MEMORANDUM FOR: The JPSS Program Record
SUBMITTED BY: JPSS Vegetation Team Lead Yunyue Yu
CONCURRED BY: JPSS Algorithm Management Project Lead Lihang Zhou
                               JPSS STAR Program Manager Ingrid Guch
APPROVED BY: JPSS Program Scientist Satya Kalluri

SUBJECT: NOAA-21 Vegetation Index and Green Vegetation Fraction Product Provisional maturity status
DATE: 01/25/2024

Provisional maturity status declaration for JPSS NOAA-21 Vegetation Index and Green Vegetation Fraction
Maturity Review Date: **01/25/2024**
Effective Date: **01/25/2024**
Operational System: **NDE, Version v2r2**

The JPSS Algorithm Maturity Readiness Review Board approved the release of the JPSS VIIRS Vegetation Index (VI) and Green Vegetation Fraction (GVF) to the public with a Provisional maturity level quality as of 01/25/2024 (effective date), based on the JPSS Validation Maturity Review held on 01/25/2024.

1. Provisional maturity stage definition
   - 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 product status documents.

   (reference to the AMM webpage for maturity definition:
   http://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php)

2. Algorithm Description:

   2.1 List of Products (Collection Short Name (CSN))

   The official VIIRS Vegetation Index (VI) products consist of daily, weekly, and biweekly composited products, each produced at 4km global and 1km regional (CONUS-centered) scales. The official VIIRS Green Vegetation Fraction (GVF) products consist of weekly data produced at 4km global and 1km regional (CONUS-centered) scales. Access to all products can be obtained from Comprehensive Large Array-data Stewardship System (CLASS) under the category

JPSS_NGRN.

VIIRS Vegetation Index products:

VI-DLY-GLB: Daily global VI

VI-DLY-REG: Daily regional VI

VI-WKL-GLB: Weekly global VI

VI-WKL-REG: Weekly regional VI

VI-BWKL-GLB: Biweekly global VI

VI-BWKL-REG: Biweekly regional VI

Table 1. Layers contained in NOAA-21 Vegetation Index EDR files.

Output Data	Description
EVI_TOC	**VIIRS Top of Canopy Enhanced Vegetation Index**
NDVI_TOA	**VIIRS Top of Atmosphere Normalized Difference Vegetation Index**
NDVI_TOC	**VIIRS Top of Canopy Normalized Difference Vegetation Index**
I1_TOA	Top of atmosphere band I1 reflectance
I1_TOC	Top of canopy band I1 reflectance
I2_TOA	Top of atmosphere band I2 reflectance
I2_TOC	Top of canopy band I2 reflectance
M3_TOC	Top of canopy band M3 reflectance
QF1	First byte of VI quality flags
QF2	Second byte of VI quality flags
RAA	Relative azimuth angle
SZA	Solar zenith angle
VZA	View zenith angle
latitude	Latitude
longitude	Longitude
plate_carree	Data map projection
quality_information_EVI_TOC	Overall TOC EVI quality
quality_information_NDVI_TOA	Overall TOA NDVI quality
quality_information_NDVI_TOC	Overall TOC NDVI quality
Metadata Variables	Details in metadata list in ATBD

VIIRS Green Vegetation Fraction products:

    GVF-WKL-GLB: Weekly global GVF

    GVF-WKL-REG: Weekly regional GVF

Table 2. Layers contained in NOAA-21 Green Vegetation Fraction files.

Output Data	Description
gvf_4km or gvf_1km	**VIIRS Green Vegetation Fraction EDR, at 4km (global) or 1km (regional) scales**
Number_Of_Pixels	Number of pixels included in aggregation of GVF
latitude	Latitude
longitude	Longitude
plate_carree	Map projection
quality_information	Overall quality of GVF

2.2 Product requirements/Exclusions (DPS)

The Normalized Difference Vegetation Index (NDVI) is defined as

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

where ρ_{NIR} and ρ_{red} are near infrared (NIR) and red reflectances, respectively, obtained at the top of atmosphere (TOA) or top of canopy (TOC). Enhanced vegetation index (EVI) is defined as

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

where ρ_{blue} is blue band reflectance, $G = 2.5$, $C_1 = 6.0$, $C_2 = 7.5$, and $L = 1.0$. The VIIRS VI EDR includes EVI only at TOC, as opposed to NDVI which is produced for both TOA and TOC. NDVI and EVI both use the contrast between the low red reflectance and high NIR reflectance of photosynthesizing vegetation as an indicator of the presence of such vegetation. EVI incorporates the blue band in order to improve resistance to atmospheric contamination of the vegetation signal. Both vegetation indices are composited in such a way as to obtain the best quality measurement over the compositing period, through an adjustment for view zenith angle.

Green vegetation fraction (GVF) is defined as the fraction of horizontal area of a pixel covered by photosynthesizing vegetation. It is determined from the formula

$$GVF = (EVI - EVI_0) / (EVI_\infty - EVI_0)$$

where EVI_0 and EVI_∞ are the EVI values for bare soil and dense green vegetation respectively. The EVI used in the GVF computation is a smoothed value which is computed using data from the previous 15 weeks. The EVI used to generate GVF is composited using the same method as is used in the generation of the VI EDR, with an adjustment for view zenith angle.

Table 3. Vegetation Index product requirements

Attribute	Threshold	Objective
Geographic coverage	Clear, land (not ocean), daytime only	
Horizontal Cell Size	4 km	1 km
Mapping Uncertainty	4 km	1 km
Measurement Range, TOA NDVI	-1.0 to +1.0	
Measurement Range, TOC NDVI	-1.0 to +1.0	
Measurement Range, TOC EVI	-1.0 to +1.0	
Measurement Accuracy, NDVI	0.05 NDVI units	0.03 NDVI units
Measurement Precision, NDVI	0.04 NDVI units	0.02 NDVI units
Measurement Uncertainty, EVI	0.11 EVI units	
Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	

Table 4. Green Vegetation Fraction product requirements

Attribute	Threshold	Objective
Horizontal Cell Size	16 km	4km (global), 1 km (regional)
Mapping Uncertainty	4 km	1 km
Measurement Precision, Global and Regional	15%	8%
Measurement Accuracy, Global and Regional	12%	5%
Measurement Uncertainty, Global and Regional	17%	10%
Refresh	24 hours	24 hours

2.3 Quality flags (Table)

Two one-byte quality flag arrays (QF1 and QF2) are provided with the Vegetation Index Environmental Data Record (VI EDR) product.
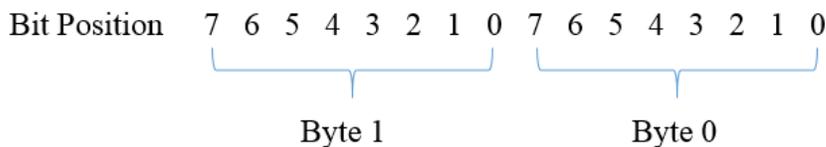
Bit Position   7 6 5 4 3 2 1 0   7 6 5 4 3 2 1 0

Byte 1   Byte 0

Table 5. Bit Layout of the Two Quality Flag Bytes in the VI EDR

Byte	VIIRS VI Flag	Result	Bits
QF1	Overall TOA NDVI Quality	0000 = Excellent 1000 = Snow/Ice 0001 = Good 1001 = Cloud 0010 = Acceptable 1010 = Estimated (CMG) 0011 = Marginal 1011 = No Data 0100 = Pass 1111 = Water/Ocean 0101 = Questionable 0110 = Poor 0111 = Cloud Shadow (Refer to Figure 13 for a flowchart of how these values are determined.)	4(bits 0-3)
	Overall TOC NDVI Quality	0000 = Excellent 1000 = Snow/Ice 0001 = Good 1001 = Cloud 0010 = Acceptable 1010 = Estimated (CMG) 0011 = Marginal 1011 = NO Data 0100 = Pass 1111 = Water/Ocean 0101 = Questionable 0110 = Poor 0111 = Cloud Shadow (Refer to Figure 13 for a flowchart of how these values are determined.)	4 (bits 4-7
QF2	EVI or EVI2	0 = EVI 1 = EVI2	1 (bit 0)
	Land Cover Type	00 = Snow/Ice 01 = Land 10 = Water/Ocean 11 = Desert	2 (bits 1-2)
	Cloud Confidence	00 = Confidently Clear 01 = Probably Clear 10 = Probably Cloudy 11 = Confidently Cloudy	2 (bits 3-4)

	Aerosol Quantity	00 = Climatology 01 = Low 10 = Average 11 = High	2 (bits 5-6)
	Cloud Shadow	0 = No Shadow 1 = Shadow	1 (bit 7)

The Green Vegetation Fraction product does not contain a quality flag array.

2.4 Product evaluation/validation

The NOAA-21 VI and GVF product Evaluation/Validation is performed preliminarily through
- Visual inspection of the VI and GVF data.
- VI and GVF data validation
    i. Cross-satellite comparisons with S-NPP and NOAA-20 VIIRS VI and GVF data
    ii. Cross-satellite comparisons with MODIS VI data
- Comparison of GVF data with Google Earth data

2.5 Product availability/reliability

The NOAA-21 VI and GVF EDR data have been produced since February 2023. There is a data gap between August 9, 2023 and October 14, 2023.

2.6 Algorithm performance dependence

The difference statistics between VIs from different satellites' VIIRS instruments meet specifications except for a small number of high VI values.

2.7 Known errors/issues/limitations
- Data gap mentioned above in Section 2.5

3. Changes to VI version 2.1 (delivered February 2021) since last version v1r4

a. VI is compositing 7 or 8 daily VI grid cells on global and regional grid to generate weekly VI. This is done to reduce processing time.

b. VI is compositing 2 weekly (if weekly period is 8 days) or 2 weekly and 2 daily (if weekly period is 7 days) grid cells on global and regional grid to generate biweekly VI. This is done to reduce processing time.

c. VI quality flags have been modified to include a more refined scheme of VI quality specification.

d. Aggregating includes only observations from the same orbit so solar and view zenith angles are more meaningful.

4. Changes to GVF version 3.0 (delivered May 2021) since last version v2r4
    a. VI is compositing 7 or 8 daily VI grid cells on global and regional grid to generate weekly VI. This is done to reduce processing time.
    b. VI is compositing 2 weekly (if weekly period is 8 days) or 2 weekly and 2 daily (if weekly period is 7 days) grid cells on global and regional grid to generate biweekly VI. This is done to reduce processing time.
    c. VI quality flags have been modified to include a more refined scheme of VI quality specification.
    d. Aggregating includes only observations from the same orbit so solar and view zenith angles are more meaningful.

5. Review board recommendations

6. Path Forward/Future Plan
    - Future Cal/Val activities
        - Implement the LTM adaptations with routine NOAA-21 VI and GVF data
        - Routine cross-comparisons
        - Validated Maturity Review, including comparison with in-situ data
    - User engagement
        - Application in NCEP models and in producing NESDIS/ STAR data
    - Improved VI and GVF products
        - 1km global VI and GVF products
        - Blended VI and GVF products with all available VIIRS data

7. Additional Items to note
    None

Additional information is available in the VI and GVF algorithm theoretical basis documents (ATBDs) and validation maturity review briefing, which can be accessed at:
   http://www.star.nesdis.noaa.gov/jpss/Docs.php

Point of Contact:

Name: Yunyue Yu
Email: yunyue.yu@noaa.gov
Phone: 301-683-2566