NDE Vegetation Product System (NVPS): Vegetation Indices (VI) and Green Vegetation Fraction (GVF)

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Project Background

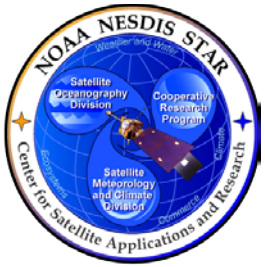
- The GVF system is currently running in NDE and the product suite includes:
  - The Green Vegetation Fraction Global Product
  - The Green Vegetation Fraction Regional Product

- Top of Atmosphere Normalized Difference Vegetation Index (TOA NDVI), Top of Canopy Normalized Difference Vegetation Index (TOC NDVI), and Top of Canopy Enhanced Vegetation Index (TOC EVI) are currently running in IDPS.
  - The VIIRS Vegetation Index Validated Stage 1 Science Maturity Review took place on September 4, 2014. Documentation is available on the STAR/JPSS website: https://www.star.nesdis.noaa.gov/jpss/documents/AMM_All/Land_VI/Validated/VIIRSVIStage1MaturityPresentationtoSTAR.pdf
  - The NDE Vegetation Product Suite Critical Design Review took place on September 29, 2016. Documentation is available on google drive: https://drive.google.com/open?id=0B-kRoSoyMpuAb3JyXzZFUjJUTmc

Project Objectives

- The VIIRS Vegetation Index products will be incorporateded into the GVF system. These include:
  - NDVI at TOA for continuity with AVHRR
  - NDVI at TOC for continuity with MODIS
  - EVI at TOC for continuity with MODIS

NDE Vegetation Products Stakeholders



- Customers/Users
  - NCEP/EMC
  - STAR
  - CLASS
  - USDA
  - USGS
  - NWS/WFO/Spokane WA
  - University of Hawaii at Manoa
  - NASA SPoRT
  - NOAA ESRL

Vegetation Index (VI) External Inputs

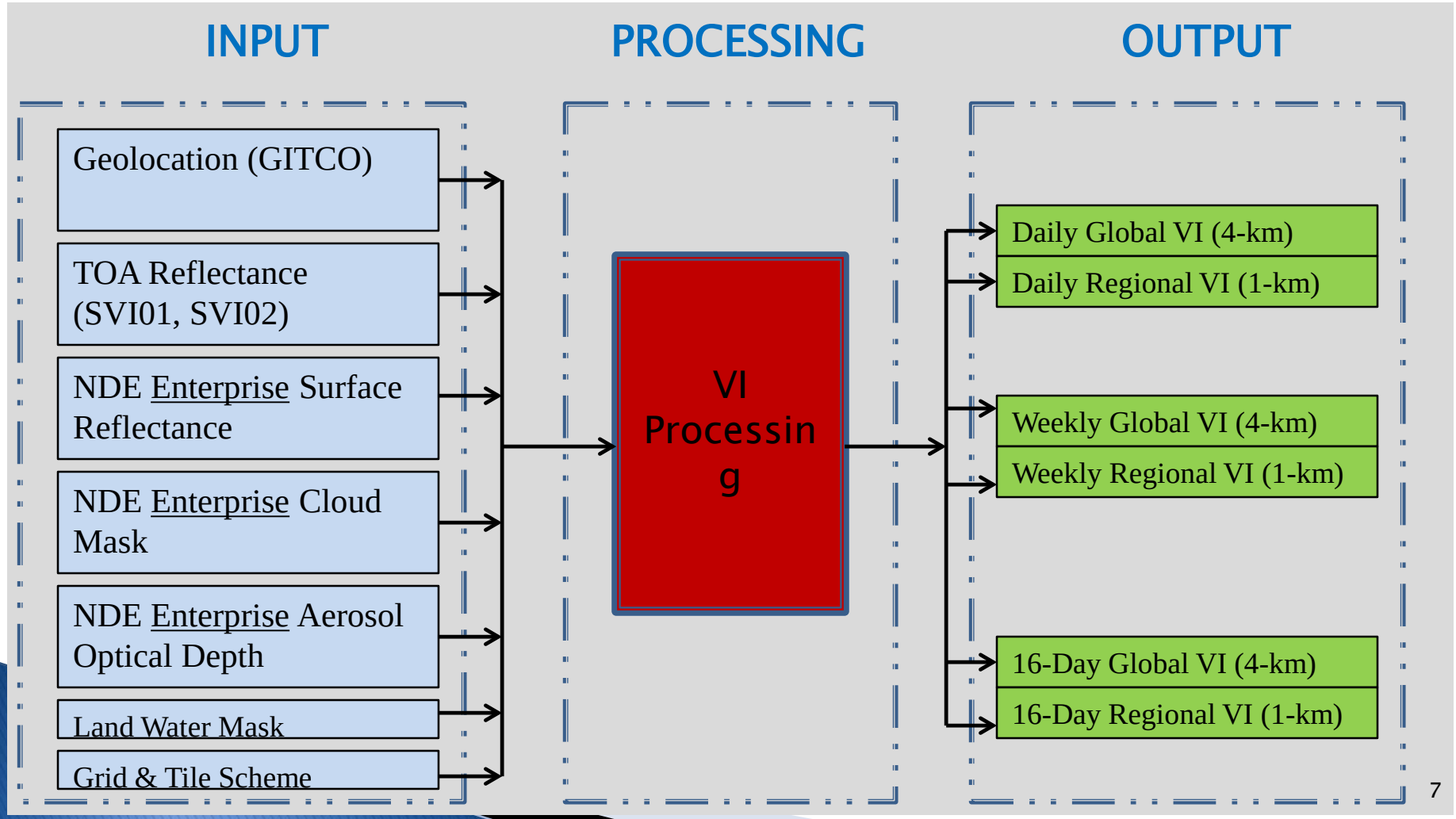
Item	Type	Source	Description
Geolocation (GITCO)	Input	IDPS	VIIRS Terrain Corrected Geolocation and geometry (imagery resolution)
TOA Reflectance (SVI01, SVI02)	Input	IDPS	IDPS VIIRS I1 and I2 SDR bands at imagery solution
Aerosol Optical Depth	Input	NDE EAOT	NDE VIIRS Enterprise aerosol optical depth product (EAOT) at moderate resolution
Cloud Mask	Input	NDE ECM	NDE VIIRS Enterprise Cloud Mask (ECM) at moderate resolution
Surface Reflectance	Input	NDE ESR	NDE VIIRS Enterprise Surface reflectance (ESR) I1, I2 and M3 bands (granule files)
Land Water Mask	Input	Ancillary	Derived from MODIS global water mask (MOD44W) by projecting to the VIIRS GVF grid (used by the operational NDE VIIRS GVF)
Grid and Tile Scheme	Input	Ancillary	The origin and spatial resolution and partition of the VI coordinate system (used by the operational NDE VIIRS GVF)

Outputs

Sample Filename	Data from Filename
VI-GLB*.nc (Global) VI-REG*.nc (Regional) • Daily • 7-Day (Weekly) • 16-Day (Bi-Weekly)	-TOA NDVI -TOC NDVI -TOC EVI -Reflectance I1 -Reflectance I2 -Surface Reflectance I1 -Surface Reflectance I2 -Surface Reflectance M3 -Solar Zenith Angle -Viewing Zenith Angle -Relative Azimuth Angle -Quality Flags: QF1, QF2, QF3, QF4

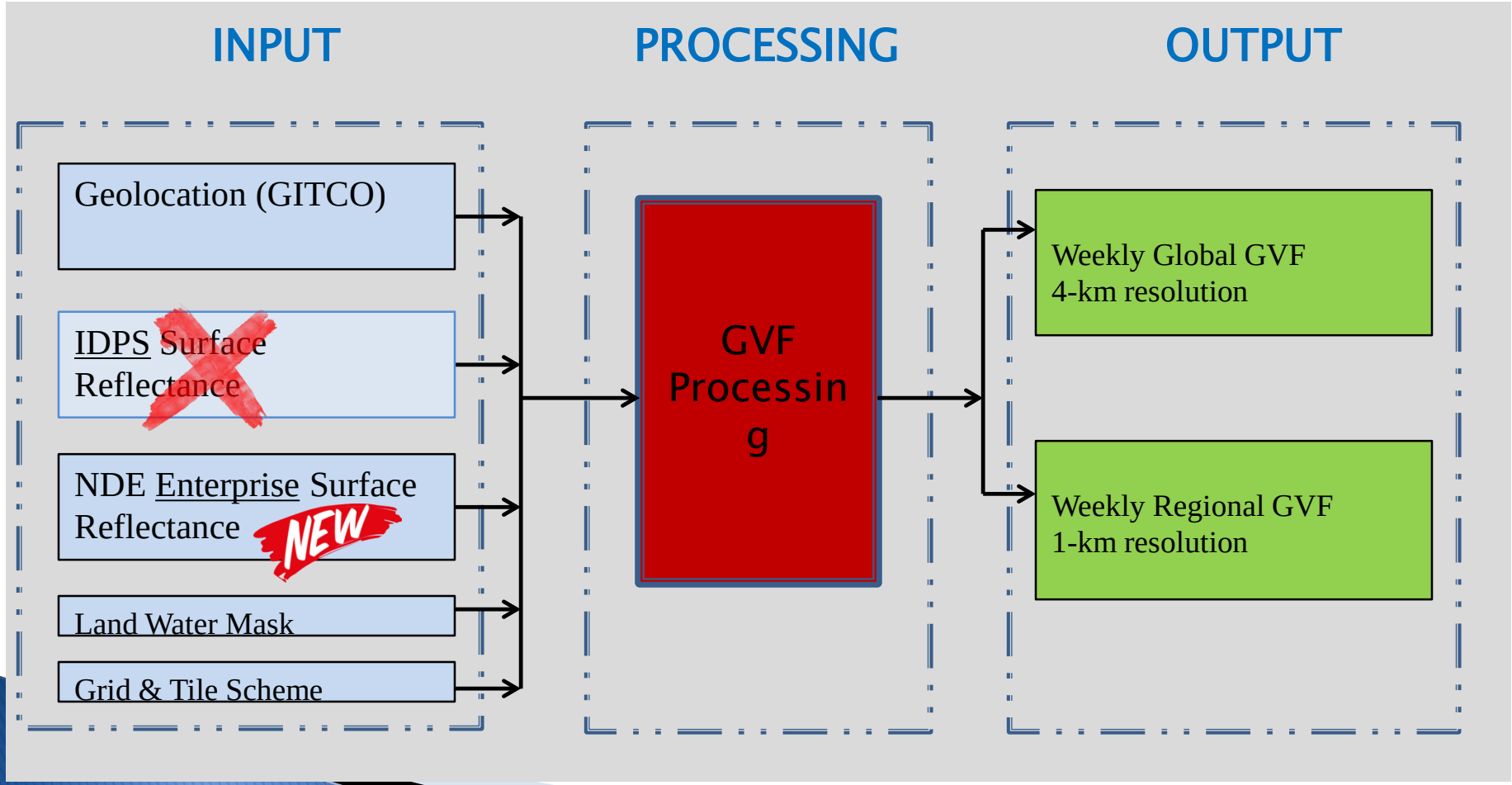
VI Context-Layer

- The Context Layer is the highest level of the software architecture. It describes the flows between the system and its external interfaces

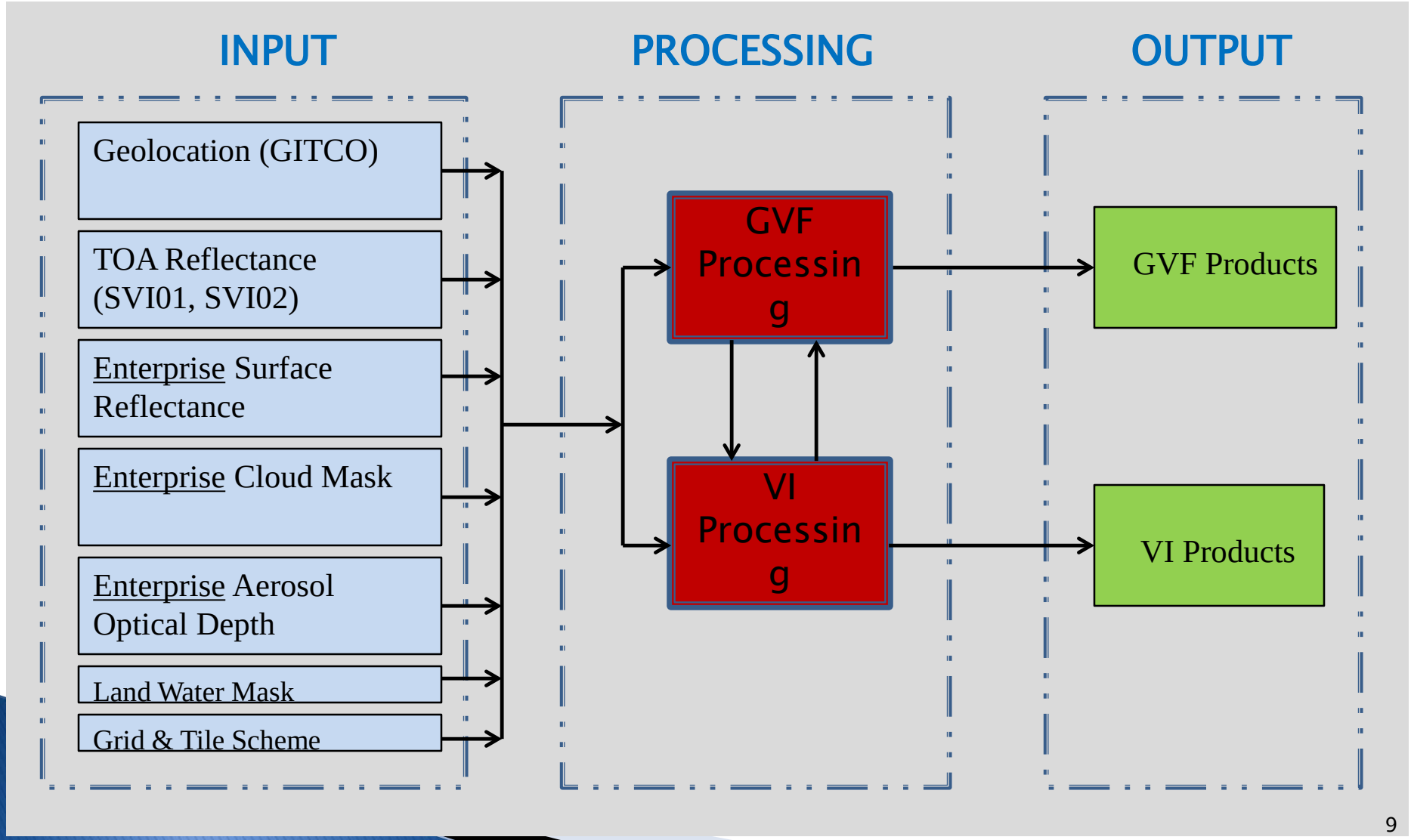


GVF Context–Layer Changes to the GVF system

- IDPS Surface Reflectance is replaced by the NDE Enterprise Surface Reflectance



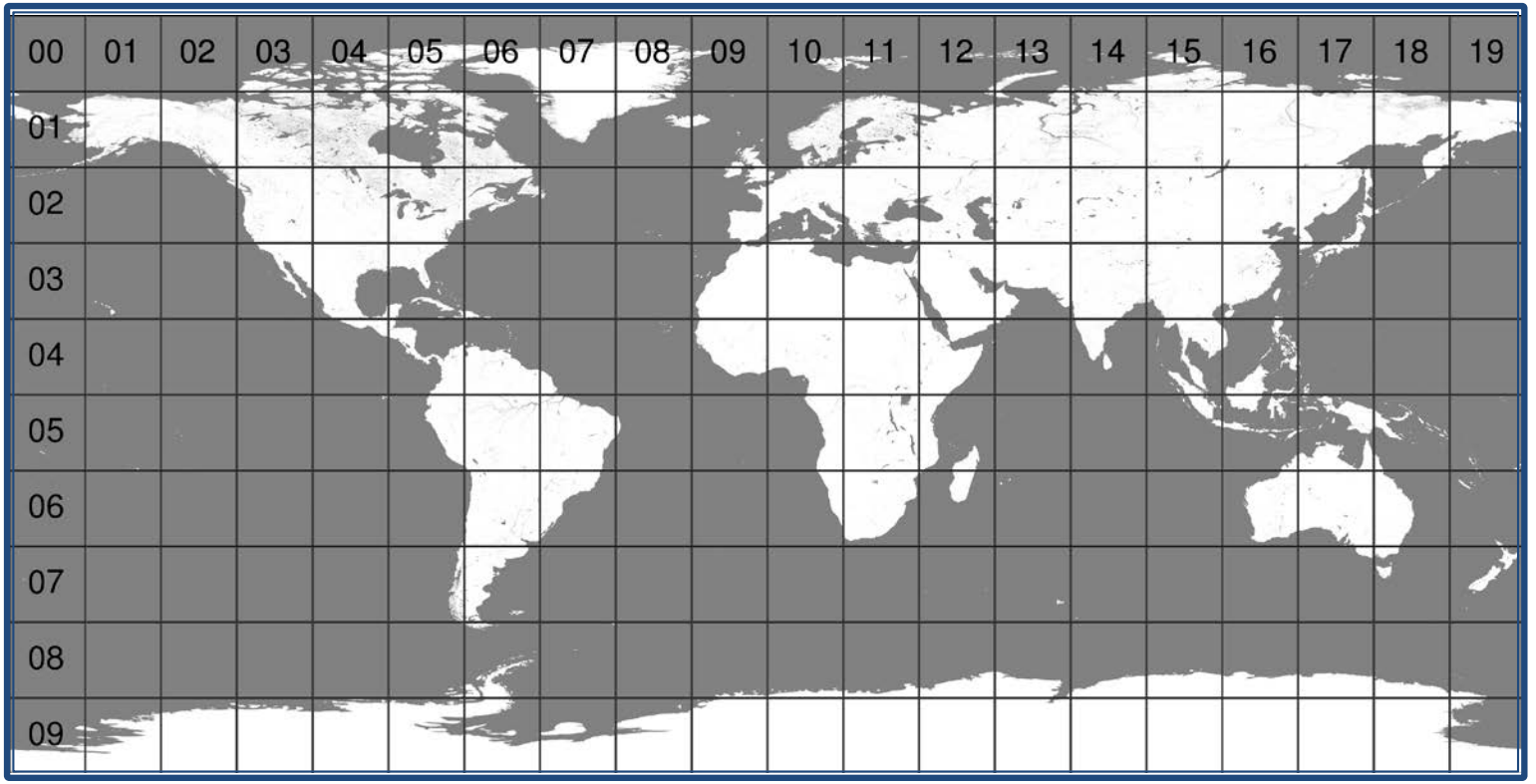
NVPS Context-Layer



The VI Global Grid and Tile Scheme (1/2)

- The VI grid system is divided into square tiles to facilitate parallel computing spatially and therefore faster processing
- The VI grid is a set of tiles that are 18 degrees square
- 200 tiles (20 tiles horizontally and 10 tiles vertically) are needed to cover the entire globe
- Each 18°x 18° tile has 6000 x 6000 grid cells (0.003° pixels)
- The grid provides global coverage in Geographic Lat/Lon projection at a resolution of 0.003°

The VI Global Grid and Tile Scheme (2/2)

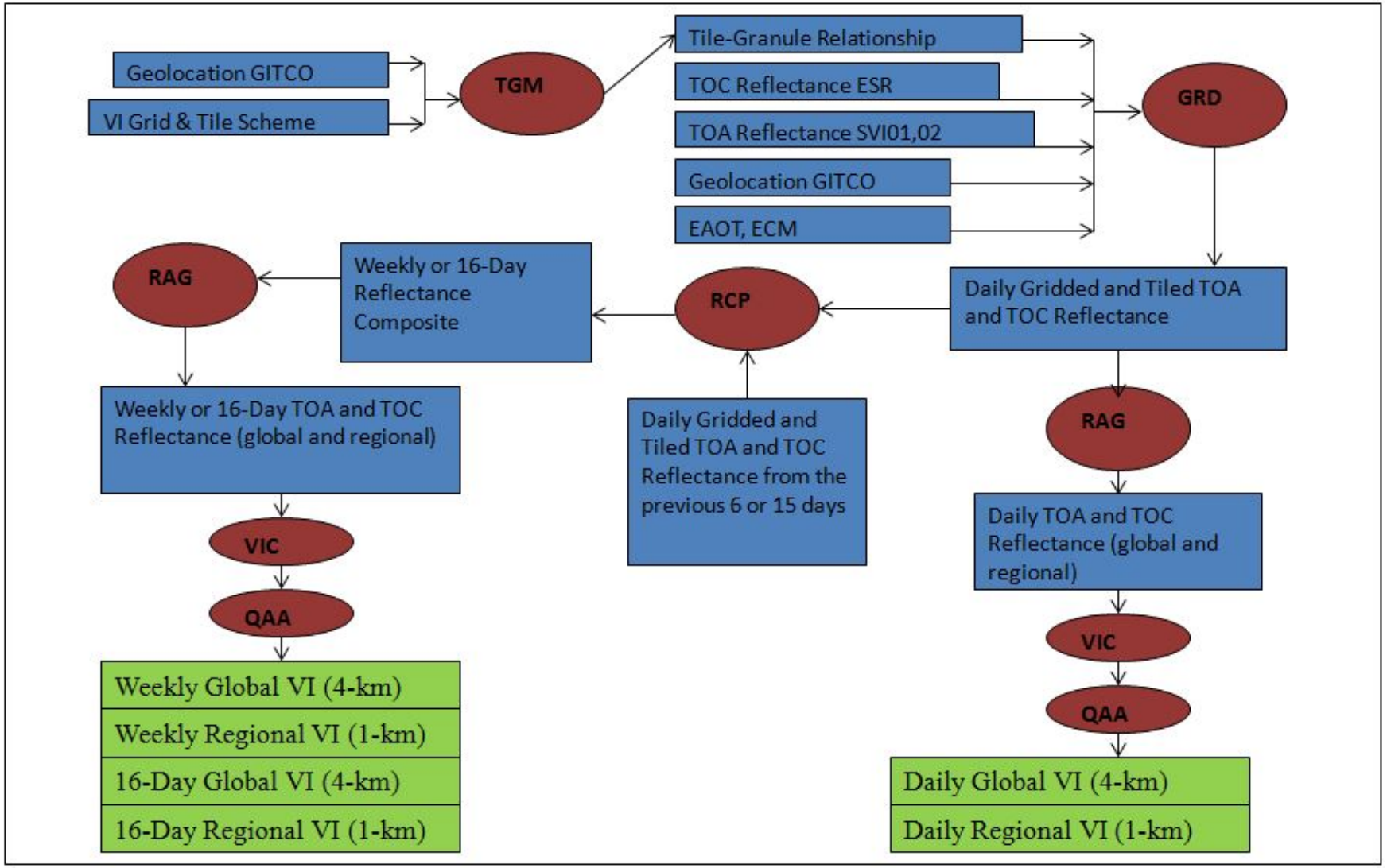


The upper-left corner of the tile map is 180° W, 90°N. Each tile is 18° x 18°, with 6000 x 6000 grid cells (0.003° pixels). Only those tiles that contain land but are not in the Antarctic Region are processed (There are 122 non-fill tiles)

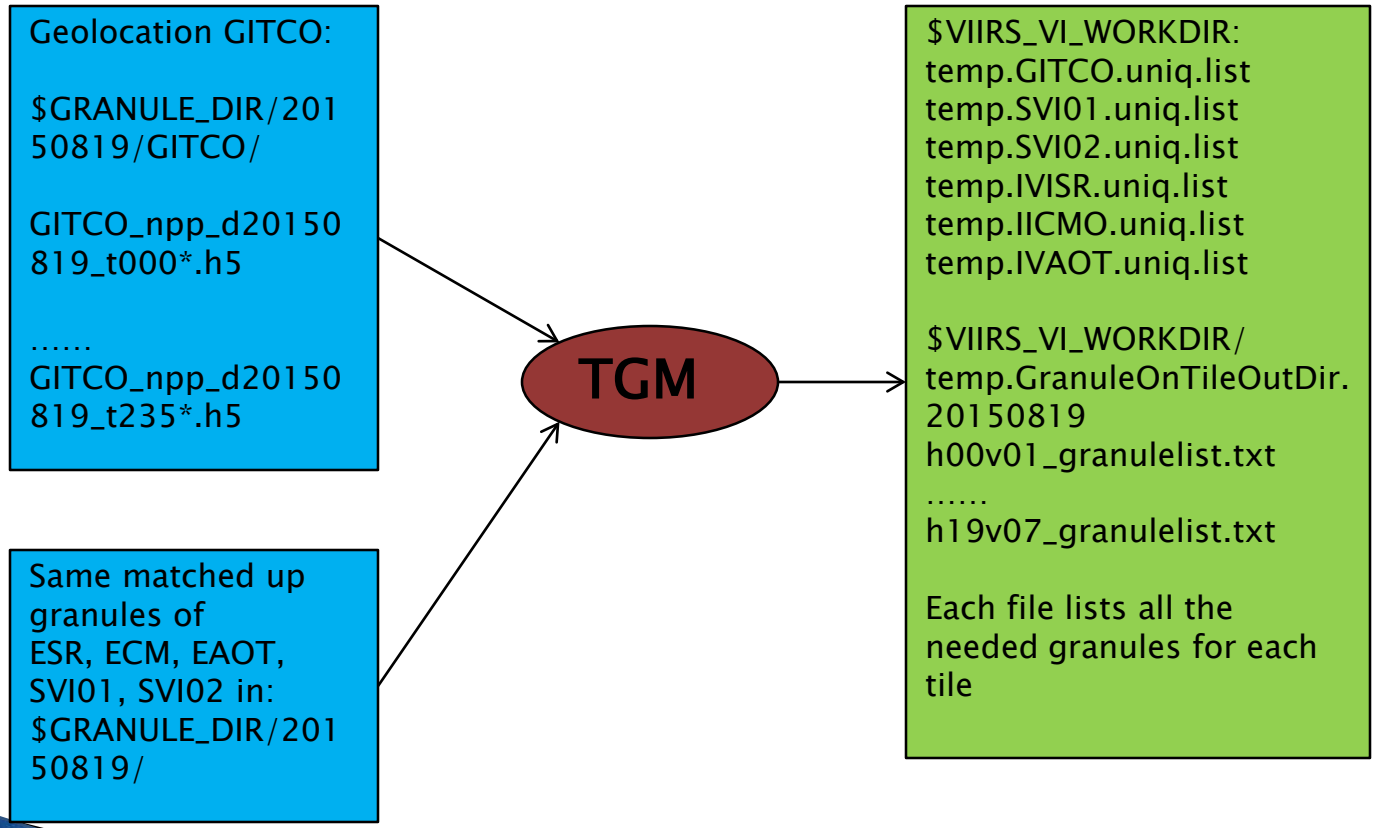
Units of VI Algorithm:

- TGM: Tile Granule Mapper
- GRD: Reflectance Gridder
- RCP: Reflectance Compositor
- RAG: Reflectance Aggregator
- VIC: Vegetation Index Calculator
- QAA: Quality Assurance Assigner

Vegetation Index System–Layer Data Flows



Tile-Granule Mapper (TGM) Unit



Reflectance Gridder (GRD) Unit

All Input Granules:

$GRANULE_DIR/20150819/
GITCO/
ESR
EAOT
ECM
SVI01
SVI02

Granulelist:

$VIIRS_VI_WORKDIR/
temp.GranuleOnTileOutDir.
20150819
h00v01_granulelist.txt
……
h19v07_granulelist.txt

GRD

$VIIRS_VI_WORKDIR/daily_sr/201
50819/
VI-SR_
s20150819_e20150819_h00v01_
c201704211757510.h5
……
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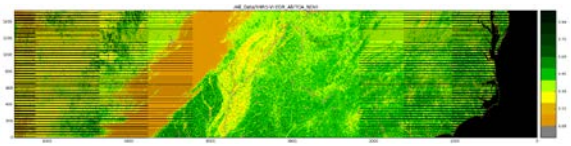
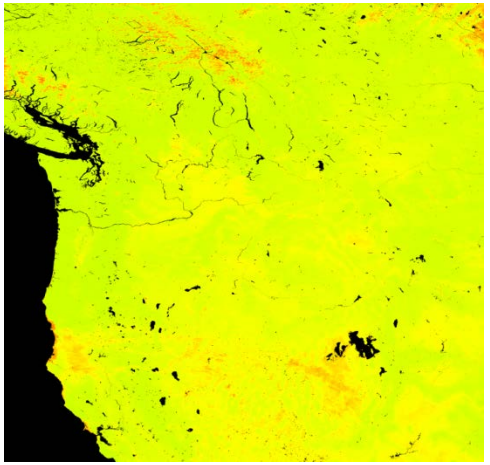
c201704212302540.h5



Granule space (one VIIRS granule)



Grid space (one tile)

Reflectance Compositor (RCP) Unit

All the tile files in the past 7 days:

$VIIRS_VI_WORKDIR/daily_sr/20160812/
$VIIRS_VI_WORKDIR/daily_sr/20160813/
……
$VIIRS_VI_WORKDIR/daily_sr/20160818/

→ RCP (weekly) →

$VIIRS_VI_WORKDIR/weekly_sr/20160812-20160818/
VI-SR_s20160812_e20160818_h00v01_c20170425145 0370.h5
……
VI-SR_s20160812_e20160818_h19v07_c20170425165 7040.h5

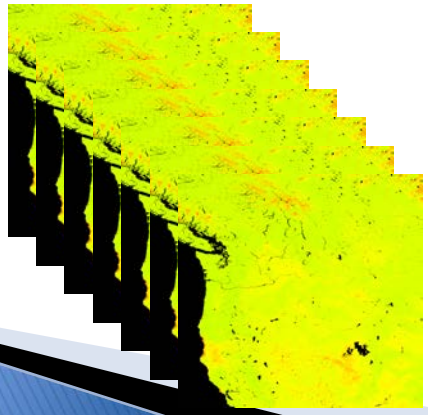
All the tile files in the past 16 days:

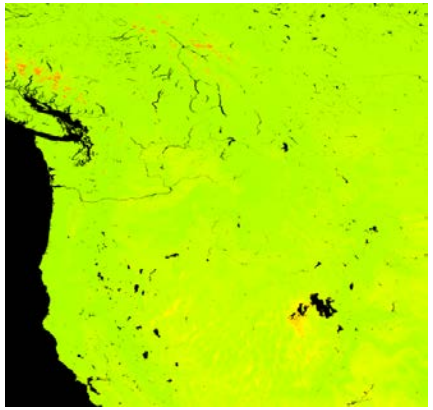
$VIIRS_VI_WORKDIR/daily_sr/20160812/
$VIIRS_VI_WORKDIR/daily_sr/20160813/
……
$VIIRS_VI_WORKDIR/daily_sr/20160827/

→ RCP (biweekly) →

$VIIRS_VI_WORKDIR/biweekly_sr/20160812-20160827/
VI-SR_s20160812_e20160827_h00v01_c20170425145 2200.h5
……
VI-SR_s20160812_e20160827_h19v07_c20170425181 2150.h5

Daily reflectance
(7 or 16 tiles)





Composited reflectance
(weekly or bi-weekly)

Quality Assurance Assigner (QAA) Unit Daily

RAG, VIC, QAA

$VIIRS_VI_WORKDIR/daily_sr/20150819/
VI-SR_s20150819_e20150819_h00v01_c201704211757510.h5
……
VI-SR_s20150819_e20150819_h19v07_c201704212302540.h5

RAG, VIC, QAA
(daily)

$VIIRS_VI_WORKDIR/daily_aasr/20150819/

VI-GLB_v1r0_npp_s20150819_e20150819_c201704241434170.nc
VI-GLB_v1r0_npp_s20150819_e20150819_c201704241434170_stat.txt

VI-REG_v1r0_npp_s20150819_e20150819_c201704241534310.nc
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VI-EVI-GLB_v1r0_npp_s20150819_e20150819_c201704241434170.tif
VI-EVI-REG_v1r0_npp_s20150819_e20150819_c201704241534310.tif

VI-TOA-NDVI-GLB_v1r0_npp_s20150819_e20150819_c201704241434170.tif
VI-TOA-NDVI-REG_v1r0_npp_s20150819_e20150819_c201704241534310.tif

VI-TOC-NDVI-GLB_v1r0_npp_s20150819_e20150819_c201704241434170.tif
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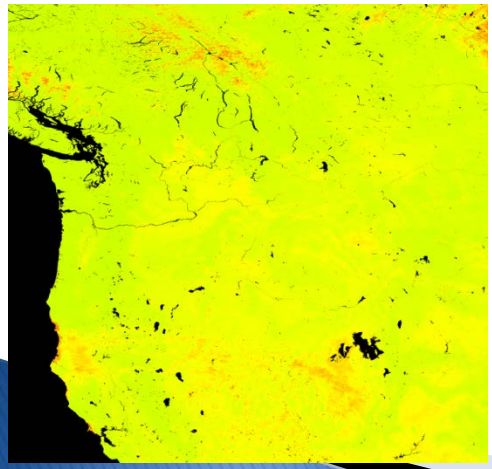

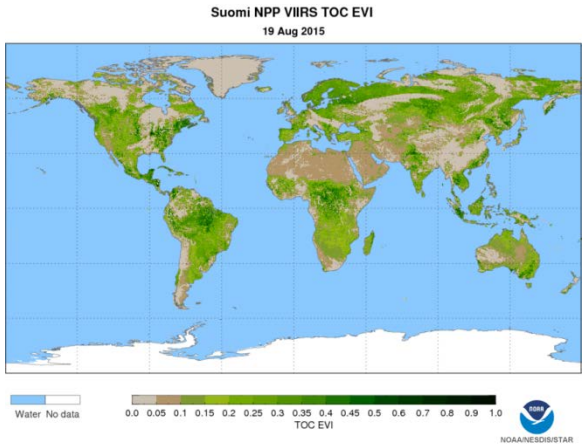

Daily TOC EVI 2015-08-19

Quality Assurance Assigner (QAA) Unit Weekly or Biweekly

$VIIRS_VI_WORKDIR/weekly_sr/20160812-20160818/
VI-SR_s20160812_e20160818_h00v01_c201704251450370.h5
……
VI-SR_s20160812_e20160818_h19v07_c201704251657040.h5

RAG VIC QAA (weekly)

$VIIRS_VI_WORKDIR/weekly_aasr/20160812-20160818/
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VI-GLB_v1r0_npp_s20160812_e20160818_c201704252004470_stat.txt

VI-REG_v1r0_npp_s20160812_e20160818_c201704252125020.nc
VI-REG_v1r0_npp_s20160812_e20160818_c201704252125020_stat.txt

VI-TOA-NDVI-GLB_v1r0_npp_s20160812_e20160818_c201704252004470.tif
VI-TOA-NDVI-REG_v1r0_npp_s20160812_e20160818_c201704252125020.tif

VI-TOC-NDVI-GLB_v1r0_npp_s20160812_e20160818_c201704252004470.tif
VI-TOC-NDVI-REG_v1r0_npp_s20160812_e20160818_c201704252125020.tif

VI-EVI-GLB_v1r0_npp_s20160812_e20160818_c201704252004470.tif
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$VIIRS_VI_WORKDIR/biweekly_sr/20150819/
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……
VI-SR_s20160812_e20160827_h19v07_c201704251812150.h5

RAG VIC QAA (bi-weekly)

$VIIRS_VI_WORKDIR/biweekly_aasr/20160812-20160827/
VI-GLB_v1r0_npp_s20160812_e20160827_c201704252006070.nc
VI-GLB_v1r0_npp_s20160812_e20160827_c201704252006070_stat.txt

VI-REG_v1r0_npp_s20160812_e20160827_c201704252127220.nc
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VI-EVI-GLB_v1r0_npp_s20160812_e20160827_c201704252006070.tif
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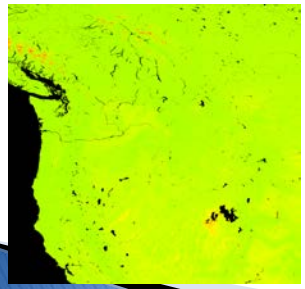
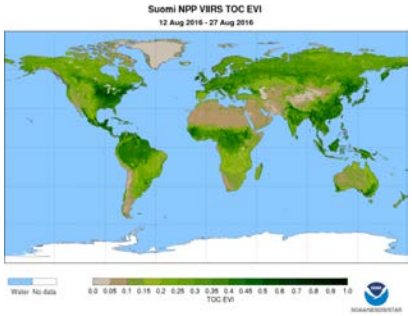
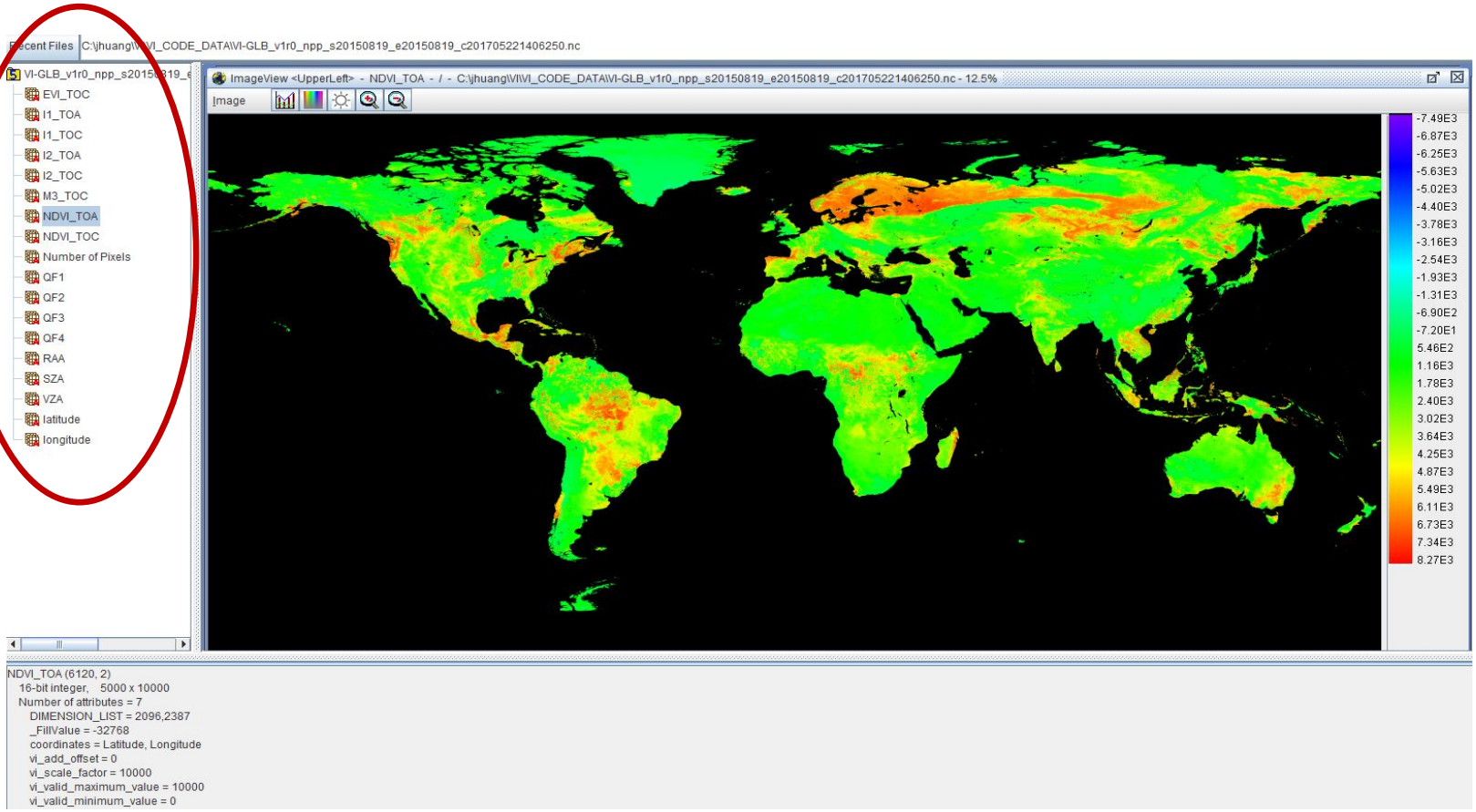




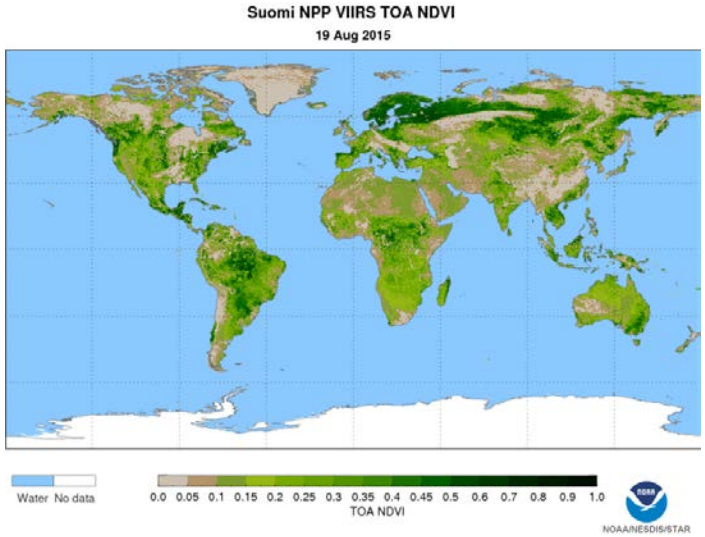
Bi-weekly TOC EVI Aug 12-27, 2016

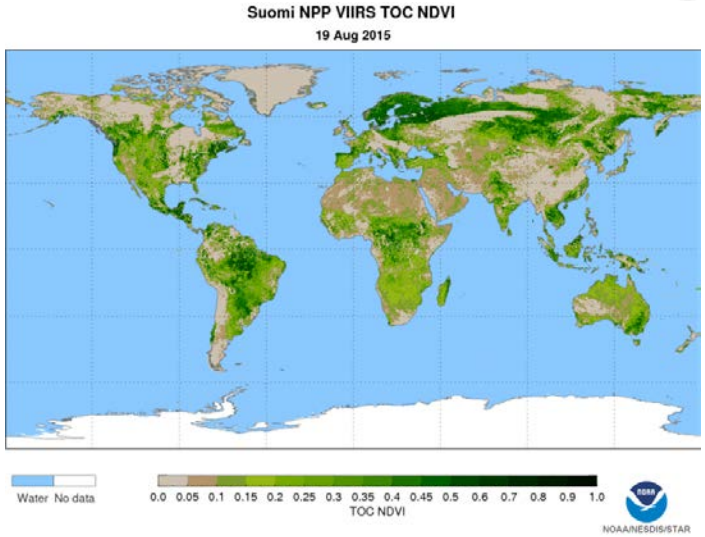
Prototype Global Daily VI Output File NetCDF4

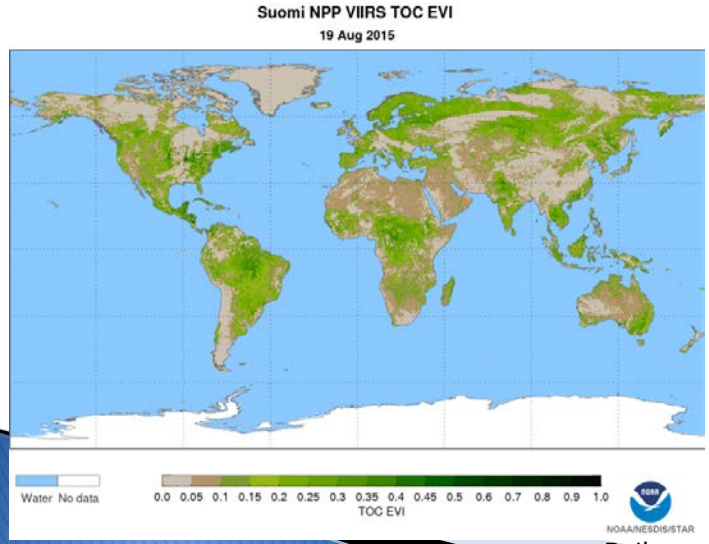


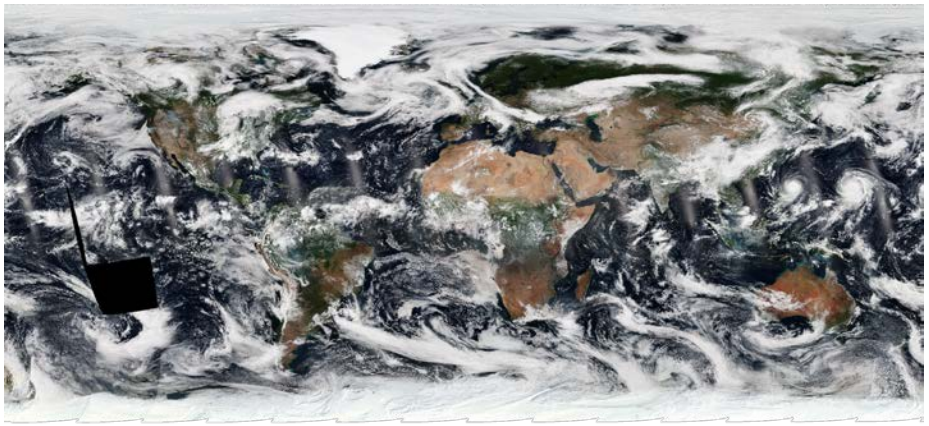
HDFView screen capture

Vegetation Index Daily Global Products (4 km res)





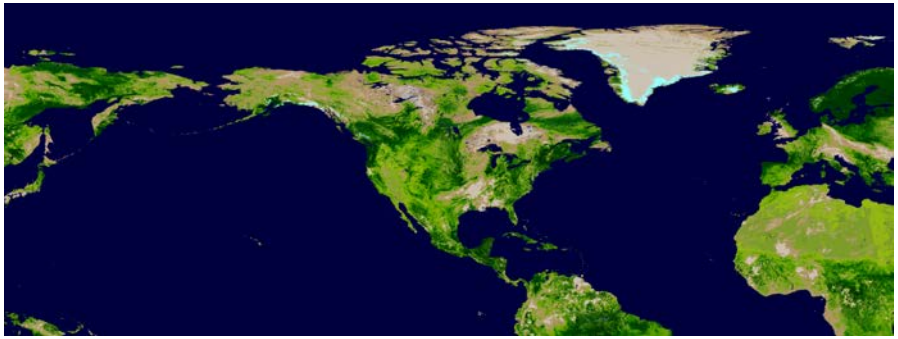




Daily products generated with the **Enterprise Surface Reflectance** granule data in NetCDF format

Vegetation Index Daily Regional Products

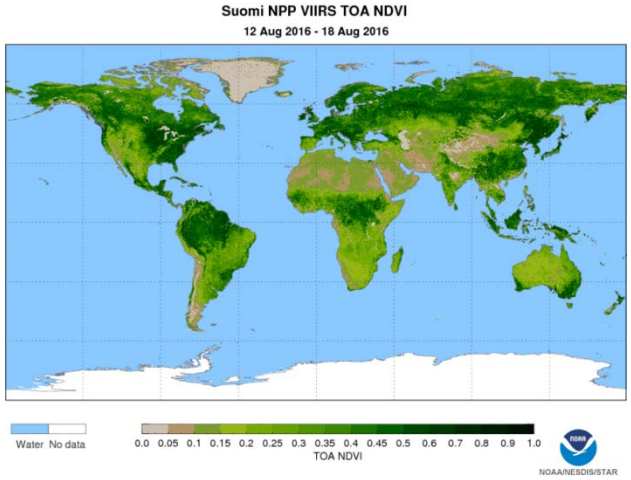
REGIONAL TOA NDVI 2015/08/19

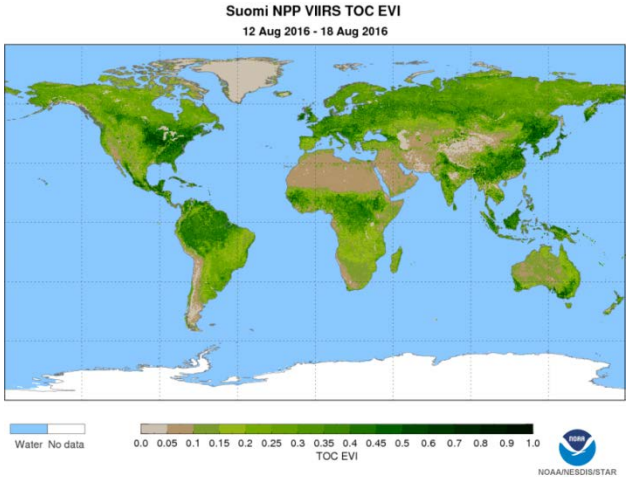


REGIONAL TOC NDVI 2015/08/19

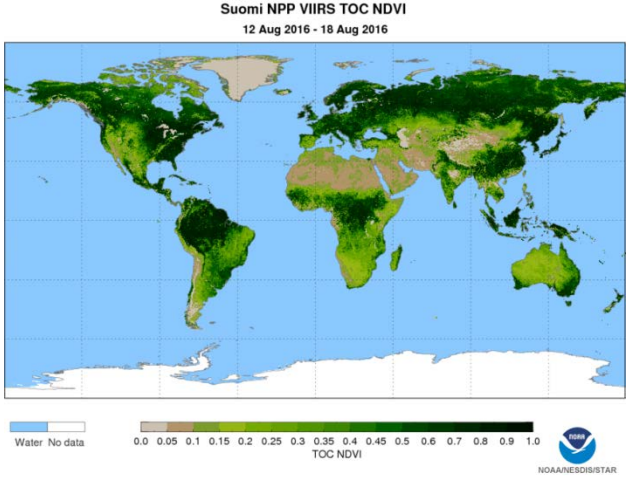
REGIONAL TOC EVI 2015/08/19

Vegetation Index Weekly Global Products

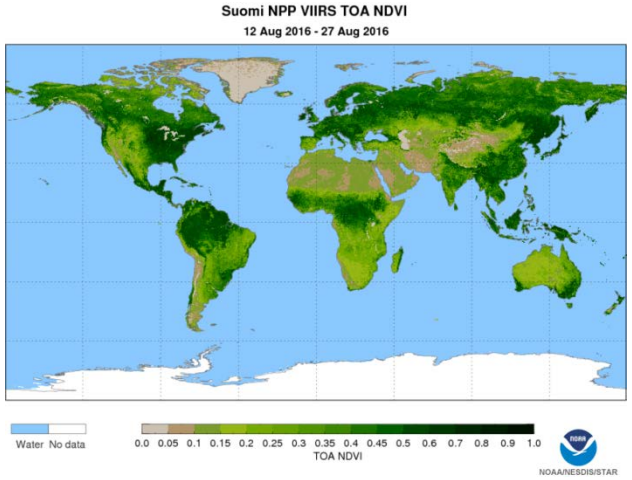


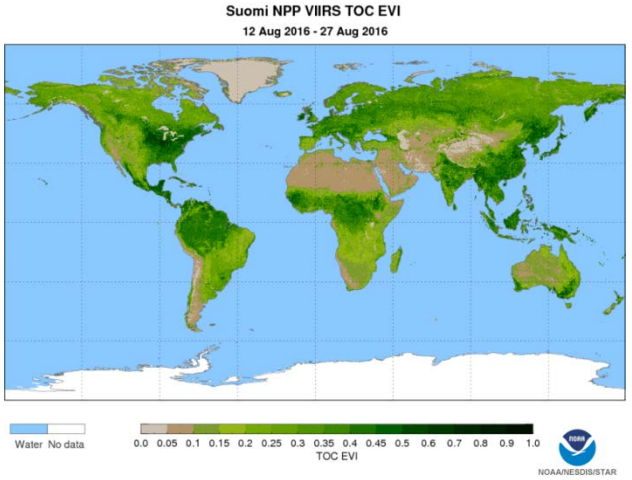


Global weekly products generated from Surface Reflectance granule Data in HDF5 format (from the IDPS)

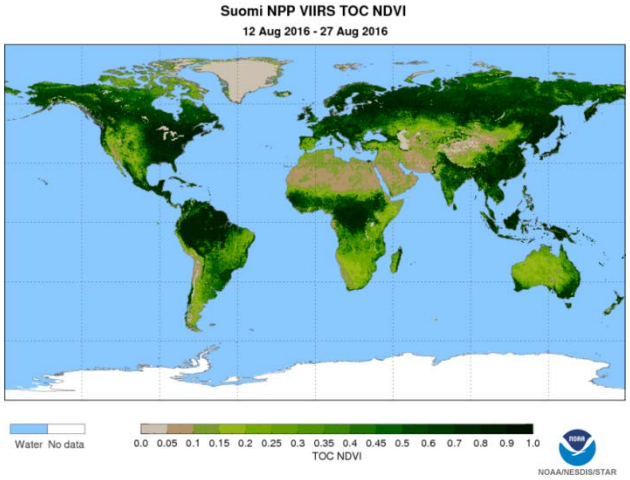


Vegetation Index Bi-Weekly Global Products



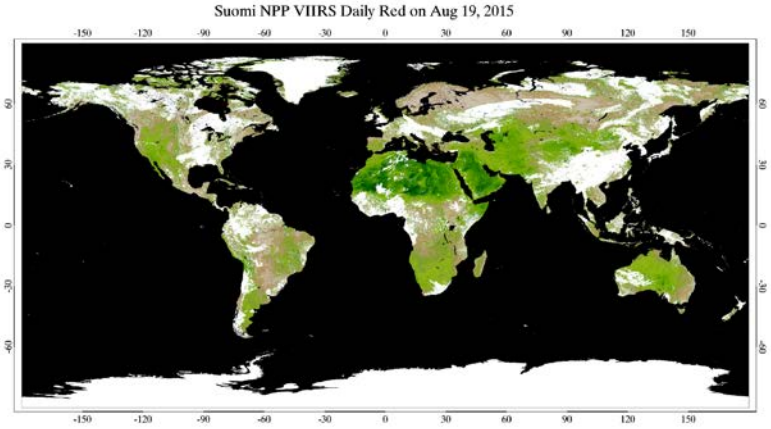


Global Bi-weekly products generated from Surface Reflectance granule Data in HDF5 format (from the IDPS)

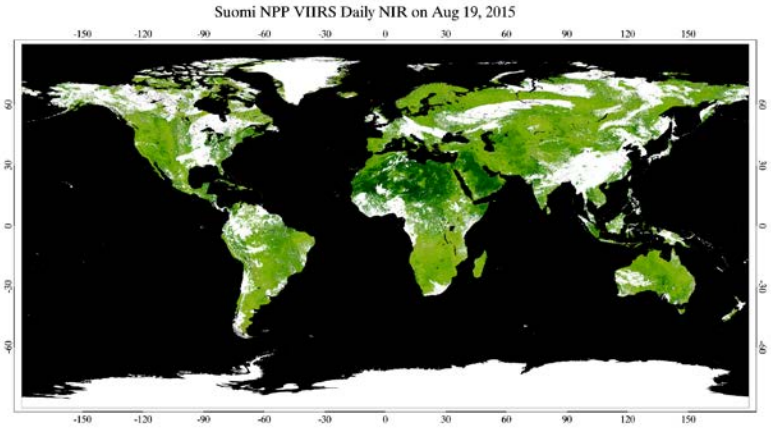


GVF System – Intermediate Files generated using Enterprise Surface Reflectance input granule data in NetCDF4 (2015-08-19)

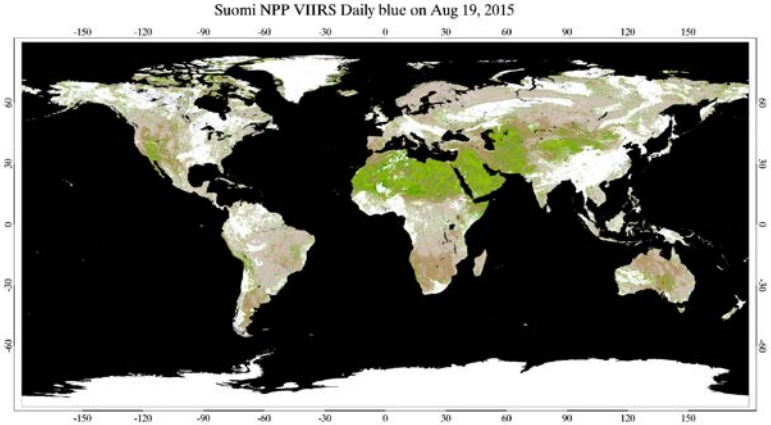
Daily VIIRS I1 ESR (Aug 19, 2015)



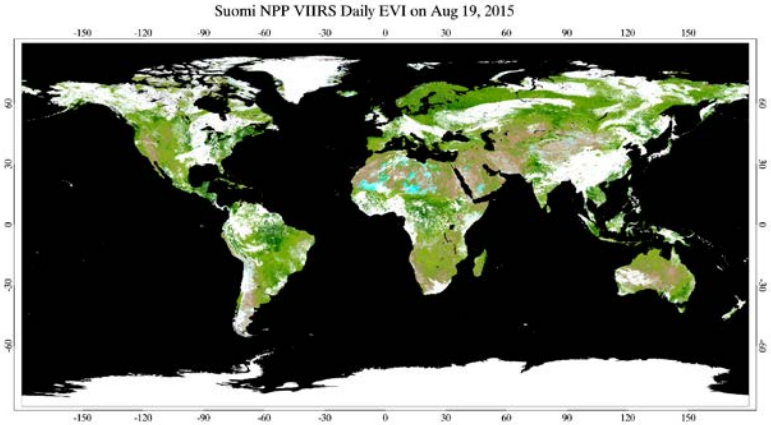
Daily VIIRS I2 ESR (Aug 19, 2015)



Daily VIIRS M3 ESR (Aug 19, 2015)

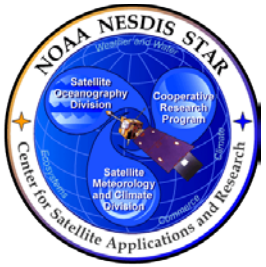


Daily EVI (Aug 19, 2015)



Intermediate files within the VIIRS GVF processing system

Validation Strategy

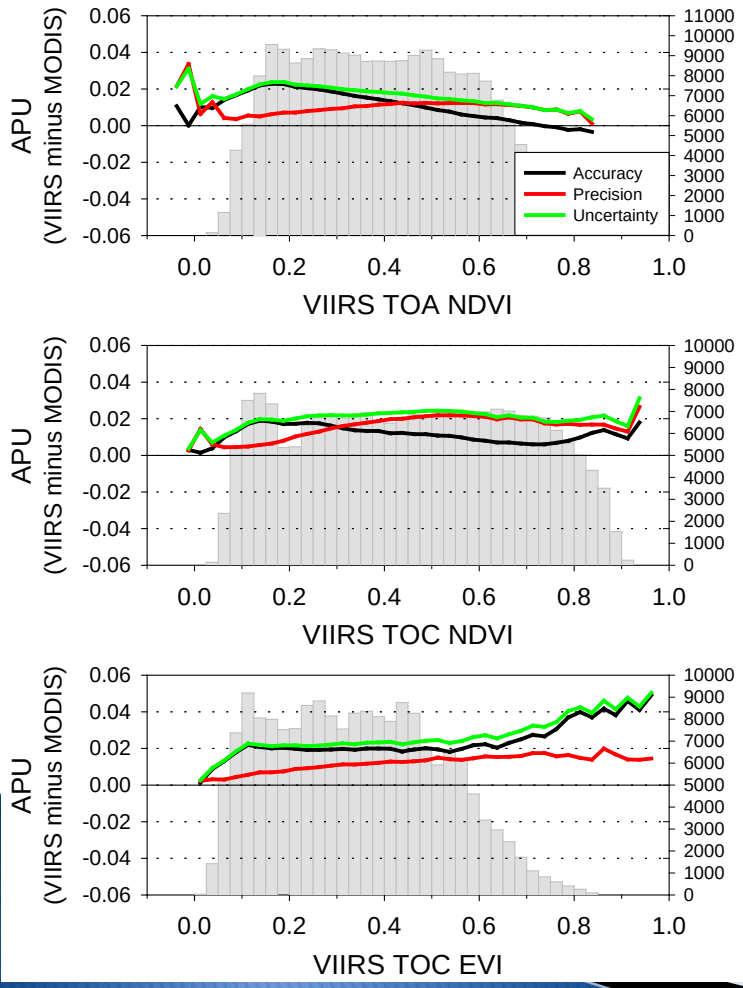


- NDE Vegetation Index (VI) products will be validated and evaluated by
  - Product inter-comparison with other satellites (e.g., MODIS, Sentinel, Landsat) over overlapping orbital tracks and over a globally-distributed set of sites
  - Time series comparison with *in situ* VI data and vegetation productivity (e.g., gross primary productivity) data over FLUXNET sites
  - Cross-comparison with AERONET-processed data

VIIRS VI EDR Global APU

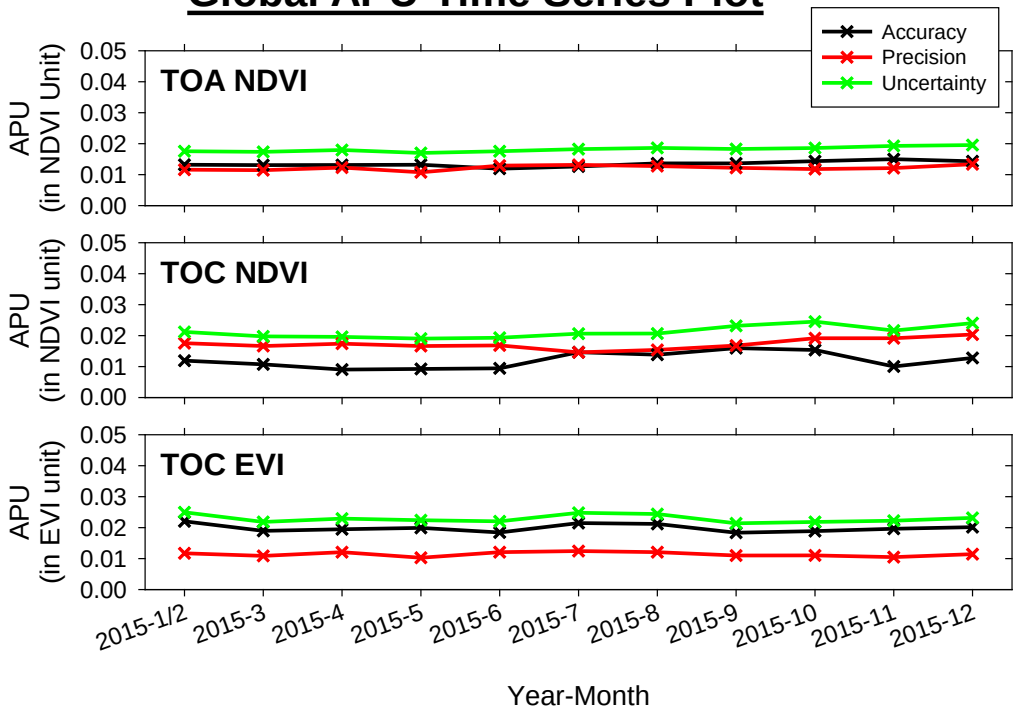
- VIIRS VI EDR meet the L1RDS requirements over time and across seasons
  - APU derived from global data using Aqua MODIS as a reference
  - VIIRS-MODIS observation pairs from matched orbital tracks used

Global APU Over Dynamic Range



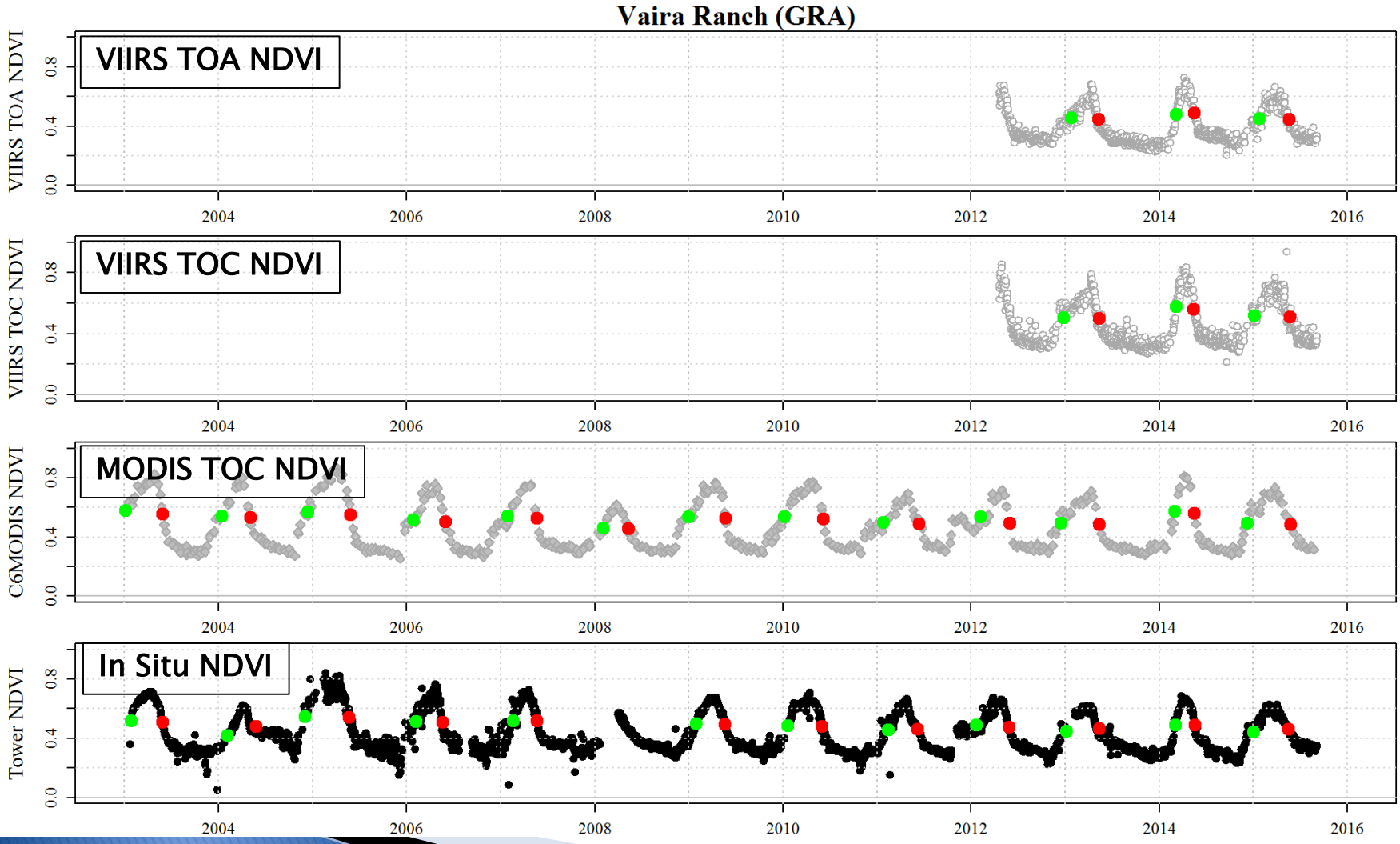
	TOA NDVI	TOC NDVI	TOC EVI
A	0.013	0.012	0.020
P	0.012	0.018	0.011
U	0.018	0.021	0.023

Global APU Time Series Plot



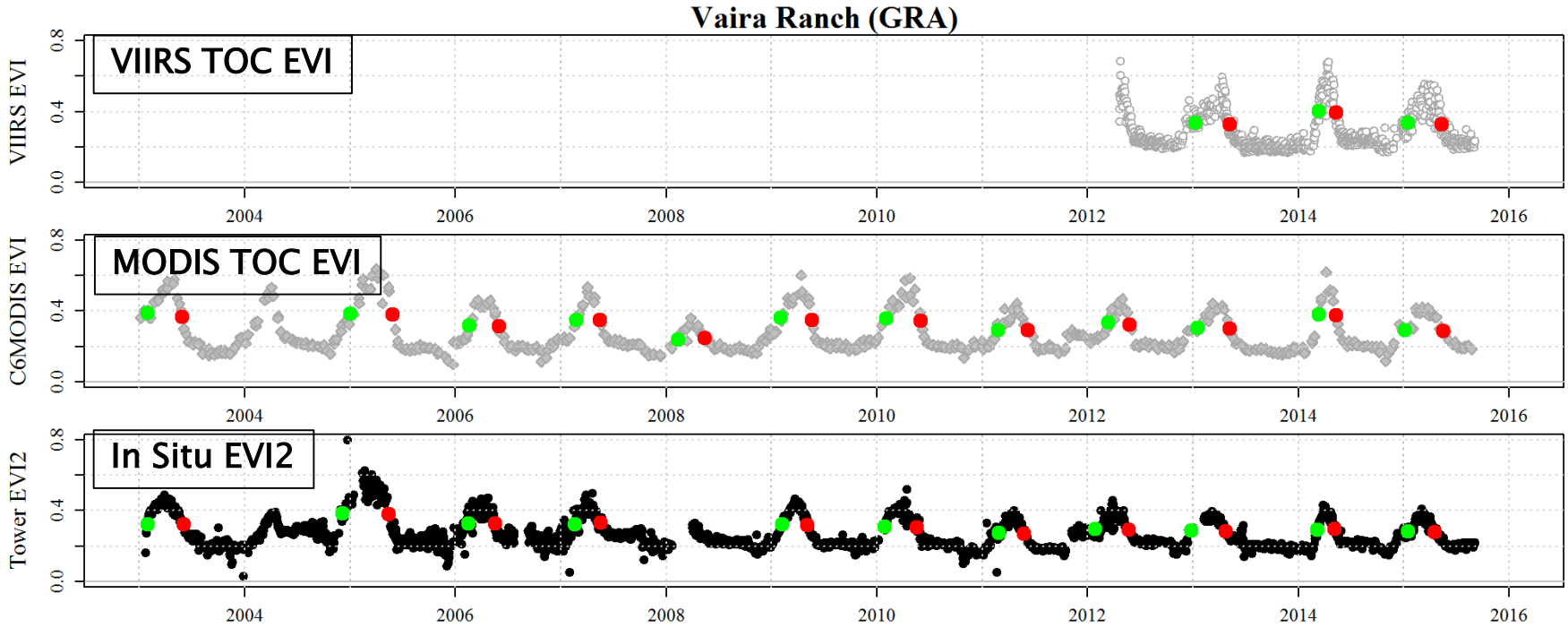
Product Inter-comparison Over a Distributed Set of Sites

- Quality of VIIRS VI EDR temporal profiles evaluated via visual inspection & comparison with Aqua MODIS and *in situ* data when available



Product Inter-comparison Over a Distributed Set of Sites

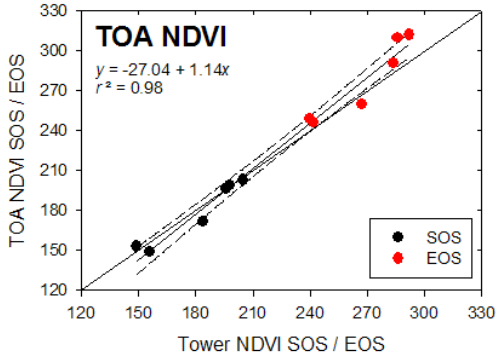
- Quality of VIIRS VI EDR temporal profiles evaluated via visual inspection & comparison with Aqua MODIS and *in situ* data when available

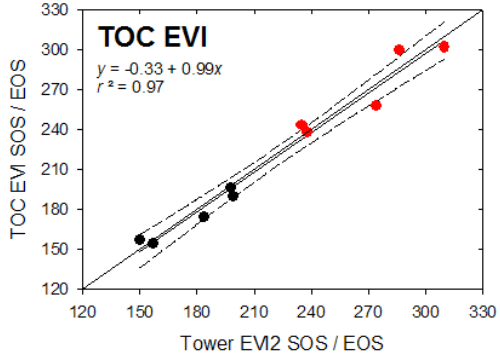


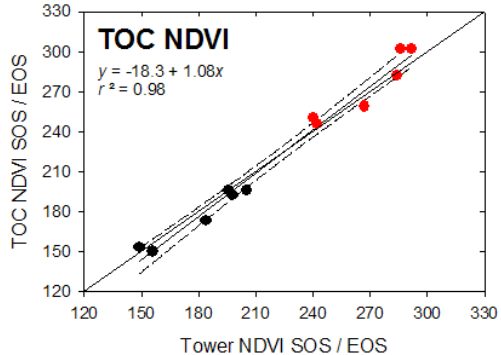
Time Series Validation Using *In Situ* Network (FLUXNET)

- 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)

VIIRS vs. In Situ: SOS & EOS



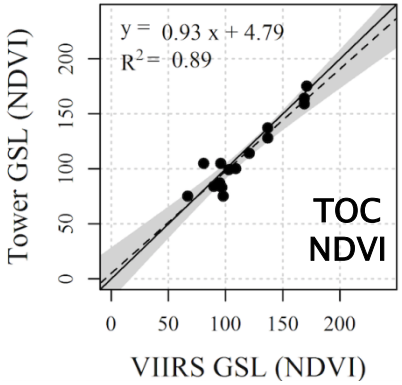


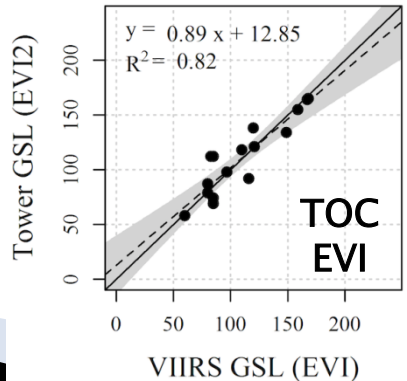


VIIRS vs. MODIS vs. In Situ Cross-Comparison of Phenological Metrics (SOS, EOS, & GSL)

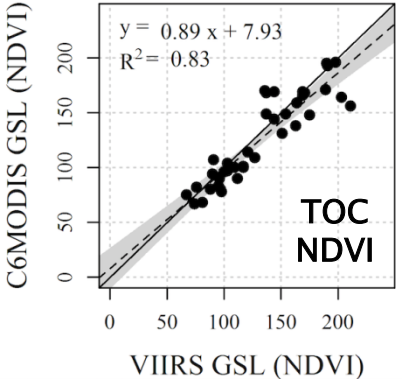
- VIIRS- & *In Situ*-derived phenological metrics corresponded well (e.g., SOS MD < 5 days; SOS RMSE < 7 days)

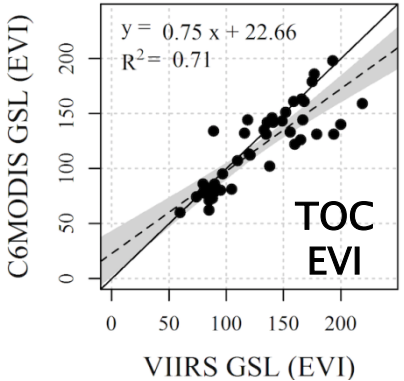
VIIRS vs. In Situ: GSL





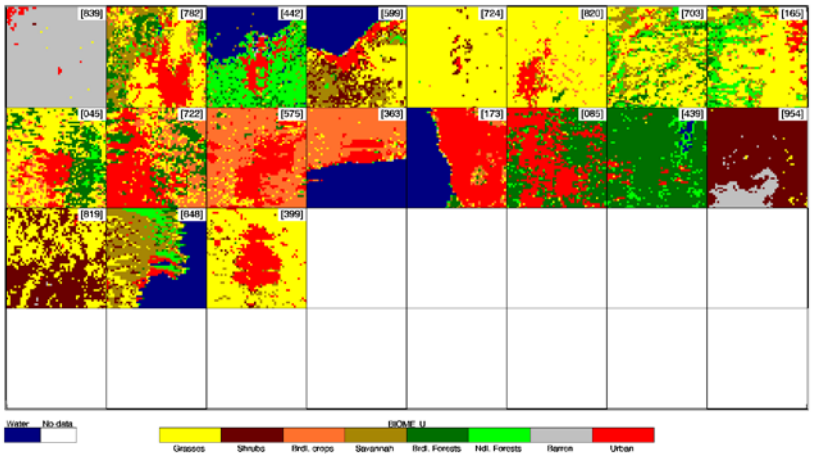
VIIRS vs. MODIS: GSL

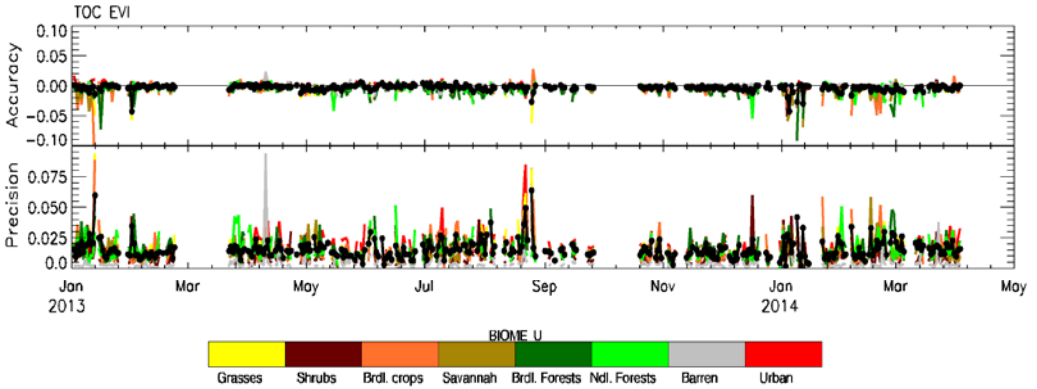


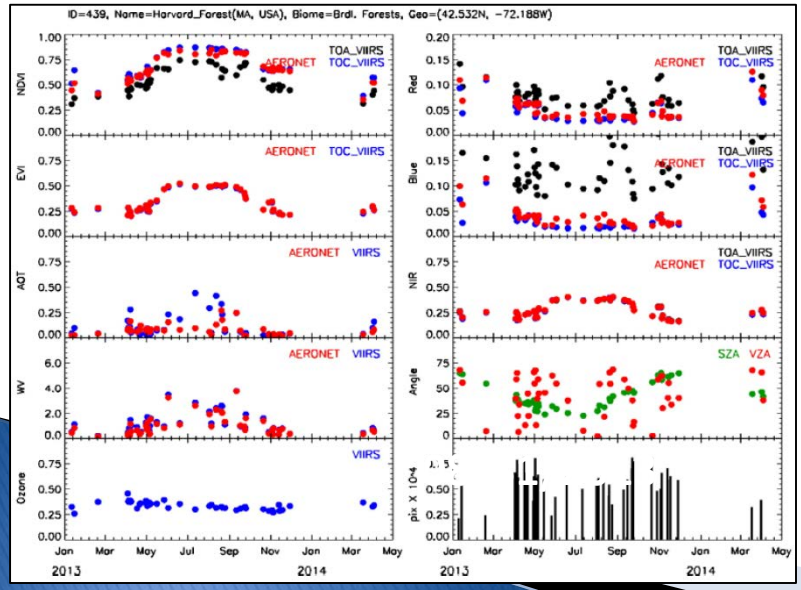


VIIRS Validation Over AERONET Sites (for TOC NDVI and TOC EVI)

- 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)

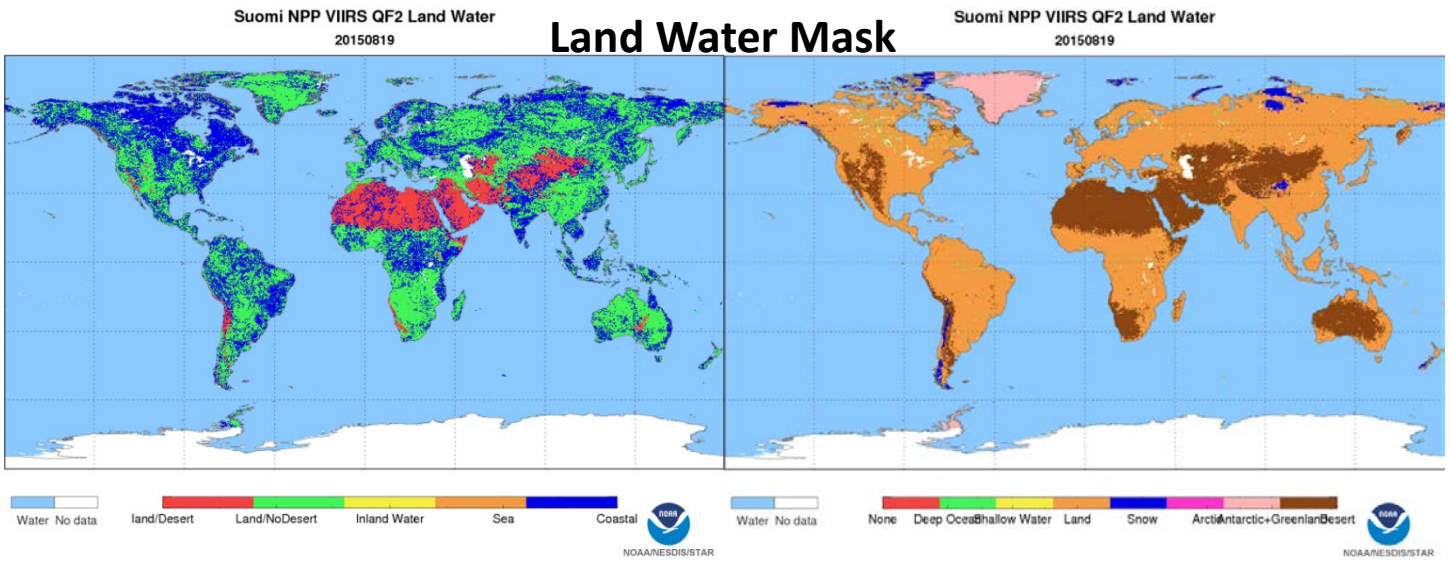
	TOC EVI	TOC NDVI
A	0.004	0.009
P	0.015	0.035
U	0.016	0.038

(Shabanov et al., 2015, RSE)

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #1: Attributable to ECM, as ESR only passes it on

IDPS



NDE

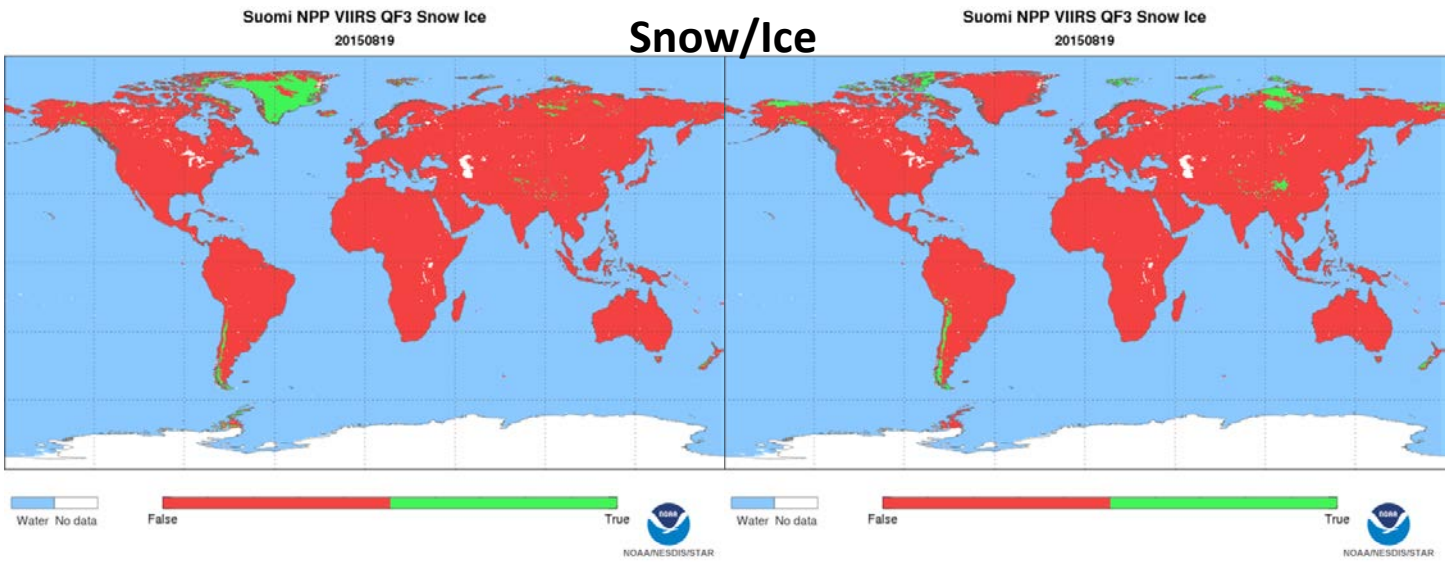
Land water mask:
The new LWM has snow in it, but Arctic and Antarctic+Greenlands are treated as separate categories.

Problem:
VI is degraded over snow/ice pixels. Over Antarctic and Greenland, we don't know whether there are snow/ice or not. We don't know how to treat Antarctic and Greenland overall (degrade them all?)

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #2: Attributable to ECM, as ESR only passes it on

IDPS



Snow/Ice

NDE

Snow/Ice:
There are no snow/ice information over Antarctic and Greenland. This is linked to the Land Water Mask issue.

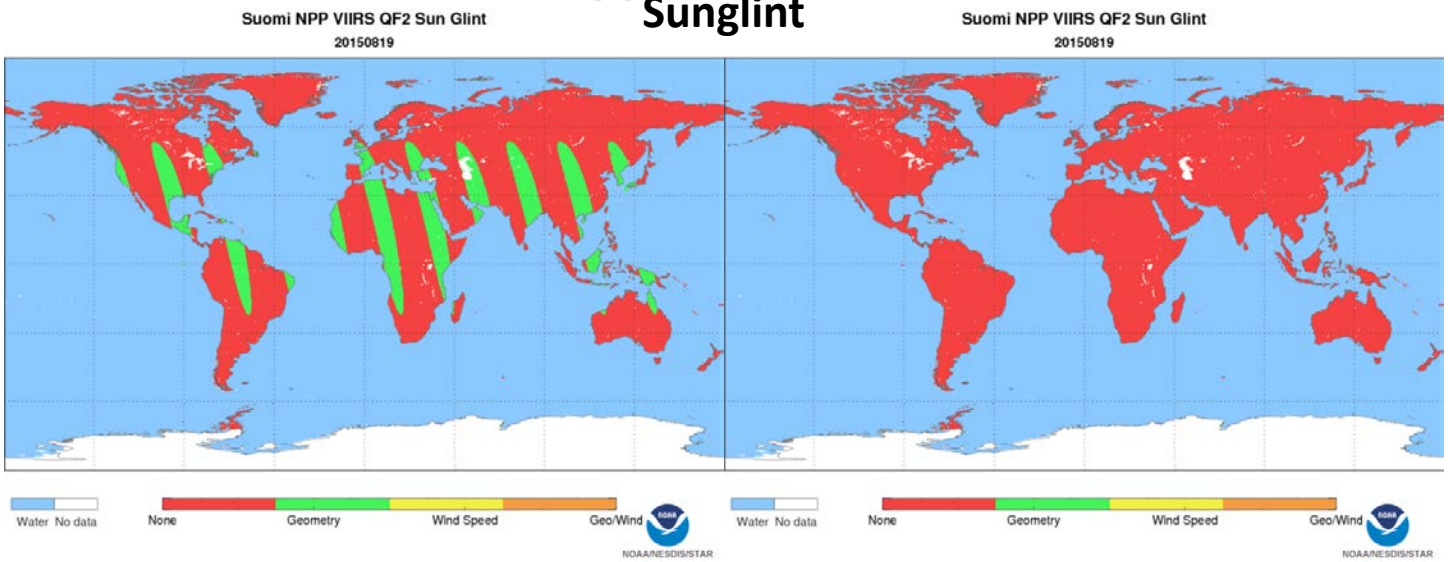
Problem:
VI is degraded over snow/ice pixels. Over Antarctic and Greenland, we don't know whether there are snow/ice or not. We don't know how to treat Antarctic and Greenland overall (degrade them all?)

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #3: Attributable to ECM, as ESR only passes it on

Sunglint

IDPS



NDE

Sunglint:

IDPS has two sunglint flags, one is geometry based (over land) and one based on wind speed (over water). NDE ECM only has the oceanic version, meaning there is no sun glint over land.

Problem:

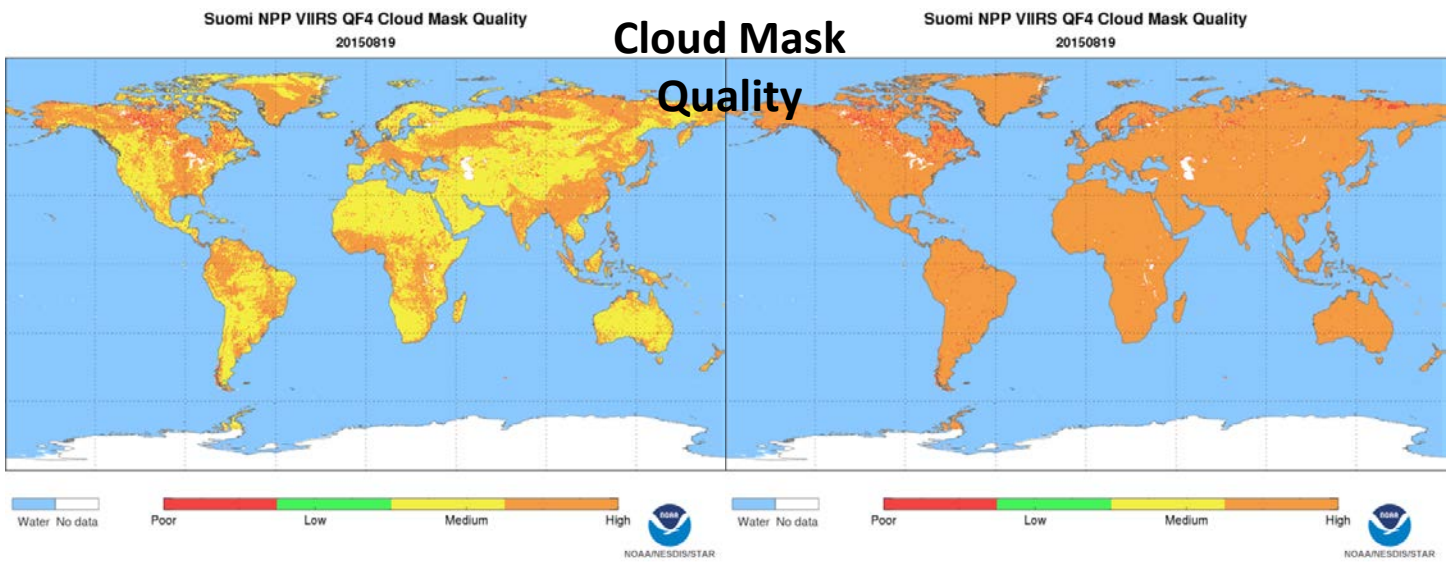
VI has known biases over pixels with sunglint over land. Without information of sun glint over land, we will have 'contaminated' VI product for the areas with sun glint over land. We hope we can get the ‘Geometry based sunglint QF’ back to ECM and ESR.

Sunglint over land is planned to be added to ECM revision 4

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #4: Attributable to ECM, as ESR only passes it on

IDPS



NDE

Cloud Mask Quality:

NDE cloud mask ECM has ‘cloudmaskqualflag’ but appears to be empty with fill value ‘-128’. So, ESR calls cloud mask high quality as long as there is a cloud mask. This is why ESR has high quality cloud mask almost everywhere.

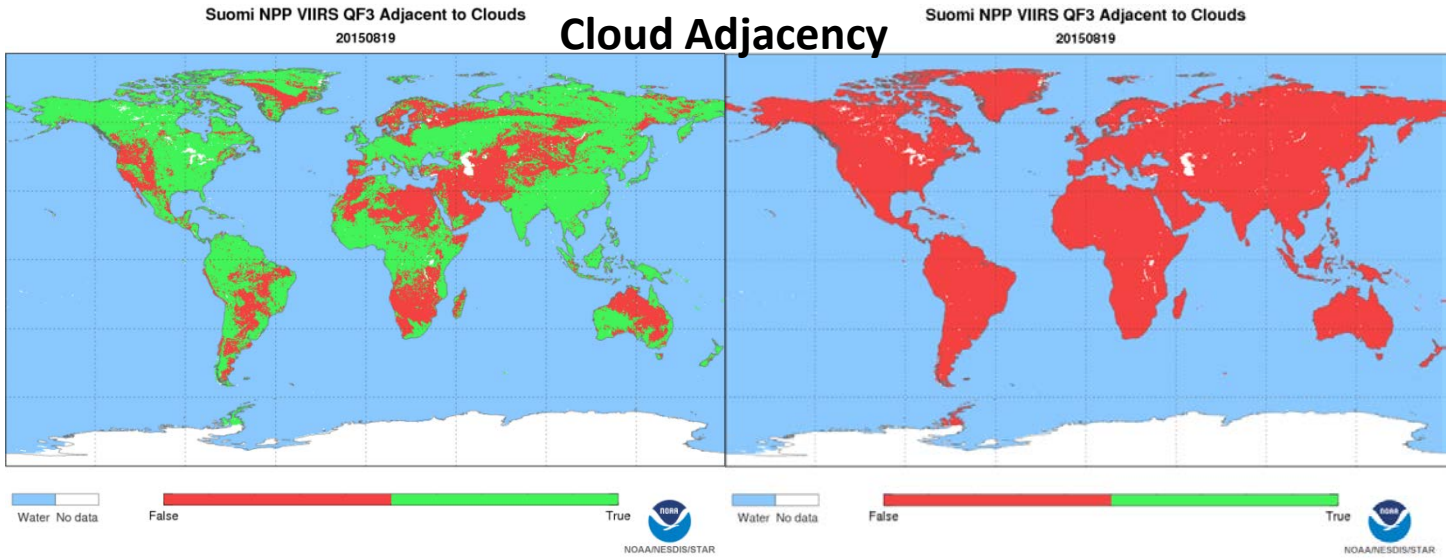
Problem:

VI does not have quality assurance criteria based on cloud mask quality yet. However, we do hope we can get a meaningful ‘cloudmaskqualflag’ in ECM.

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #5: Attributable to ECM, as ESR only passes it on

IDPS **Cloud Adjacency** **NDE**



Cloud Adjacency:
IDPS VCM has this QF, but NDE ECM does not.

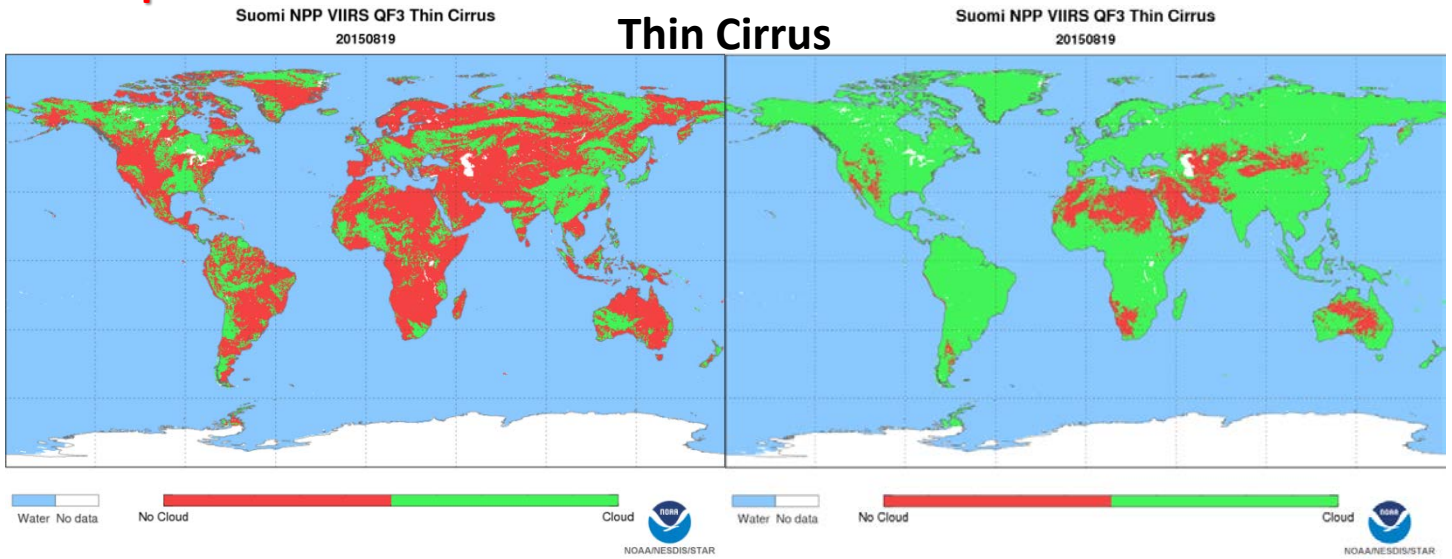
Problem:
'Cloud Adjacency' is an important parameter to avoid cloud contamination to ECM's downstream products. VI is degraded over pixels with 'cloud adjacency'. Without 'cloud adjacency' information, VI retrievals are likely 'contaminated' over pixels with cloud in adjacency.

Cloud Adjacency has been added to ECM

Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #6: Need help from both ECM and ESR

IDPS **Thin Cirrus** **NDE**



Thin Cirrus Reflective:

VCM reports either no-cloud or cloud, but ECM reports a 4-category mask here: confident clear, probably clear, probably cloudy, and confident cloudy. ESR processes this as confident clear (no-cloud) versus everything else (cloud), so the thin cirrus reflective QF will potentially look very cloudy in ESR. ESR can change the sensitivity of this flag if needed, since surface reflectance only passes it on.

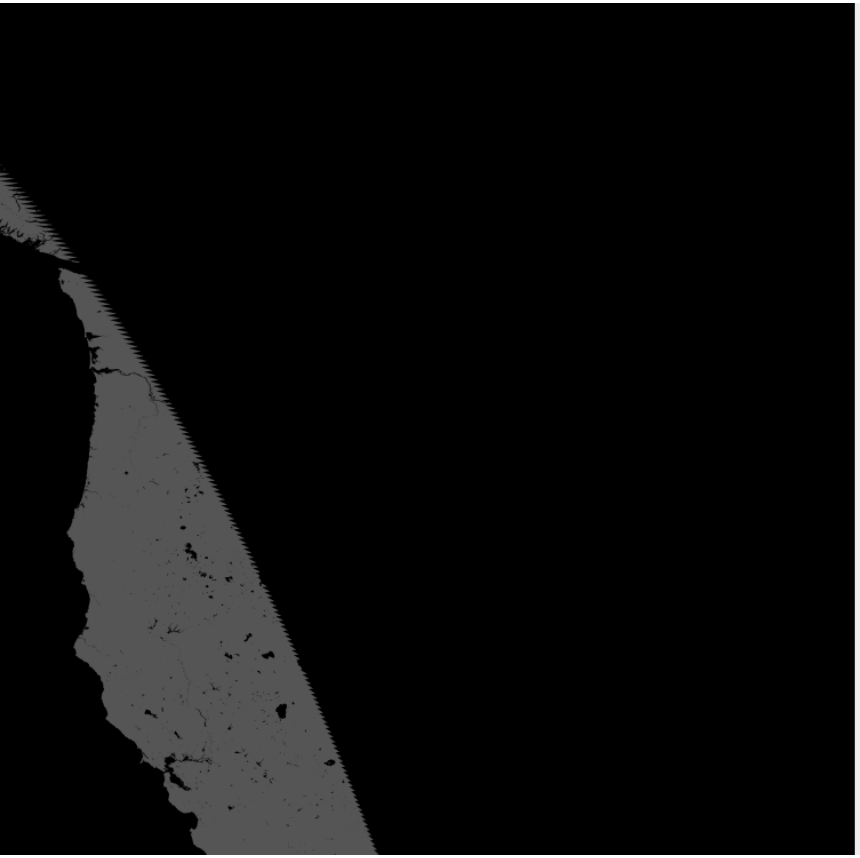
Problem:

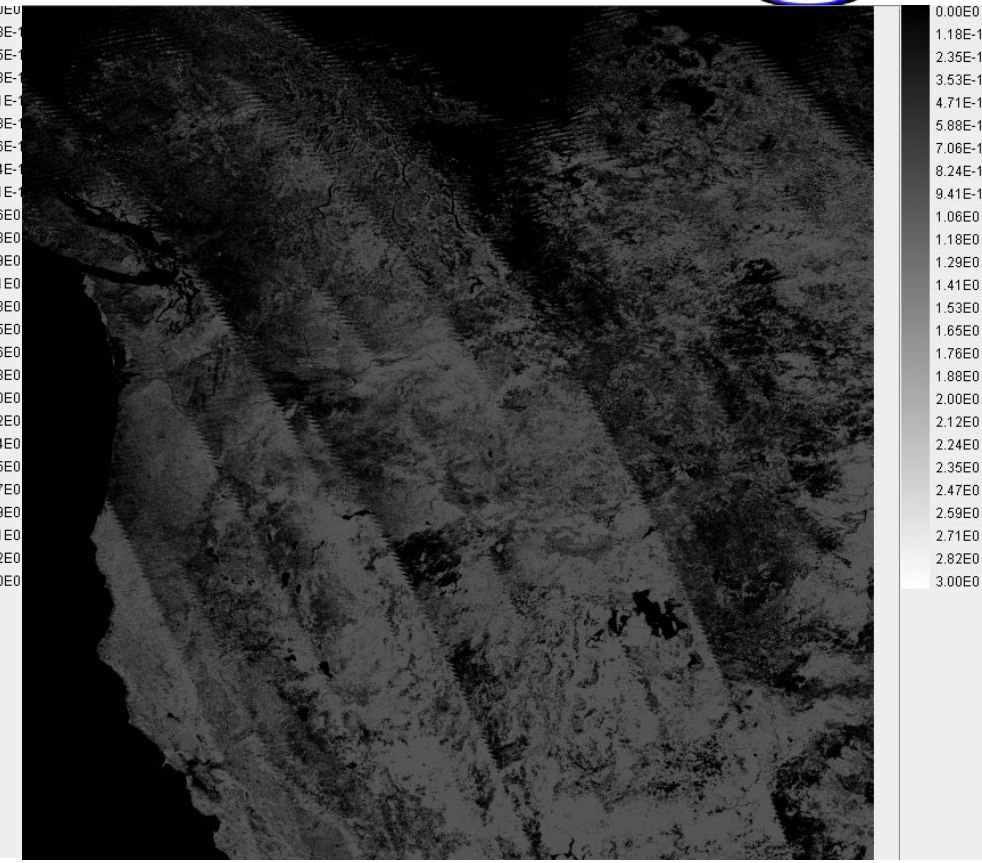
VI is degraded over pixels with ‘thin cirrus reflective’. We will appreciate ESR can change the sensitivity of this flag. Right now we have overwhelming thin cirrus reflective, which is one of the main reasons that we have ‘too many’ low quality VI.

Thin Cirrus has been added to ECM

20160819
H03V02
Sun Glint (QF2, Bit 6-7)

20160812-20160827
H03V02
Sun Glint (QF2, Bit 6-7)

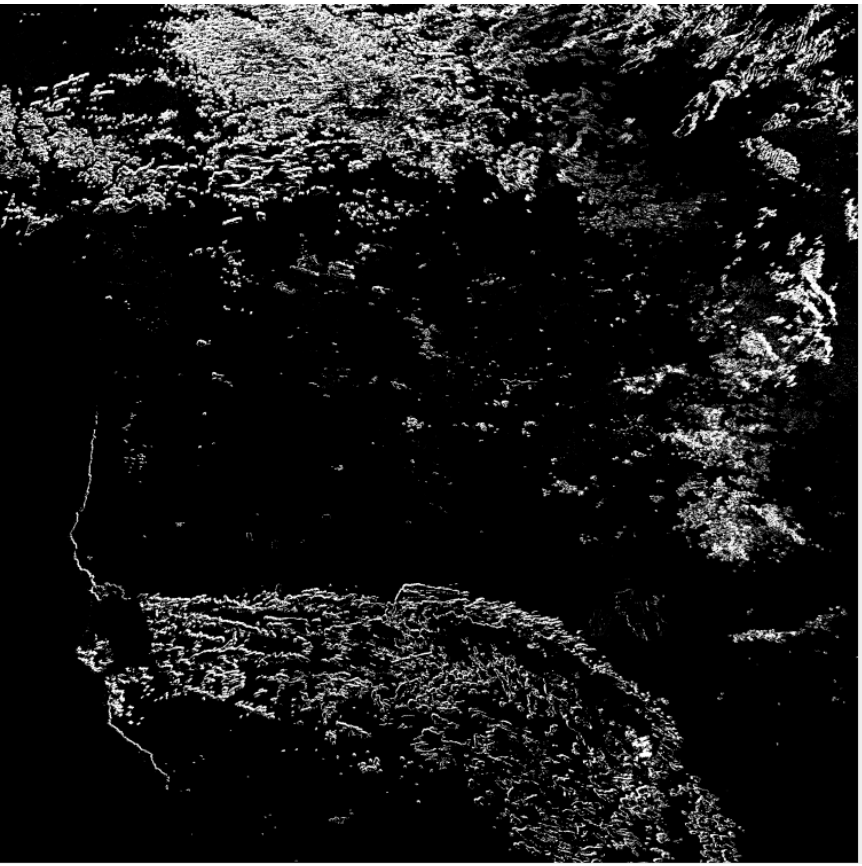


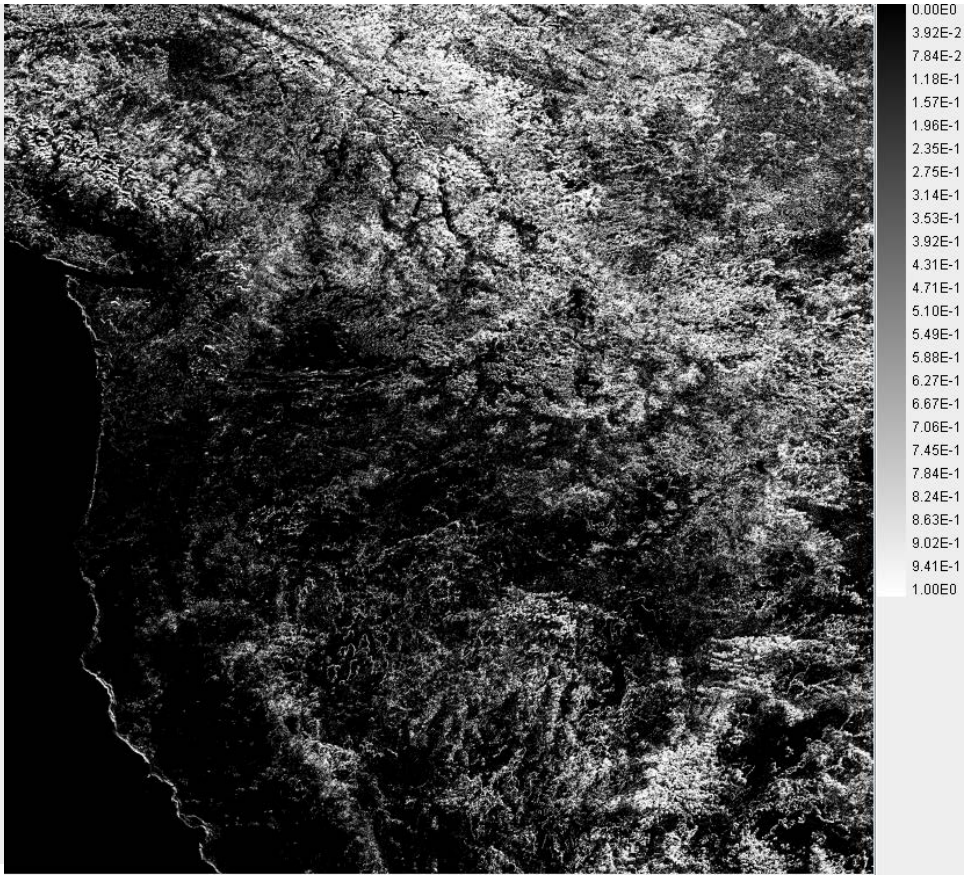


*Sun Glint	11 = Geometry & Wind 10 = Wind Speed Based 01 = Geometry Based 00 = None

20160819
H03V02
Cloud Shadow (QF4, Bit 0)

20160812-20160827
H03V02
Cloud Shadow (QF4, Bit 0)

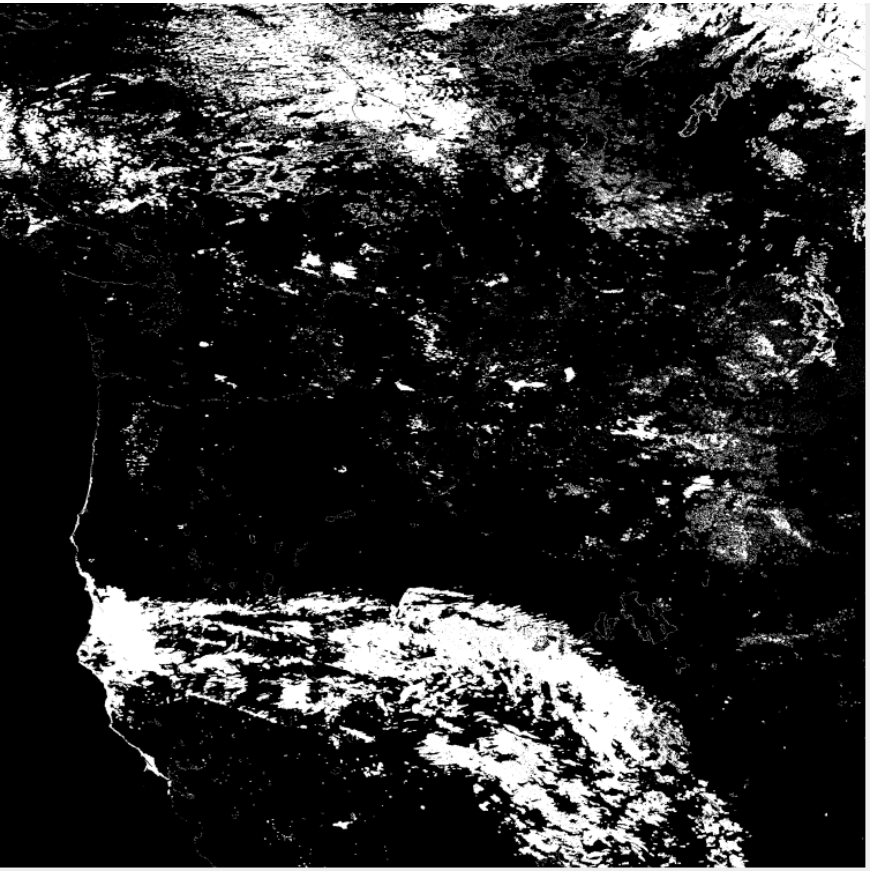


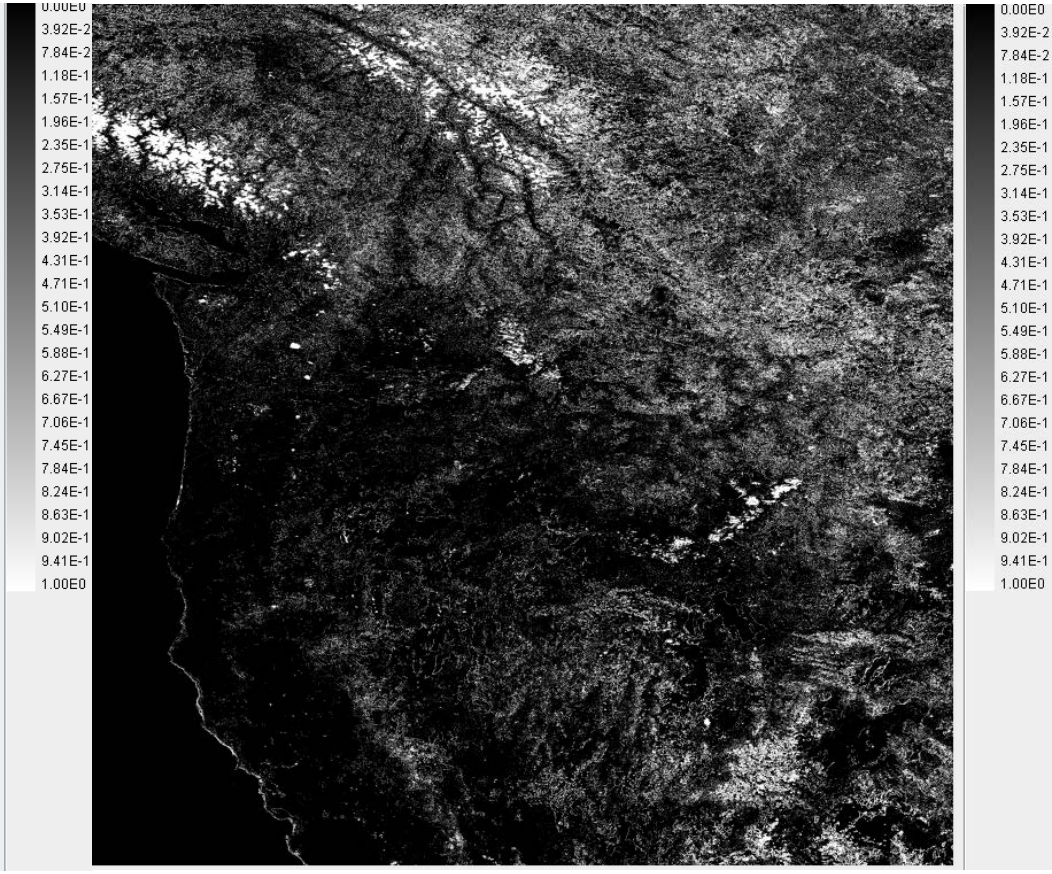


*Cloud Shadows	0 = False (no) 1 = True (yes)

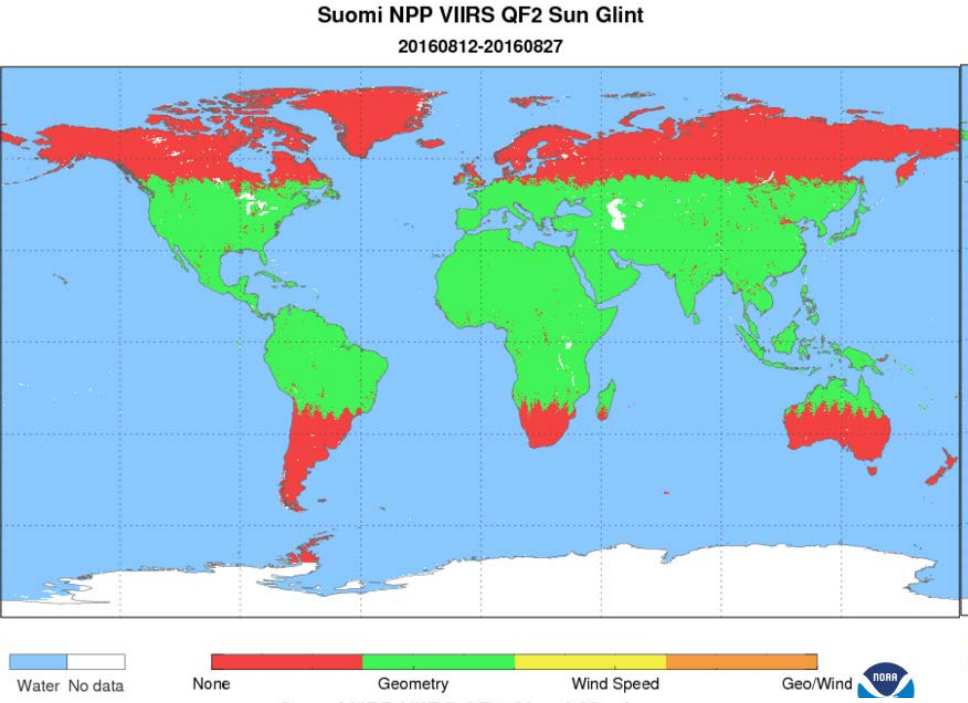
20160819
H03V02
Cloud Adjacency (QF3, Bit 5)

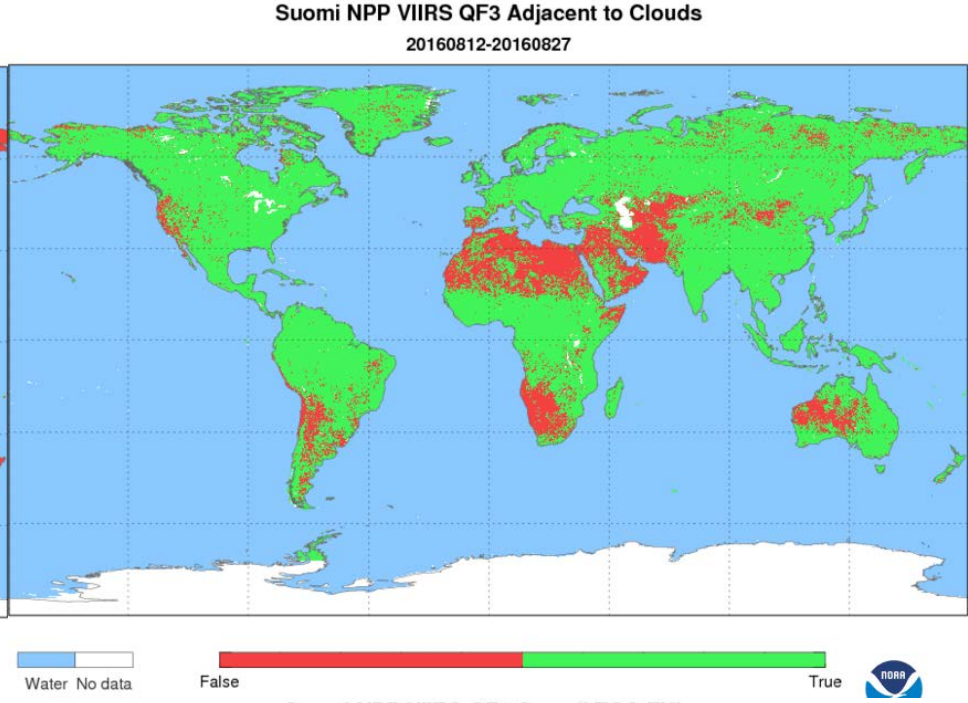
20160812-20160827
H03V02
Cloud Adjacency (QF3, Bit 5)

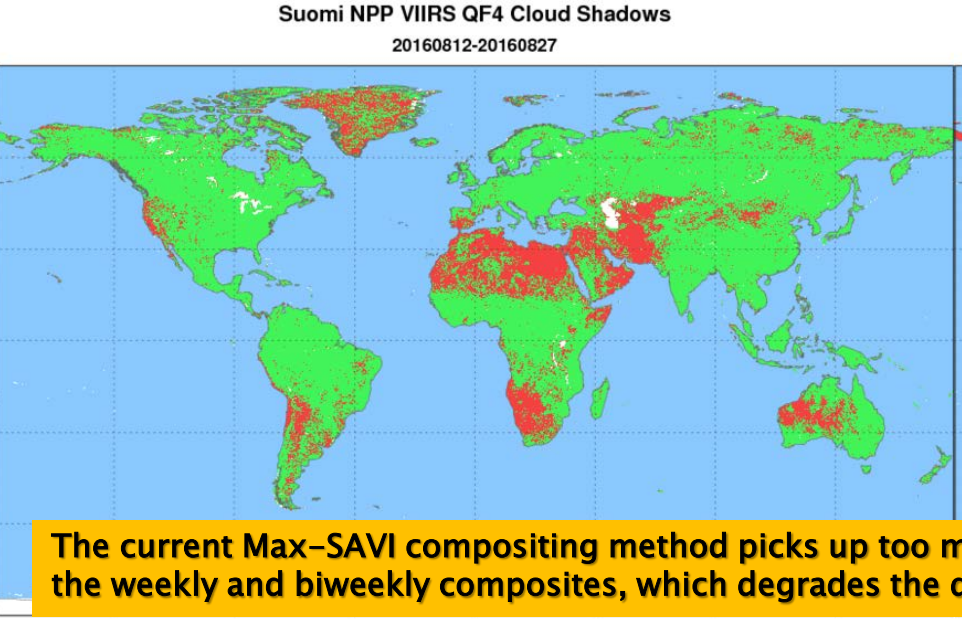


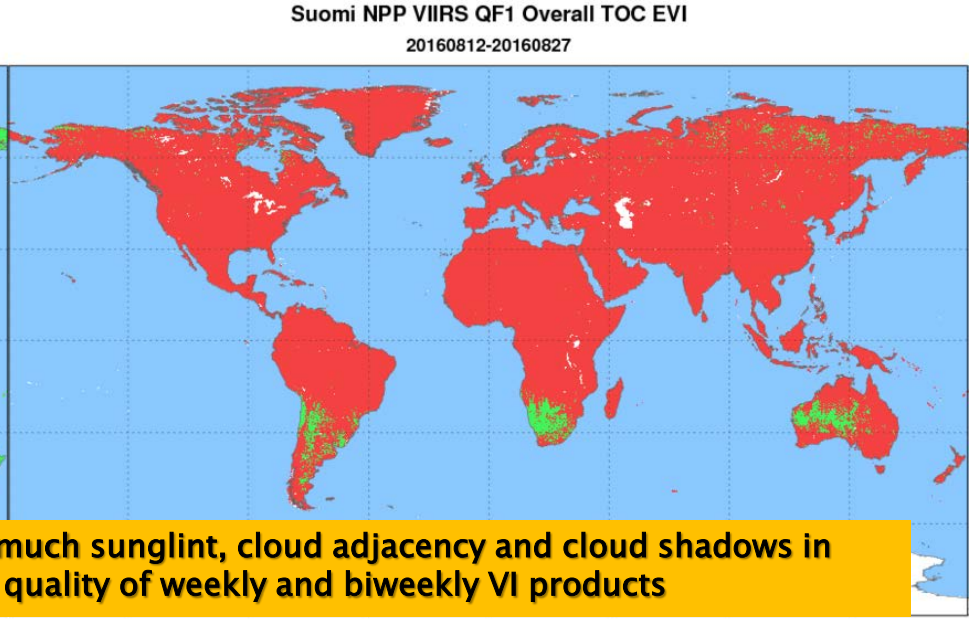


*Cloud Adjacency	0 = False (no) 1 = True (yes)









The current Max-SAVI compositing method picks up too much sunglint, cloud adjacency and cloud shadows in the weekly and biweekly composites, which degrades the quality of weekly and biweekly VI products

Summary and Conclusion

- Enterprise daily GVF and VI product were tested successfully with full day (20150819) run of Enterprise inputs.
- Enterprise weekly and bi-weekly product tested with IDPS inputs (20160812-20160827). Enterprise products started flowing on 8/15/17 for testing in preparation for the ARR in September.
- Two DAPs were delivered for code testing at NDE.
- Prepare for Algorithm Readiness Review in September 2017
- Improve the current Max-SAVI compositing method
- Improve the integration of VI and GVF systems within NVPS