[1]NOAA Center for Satellite Applications and Research, College Park, MD,
[2]AER, College Park, MD

STAR JPSS 2015 Science Team Annual Meeting, August 24-28, NCWCP College Park, MD

GVF Team Members

- Marco Vargas (NOAA/STAR) Project Lead, Development Scientist
- Zhangyan Jiang (STAR/AER) Development Scientist
- Ivan Csiszar (NOAA/STAR) Development Scientist
- Mike Ek (NOAA/NCEP/EMC) User readiness
- Yihua Wu (NOAA/NCEP/EMC) User readiness
- Weizhong Zheng (NOAA/NCEP/EMC) User readiness
- Hanjun Ding (NOAA/OSPO) Product Area Lead
- Dylan Powell (Lockheed Martin/ESPDS/NDE) AI&T
- Tom Schott (NOAA/OSD) Consultant

GVF Users

– NCEP/EMC

– CLASS

– NASA/SPoRT

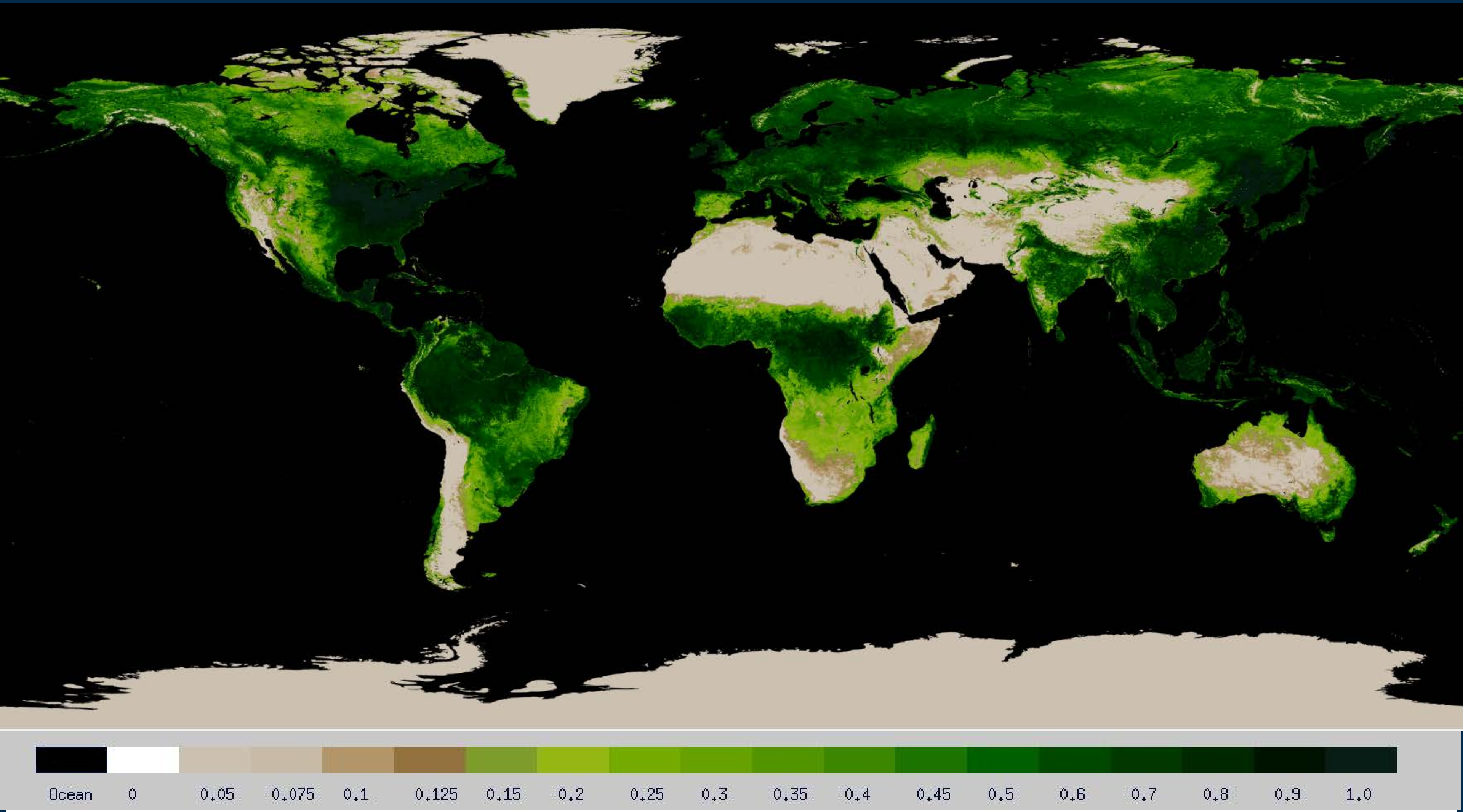
FY14-15 Accomplishments

- Delivered SNPP VIIRS GVF LINUX DAP to NDE (May 2014)
- Supported the NDE IPT team to during the integration, testing and pre-operational phase of the GVF system
- Briefed the VIIRS GVF product at the monthly SPSRB meeting for an operational decision in Sep, 2014
- The GVF product became operational within the Suomi NPP Data Exploitation (NDE) production facility in February 2015
- Started collaboration with NWS/NCEP to demonstrate that using the VIIRS GVF operational product instead of the AVHRR climatology will improve the performance of NOAA's environmental prediction suite

SNPP VIIRS GVF Product

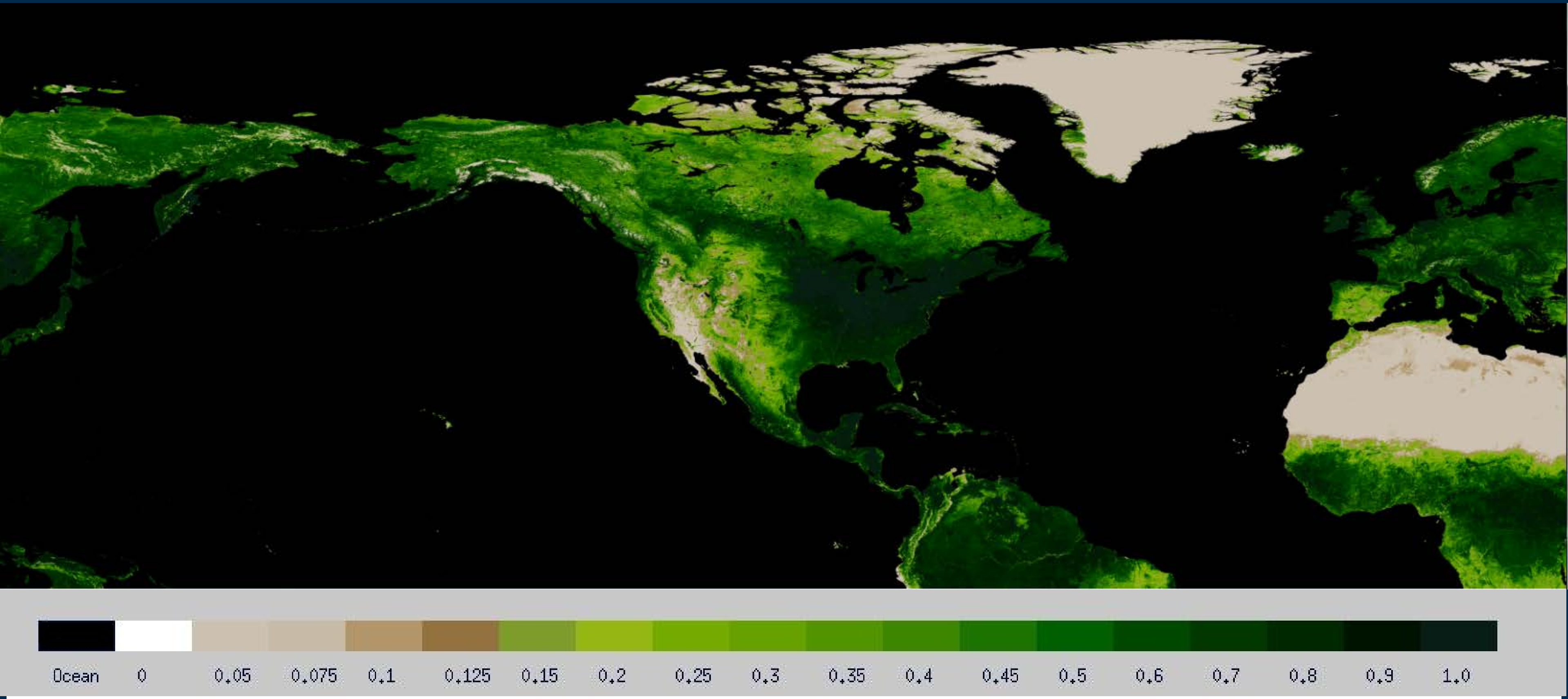
- The SNPP VIIRS GVF consists of two products:
  1) Daily Rolling Weekly GVF global (4-km resolution)
  2) Daily Rolling Weekly GVF regional (1-km resolution)
- SNPP VIIRS GVF products are derived from VIIRS surface reflectance data (Bands I1, I2 and M3)
- Surface reflectance data are gridded, composited and used for calculating the Enhanced Vegetation Index (EVI)
- GVF is derived from EVI

SNPP VIIRS GVF Global (4km res)



4km resolution weekly global GVF (August 18-24, 2015)

SNPP VIIRS GVF
Regional Product (1km res)

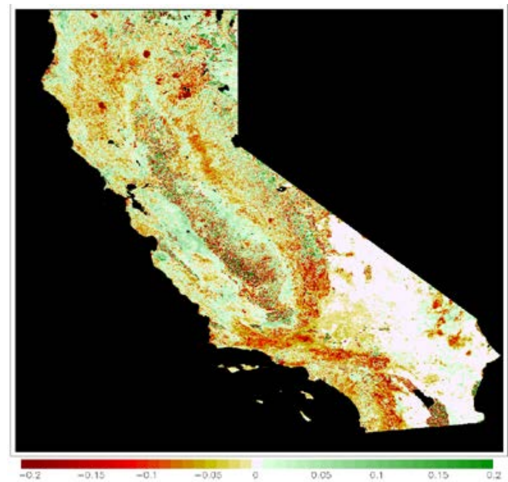


1km resolution weekly regional GVF (August 18-24, 2015). Coverage Lat 90°N - 7.5°S, Lon 130°E - 30°E

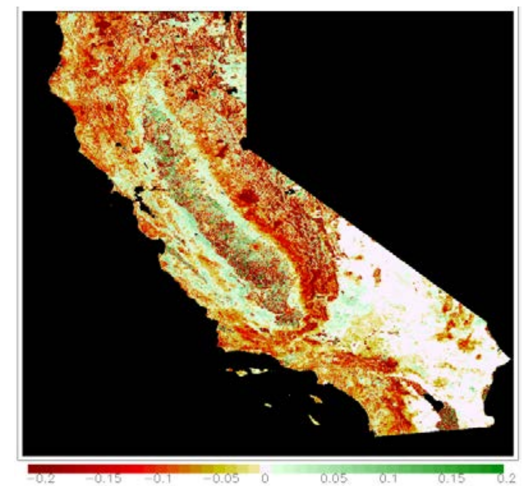
Monitoring Drought in California With SNPP VIIRS GVF

- California has been experiencing a severe drought since 2012
- Drought conditions develop gradually and they are often not identifiable immediately
- VIIRS Green Vegetation Fraction (GVF) can easily monitor <u>changes in vegetation density</u>

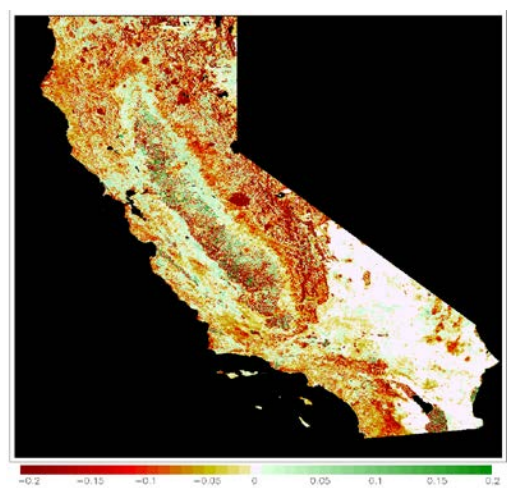
2013-08-15 minus 2012-08-15



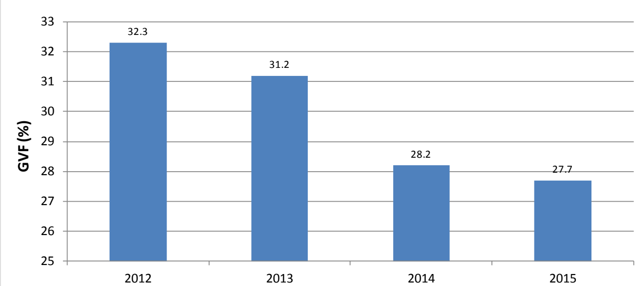
2015-08-15 minus 2012-08-15



2014-08-15 minus 2012-08-15



California mean GVF



California mean GVF in August decreased from 32.3% in 2012 to 27.7% in 2015

SNPP VIIRS GVF Validation

SNPP VIIRS GVF product Validation

- GVF product maturity: Provisional
- The SNPP VIIRS GVF pre-operational 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

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%

Path Forward towards JPSS1

- Provide VIIRS GVF continuity and upgrades for JPSS1
  - Project Plan to produce the JPSS1 VIIRS GVF
  - GVF Algorithm update/development for JPSS1
  - SNPP/JPSS1 VIIRS GVF Compatibility assessment
- Anticipated data needs for future validation
  - SNPP VIIRS GVF, AVHRR GVF, Landsat GVF
- Product Validation
  - Deliver Cal/Val plan for the JPSS1 VIIRS GVF product

Future Plans

- Advance the SNPP VIIRS GVF to validated maturity
- Continue providing SNPP VIIRS GVF algorithm maintenance and product anomaly resolution
- Develop SNPP VIIRS GVF climatology
- JPSS1 VIIRS GVF algorithm development
- Develop GVF enterprise algorithm

Summary

- The SNPP VIIRS GVF operational product is stable and performing well
- Working with NCEP to improve the use of the operational GVF product in their land modeling suite
- JPSS1 VIIRS GVF Project Plan has been written
- GVF Enterprise Algorithm in planning stage
- SNPP VIIRS GVF product available from NOAA CLASS

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

- For more information on SNPP VIIRS GVF

http://www.ospo.noaa.gov/Products

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

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