NOAA-20 VIIRS Vegetation Index (VI) and Green Vegetation Fraction (GVF) Provisional Maturity Review

Presented by Yunyue Yu

Contributed by Feng Zhao, Zhangyan Jiang, Mingshi Chen and Yuxiang He

March 21, 2019

Outline

- Overview
  - VI & GVF Cal/Val Team Members
  - Product Requirements
  - NOAA 20 VIIRS VI & GVF Status
- Evaluation of the NOAA 20 VIIRS VI & GVF
  - Beta Correction
  - Visual assessment of global/regional mosaics and quality flags
  - Check meta metric
  - Cross comparison with other satellite VI & GVF products
- Documentation (Science Maturity Check List)
- Provisional Maturity Summary
  - Evaluation Summary
  - Provisional Maturity Check list
- Path Forward to validated maturity

VI & GVF Cal/Val Team Members

	Name	Organization	Major Task
STAR/EMB	Ivan Csiszar	NOAA/NESDIS/STAR	Land Lead
	Yunyue Yu	NOAA/NESDIS/STAR	EDR Lead, algorithm development/improvement, calibration/validation, team management
	Feng Zhao	NOAA Affiliate, IMSG	Product validation and assessment,
	Mingshi Chen	NOAA Affiliate, IMSG	Algorithm development/improvement, product monitoring
	Zhangyan Jiang	NOAA Affiliate, IMSG	Algorithm development/improvement, product monitoring
	Yuxiang He	NOAA Affiliate, IMSG	Product visualization, monitoring
STAR/OPDB	Walter Wolf	NOAA/NESDIS/STAR	STAR ASSIST Lead
	Valerie Mikles	NOAA Affiliate, IMSG	STAR ASSIST, Algorithm System integration
	Michael Wilson	NOAA Affiliate, IMSG	STAR ASSIST, Algorithm System integration

VI Product 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

GVF Product Requirements

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

Source: Level 1 Requirements SUPPLEMENT – Final Version 2.9 June 27, 2013

JPSS Data Products Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

2. <u>Provisional</u>

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting

NOAA 20 VIIRS VI & GVF Status

- Enterprise VIIRS VI & GVF algorithm has been delivered and integrated into the framework. DAP to NDE was delivered in November, 2018 and updated due to file naming convention in February, 2019.
- The enterprise VIIRS VI production for NOAA-20 data has been pended in the NDE system due to the system threading restriction.
- NOAA-20 VI and GVF data for the provisional maturity evaluation were prepared by ASSIST (Michael Wilson)
- General issues observed during beta stage were fixed. The science code was updated since the beta review
- LUT issue in NOAA-20 SR was fixed in December, 2018, data available from Feb 2019, which limits the amount of our testing data for VI & GVF

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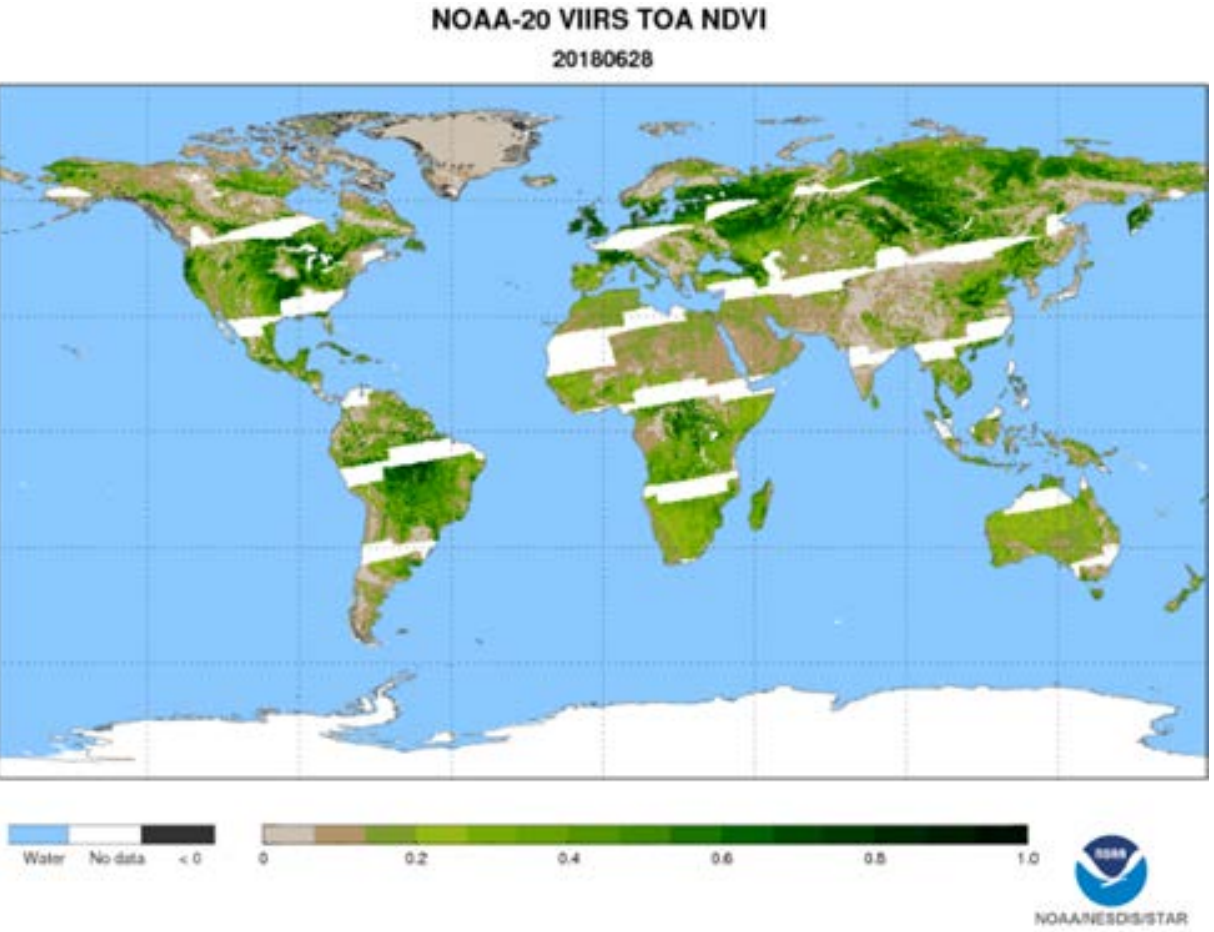
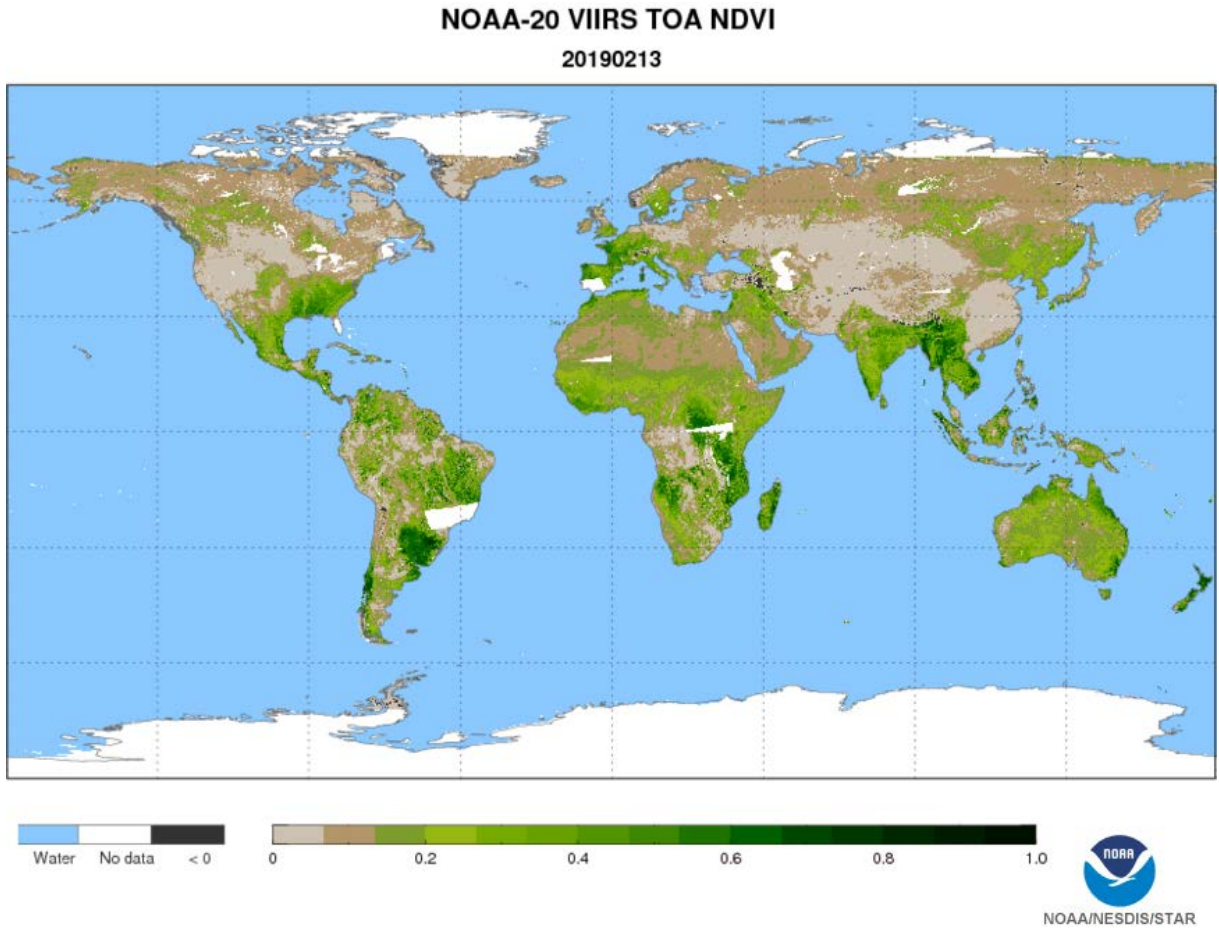
NOAA-20 VIIRS VI & GVF Evaluation method

- **Beta Review Correction**
- **Visual assessment of global/regional mosaics and quality flags**
- **Check meta metrics**
- **Cross-comparison with SNPP VI/GVF products**

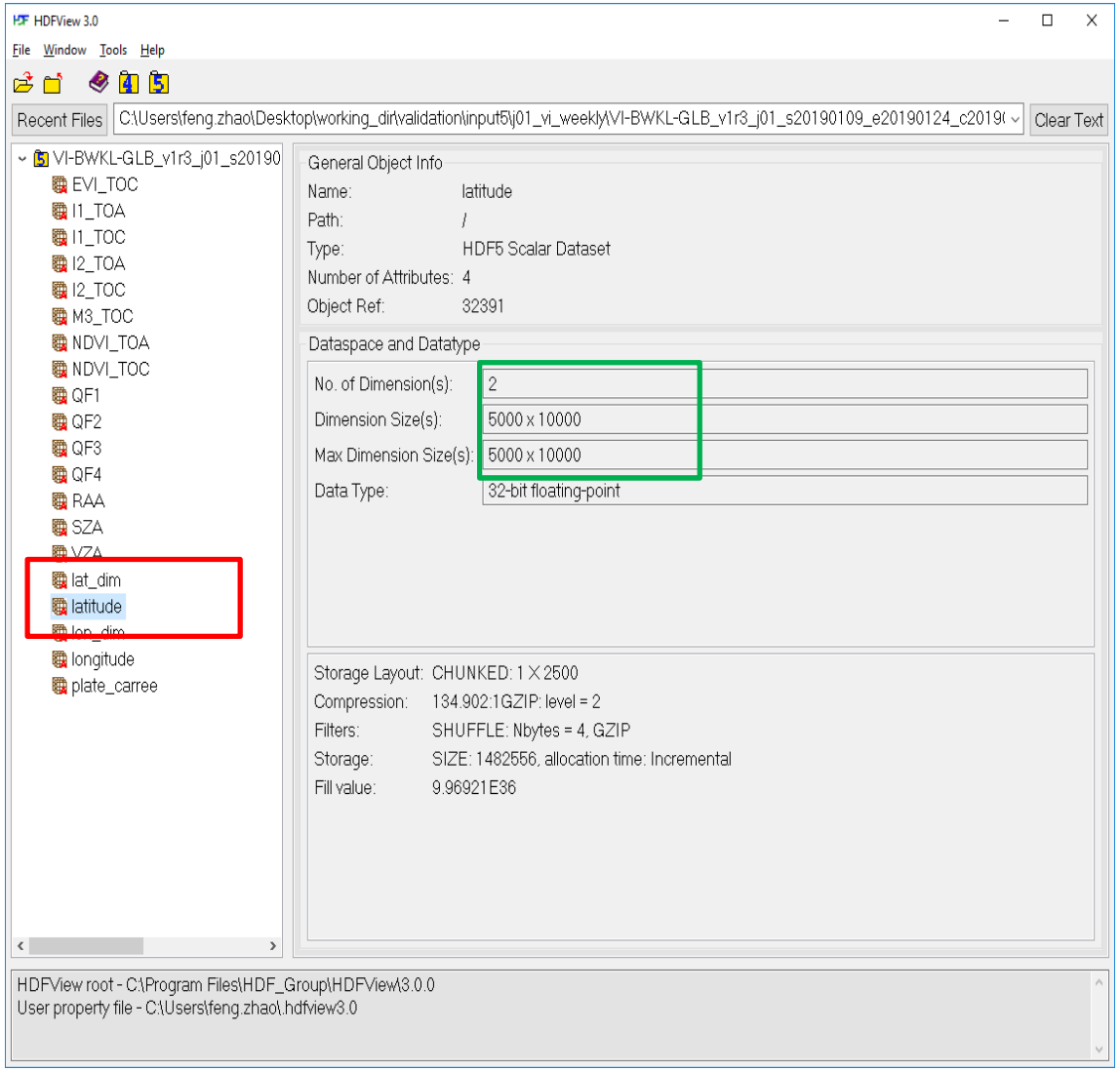
Beta Issue 1: Dropout Fixed

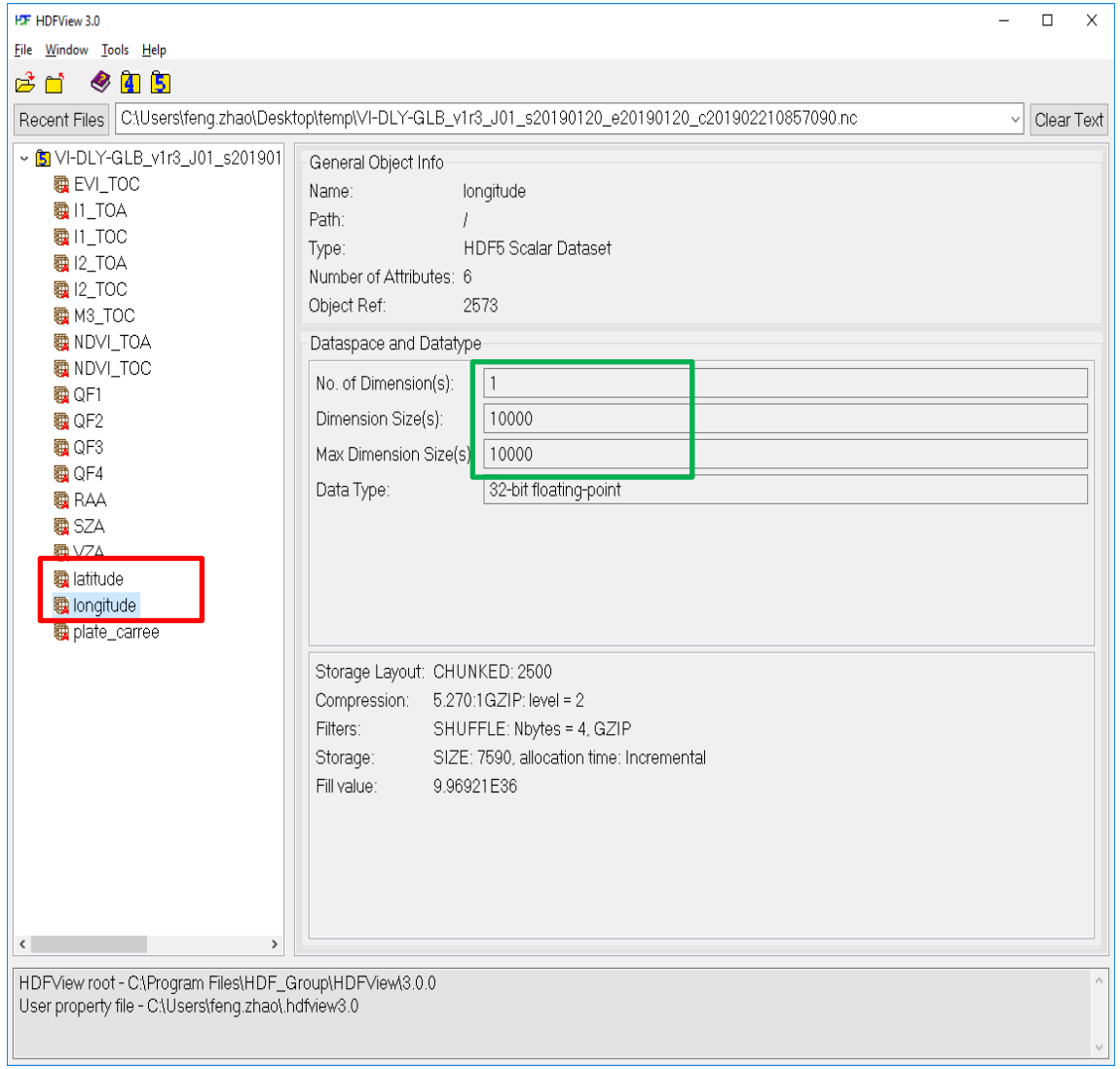




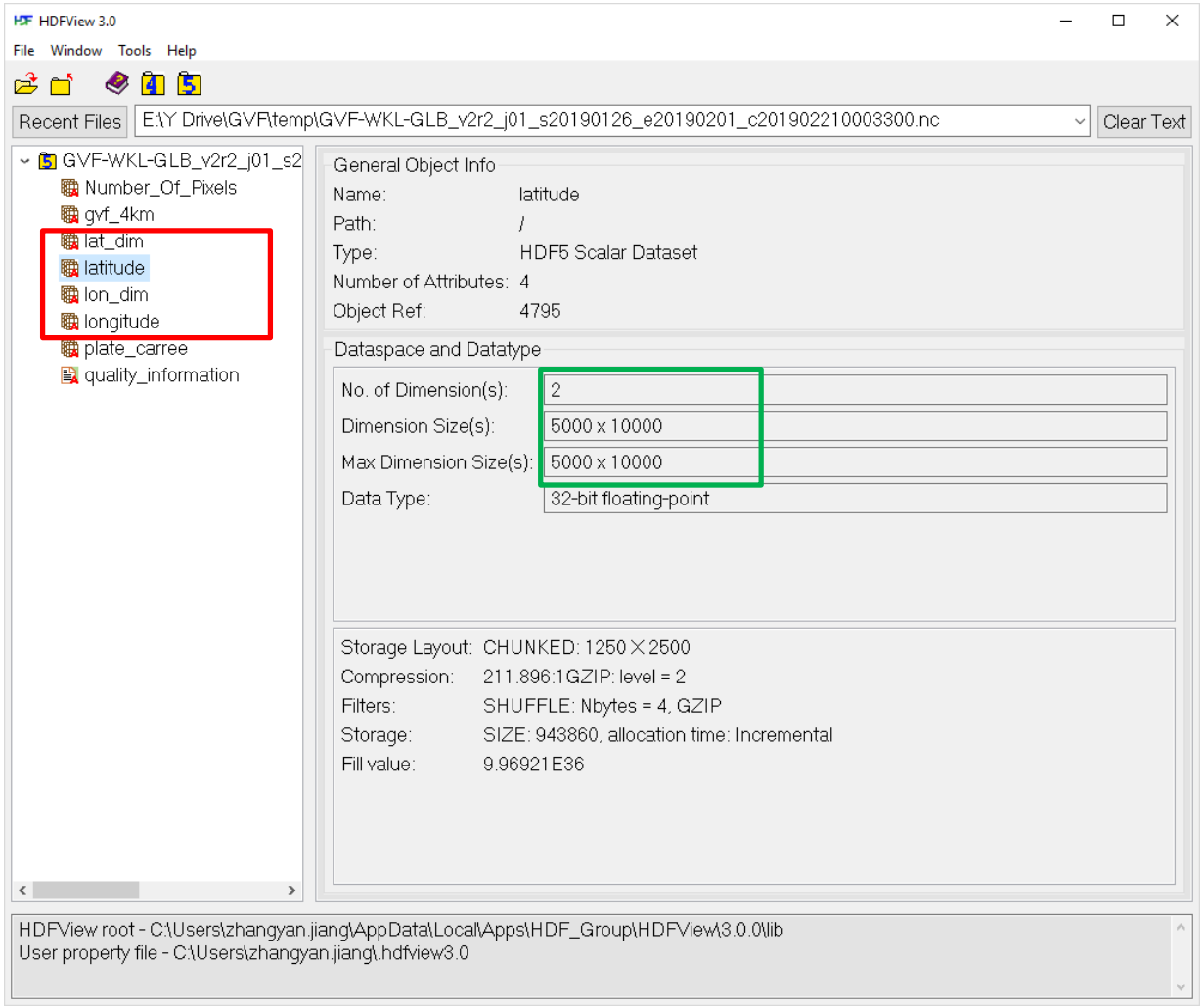
During Beta Review, VIIRS VI & GVF group identified the dropout issue due to a bug in SR granule provided by NDE. This issue was soon fixed.

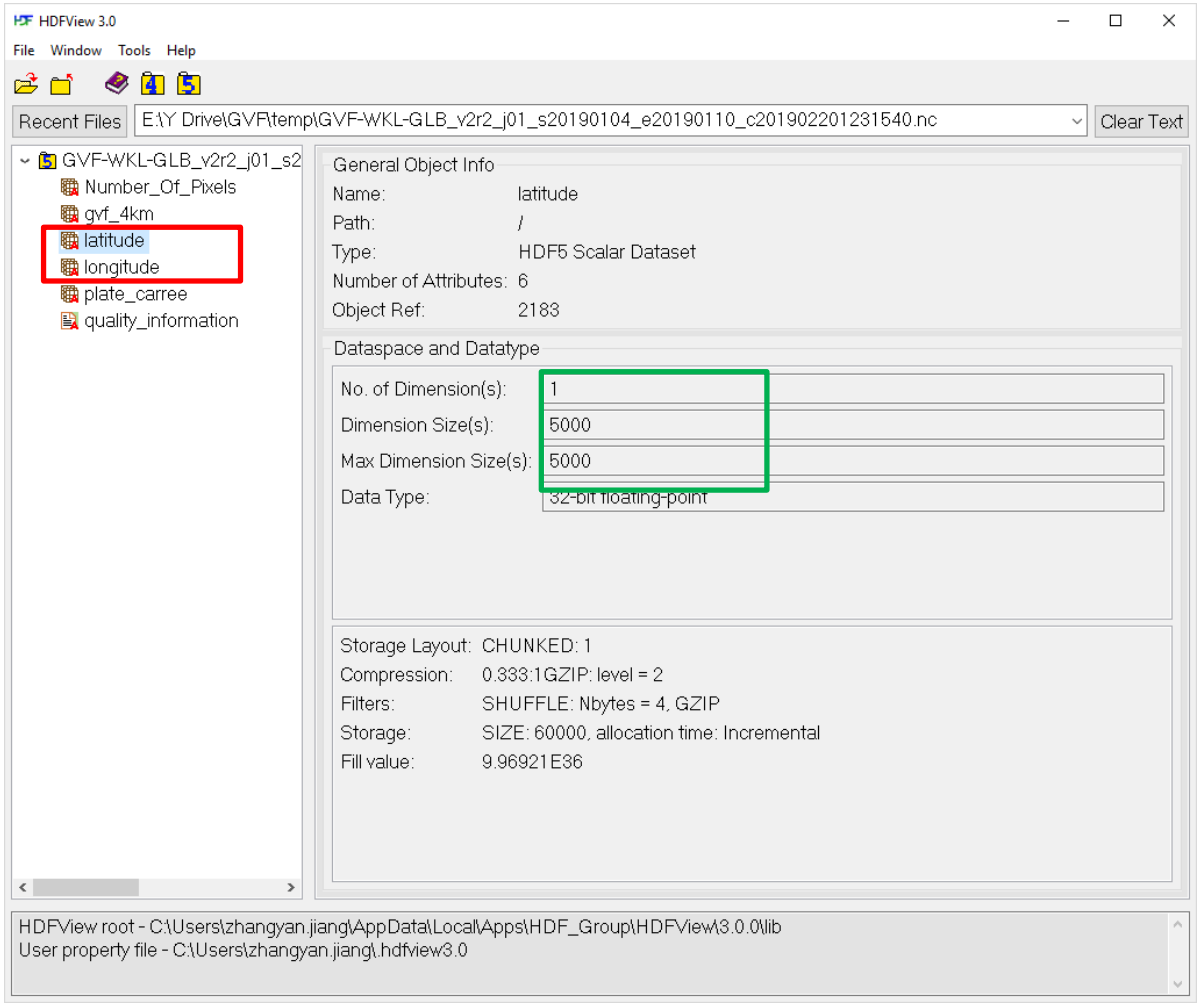
Beta Issue 2: VI Lat/lon info Simplified



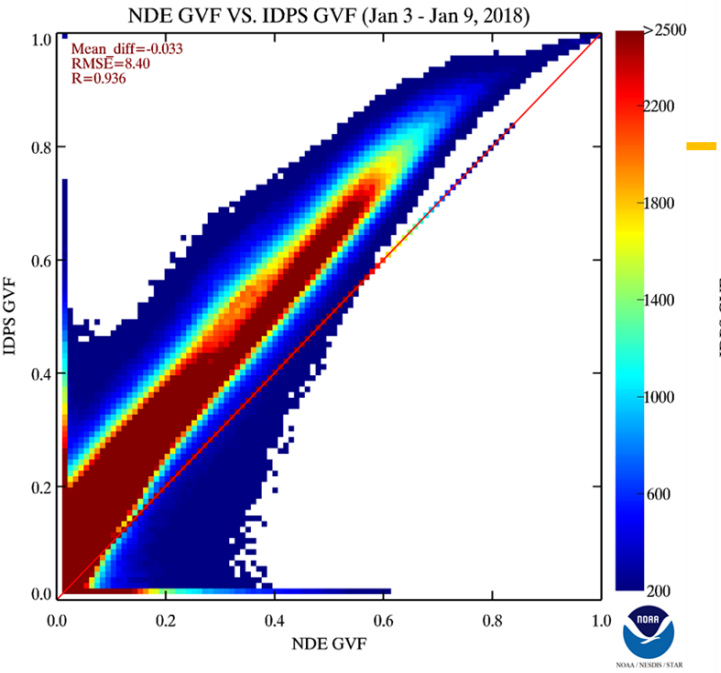


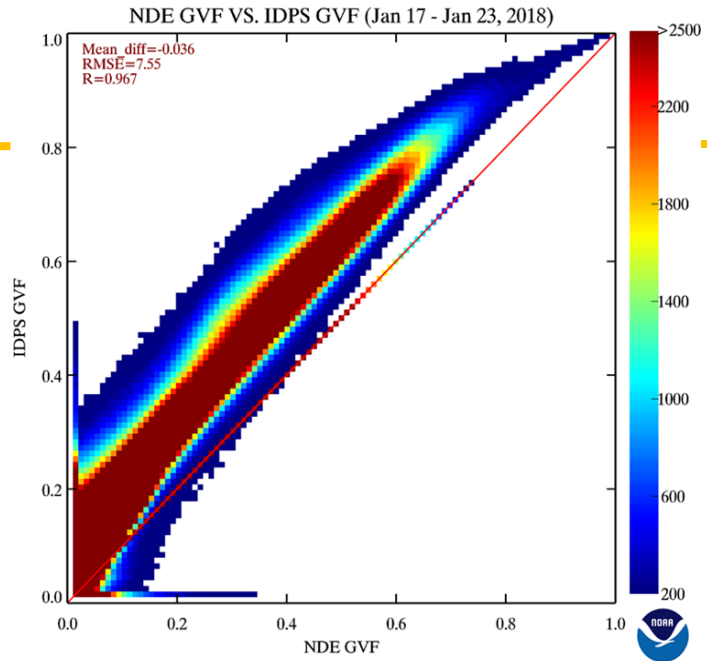
Beta Issue 2: GVF Lat/lon info Simplified





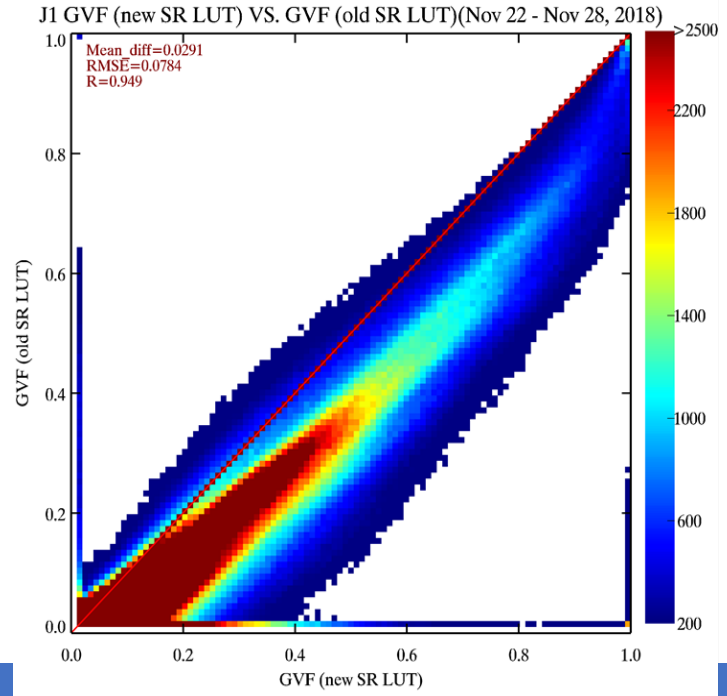
Beta Issue 3: Inconsistency between IDPS & NDE

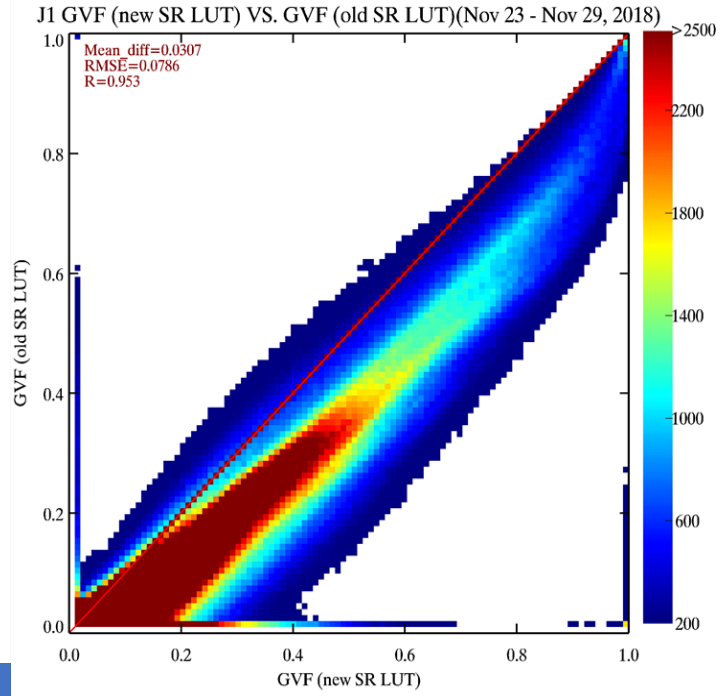




Before LUT fix:
NDE GVF < IDPS GVF

LUT table in the order
M1, M2, M3, M4, M5, M6, M7, M8, M10, M11
when they should have been this way:
M1, M2, M3, M4, M5, M7, M8, M10, M11, I1

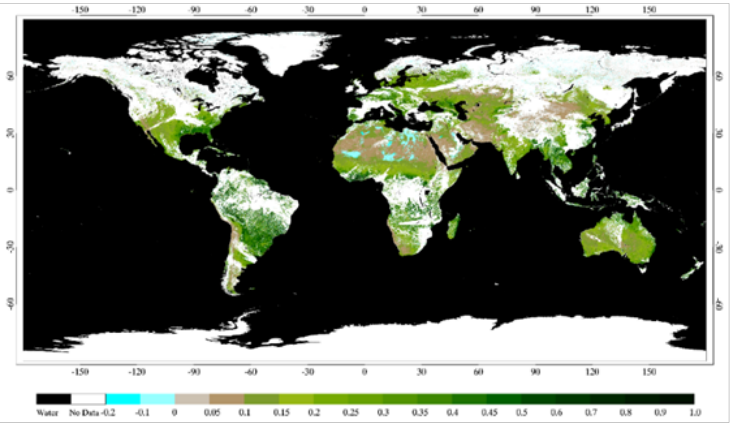




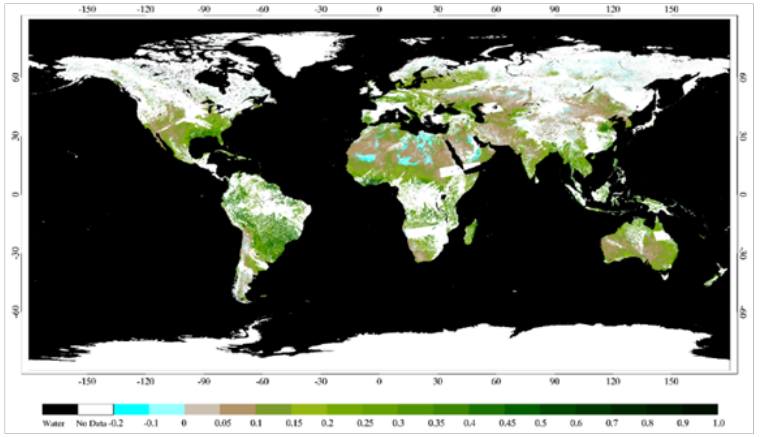
After LUT fix:
New NDE GVF > NDE GVF

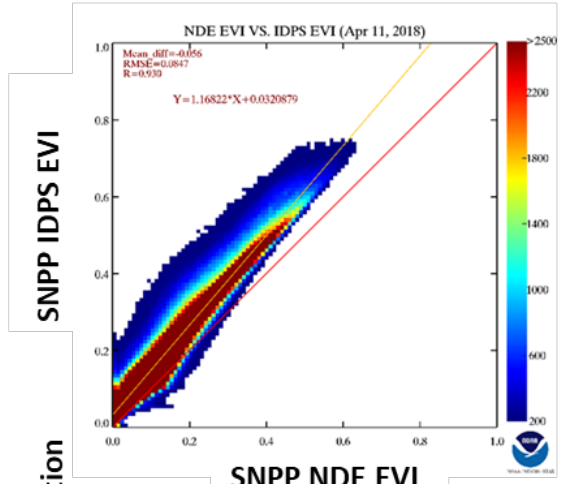
Beta Issue 3: Inconsistency between IDPS & NDE

SNPP IDPS EVI collected on Apr. 11, 2018

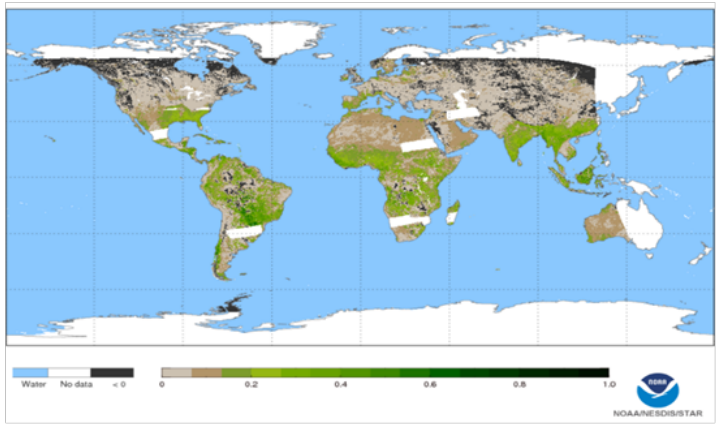


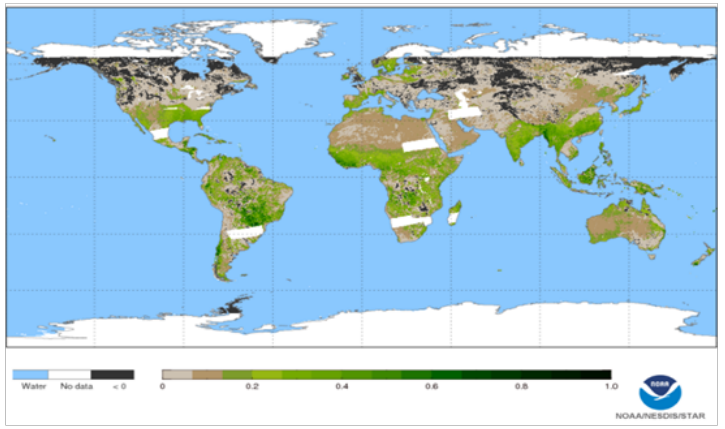
SNPP NDE EVI collected on Apr. 11, 2018

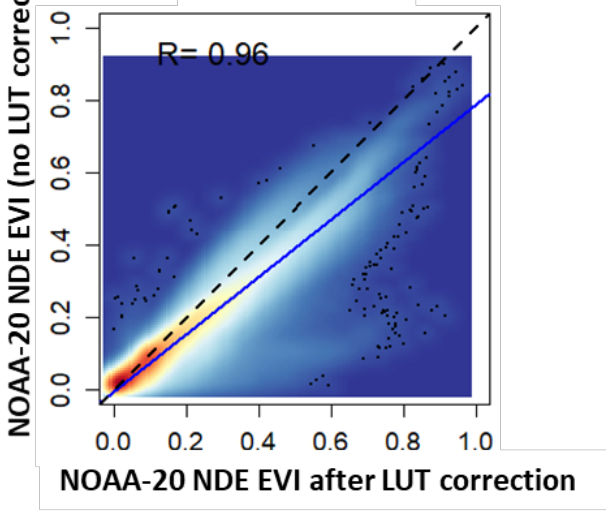




NOAA-20 NDE EVI collected on Nov. 27, 2018 (after LUT correction)







After NOAA-20 beta maturity review, this bug was fixed, and the resultant EVI reverse the lower underestimate of VIIRS VI right figure in lower row). As a result, it is expected the NDE VI product is more consistent to IDPS VI product.

NOAA-20 VIIRS VI & GVF Evaluation method

- **Beta Review Correction**
- **Visual assessment of global/regional mosaics and quality flags**
- **Check meta metrics**
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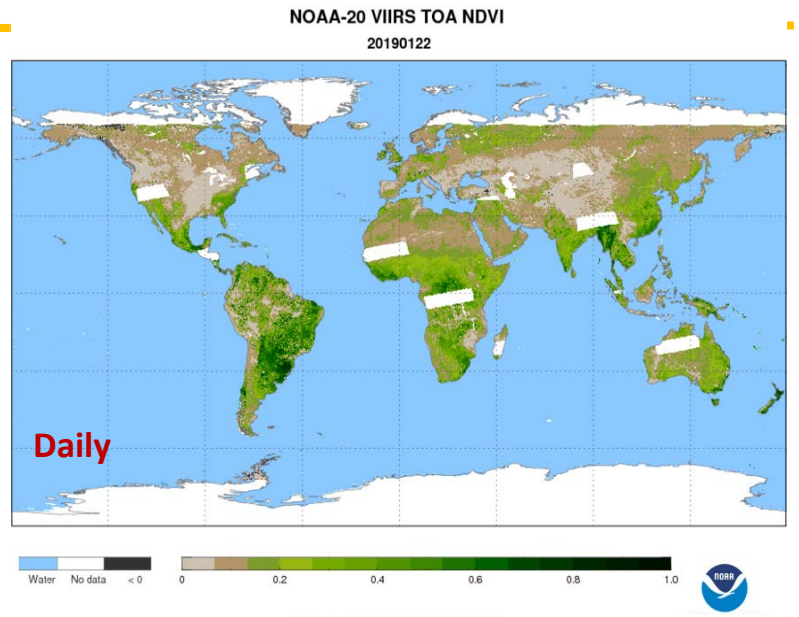
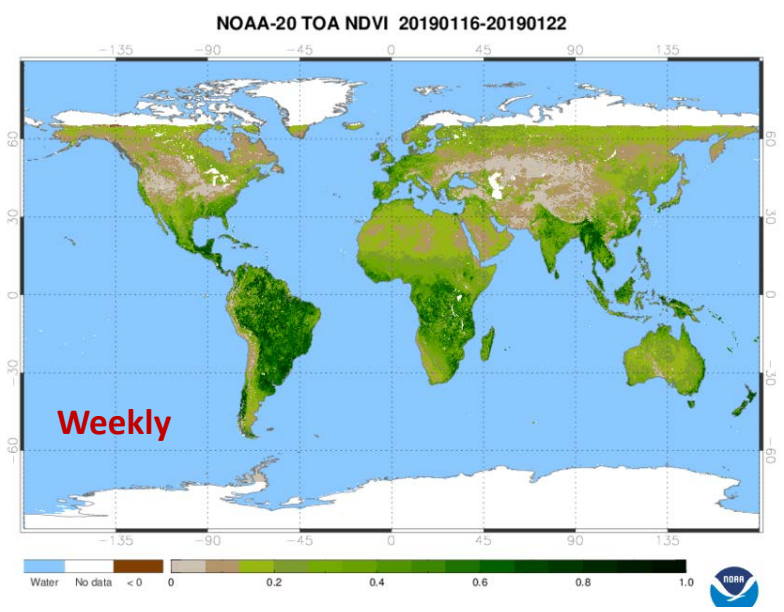
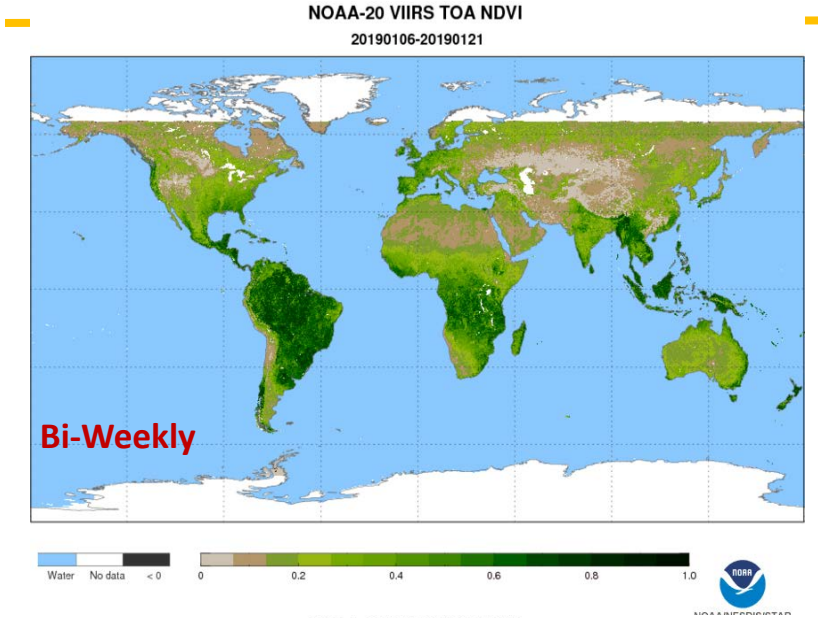
NOAA-20 VIIRS VI & GVF Evaluation method

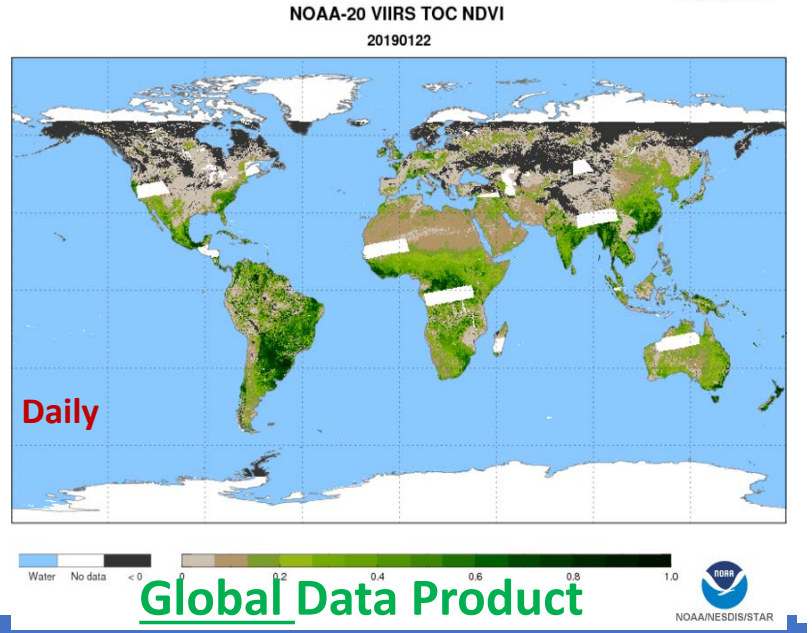
TOA NDVI

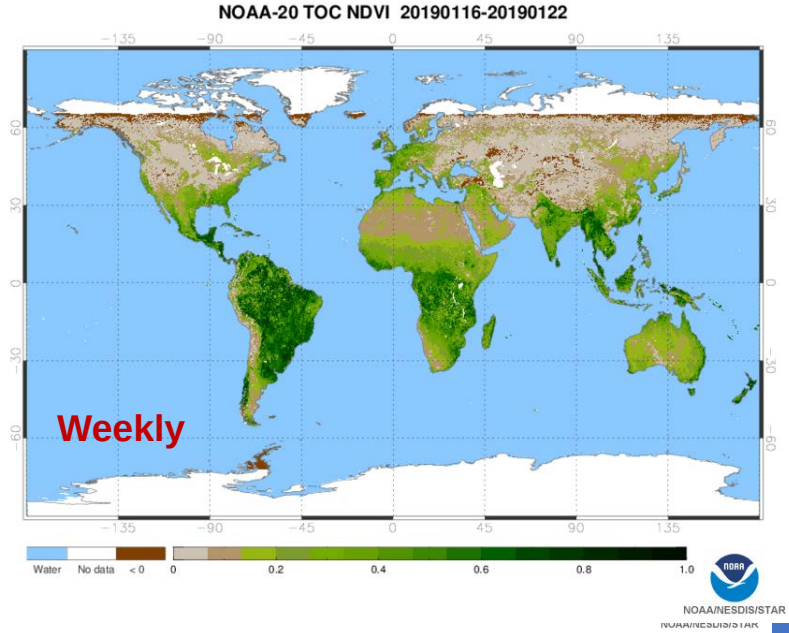


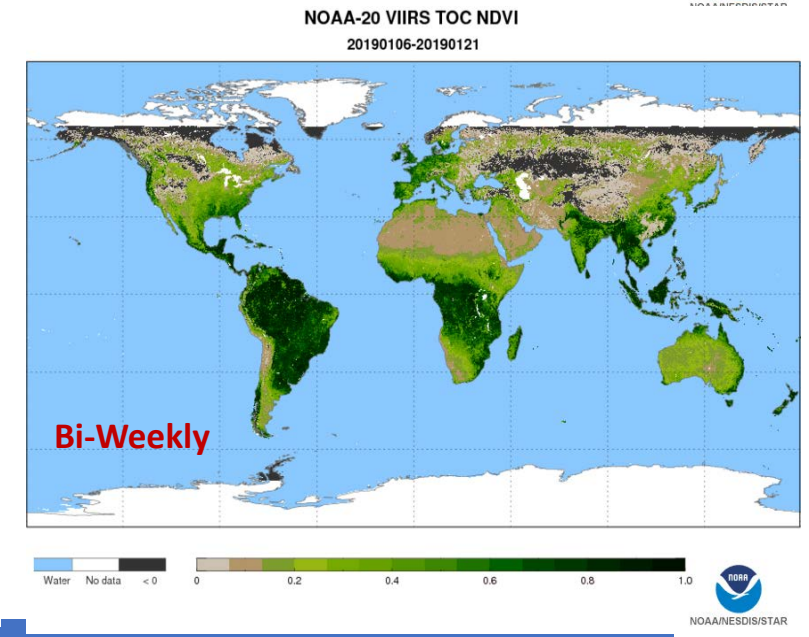




TOC NDVI

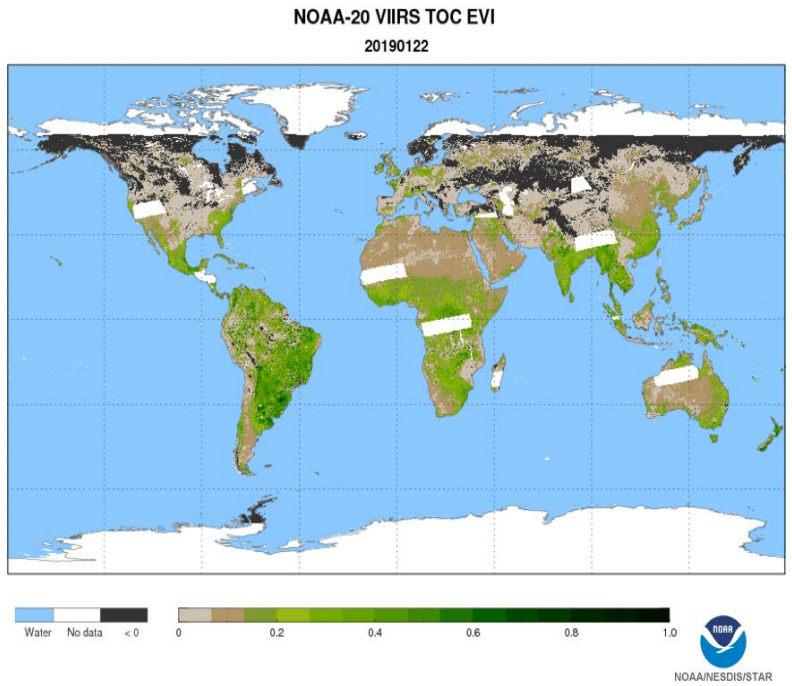
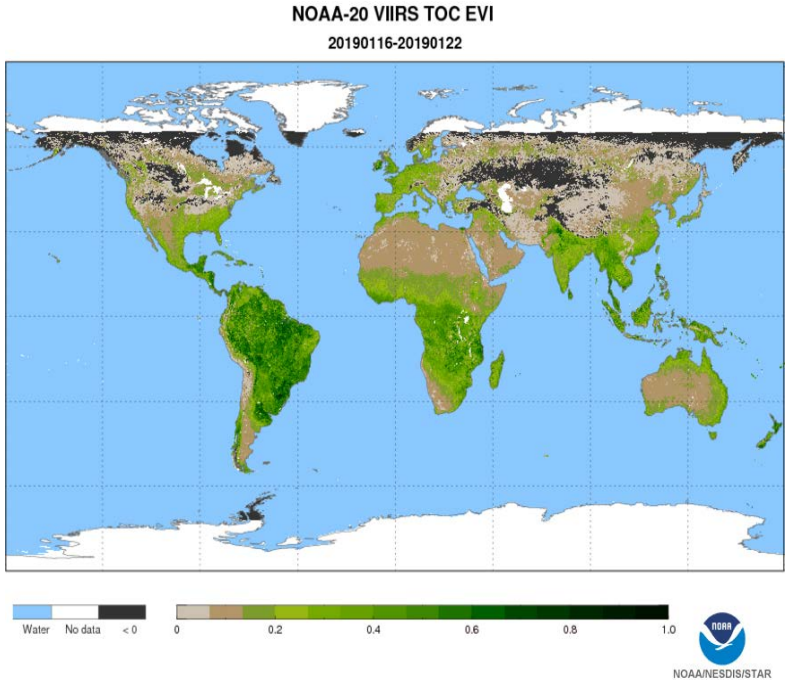
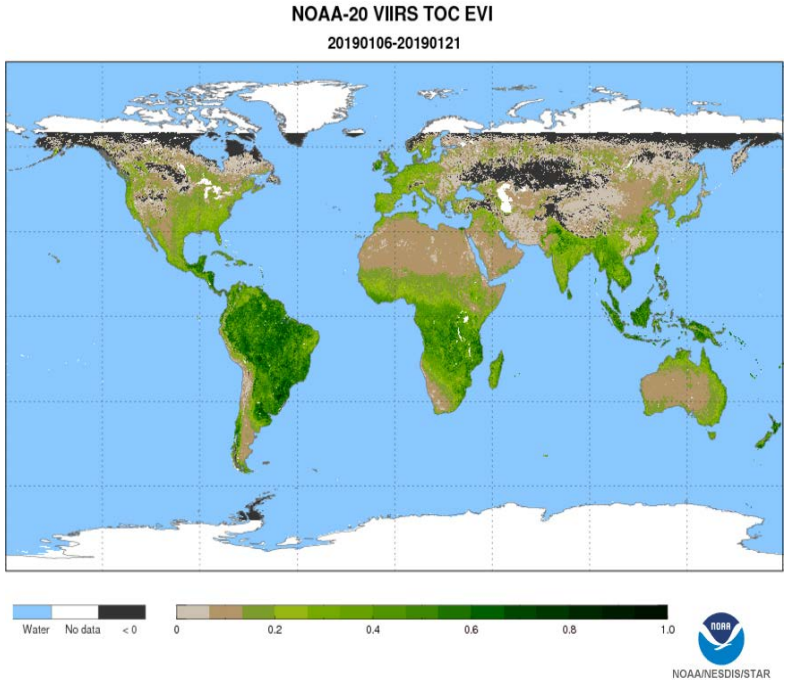






Global Data Product

NOAA-20 VIIRS VI & GVF Evaluation method

	Daily	Weekly	Biweekly
TOC EVI			

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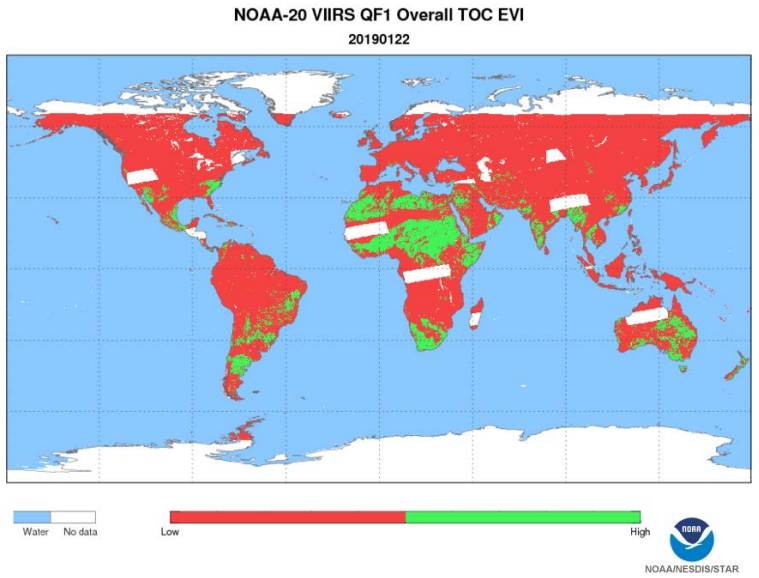
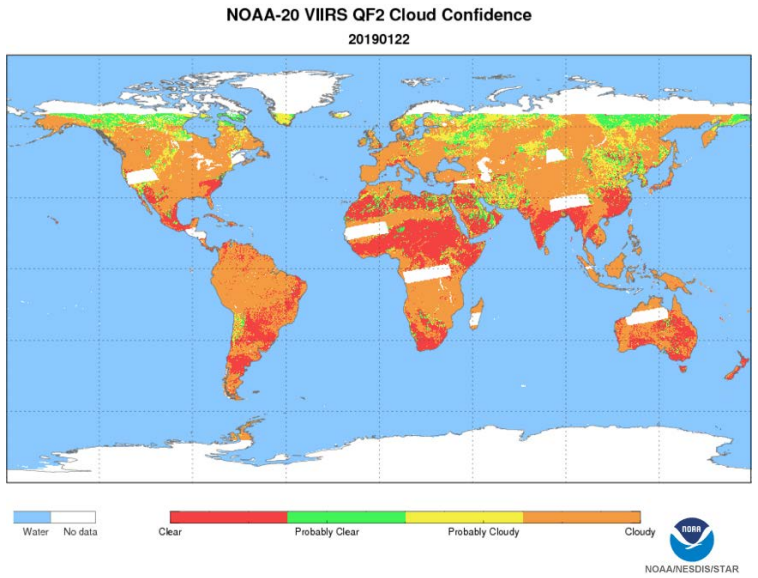
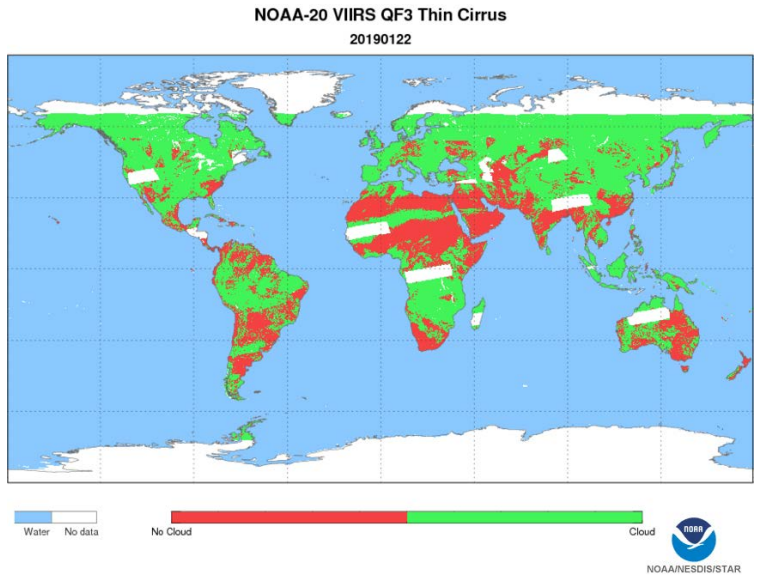
Global Data Product

NOAA-20 VIIRS VI & GVF Evaluation method







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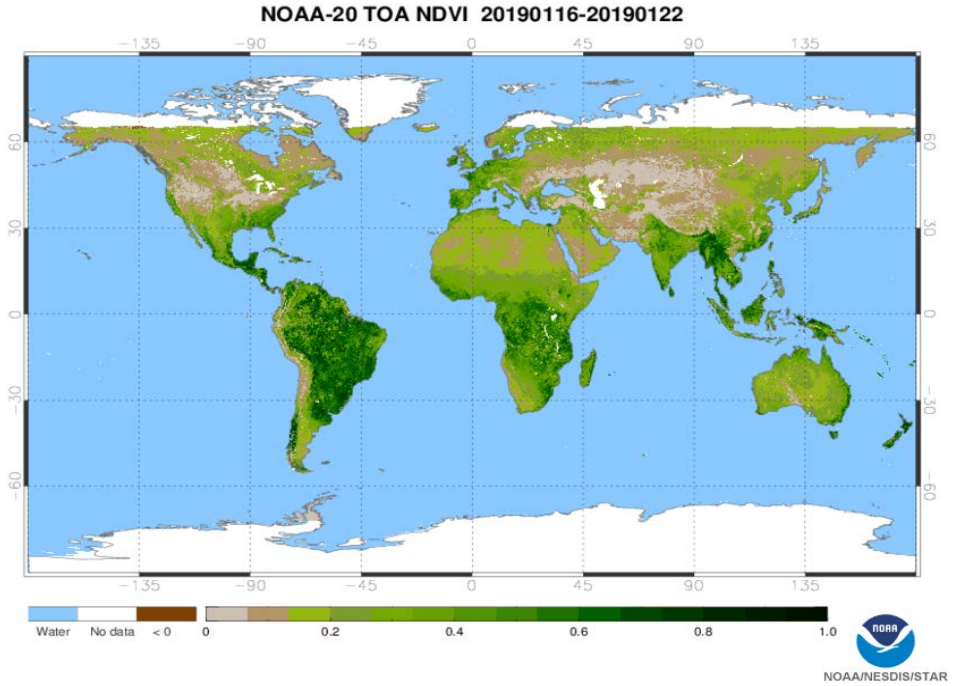
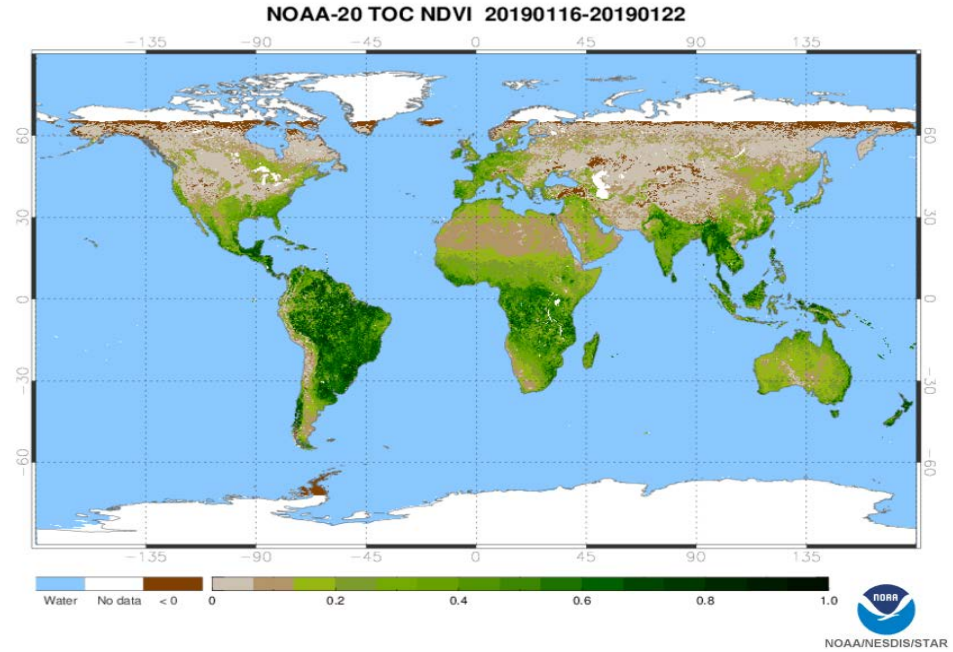
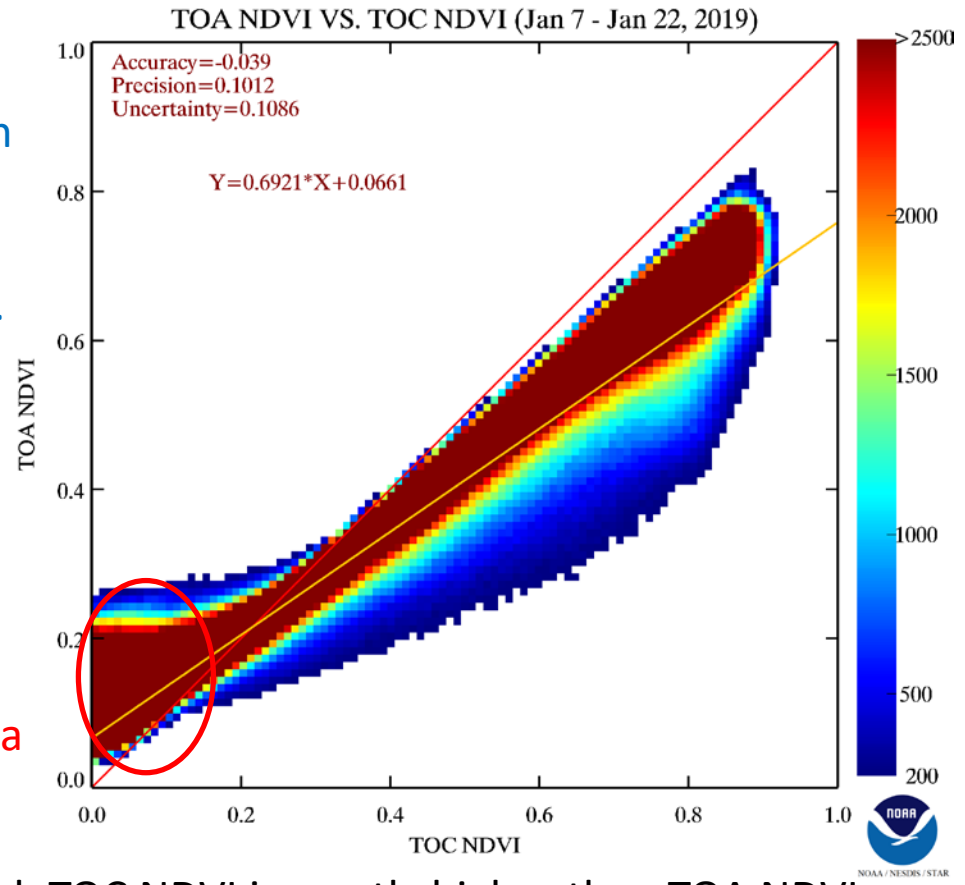
Sample QA layers

TOA NDVI – TOC NDVI comparison





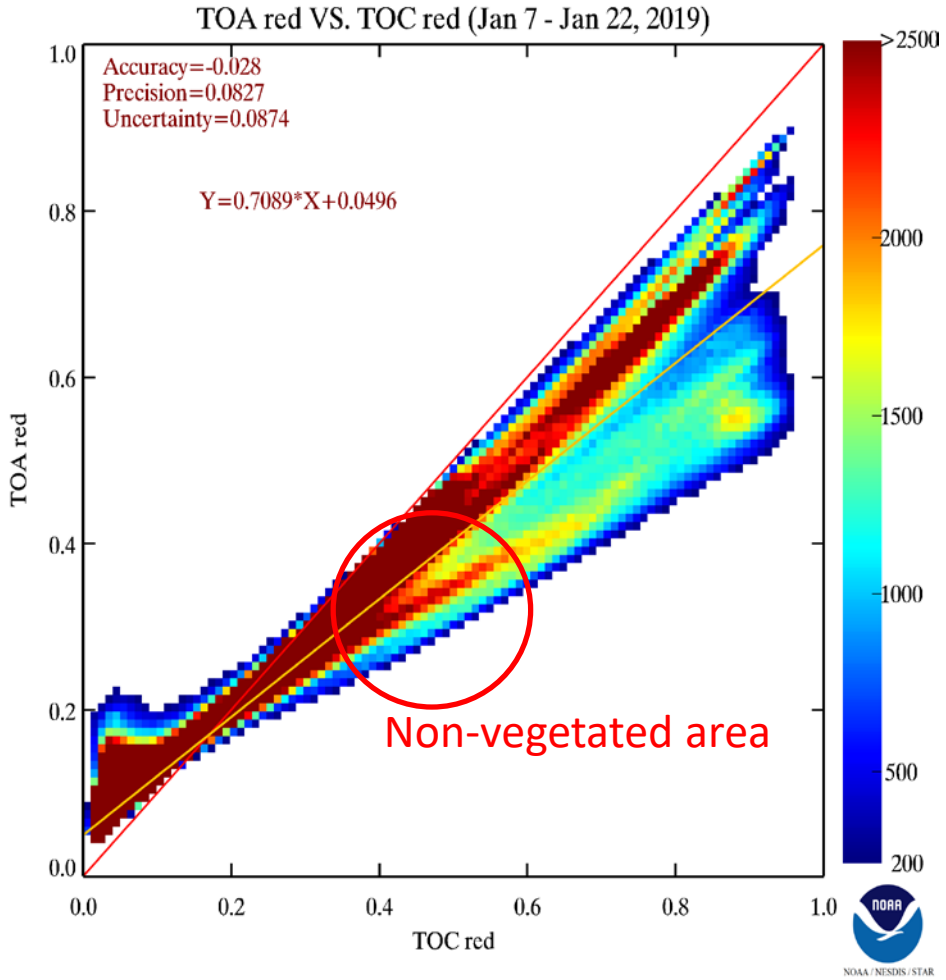
We observed that TOA NDVI can be higher than TOC NDVI over areas NDVI is lower than 0.2. The right plots illustrate such difference, and next slide explained why it occurs.

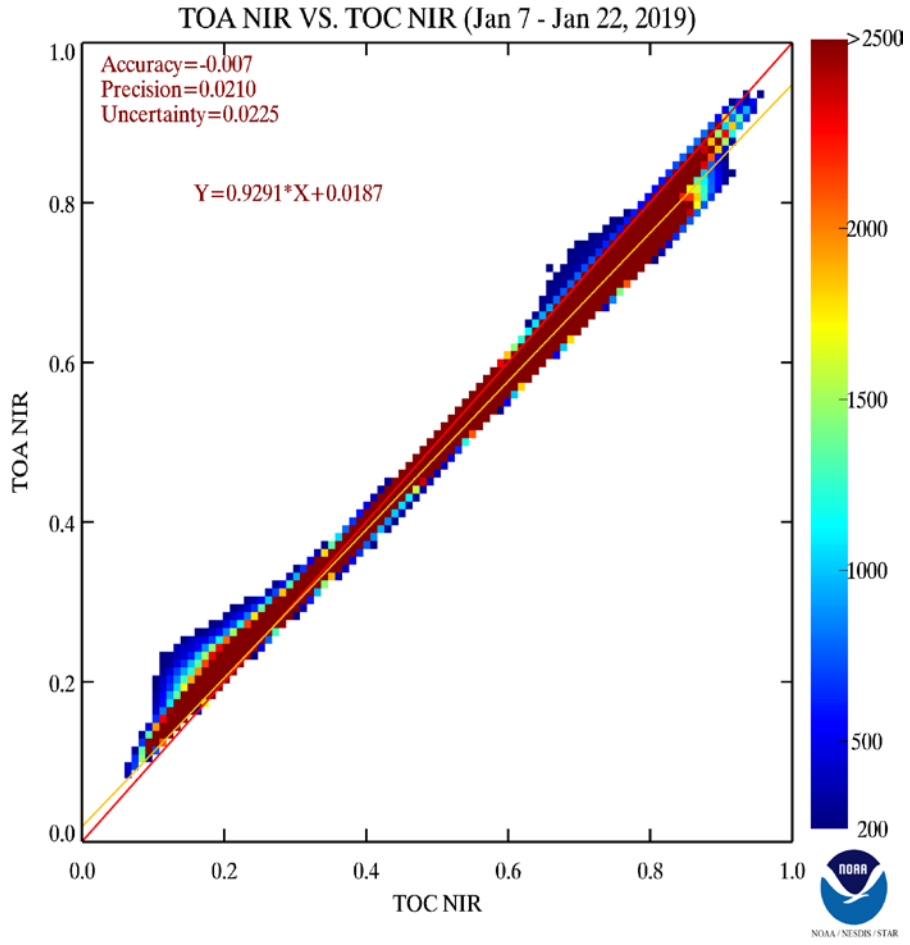


Non-vegetated area

- As expected, TOC NDVI is mostly higher than TOA NDVI over vegetated areas (TOC_NDVI>0.3).
- However, TOC NDVI is not always higher than TOA NDVI
- TOC NDVI is lower than TOA NDVI over non-vegetated areas (TOC_NDVI<0.2), which explains TOA NDVI is greener than TOC NDVI over the Sahara desert

TOA - TOC reflectance comparison





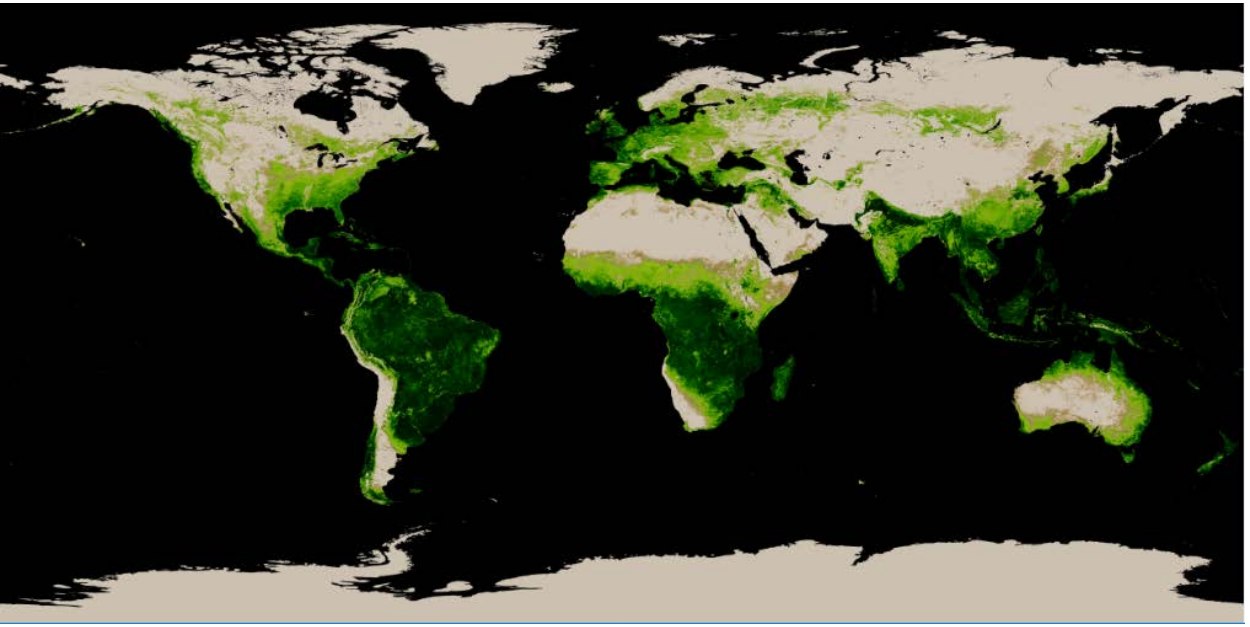
Atmosphere has stronger impact on red than NIR

- TOA red is lower than the TOC red in non-vegetated area
- TOA NIR is close to TOC NIR
- Lower TOA red results in higher TOA NDVI values over non-vegetated area

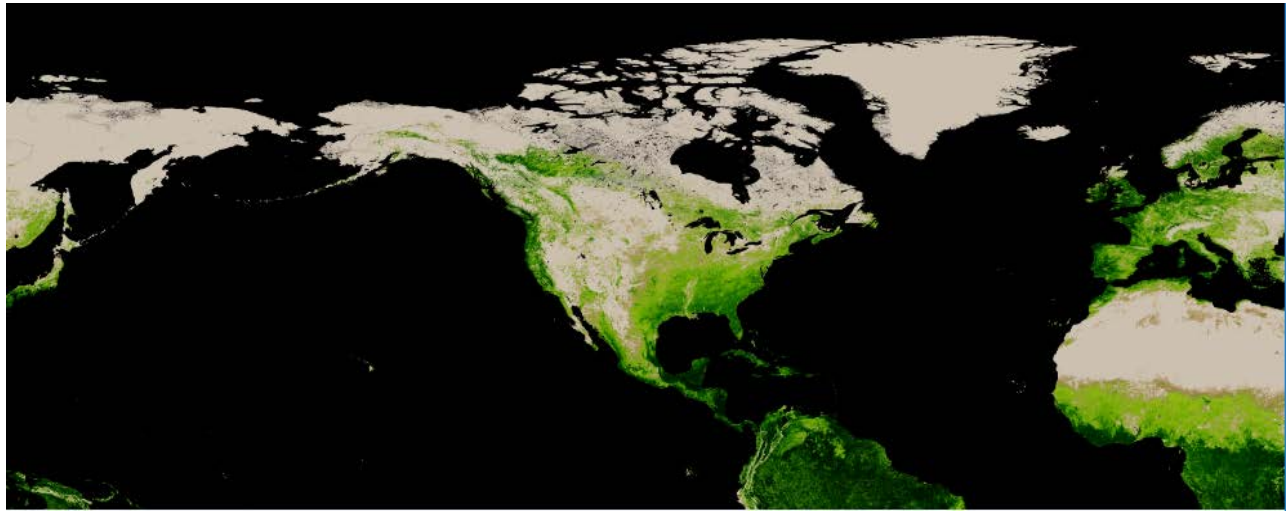
NOAA-20 VIIRS VI & GVF Evaluation method

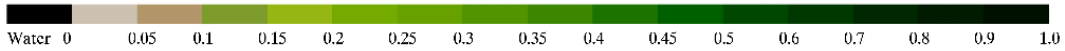
NOAA-20 VIIRS weekly GVF sample images

Global GVF (Feb 19-25, 2019)



Regional GVF (Feb 19-25, 2019)





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NOAA-20 VIIRS VI & GVF Evaluation method

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- **Visual assessment of global/regional mosaics and quality flags**
- **Check meta metrics**
- **Cross-comparison with other satellite VI/GVF products**

NOAA-20 VIIRS VI & GVF Evaluation method

- Global VI statistics (min, max, mean, std, N_pix)

Area	Ecosystem	lon_W	lon_E	lat_S	lat_N	N_pix_evi	min_evi	max_evi	mean_evi	std_evi	N_pix_toandvi	min_toandvi	max_toandvi	mean_toandvi	std_toandvi	N_pix_tocndvi	min_tocndvi	max_tocndvi	mean_tocndvi	std_tocndvi
Global	global	-180	180	-40	40	3681510	-0.47	0.782	0.143	0.128	3681510	-0.79	0.848	0.23	0.183	3681510	-1	0.959	0.201	0.192
E-Sahara(LYBIA)	desert	23	24	28	29	841	0.105	0.115	0.11	0.002	841	0.141	0.163	0.146	0.002	841	0.112	0.132	0.117	0.003
Great-Sandy(AUS)	semi-desert	125	126	-21	-20	841	0.085	0.161	0.117	0.013	841	0.198	0.289	0.229	0.014	841	0.155	0.257	0.193	0.015
Colorado(USA)	steppe	-103	-102	36	37	841	0.041	0.522	0.227	0.076	841	0.079	0.666	0.325	0.097	841	0.052	0.661	0.304	0.102
Illinois(USA)	crops	-89	-88	39	40	841	0.321	0.758	0.621	0.051	841	0.468	0.84	0.788	0.038	841	0.44	0.833	0.778	0.041
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	841	0.065	0.623	0.274	0.143	841	0.102	0.676	0.314	0.125	841	0.064	0.712	0.298	0.15
Oregon(USA)	coniferous_forest	-123	-122	43	44	377	0.153	0.505	0.406	0.055	377	0.329	0.79	0.722	0.061	377	0.283	0.778	0.701	0.065
Amazon(BRAZIL)	tropical_forest	-63	-62	-3	-2	810	-0.03	0.441	0.055	0.107	810	-0.002	0.739	0.097	0.151	810	-0.027	0.734	0.075	0.159

- Regional VI statistics (min, max, mean, std, N_pix)

Area	Ecosystem	lon_W	lon_E	lat_S	lat_N	N_pix_evi	min_evi	max_evi	mean_evi	std_evi	N_pix_toandvi	min_toandvi	max_toandvi	mean_toandvi	std_toandvi	N_pix_tocndvi	min_tocndvi	max_tocndvi	mean_tocndvi	std_tocndvi
E-Sahara(LYBIA)	desert	23	24	28	29	12544	0.103	0.117	0.11	0.002	12544	0.139	0.165	0.146	0.003	12544	0.11	0.134	0.117	0.003
Colorado(USA)	steppe	-103	-102	36	37	12656	-0.018	0.711	0.216	0.1	12656	0.045	0.807	0.33	0.122	12656	-0.089	0.83	0.307	0.131
Illinois(USA)	crops	-89	-88	39	40	12537	0.111	0.831	0.622	0.077	12537	0.276	0.865	0.786	0.054	12537	0.236	0.862	0.776	0.058
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	12603	0.042	0.828	0.268	0.153	12603	0.082	0.738	0.324	0.154	12603	0.044	0.915	0.308	0.184
Oregon(USA)	coniferous_forest	-123	-122	43	44	5344	-0.067	0.591	0.408	0.067	5344	-0.072	0.82	0.724	0.074	5344	-0.586	0.807	0.702	0.08

NOAA-20 VIIRS VI & GVF Evaluation method

- Global GVF statistics (min, max, mean, std, N_pix)

Area	Ecosystem	lon_W	lon_E	lat_S	lat_N	num_pixels	min_gvf	max_gvf	mean_gvf	std_gvf
Global	global	-180.0	180.0	-40.0	40.0	5875621	1.0	100.0	33.7	30.7
E-Sahara(LYBIA)	desert	23.0	24.0	28.0	29.0	841	3.0	7.0	4.3	0.6
Great-Sandy(AUS)	semi-desert	125.0	126.0	-21.0	-20.0	841	1.0	18.0	9.4	2.9
Colorado(USA)	steppe	-103.0	-102.0	36.0	37.0	841	2.0	46.0	12.9	8.6
Illinois(USA)	crops	-89.0	-88.0	39.0	40.0	841	2.0	31.0	14.5	5.0
Kentucky(USA)	broad_leaf_forest	-85.0	-84.0	36.0	37.0	841	16.0	51.0	29.7	5.9
Oregon(USA)	coniferous_forest	-123.0	-122.0	43.0	44.0	841	1.0	76.0	45.1	12.4
Amazon(BRAZIL)	tropical_forest	-63.0	-62.0	-3.0	-2.0	812	23.0	99.0	72.4	12.2

- Regional GVF statistics (min, max, mean, std, N_pix)

Area	Ecosystem	lon_W	lon_E	lat_S	lat_N	num_pixels	min_gvf	max_gvf	mean_gvf	std_gvf
E-Sahara(LYBIA)	desert	23.0	24.0	28.0	29.0	12544	2.0	7.0	4.3	0.7
Colorado(USA)	steppe	-103.0	-102.0	36.0	37.0	12656	1.0	100.0	12.7	12.5
Illinois(USA)	crops	-89.0	-88.0	39.0	40.0	12539	1.0	72.0	14.5	6.6
Kentucky(USA)	broad_leaf_forest	-85.0	-84.0	36.0	37.0	12643	1.0	82.0	29.5	8.0
Oregon(USA)	coniferous_forest	-123.0	-122.0	43.0	44.0	12615	1.0	96.0	45.3	17.5

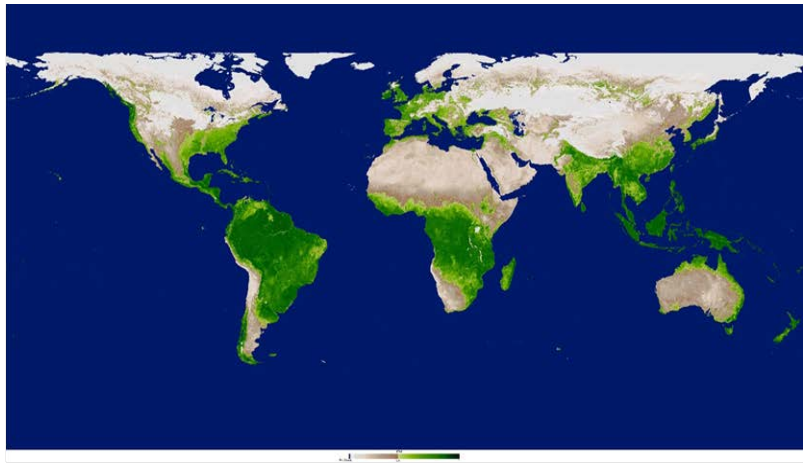
NOAA-20 VIIRS VI & GVF Evaluation method

- **Beta Review Correction**
- **Visual assessment of global/regional mosaics and quality flags**
- **Check meta metrics**
- **Cross-comparison with other satellite VI/GVF products**

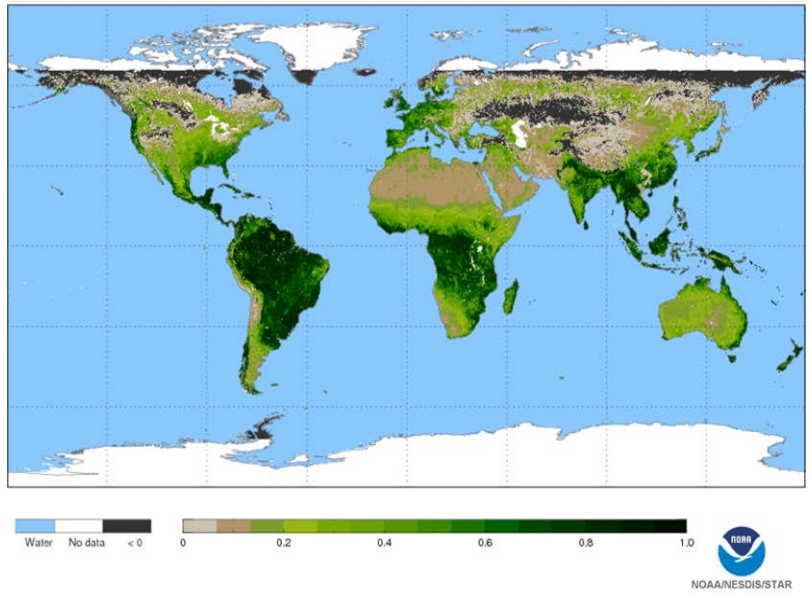
NOAA-20 VIIRS VI Evaluation method

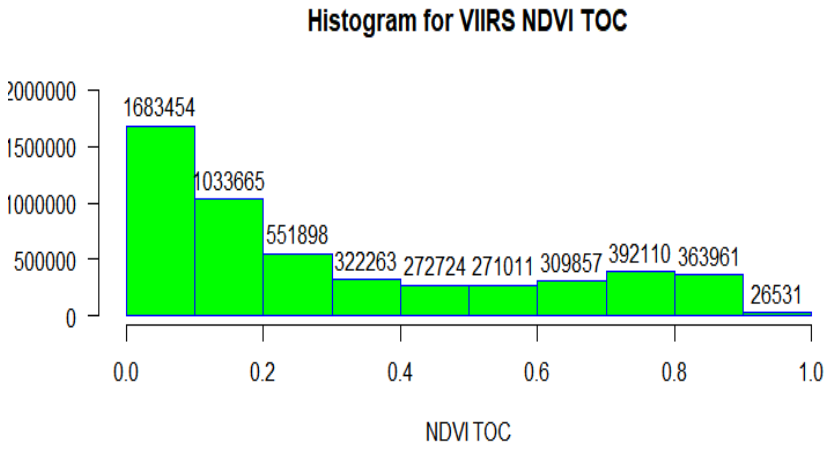
Time Period: 0109 – 0124, 2019

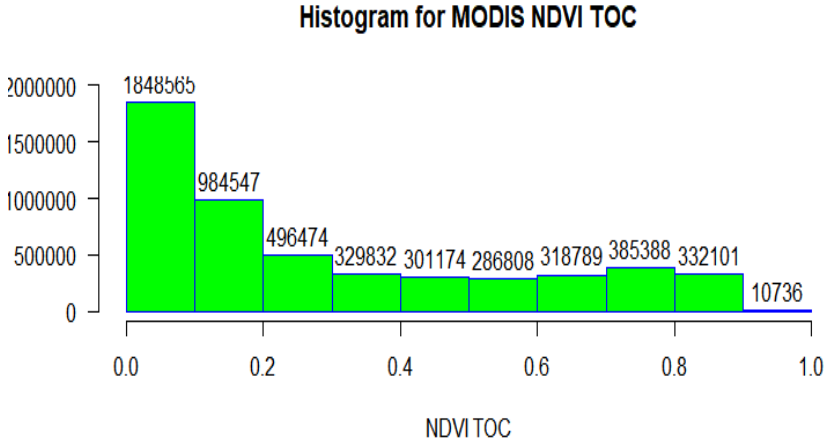
MODIS biweekly composite VI



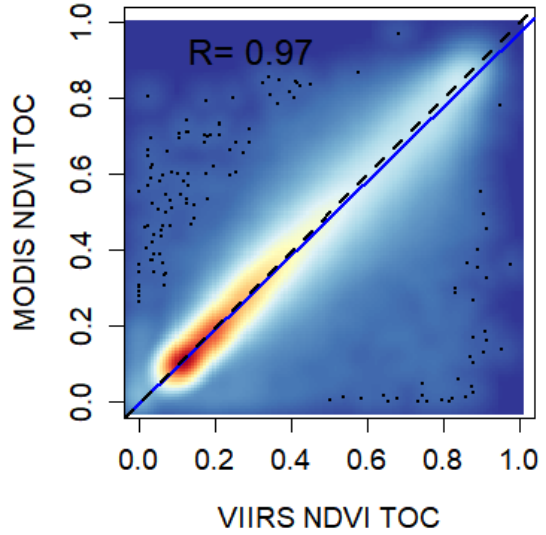
VIIRS biweekly composite VI







VI Comparisons to MODIS Data : TOC NDVI Case

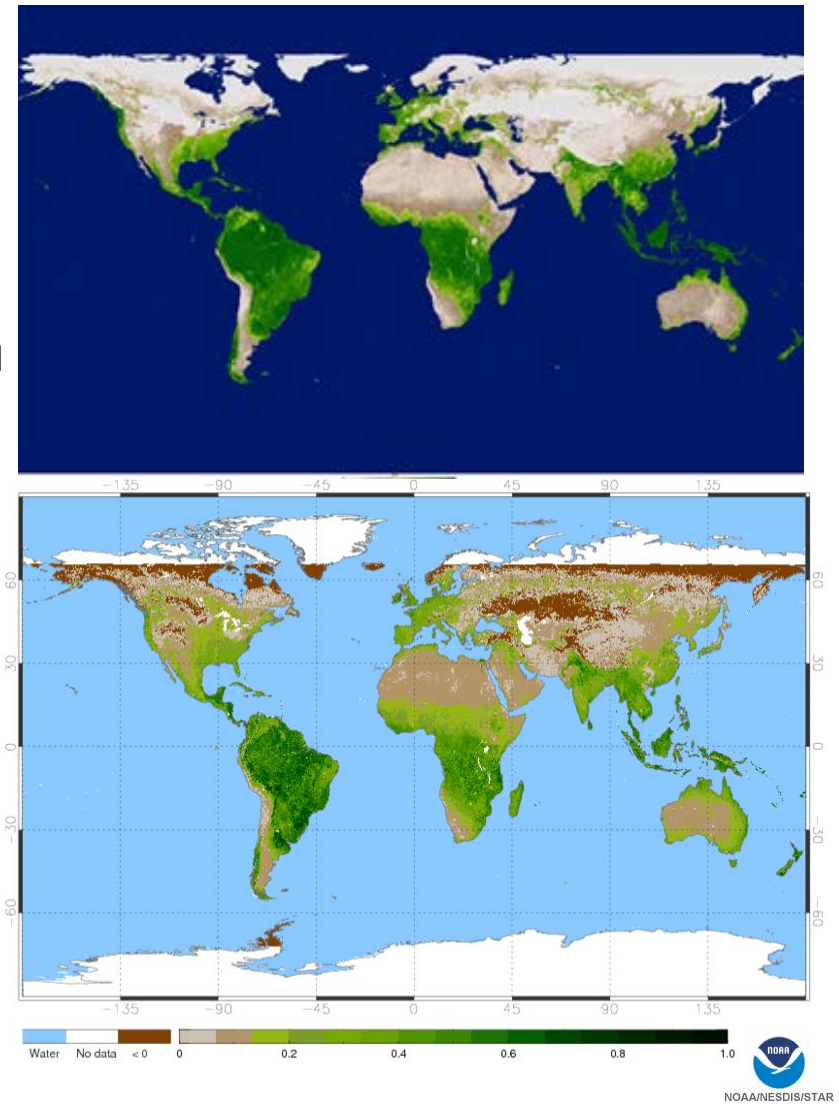


NOAA-20 VIIRS VI Evaluation method

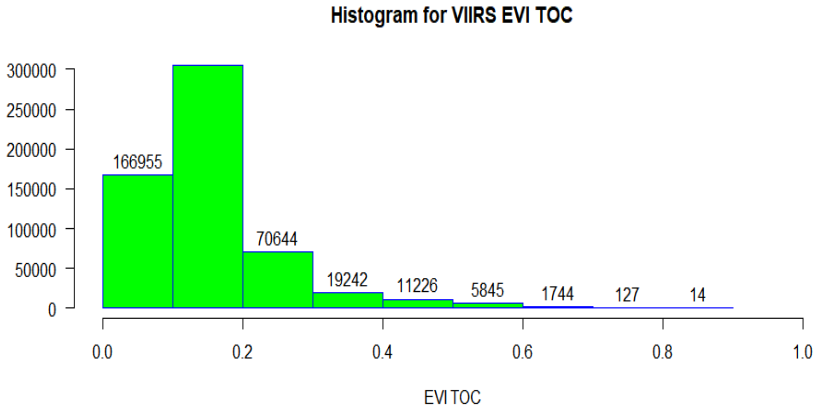
Time Period: 0109 – 0124, 2019

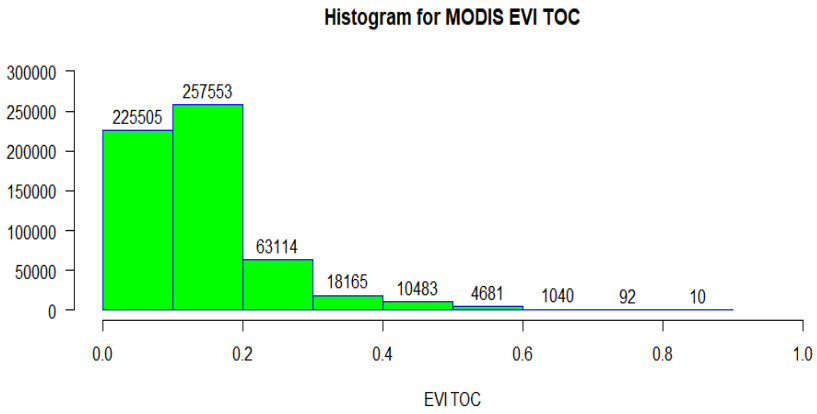
MODIS biweekly composite EVI

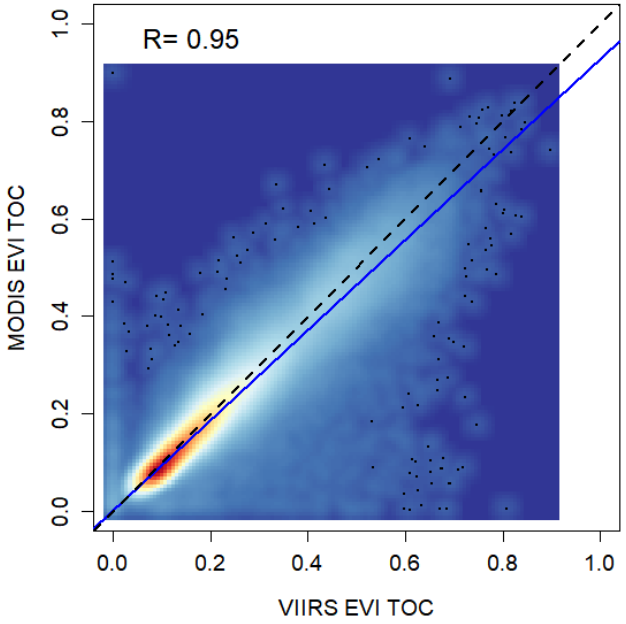
VIIRS biweekly composite EVI



VI Comparisons to MODIS Data : TOC EVI Case



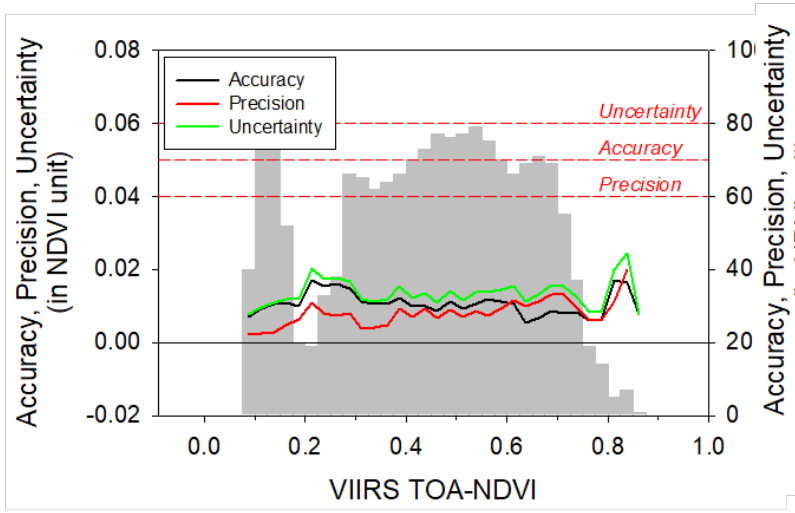




NOAA-20 VIIRS VI Evaluation method

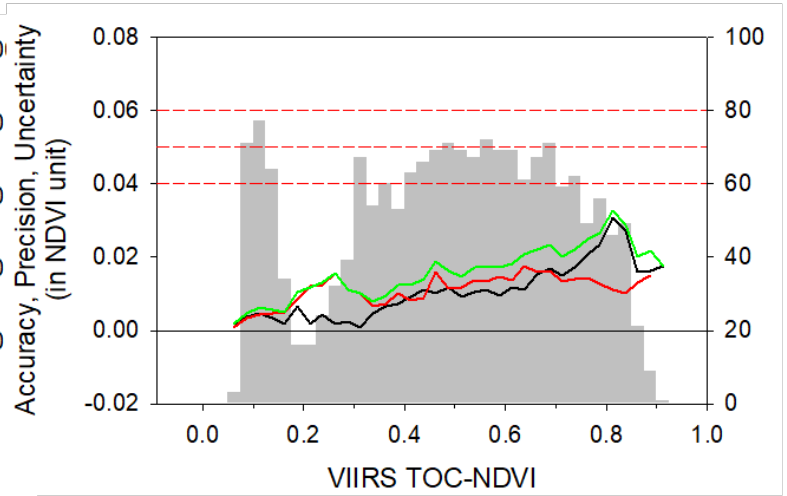
- APUs (accuracy, precision, and uncertainty) of all of the three VIIRS vegetation indices were very small, well below the Level 1 requirements, over their entire dynamic ranges.

TOA NDVI



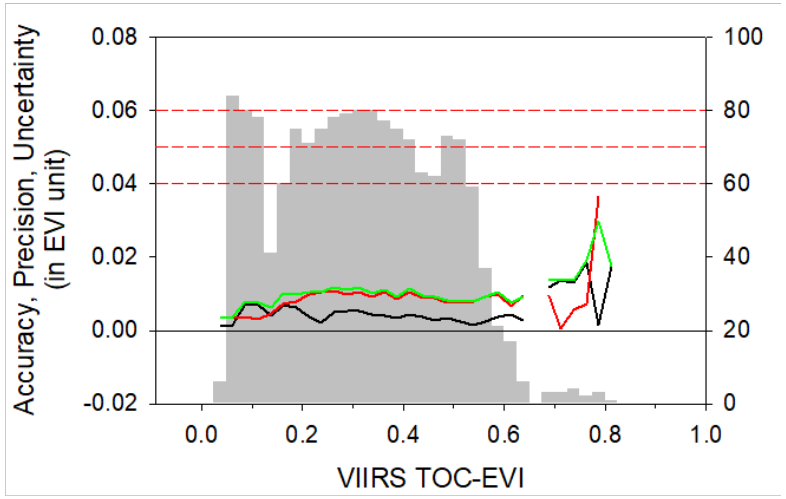
TOA-NDVI	Global APU	L1R
Accuracy	0.010	0.05
Precision	0.009	0.04
Uncertainty	0.014	0.06

TOC NDVI



TOC-NDVI	Global APU	L1R
Accuracy	0.010	0.05
Precision	0.014	0.04
Uncertainty	0.017	0.06

TOC EVI

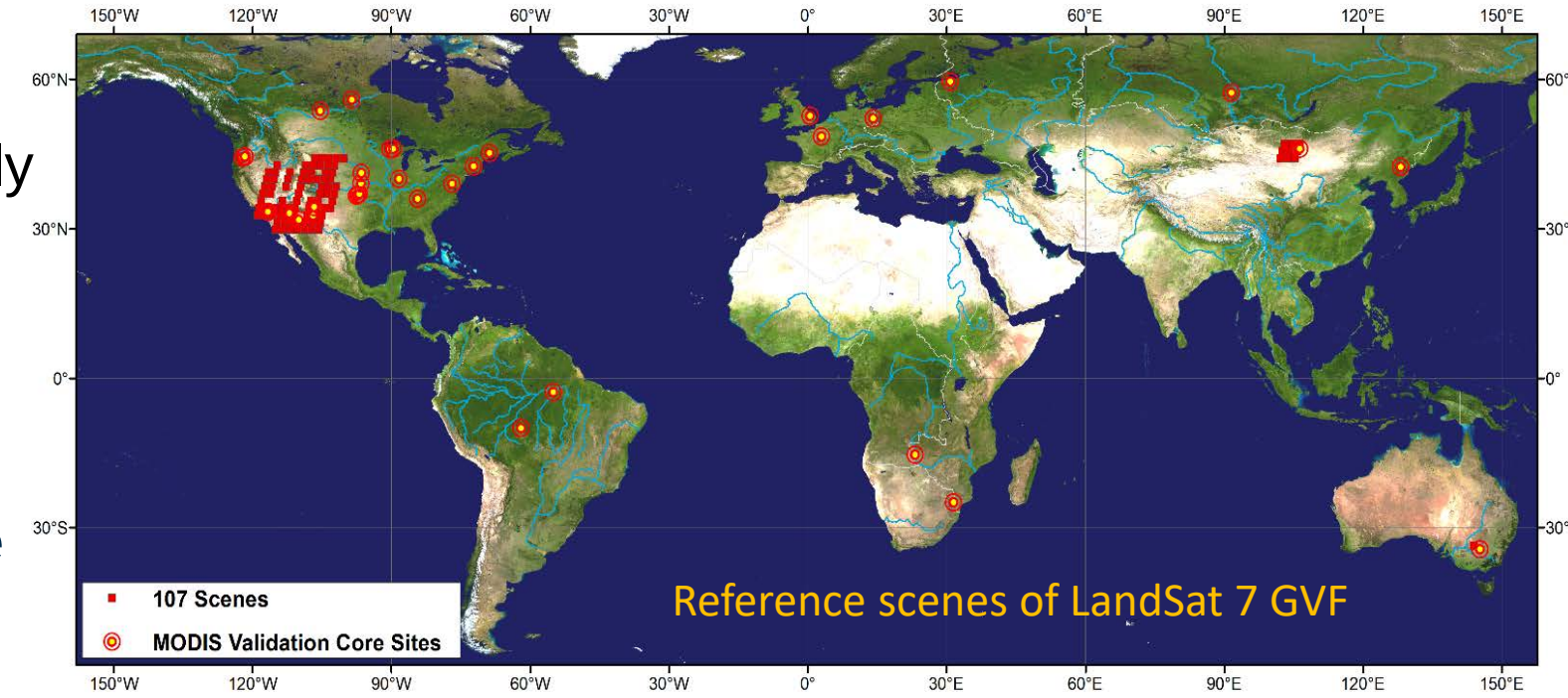


TOC-EVI	Global APU	L1R
Accuracy	0.001	0.05
Precision	0.010	0.04
Uncertainty	0.010	0.06

NOAA-20 VIIRS GVF Evaluation method

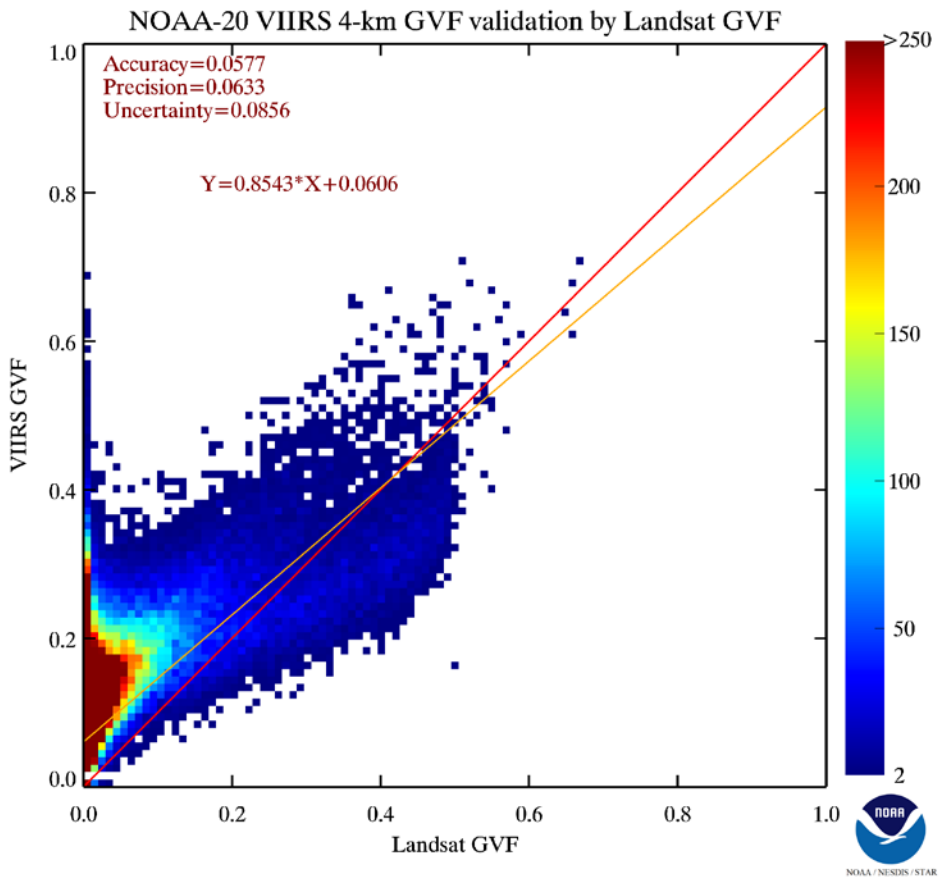
GVF validation Method

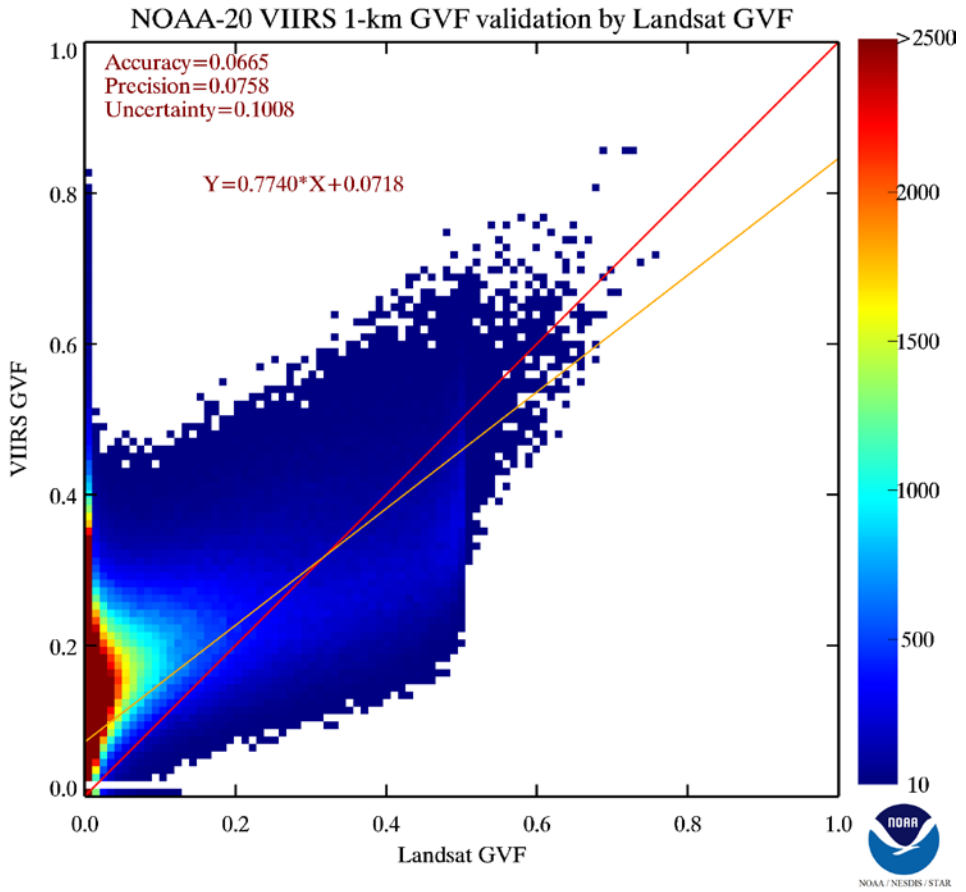
- Reference GVF data derived from 107 Landsat ETM+ images globally over 30 EOS validation core sites (most at North America)
- Period: 1/3/2019 - 2/28/2019 (winter at north hemisphere)
- The ETM+ surface reflectance are downloaded from USGS at https://earthexplrer.usgs.gov/



- Decision-tree classification method used to classify the 30-m Landsat pixels into 3 vegetation levels (GVF=0, 0.5 or 1)
- Landsat classified images reprojected to the VIIRS GVF projection and 30-m GVF are aggregated to 4km GVF
- Generated comparative statistics (Accuracy, Precision, Uncertainty)

NOAA-20 VIIRS GVF Evaluation method

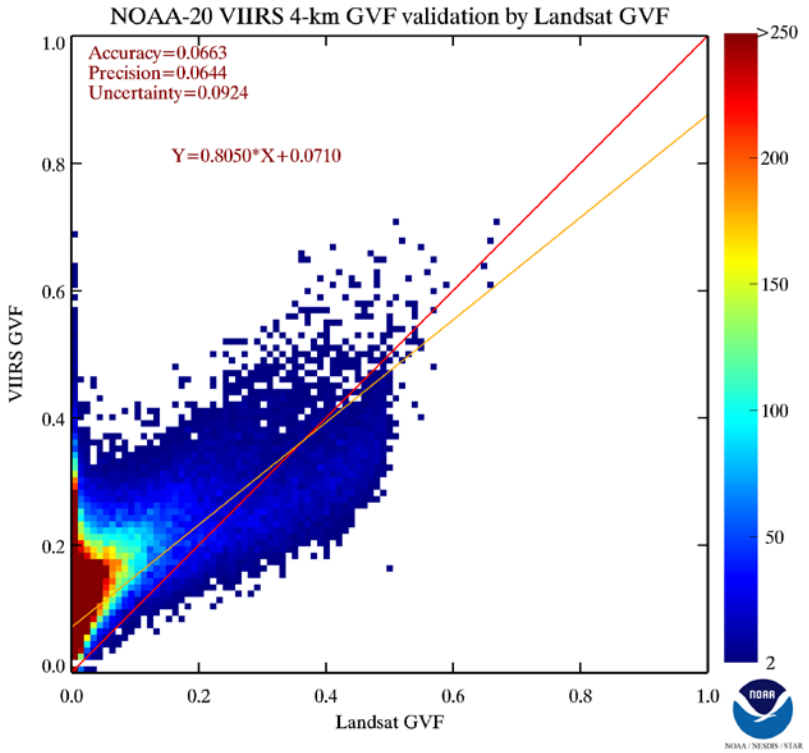




- Since most of the Landsat data are acquired in North America (winter time), GVF values are mostly low (<0.5)
- Overall VIIRS GVF is correlated to Landsat GVF
- Accuracy, precision and uncertainty values are less than 0.1 (meet the requirements)
- Comprehensive Landsat data at different seasons, particularly the high GVF value data, will be used in further validation efforts

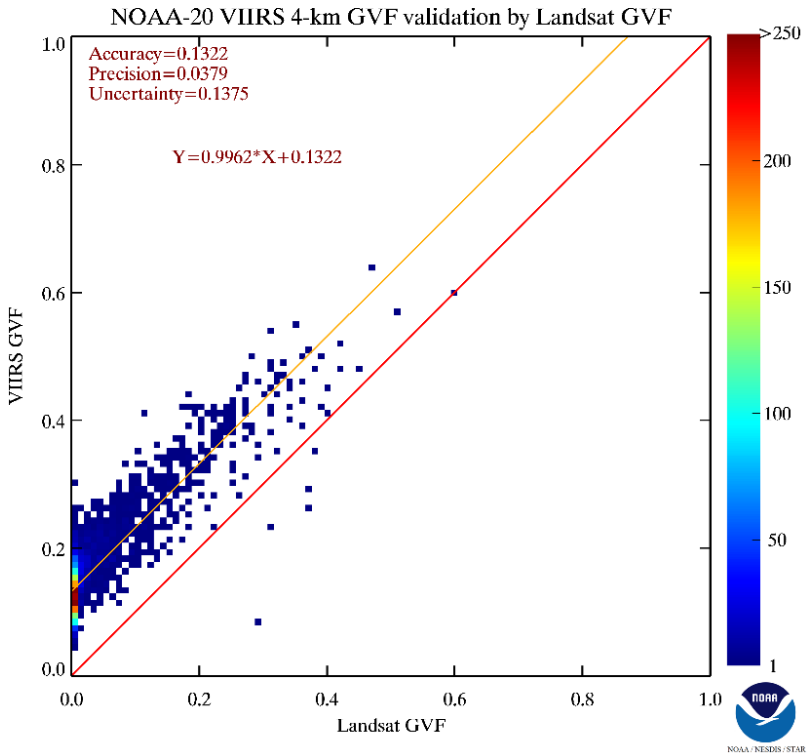
NOAA-20 VIIRS GVF Evaluation method

North America



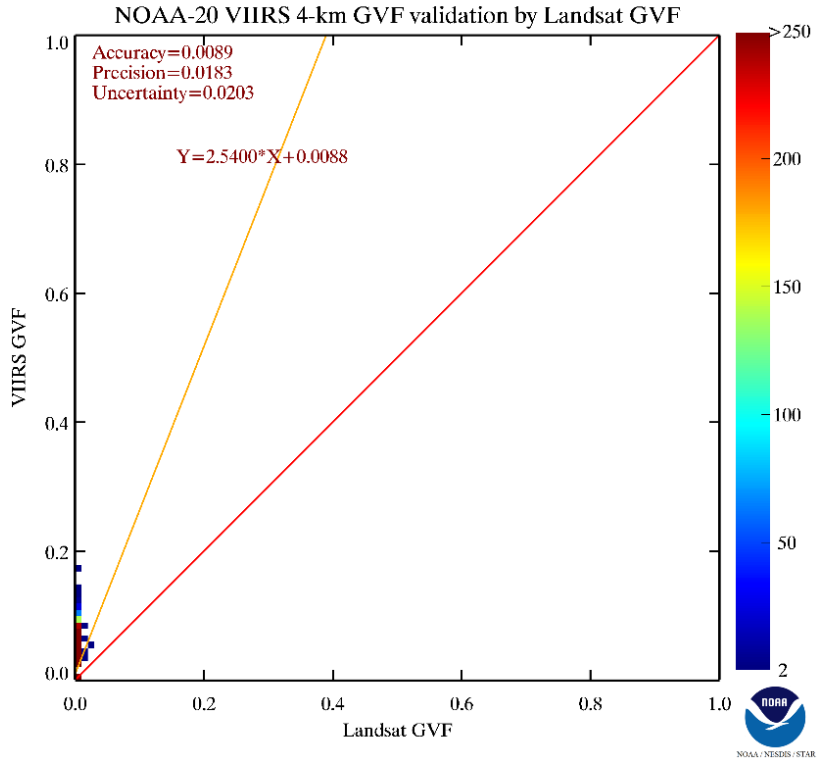
- GVF values are low (<0.5) in North America in winter time
- Regression lines are close to the 1:1 lines)

Australia



- VIIRS GVF is linearly related to, but higher than the Landsat GVF at the Australia site
- Large bias, but good precision value

North Asia



- Both VIIRS GVF and Landsat GVF are close to 0 at North Asia
- APU values are very low

NOAA-20 VIIRS GVF Evaluation method

- VIIRS GVF product performance requirements from JPSS L1RD supplement (threshold) versus observed/validated

Global APU Estimates

Attribute	Threshold	Observed/validated
Measurement Accuracy		
1) Global	0.12	0.058
2) Regional	0.12	0.067
Measurement Precision		
1) Global	0.15	0.063
2) Regional	0.15	0.076
Measurement Uncertainty		
1) Global	0.17	0.086
2) Regional	0.17	0.101

Evaluation/Validation Summary

NOAA 20 VI & GVF has performance well based on our local computation, though the data is still limited and longer period of validation is necessary.

- Visual assessment of VI &GVF products shows that the NOAA-20 VI & GVF algorithm production looks reasonable
- No issues found in visual assessment of quality flags
- Metadata metrics suggests that NOAA-20 VI & GVF products are quantitatively reasonable
- Cross-comparison demonstrated high consistency between NOAA-20 VI and MODIS VI
- Cross-comparison demonstrated good consistency between NOAA-20 GVF and Landsat-derived GVF

Requirement Check List – Vegetation Indices

JERD	Requirement	Performance
	Applicable Conditions: 1. Clear, land (not ocean), daytime only	
JERD-2443	The algorithm shall produce a vegetation indices product with a horizontal cell size of 0.4 km	Yes
JERD-2536	The algorithm shall produce a vegetation indices product with a mapping uncertainty (3 sigma) of 4 km	Yes
JERD-2537	The algorithm shall produce a vegetation indices product with a measurement range of: -1 to +1 for $NDVI_{TOA}$, EVI, and $NDVI_{TOC}$	Yes, it is defined in algorithm
JERD-2538	The algorithm shall produce a vegetation indices product with a measurement accuracy of 0.05 NDVI units for $NDVI_{TOA}$	Yes, see validation results
JERD-2539	The algorithm shall produce a vegetation indices product with a measurement precision of 0.04 NDVI units for $NDVI_{TOA}$	Yes, see validation results
JERD-2540	The algorithm shall produce a vegetation indices product with a measurement accuracy of 0.05 NDVI units for EVI	Yes, see validation results
JERD-2541	The algorithm shall produce a vegetation indices product with a measurement precision of 0.04 NDVI units for EVI	Yes, see validation results
JERD-2542	The algorithm shall produce a vegetation indices product with a measurement accuracy of 0.05 NDVI units for $NDVI_{TOC}$	Yes, see validation results
JERD-2543	The algorithm shall produce a vegetation indices product with a measurement precision of 0.04 NDVI units for $NDVI_{TOC}$	Yes, see validation results

Requirement Check List – Green Vegetation Fraction

JERD	Requirement	Performance
JERD-2120	The algorithm shall produce a GVF product that has a horizontal cell size of 16 km	Yes
JERD-2121	The algorithm shall produce a GVF product that has a mapping uncertainty (3 sigma) of 4 km	Yes
JERD-2122	The algorithm shall produce a GVF product that has a measurement precision of 15% globally and regionally	Yes, see validation results
JERD-2123	The algorithm shall produce a GVF product that has a measurement accuracy of 12% globally and regionally	Yes, see validation results
JERD-2124	The algorithm shall produce a GVF product that has a measurement uncertainty of 17% globally and regionally	Yes, see validation results

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large but still limited (i.e. not necessarily globally or seasonally representative) is minimally validated, number of independent measurements obtained from selected locations, periods, and associated ground truth or field campaign efforts.	Yes. Multiple dataset comparisons are conducted using available MODIS VI and Landsat derived GVF product. Limitations are noted in readme.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance baseline)	Yes. Evaluation documents are available to users upon request.
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested and shared with the user community	Yes. The performance analyses are all documented. Monitoring results (weekly) are recorded and shared through ftp site. Weakness and further improvements are filed.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization	Yes. Limitations are noted in the Readme.

Documentations

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	In preparation

Path Forward/ Future Plan

- Product refinement
  - LUT for the enterprise NOAA 20 SR needs further evaluation and calibration with more data available.
  - Algorithm and software improvements are necessary for speeding up the operational run
  - QF layer refinement for VIIRS VI & GVF is ongoing
  - VIIRS VI & GVF operational code merge.
- Global /Comprehensive Validation
  - AERONET based validation
  - Global in situ data collection (FLUXNET)
  - Extend the cross satellite comparisons (MODIS, SNPP and NOAA-20)
- Gridded NOAA 20 VI & GVF 1km product generation
- Promote VIIRS VI & GVF data usage in NOAA climate model application

Thanks for your attention.