JPSS STAR Algorithm and Data Products (ADP) Beta Review

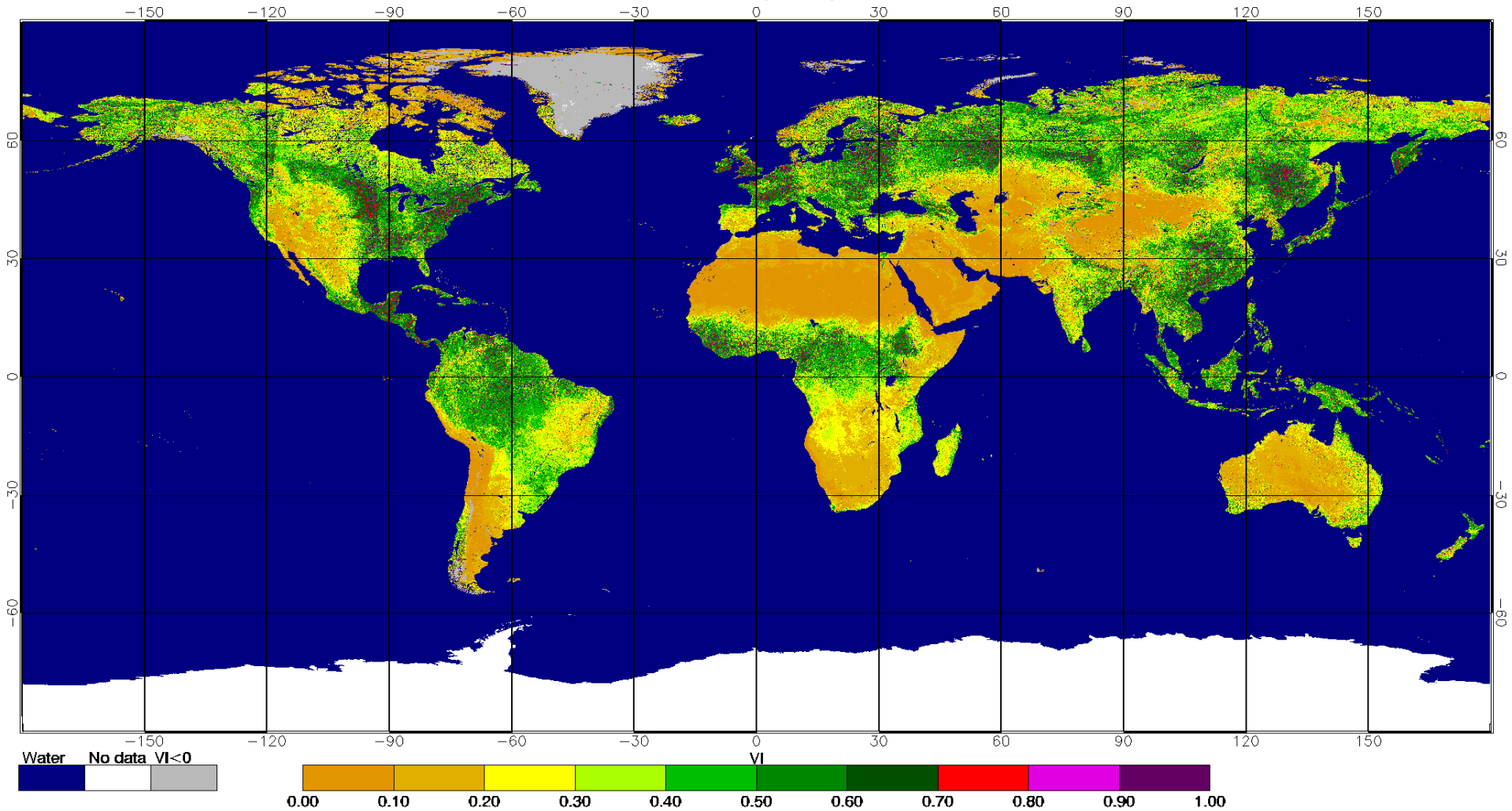## Suomi NPP Vegetation Index EDR

Marco Vargas VI-EDR Algorithm Lead
Tomoaki Miura VI-EDR Cal/Val Lead
12/19/2012

Overview of VI EDR Data Products

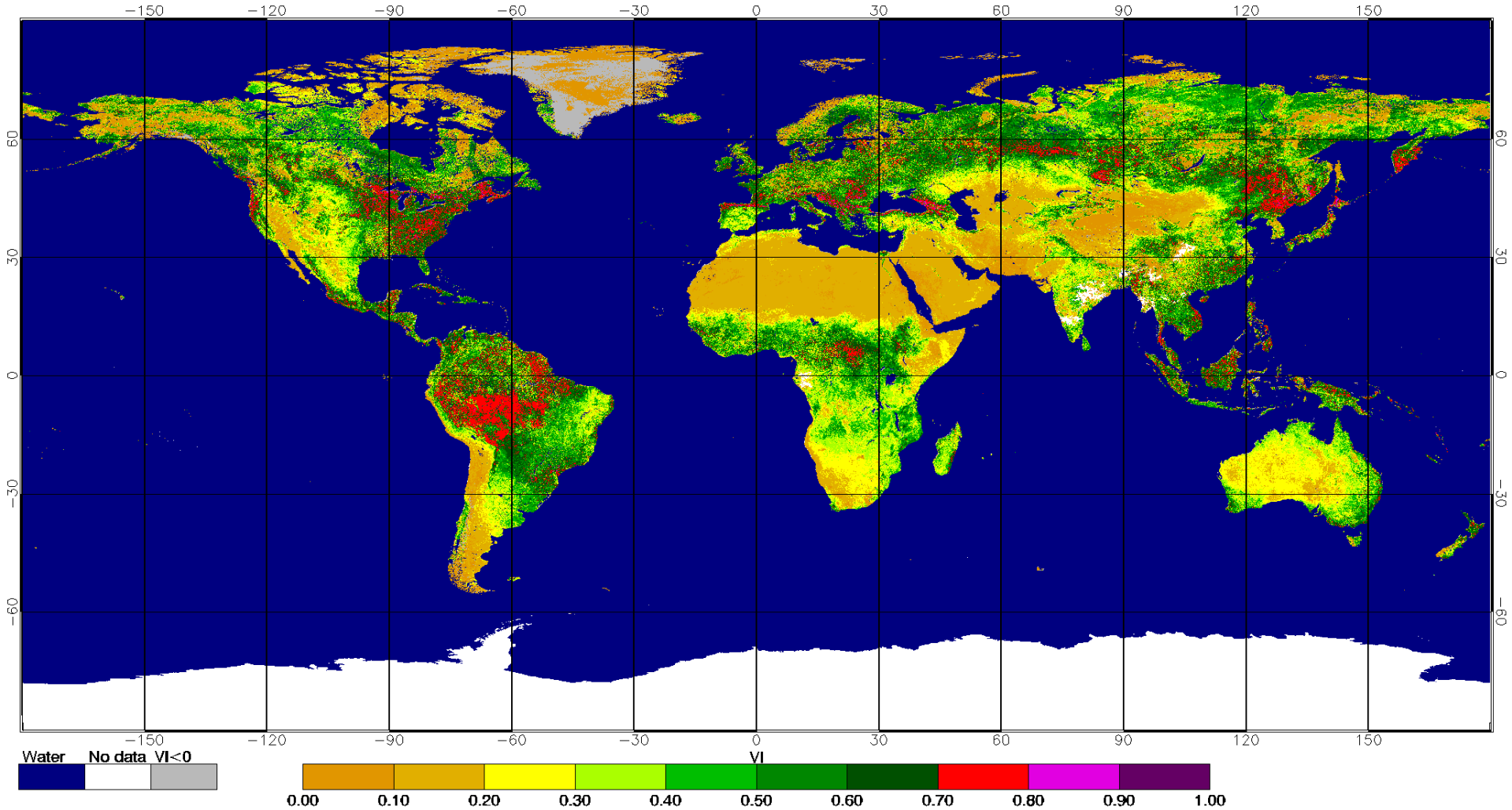## SNPP VIIRS TOC EVI 16-day composite

VIIRS TOC EVI for July 11 - July 26, 2012

Overview of VI EDR Data Products

SNPP VIIRS TOA NDVI 7-day composite

VIIRS TOA NDVI for July 15 - July 21, 2012

Vegetation Index EDR Team Members

- Marco Vargas (NOAA/NESDIS/STAR) STAR VI EDR algorithm lead

- Tomoaki Miura (University of Hawaii) VI Cal/Val lead

- Nikolay Shabanov (STAR/IMSG) Product monitoring and validation, algorithm development

- Alfredo Huete (UTS) Cal/Val Team Member

- Leslie Belsma (Aerospace) Land JAM

- Alain Sei (NGAS) External Partner, Consultant

- Michael Ek (NOAA/NCEP) User readiness

- Jesse Meng (NOAA/NCEP) User readiness

- Ivan Csiszar (NOAA/NESDIS/STAR) STAR Land EDRs Chair

- Jeff Privette (NOAA/NESDIS/NCDC) Product validation lead, Land EDRs Co-Chair

Beta Maturity Definition

- Early release product
- Minimally validated
- May still contain significant errors
- Versioning not established until a baseline is determined
- Available to allow users to gain familiarity with data formats and parameters
- Product is not appropriate as the basis for quantitative scientific publications, studies or applications

Background of VI EDR Product

• VI EDR consists of two vegetation indices: the TOA **Normalized Difference Vegetation Index** (TOA-NDVI) and the TOC **Enhanced Vegetation Index** (TOC-EVI).

• VI EDR provides continuity with NASA EOS **MODIS** and NOAA POES **AVHRR**.

•**TOA - NDVI:** Top of the Atmosphere Normalized difference vegetation index is most directly related to absorption of photosynthetically active radiation, but is often correlated with biomass or primary productivity.

• **TOC – EVI:** Top of the Canopy Enhanced Vegetation Index EVI was developed to optimize the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a reduction in atmosphere influences.

•Vegetation Index (VI) is one key parameter to specify the boundary condition in global climate models, weather forecasting models and numerous remote sensing applications for monitoring environmental state and its change.

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VIIRS Vegetation Index EDR

- **Product Description**: Provides the <u>Normalized Difference Vegetation Index (NDVI)</u> and the <u>Enhanced Vegetation Index (EVI)</u> at 375 m on a daily basis.

- **Retrieval Strategy**:

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

  – The **NDVI** derived from TOA reflectance:

  – The **EVI** derived from TOC reflectance with a different gain factor from that of the MODIS equation:

  $$EVI = (1+L) \cdot \frac{\rho_{I2}^{TOC} - \rho_{I1}^{TOC}}{\rho_{I2}^{TOC} + C_1 \cdot \rho_{I1}^{TOC} - C_2 \cdot \rho_{M3}^{TOC} + L}$$
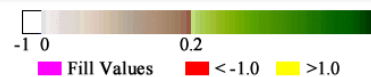
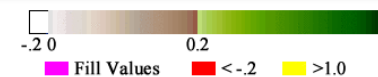- **Product Layers**:
  Includes quality flags on

  – Land/water

  – Cloud confidence including thin cirrus

  – Heavy aerosol loadings

  – Exclusion conditions
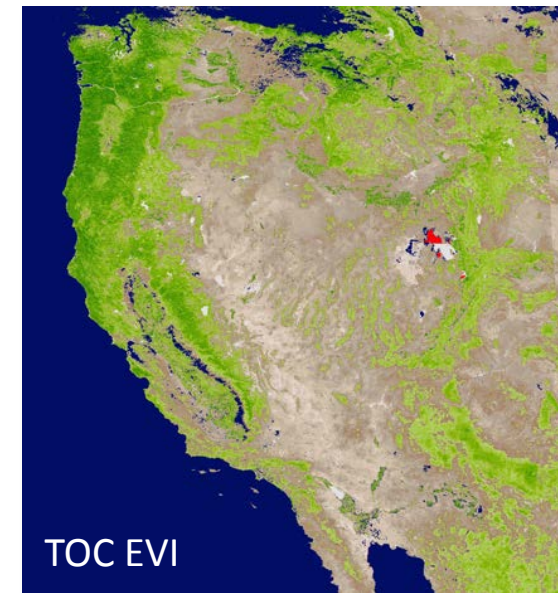
<u>VIIRS VI EDR</u>
<u>Oct. 1, 2012</u>
<u>(Mx 6.3)</u>

TOA NDVI

TOC EVI

Overview of Vegetation Index EDR

- TOA NDVI will provide continuity with the AVHRR heritage product
- TOC EVI will provide continuity with the MODIS heritage product
- These indices are produced at the VIIRS image channel resolution (i.e. nominally 375m at nadir).
- VI EDR uses Spectral bands I1, I2 and M3
- The VIIRS Vegetation Index EDR is computed after the RDR, SDR, and intermediate products processing is complete.
- Product style: Swath
- File Format: HDF5
- Measurement Exclusion Conditions:
    1) SZA > 85 deg for both NDVI and EVI (NIGHT TIME)
    2) AOT > 1.0 for EVI
    3) Confidently cloudy
- Retrievals are not performed over ocean or coastal
- VI calculated for LAND retrievals including inland water bodies and rivers.
- Assumption for EDR validation is that the **VIIRS SDR is calibrated.**
    - Beta versions of SDR have been used to help algorithm and instrument assessments during EOC and the early stages of ICV.

L1RD Requirements

Table 5.5.9 - Vegetation Index (NDVI) (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
NDVI Applicable conditions: 　1. Clear, daytime only		
a. Horizontal Cell Size	4 km	1 km
b. Mapping Uncertainty, 3 Sigma	4 km	1 km
c. Measurement Range		
1. NDVI (NDVI Units)	-1 to +1	
2. EVI (EVI Units) (1)	-1 to +1	
3. $NDVI_{TOC}$ ($NDVI_{TOC}$ Units) (1)	-1 to +1	
d. Measurement Accuracy - NDVI	0.05 NDVI units	0.03 NDVI units
e. Measurement Precision - NDVI	0.04 NDVI units	0.02 NDVI units
f. Measurement Uncertainty - EVI	0.11 EVI units	None
g. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	24 hrs.
h. TOC	As part of the Vegetation Index EDR processing, the system shall deliver a Top of Canopy NDVI ($NDVI_{TOC}$) product.	
		v2.2, 9/23/12

Source: Level 1 Requirements SUPPLEMENT – Final Version 2.3 November 2, 2012

- NCEP- National Centers for Environmental Prediction (Michael Ek/Jesse Meng/Yihua Wu/Matthew Rosencrans)
- STAR - Center for Satellite Applications and Research (Felix Kogan)
- CLASS - Comprehensive Large Array-data Stewardship System (John Bates)
- USDA - United States Department of Agriculture (Eric Luebehusen)
- The Climate Corporation – Pavel Machalek
- USGS - U.S. Geological Survey
- UH - University of Hawaii
- UA - University of Arizona
- UTS - University of Technology Sydney

Vegetation Index EDR Dataflow

- The VIIRS Vegetation Index EDR requires: calibrated TOA reflectances (bands I1, I2), SDR
- auxiliary data (solar zenith angle)
- Surface Reflectance (bands I1, I2, M3, Land Quality Flags).
- VI coefficients
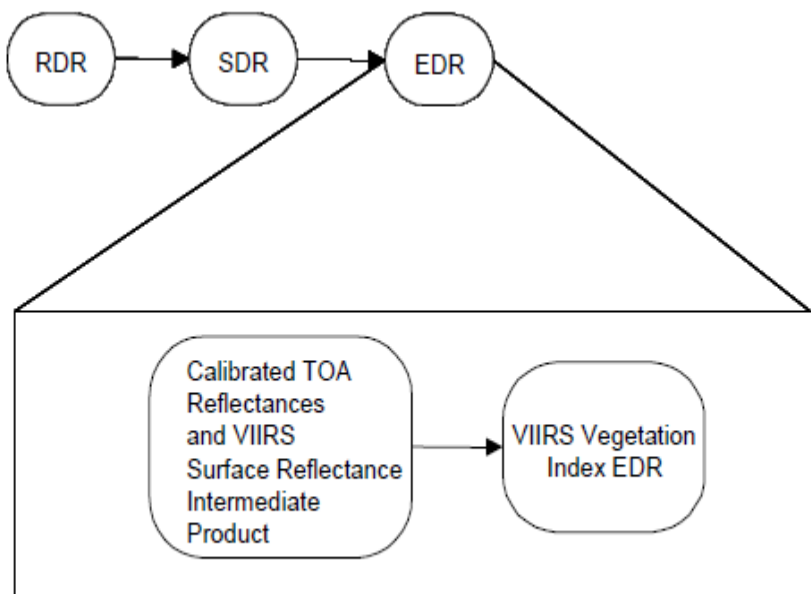
Figure 1. Processing chain associated with VIIRS Vegetation Index EDR (OAD VIIRS VI EDR 474-00063 January 18, 2012).
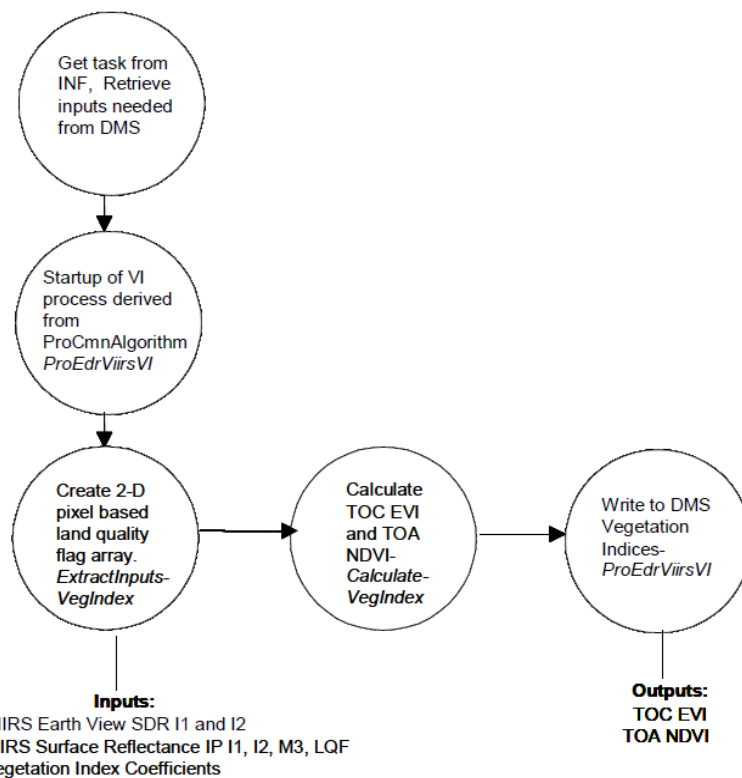
Figure 2. Data Flow Diagram of Overall VVI EDR Call Sequence from the Main Program (OAD VIIRS VI EDR 474-00063 January 18, 2012).

History of Algorithm changes/updates

DR#	Reason	Status
DR 4622	Erroneous quality flag for missing input data	VI-EDR team is preparing an enhanced set of QFs to improve the VI product quality. We expect to close this DR before provisional release (Sept 2013)
DR 4380	EVI requirements in L1RD in error	Open
DR 4379	L1RD drops wavelengths, needs to be defined	We expect to close this DR before provisional release (Sept 2013)
DR 4377	Baseline of ephemeral tuning coefficients	We expect to close this DR before provisional release (Sept 2013)
DR 4376	Vegetation Index: L1RD requires NDVI TOC	Open
DR 4297	Thin Cirrus Correction and Flagging	Approved for Future Re-evaluation
DR 4290	EVI Quality should degrade AOT>1	QF update in preparation, we expect to close this DR before provisional release (Sept 2013)
DR 3375	Byte 0 Quality Flag Structure	Closed
DR 2887	Erroneous thin cirrus test in vegetation index	Closed

Beta Maturity Evaluation

- Internal performance evaluation
  - Assessment of data structure and integrity
  - Quality assessment at granule level
  - Quality assessment using regional/global mosaics
  - Visual assessment of quality flags
- External performance evaluation
  - Comparison with Aqua MODIS (and AVHRR) using regional/global mosaics
  - Assessment of time series using Aqua MODIS (and AVHRR) as a reference

Beta Maturity Evaluation

- Many fill-valued pixels found over bright targets only for TOC-EVI
  - Fill-valued M3 surface reflectance, likely due to the overestimation of AOT
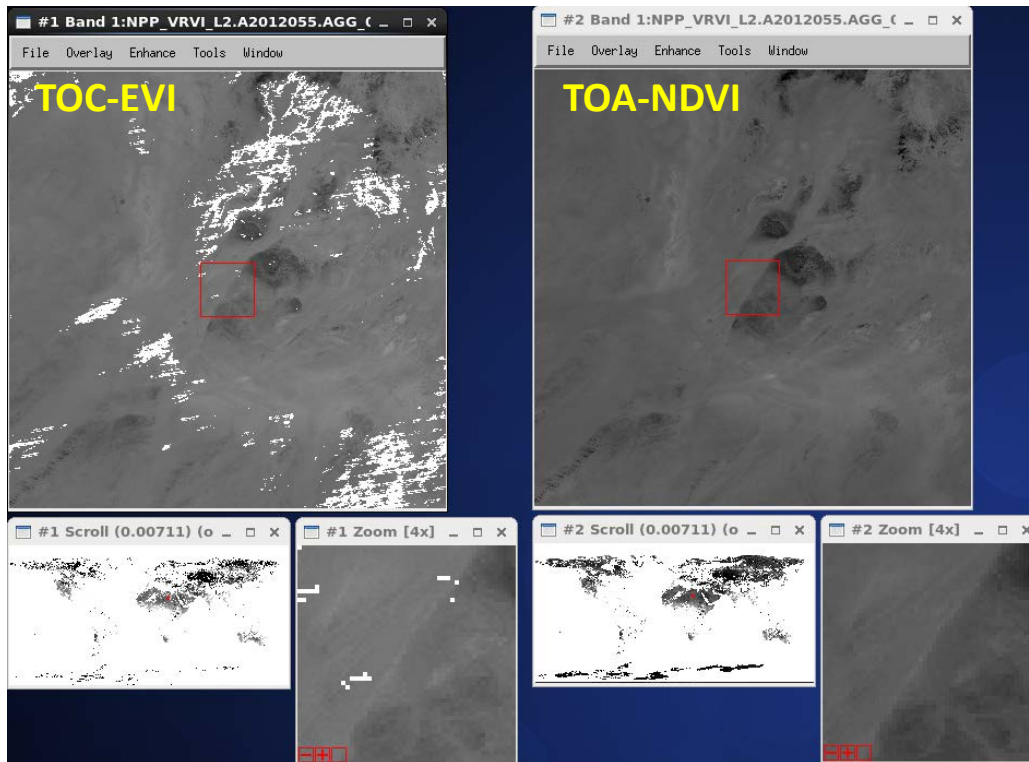
- QFs of SR IP indicating:
  - "Poor M3 SDR" (NA_FLOAT32_FILL: -999.9), or
  - ERR_FLOAT32_FILL (-999.5)

VIIRS EDR over Sahara 2012-055 (Mx 5.2)

Beta Maturity Evaluation

- Erroneous EVI values over snow/ice covered surface
  - EVI values become unrealistically high or low.

VIIRS False Color Composite and VI EDR
Greenland, 2012-219 (Mx 5.3)
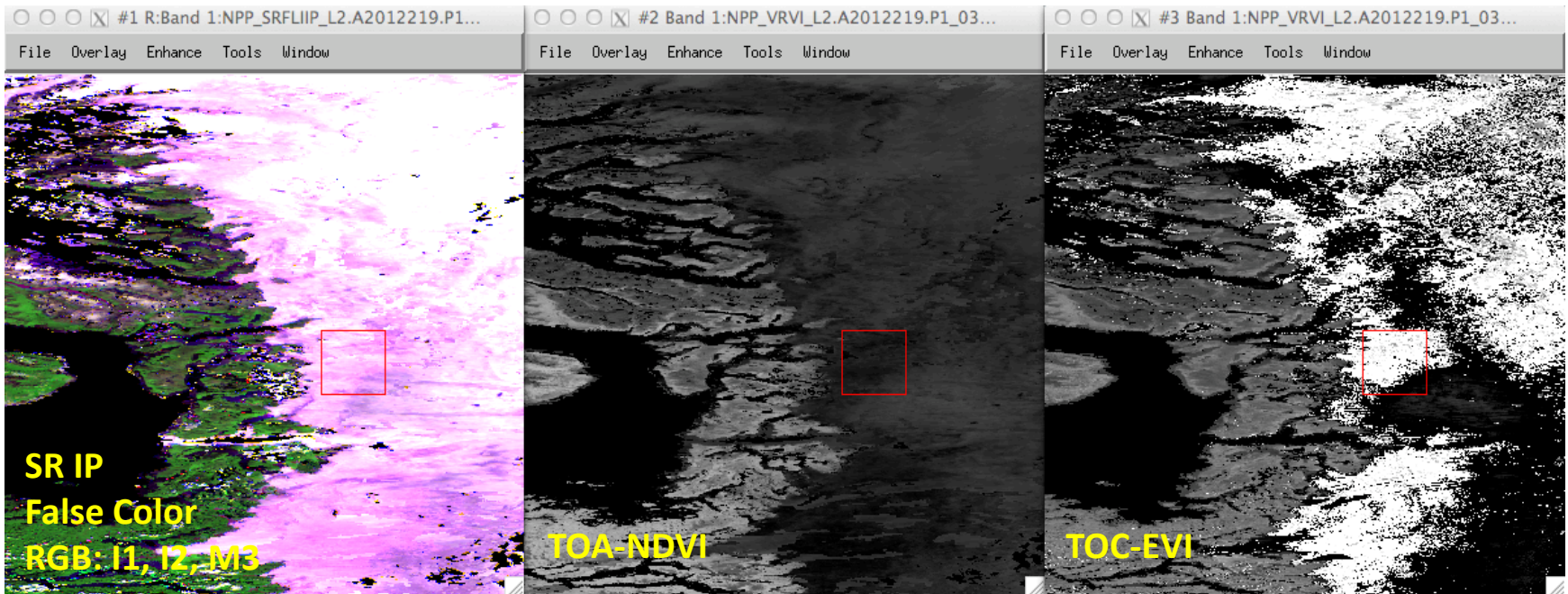
Beta Maturity Evaluation

- Erroneous EVI values over residual clouds
  - EVI values become unrealistically high or low.

Ukraine, 2012-219, VIIRS False Color Composite and VI EDR (Mx 5.3)
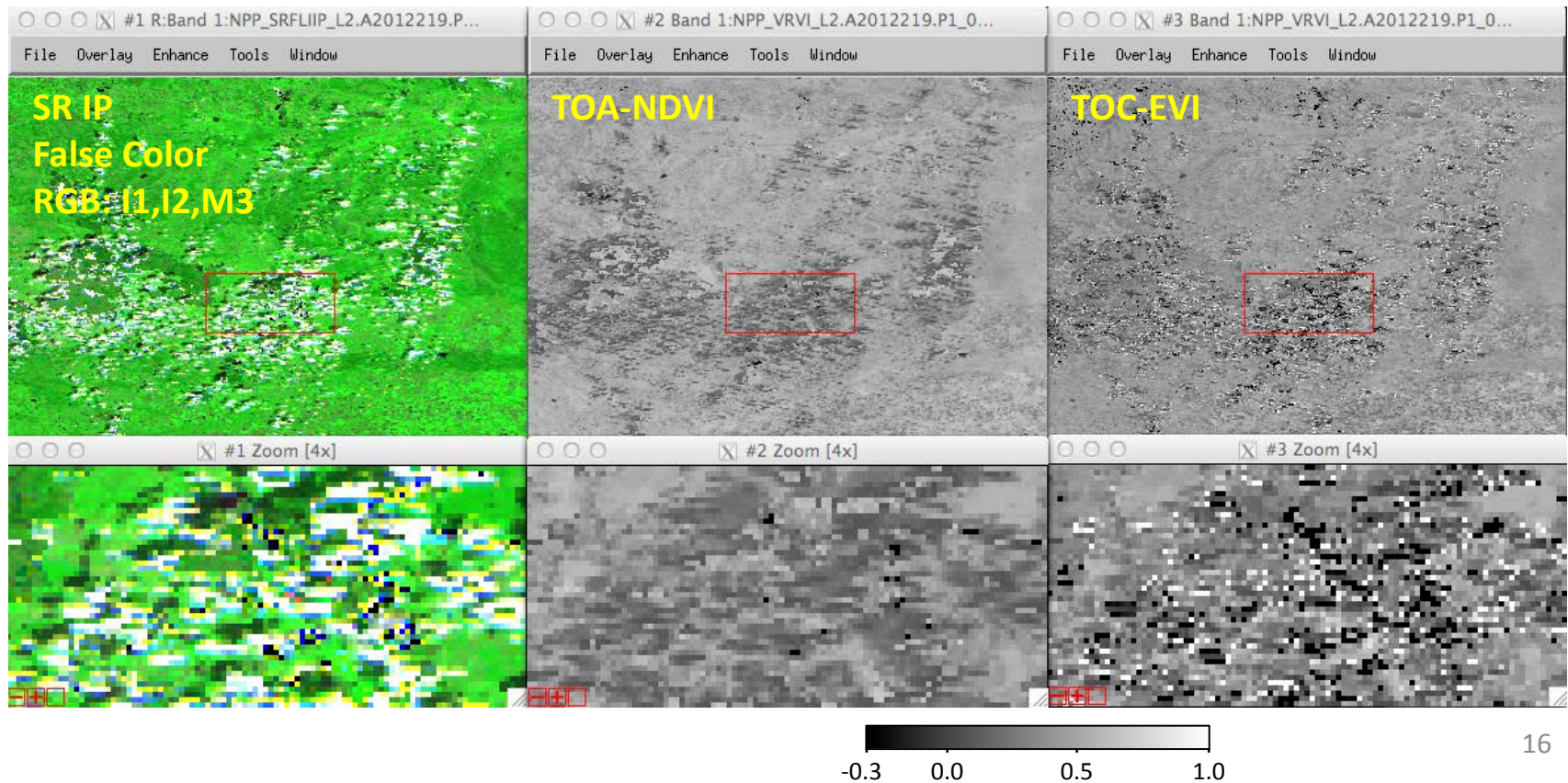
Beta Maturity Evaluation

- Regional mosaic comparisons with Aqua MODIS
  - Near-simultaneous nadir observations
    - Overlapped orbital tracks with view zenith angles < ±10 degrees
    - Every 8 days
    - Solar zenith angle differences of 1-2 degrees
  - Screened by quality flags
    - Only using MODIS QA at this point

**Orbital Tracks with $\theta_v < \pm10^o$
for 2012-211 (July 29)
Blue: NPP VIIRS
Red: Aqua MODIS**
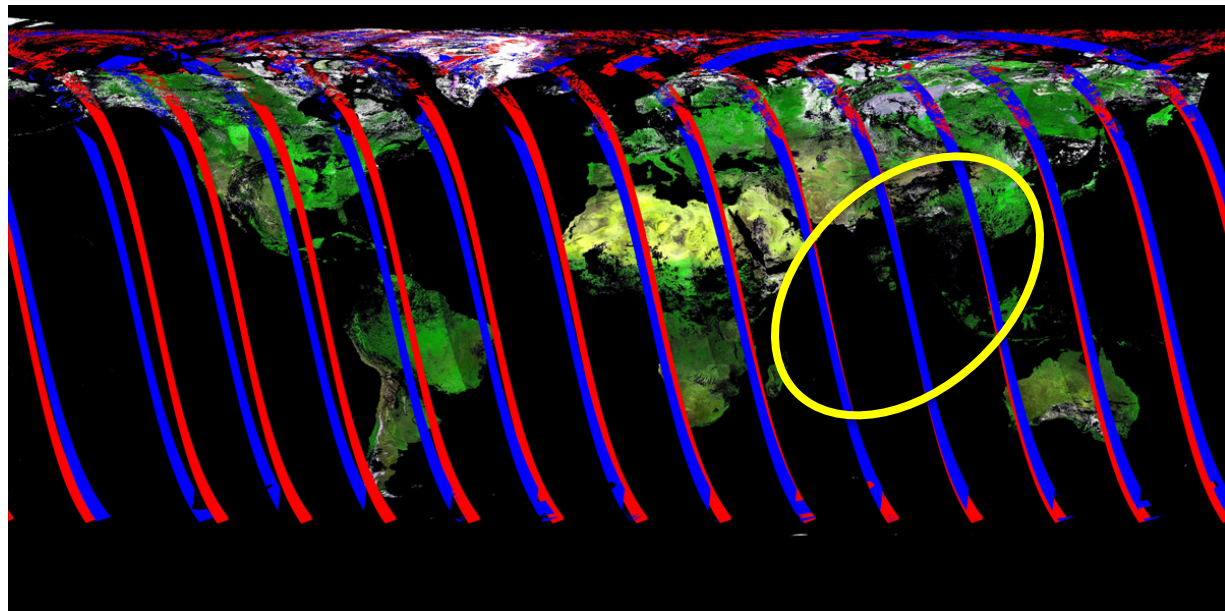
Beta Maturity Evaluation

* APU metrics of VIIRS VI EDR (in reference to Aqua MODIS) consistent over time.
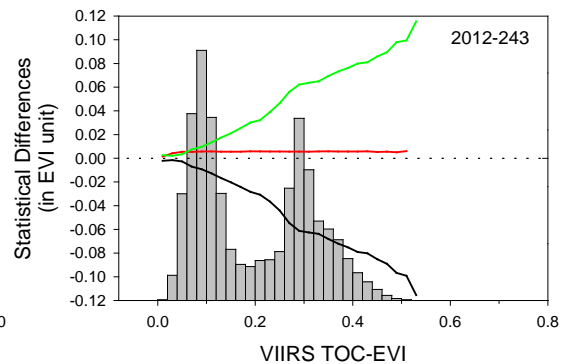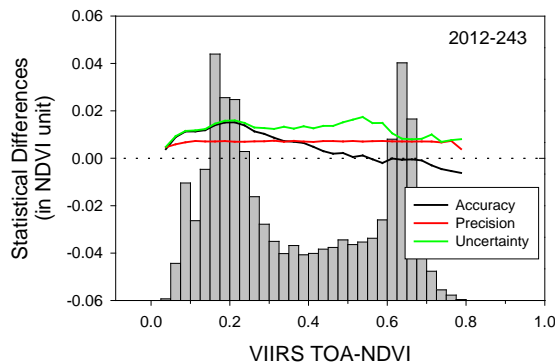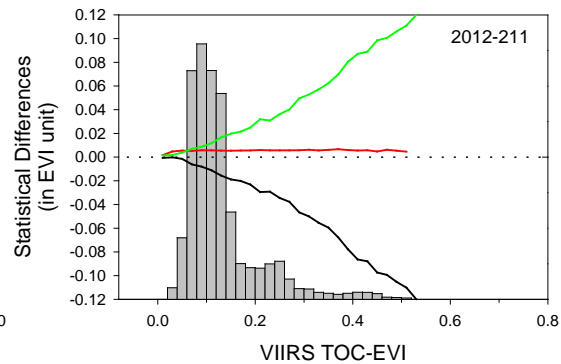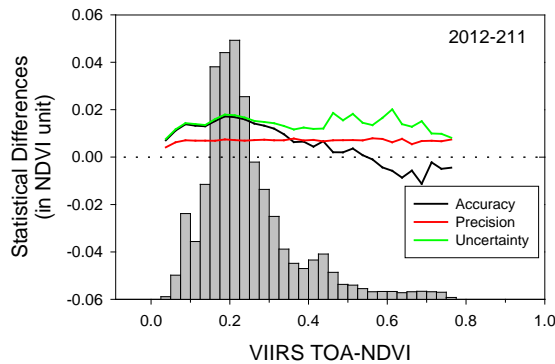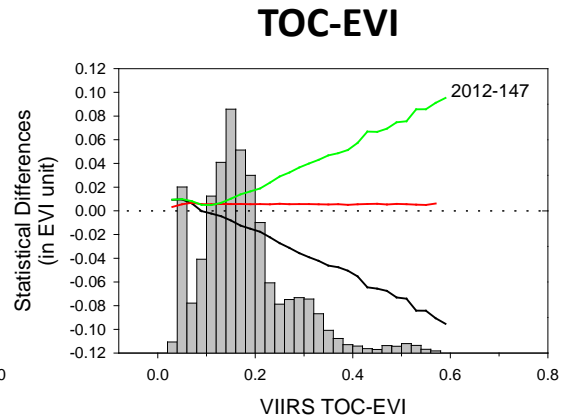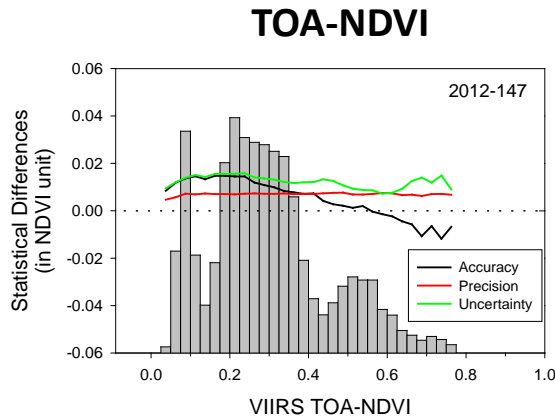
TOA-NDVI

TOC-EVI

APU Summary Tables

2012-147

	TOA-NDVI	TOC-EVI
A	0.005	-0.04
P	0.007	0.005
U	0.012	0.05

2012-211

	TOA-NDVI	TOC-EVI
A	0.005	-0.05
P	0.007	0.006
U	0.014	0.06

2012-243

	TOA-NDVI	TOC-EVI
A	0.005	-0.05
P	0.007	0.006
U	0.012	0.06

Beta Maturity Evaluation

- VIIRS VI temporal profiles (3 km-by-3 km window) depicting seasonal changes comparable to those of Aqua MODIS
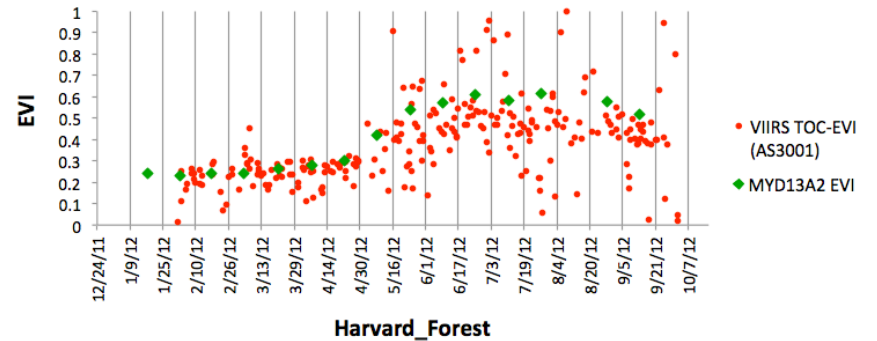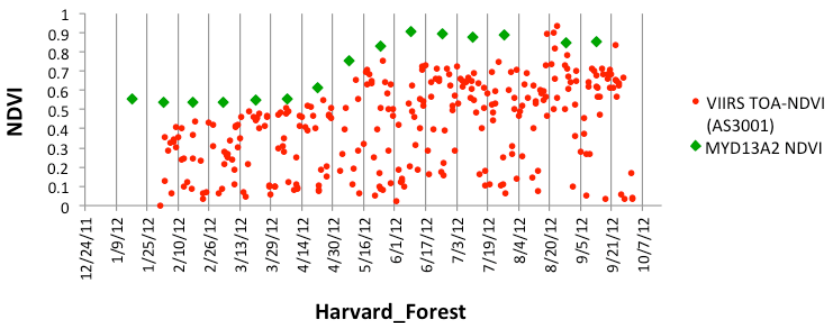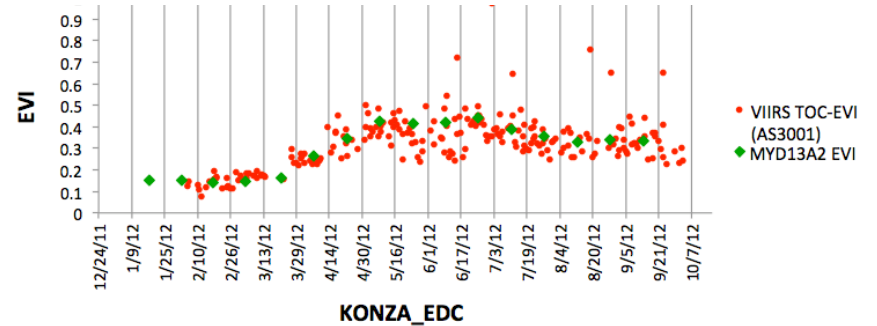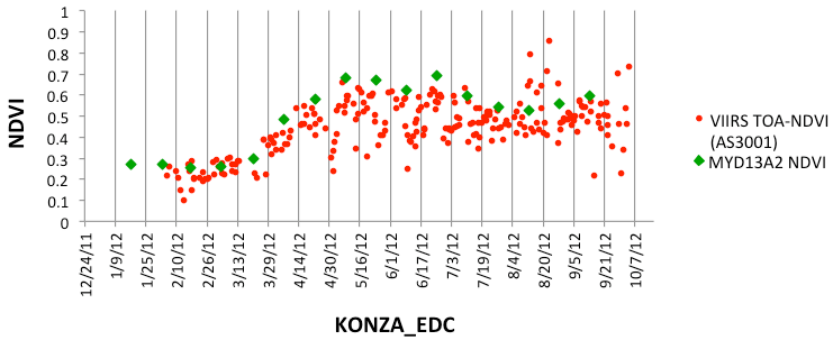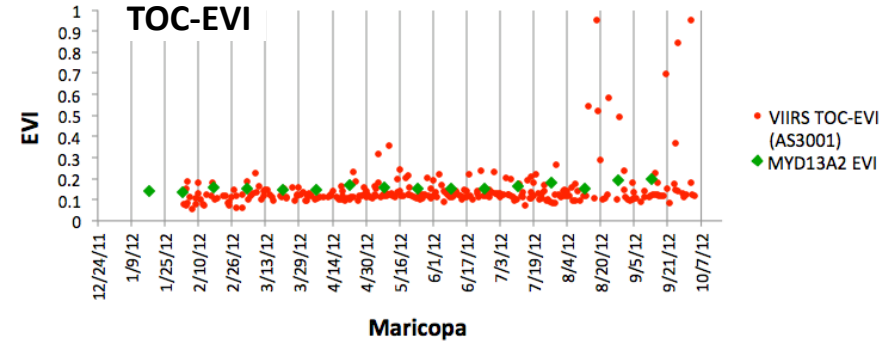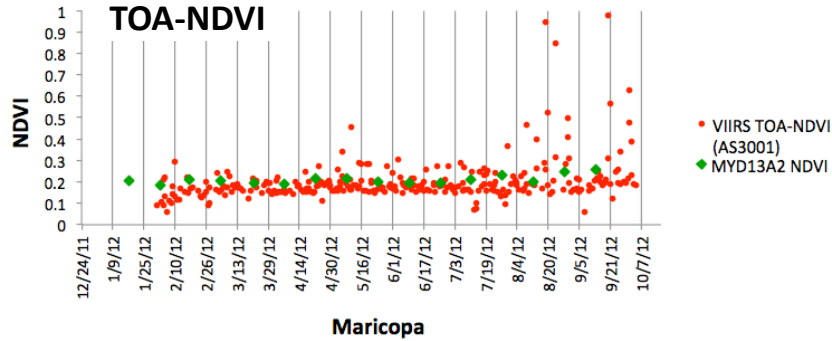
Beta Maturity Evaluation

- Good/intact data structure and integrity:
  - Residual clouds
  - Missing EVI values over bright surfaces
  - Erroneous EVI values over snow/ice and residual clouds
- Regional mosaic comparisons:
  - Dates examined: 2012-055, 107-251 (every 8 day), & 307.
  - Consistent over time
  - Bias similar to those predicted from pre-launch validation results (Hyperion spectral synthesis analysis)
- Time series:
  - Land cover types examined: broadleaf forest, woodland, shrubland, grassland, cropland, urban
  - All seasonal trends comparable to those of MODIS although subject to more unsystematic noises (variations)

VIIRS VI product Quality Control tool at STAR
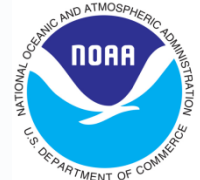
- **Web-based tool was implemented at STAR for continuous (NRT in the future) monitoring of performance of VIIRS VI product time series at global scale (especially important at the early stage of VIIRS mission to detect/trace anomalies, trends and conformity to physically principles).**

- **VIIRS VI product is compared with heritage MODIS and AVHRR VI products.**

- **Analysis includes daily and compositing VI and QC maps, maps of VI difference (VIIRS- MODIS, VIIRS-AVHRR), histograms and time series of statistics at biome-by-biome level and globally.**
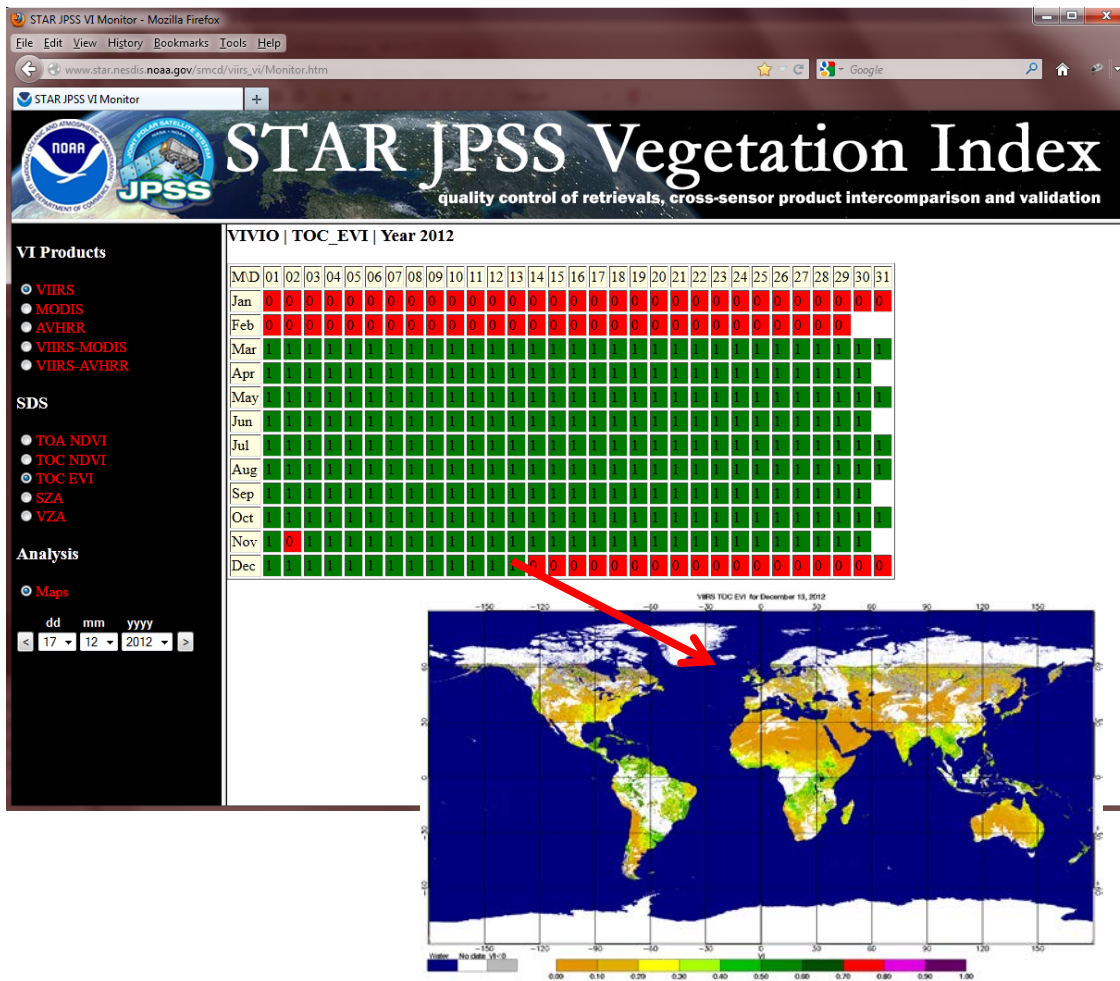

http://www.star.nesdis.noaa.gov/smcd/viirs_vi/Monitor.htm

Beta Maturity Evaluation

Data sets analyzed

- **Global <u>VIIRS</u>, <u>MODIS</u> and <u>AVHRR VI products</u> from March to July 2012.**
- **VIIRS daily and compositing VI products corresponding to MODIS and AVHRR data sets.**
- **MODIS vegetation index TOC-EVI 16-day composites**
- **NOAA-18 AVHRR TOA-NDVI 7day composites.**
- **MODIS Land cover LAI/FPAR 6-biomes land cover, annual product, ancillary data set, allowing biome-level analysis**
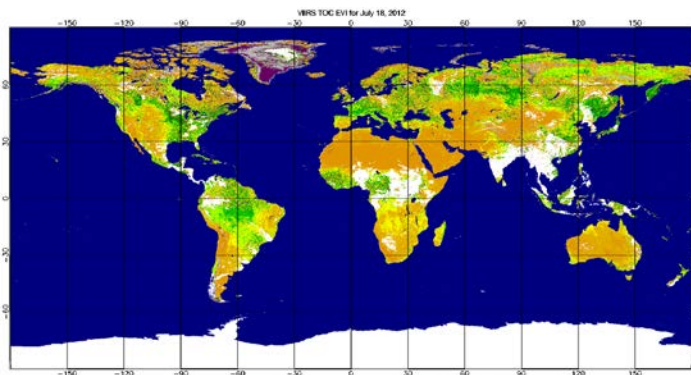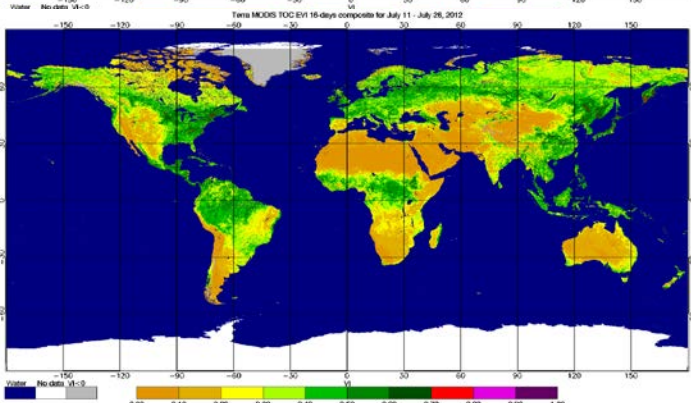
MODIS LAI/FPAR 6-biome Land Cover
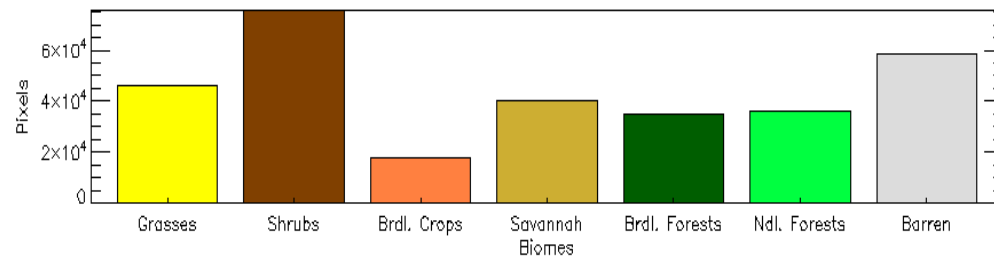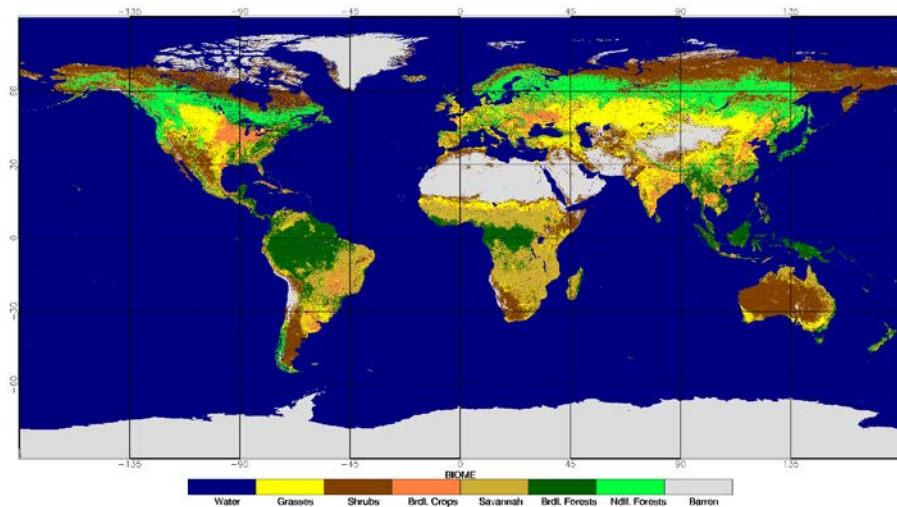
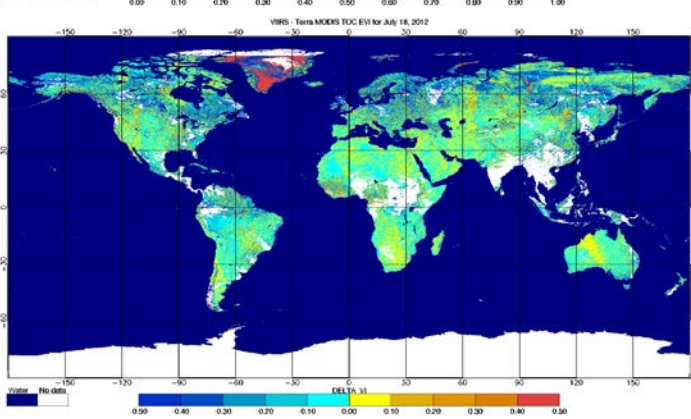# MODIS vs. Suomi NPP VIIRS Enhanced Vegetation Index (EVI)


- **Analysis of <u>daily</u> VIIRS TOC-EVI (VIIRS: July 18, 2012, vs. MODIS: July 11 – July 26, 2012)**
- **Overall, spatial patterns and histograms of VIIRS and MODIS TOC EVI are consistent**
- **However, VIIRS TOC EVI exhibits anomalously high values over snow-covered areas at high SZA (i.e., Greenland)**
- **Also cloud leakage is pronounced at Northern latitudes (patterns of unusually low VI or negative difference). Those also can bee seen in histograms, as increased weight at low VI values.**
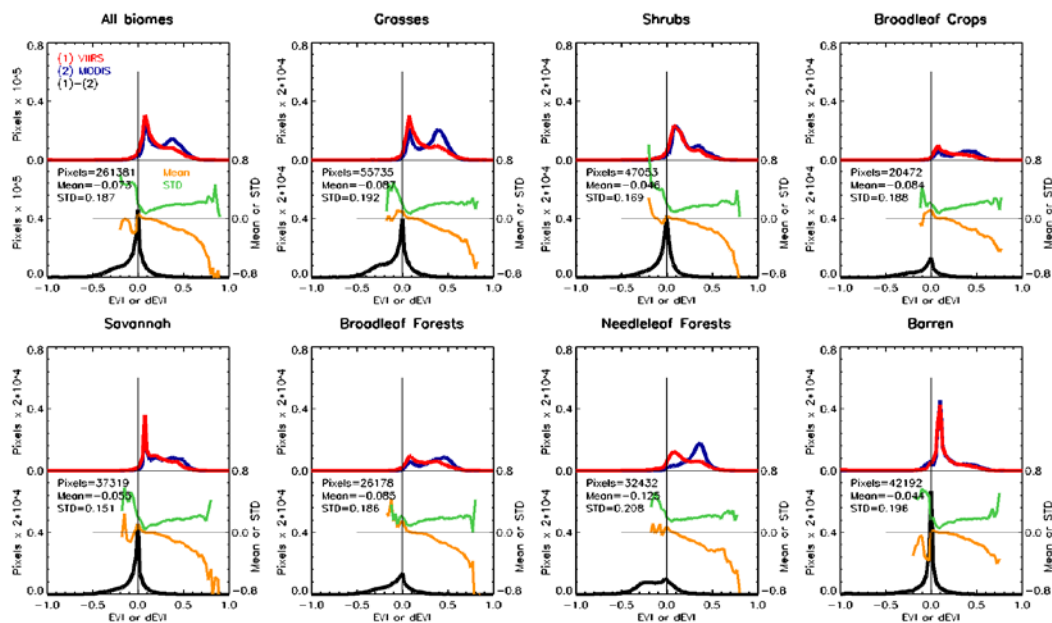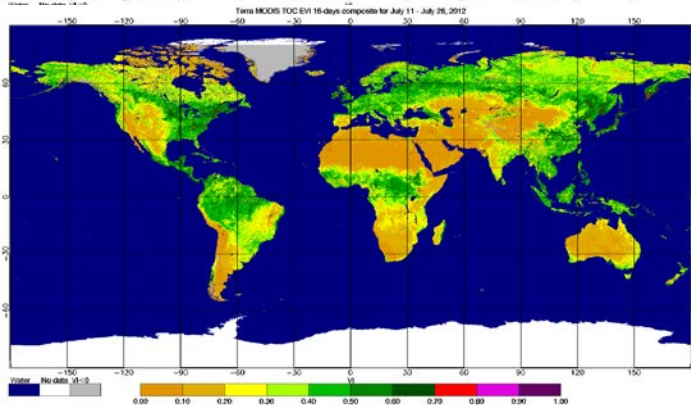
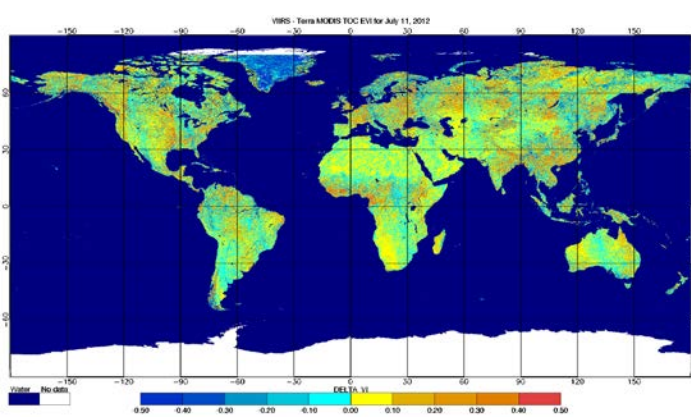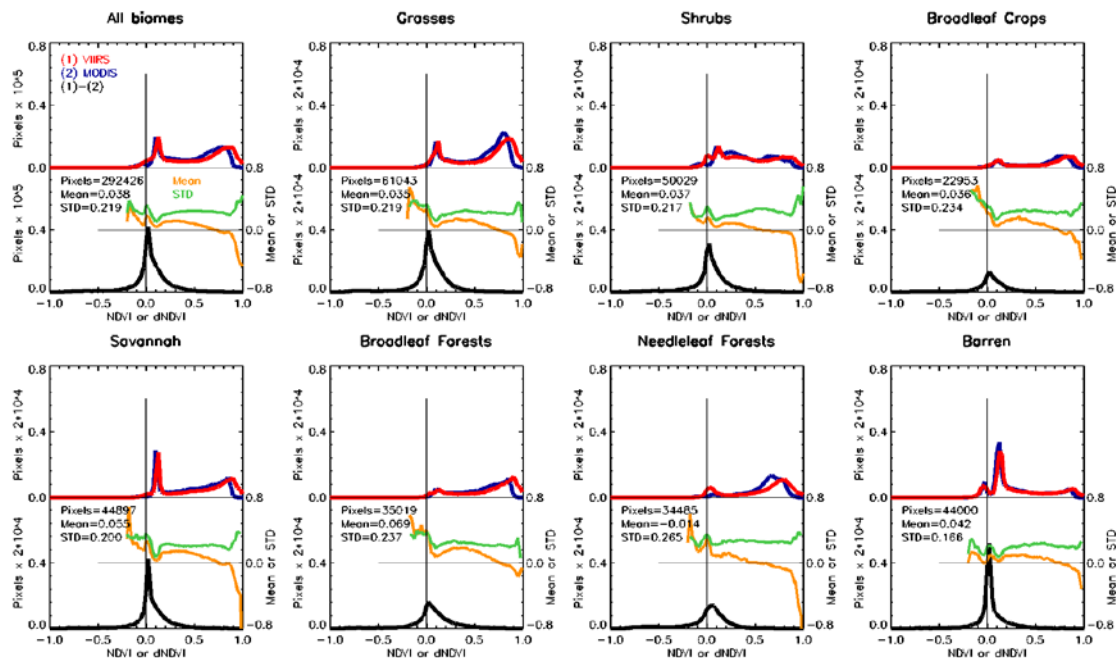# MODIS vs. Suomi NPP VIIRS Enhanced Vegetation Index (EVI)
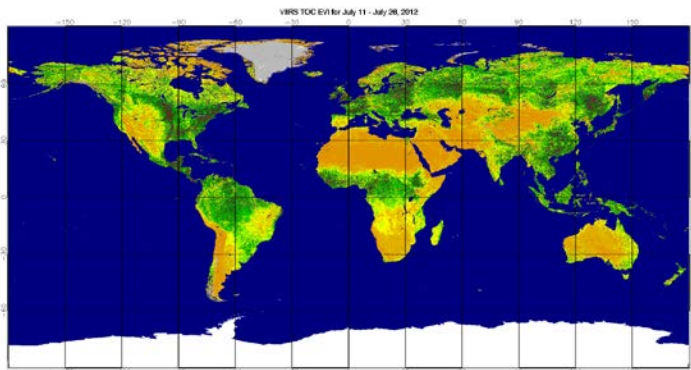
- Analysis of <u>16-day compositing</u> VIIRS TOC-EVI (VIIRS and MODIS for: July 11 – July 26, 2012)
- 16-day Compositing removes gaps associated with cloudy pixels
- Compositing also removes low VI values (due to cloud under screening).
- However, simplified compositing implemented (selection of closest to nadir observations) is not up to MODIS accuracy, due to current limitations of VIIRS QC (i.e., lack of aerosol contamination level)
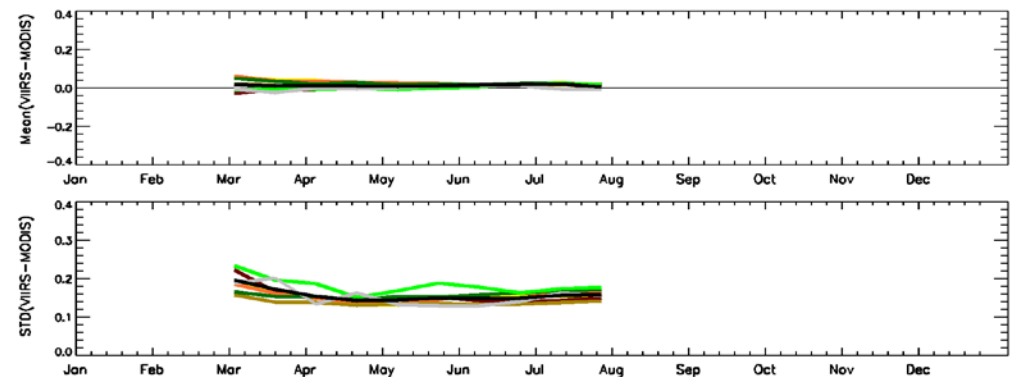
Time Series of VIIRS-MODIS TOC EVI
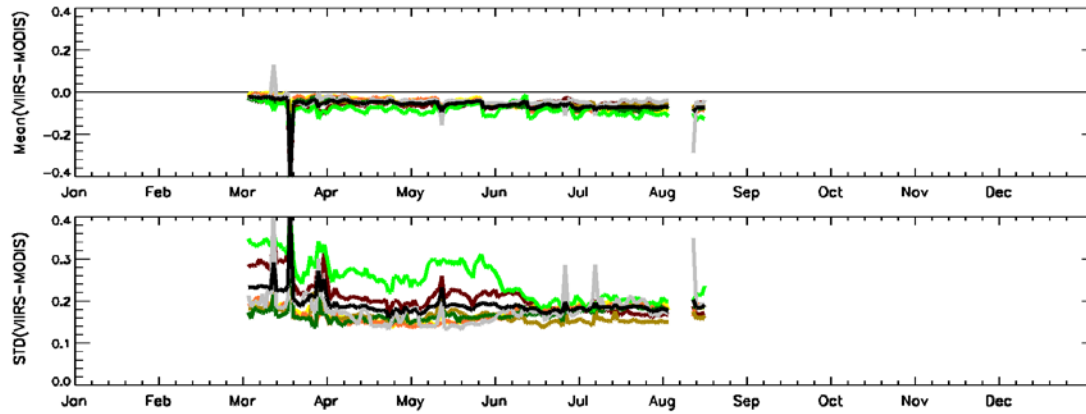
- **Daily VIIRS TOC EVI systematically underestimates compositing MODIS TOC EVI at the global scale. This is due to cloud leakage in VIIRS Cloud Mask. This is especially noticeable over Needle leaf forest (Northern high latitudes)**

- **This discrepancy has an increasing trend from Spring to Summer probably due to natural seasonality of cloud coverage**

- **Compositing virtually removes systematic bias between VIIRS and MODIS TOC EVI, and decreases STD, especially for Needle leaf forests.**

AVHRR vs. Suomi NPP VIIRS
Normalized Difference Vegetation Index (NDVI)

- Analysis of **daily** VIIRS TOA-NDVI (VIIRS: July 15, 2012, vs. NOAA-18 AVHRR: July 15 – July 21, 2012)
- Overall, spatial patterns and histograms of VIIRS and AVHRR TOA NDVI are consistent
- VIIRS NDVI is higher than AVHRR NDVI especially at the Southern hemisphere (this is probably a radiometric effect arising due to large differences in sensor bandwidths)
- However, at the Northern hemisphere cloud leakage in VIIRS data dominates and VIIRS TOA NDVI is lower than AVHRR 7-day NDVI. Cloud leakage exhibits well-pronounced signatures in the histograms
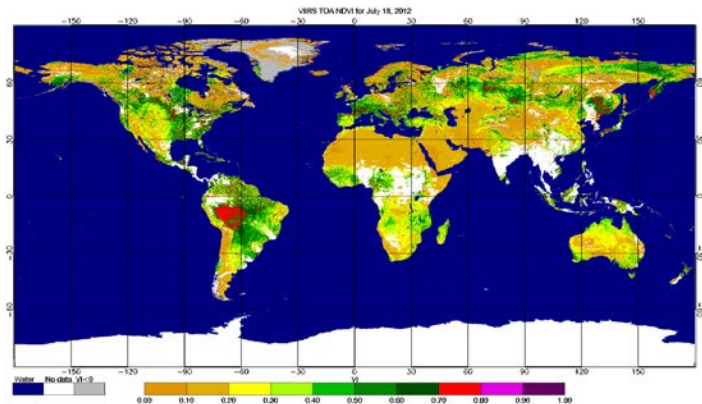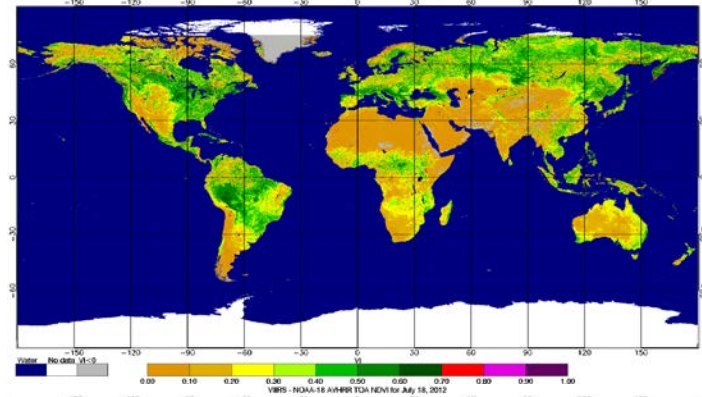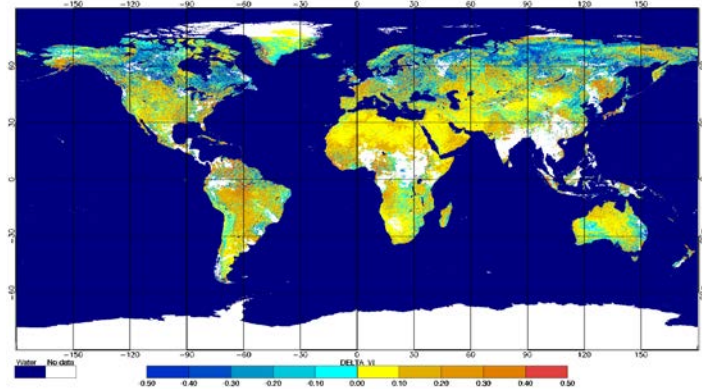
AVHRR vs. Suomi NPP VIIRS
Normalized Difference Vegetation Index (NDVI)
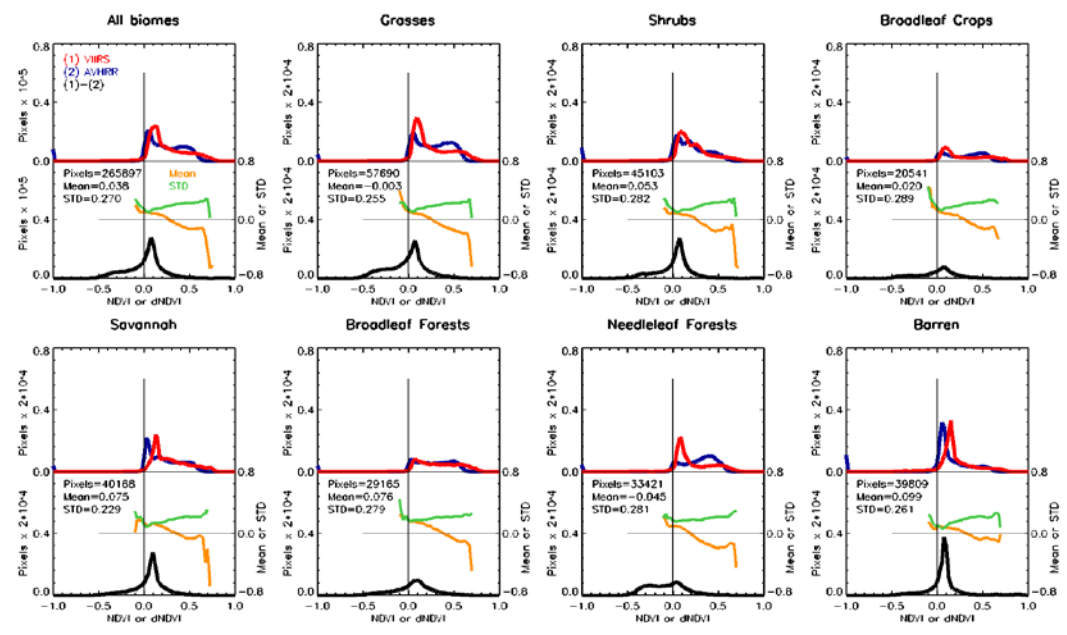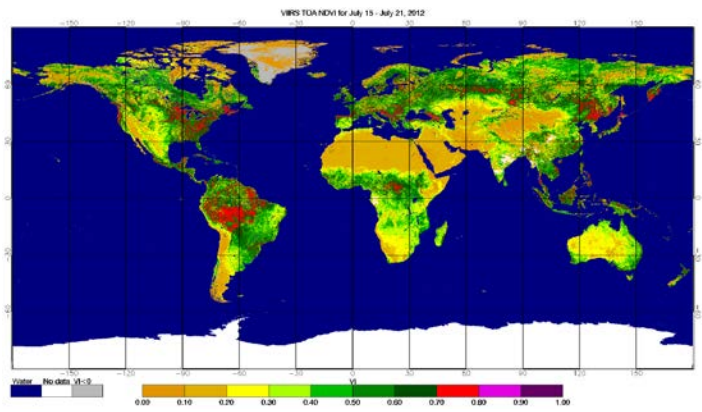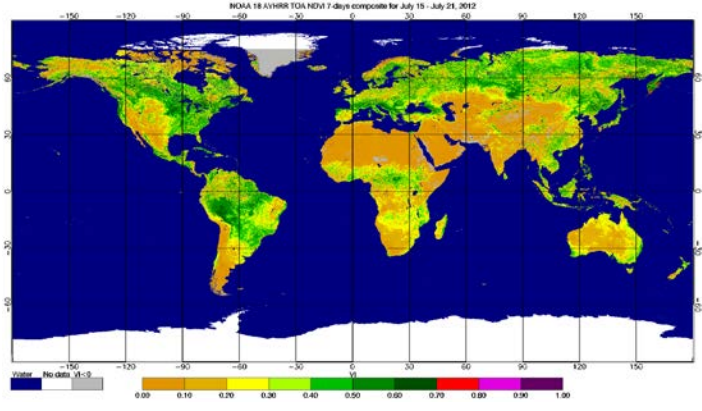
VIIRS

AVHRR

Difference VIIRS minus AVHRR
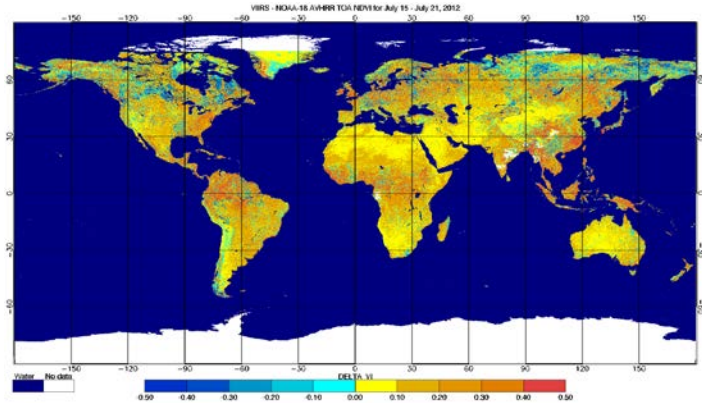
- **Analysis of <u>7-day compositing</u> VIIRS TOA-EVI (VIIRS and NOAA-18 AVHRR for: July 15 – July 21, 2012)**
- **7-day Compositing removes gaps and cloud leakage. However, due to short time interval and simplified compositing, residual cloud leakage may persist at some areas at the Northern latitudes (map of difference)**
- **After compositing it becomes clear that AVHRR data are systematically lower all over the globe). This systematic bias is seen over global and biome-by-biome histograms.**
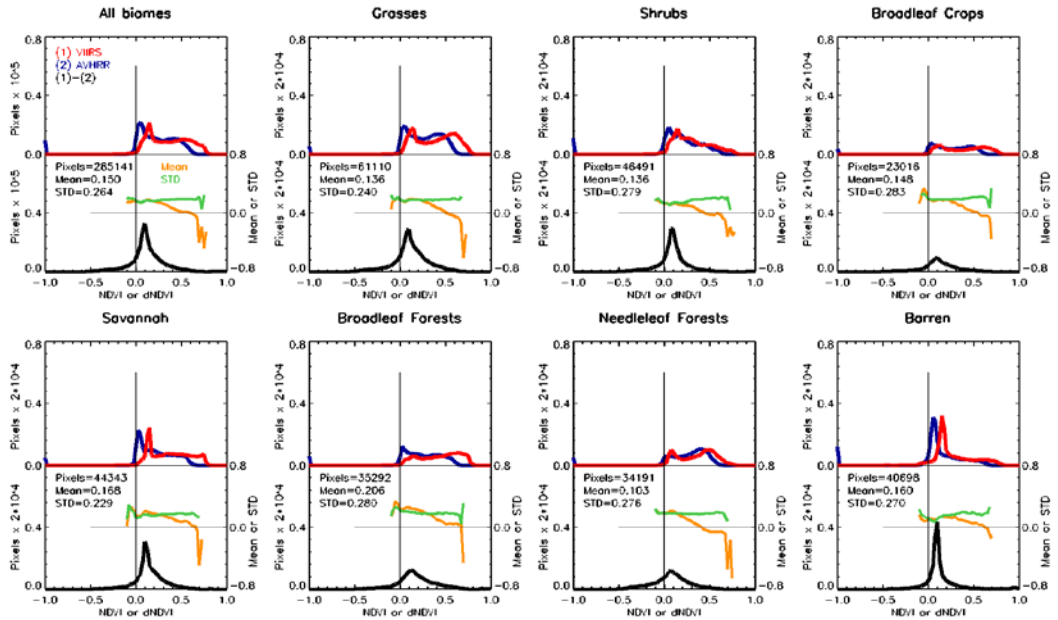
Time Series of VIIRS- NOAA-18 TOA NDVI
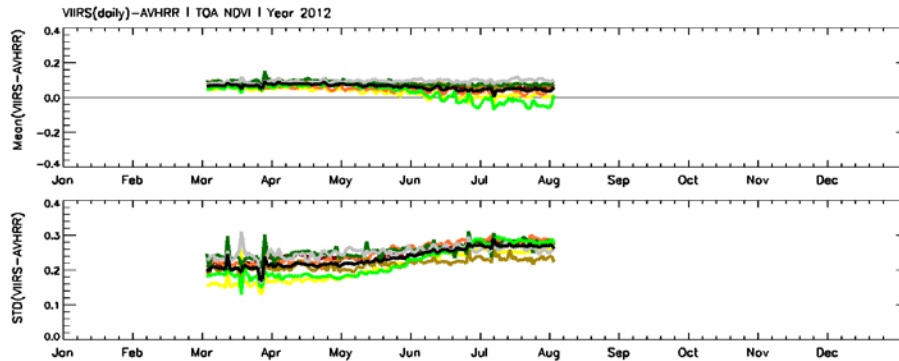
- **Daily VIIRS TOA NDVI systematically overestimates compositing AVHRR TOA NDVI at global scale. This is due to cloud leakage in VIIRS Cloud Mask.**

- **However, this discrepancy decreases from Spring to Summer due to counter-balancing effect of increasing cloud leakage.**

- **Compositing removes effect of cloud leakage and make clear systematic bias between VIIRS and AVHRR TOA NDVI.**
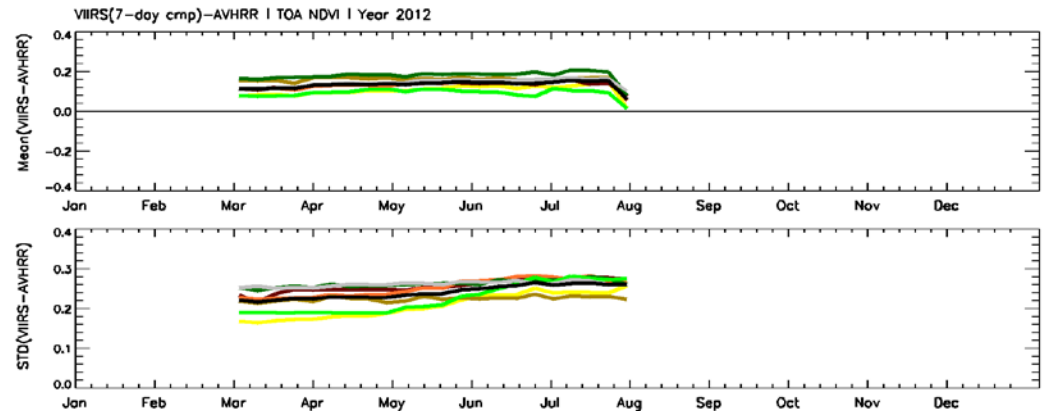
Summary of VIIRS VI Performance at Global Scale

VIIRS VI data	TOA NDVI	TOC EVI
Reference	NOAA-18 AVHRR	MODIS
Mean (VIIRS-Reference)	+0.05	-0.05
STD (VIIRS-Reference)	0.25	0.20
Detected anomalies	1) Trend of increasing negative anomalies over Northern high latitudes from Spring to Summer. This is under-screening of atmospheric impact and can be reduced by compositing. 2) However, aside from cloud impact, TOA NDVI from VIIRS is higher compared to that from AVHRR. This can be seen even in the daily VIIRS data affected by clouds. Most probable reason for overestimation is an impact of sensors bandwidth differences.	1)Trend of increasing negative anomalies over Northern high latitudes from Spring to Summer. This is an effect of cloud leakage which can be eliminated by compositing. 2)Large positive TOC EVI anomalies are observed over Northern high latitudes (Greenland and Siberia during winter). This is due to retrievals under snow at high SZA. Anomalies can be screened away by tracing data with negative denominator in the equation of TOC EVI.

Beta Maturity Evaluation

- Consistency of global spatial patterns between VIIRS-VI and heritage VI (AVHRR TOA-NDVI and MODIS TOC EVI)

- Time series of global VI EDR generally match heritage VI

- However, daily VIIRS TOC EVI data are (1) substantially affected by residual clouds and (2) anomalously high values at snow covered areas are present at Northern high latitudes. Compositing of VIIRS TOC EVI removes atmospheric effect and makes VIIRS TOC EVI highly consistent with MODIS

- Daily VIIRS TOA NDVI are also affected by residual clouds in the same way as TOC EVI. However, after compositing, VIIRS data are systematically higher than AVHRR data

Enhancements to be proposed/examined for the VI EDR

1) Adding TOC-NDVI

2) Updating/revising QA fields (same as MODIS)

3) Refining the EVI algorithm

   - A backup algorithm over snow/ice covered areas
   - Coefficient adjustment or an EVI2 algorithm

4) Temporal compositing

5) EVI equation revision: the gain factor

VIIRS

$$EVI = (1+L) \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + C_1\rho_{red} - C_2\rho_{blue} + L}$$

MODIS

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

Future Plan

- Near-term
  - Algorithm refinement
  - Evaluate Top Of Canopy (TOC) NDVI produced from Surface Reflectance IP
  - ASRVN, Tower Reflectance, FLUXNET: obtain initial APU estimates before provisional release; continue the analysis to increase a number of sites with longer time series

- Mid-to-long term
  - Full evaluation of updated science algorithm and code
  - Provisional release of VI EDR by September 2013
  - Validated Version 1 status by July 2014

Summary of Findings

- Initial results show that the **<u>VIIRS Vegetation Index EDR product is performing well</u>**.
  - No obvious problems present at this time, including data structure
  - Retrievals expected to improve significantly with improvements in upstream processing.
- **<u>VI EDR has met the beta stage</u>** based on the definitions and the evidence shown
  - Exceeding the definition of beta in most cases