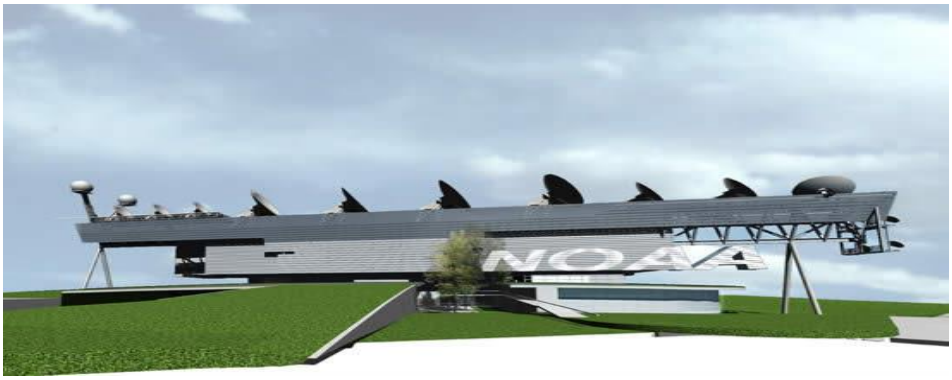
Environmental Satellite Processing Center



NDE Vegetation Products System (NVPS)
External User Manual

Version 2.0

TITLE: NDE VEGETATION PRODUCTS SYSTEM EXTERNAL USER MANUAL

VERSION 2.0

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APPROVAL SIGNATURES:

_____ April 12, 2018
Hanjun Ding Date
NVPS Product Area Lead

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1. PRODUCTS

This is an external user's manual document describing the NDE Vegetation Products System (NVPS). The system was developed at the Center for Satellite Applications and Research (STAR). It will be delivered to the S-NPP Data Exploitation (NDE) team and integrated into the NDE Data Handling System (DHS) where it will run in an operational manner.
The intended Users of the External User Manual (EUM) are end users of the output products, and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and product testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system (those outside of the OSPO and NDE). The output files are defined as those leaving the NDE DHS for public use.

1.1. Product Overview

1.1.1. Product Requirements

All Vegetation products basic and derived requirements are available in the JPSS NDE Vegetation Products System Requirements Allocation Document (RAD). These requirements identify the users and their needs with respect to file content, format, latency, and quality. This document is available upon request from the Product Area Lead (PAL), listed in the table below.

1.1.2. Product Team

The NVPS development product team consists of members from STAR and OSPO. The roles and contact information for the different product team members are identified in Table 1-1.

Table 1-1 Product Team Members

Team Member	Organization	Role	Contact Information
Yunyue Yu	STAR	STAR Product Lead	5830 University Research Court Riverdale, MD. 20740 Phone: 301-683-2566

			Email: yunyue.yu @noaa.gov
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Donna McNamara	OSPO	Data Distribution	NSOF 1372 4231 Suitland Rd Suitland MD 20746 Phone: (301)817-3803 Email; donna.mcnamara@noaa.gov

1.1.3. Product Description

The NVPS will continue to generate the current operational VIIRS Green Vegetation Fraction (GVF) products as well as the new gridded VIIRS vegetation indices (VI). The new VIIRS vegetation indices generated by the NVPS are the Top of the Atmosphere (TOA) Normalized Difference Vegetation Index (NDVI), the Top of the Canopy (TOC) NDVI, and the TOC Enhanced Vegetation Index (EVI). All the NVPS products are derived from reflectance data from the Visible Infrared Imager Radiometer Suite (VIIRS) sensor onboard Suomi National Polar-orbiting Partnership (S-NPP) satellite, for applications in numerical weather and seasonal climate prediction models at the National Centers for Environmental Prediction (NCEP). The NVPS retrieval algorithm uses TOA VIIRS red (I1), TOA VIIRS

near-infrared (I2) reflectance bands, as well as TOC VIIRS red (I1), TOC VIIRS near-infrared (I2), and TOC VIIRS blue (M3) surface reflectance bands to calculate the TOA NDVI, TOC NDVI and TOC EVI. These 3 vegetation indices will be produced daily, weekly and bi-weekly at 4-km resolution (global scale) and 1-km resolution (regional scale). GVF is derived from the TOC EVI and is only generated weekly. The weekly and bi-weekly composited VI products are generated every day. Details on the content of all NVPS external output files are shown in section 1.3.

1.2. Product History

The NVPS is an upgrade to the S-NPP VIIRS GVF system that has been running operationally at NDE since February 2015. The S-NPP VIIRS GVF software system has been enhanced to generate along with the GVF products a gridded version (globally and regionally) of the VIIRS Vegetation Index (VI) EDR products that are currently being generated operationally at the Joint Polar Satellite System (JPSS) Interface Data Processing System (IDPS). The VIIRS VI EDR products will be turned off from the IDPS after the new NDE NVPS products are validated.

1.3. Product Access

All NVPS output data files will be made available by the NDE DHS on the NDE data distribution server at ESPC in a near real time manner. For access to this server, information about data files, and associated documentation, the NVPS PAL should be contacted (see Table 1-1-1).

NESDIS Policy on Access and Distribution of Environmental Data and Products is provided at: http://www.ospo.noaa.gov/Organization/About/access.html.

Users need to fill out the Data Access Request Form located on this site and submit to the PAL with a copy to nesdis.data.access@noaa.gov. This address provides the OSPO Data Access Team a copy of the correspondence. The process is defined in the following diagram. Once the request is approved by the OSPO management the data will be delivered by the Product Distribution and Access (PDA) system. The ESPC Data Distribution Manager, Donna McNamara (donna.mcnamara@noaa.gov) should be contacted for any data accessibility and data distribution problems.

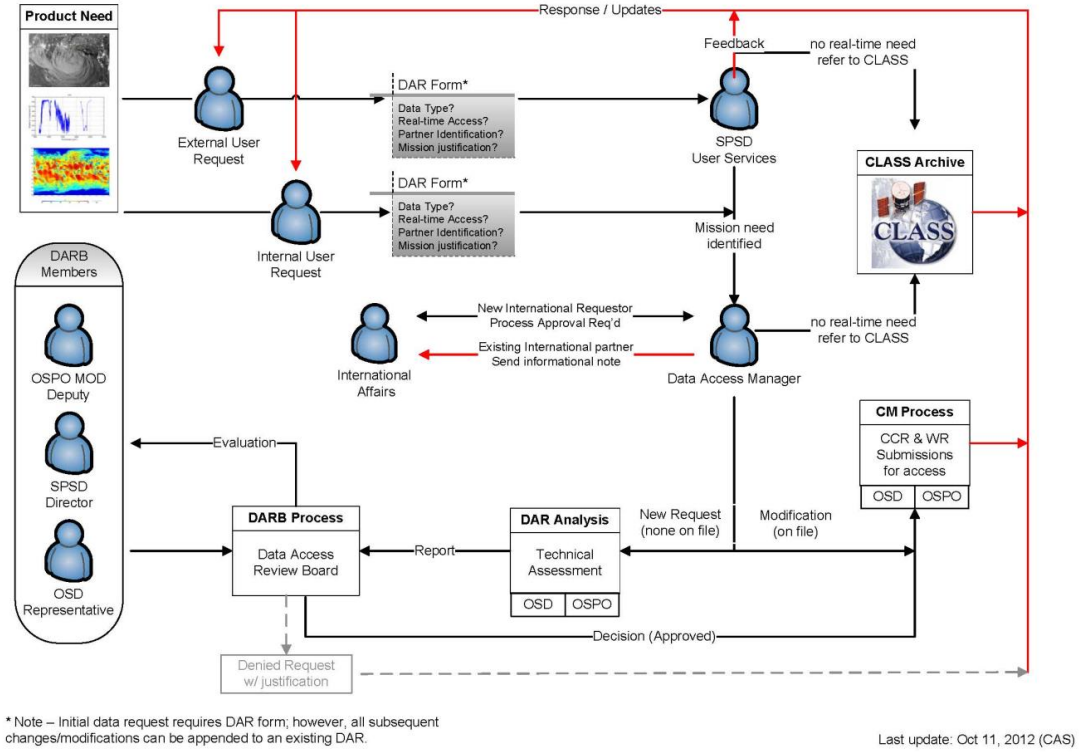

Figure 1-1 NDE Data Access Process

The NVPS data format is defined in the Table 1.2

In order to obtain the NVPS data, users need to fill out the Data Access Request Form located on http://www.ospo.noaa.gov/Organization/About/access.html and submit it to the PAL with a copy to nesdis.data.access@noaa.gov. CLASS will be archiving the global NVPS data products in netCDF4 format for distributing to the non real time users. NDE pushes the data to CLASS with the associated metadata in the standard format.

Table 1-2 Inputs for the NVPS

Input Data Products	Used in Algorithm	Description	Format	Source
GITCO	GVF, VI	Geolocation	H5	IDPS

SVI01	VI	TOA Reflectance at 640 nm	H5	IDPS
SVI02	VI	TOA Reflectance at 865 nm	H5	IDPS
JRR-SURFREFL	GVF, VI	Surface Reflectance	netCDF4	NDE
JRR-CLOUDMASK	VI	Cloud Mask	netCDF4	NDE
JRR-AOD	VI	Aerosol Optical Depth	netCDF4	NDE

Table 1-3 lists all external distributed NVPS files and their formats.

Table 1-3 NVPS Output Files

File	Description	Format	Size/file
GVF-WKL-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss].nc	This is the weekly regional GVF product	netCDF4	Typical file size 65 MB.
GVF-WKL-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss].nc	This is the weekly global GVF product	netCDF4	Typical file size 11 MB.
GVF-WKL-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss].tif	Browse image of the regional GVF product	Geotiff	Typical file size 34 MB
GVF-WKL-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss].tif	Browse image of the weekly global GVF product	Geotiff	Typical file size 5 MB
GVF-WKL-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss]_stat.txt	Statistics file of the weekly regional GVF product for monitoring purposes	text	Typical file size 10 KB
GVF-WKL-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD7] _c[YYYYMMDDhhmmsss]_stat.txt	Statistics file of the weekly global GVF product for monitoring purposes	text	Typical file size 10 KB
VI-[DLY,WKL,BWKL]-REG	This is the daily, weekly or biweekly regional VI	netCDF4	Typical file

_vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 or 16]_c[YYYYMMDDhhmmsss].nc	product		size 1.6 GB.
VI-[DLY,WKL,BWKL]-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].nc	This is the daily, weekly or biweekly global VI product	netCDF4	Typical file size 245 MB.
VI-TOA-NDVI-[DLY,WKL,BWKL]-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOA NDVI regional VI product	Geotiff	Typical file size 45 MB
VI-TOA-NDVI-[DLY,WKL,BWKL]-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOA NDVI daily, weekly or biweekly global VI product	Geotiff	Typical file size 7 MB
VI-TOC-NDVI-[DLY,WKL,BWKL]-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOC NDVI daily, weekly or biweekly regional VI product	Geotiff	Typical file size 45 MB
VI-TOC-NDVI-[DLY,WKL,BWKL]-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOC NDVI daily, weekly or biweekly global VI product	Geotiff	Typical file size 7 MB
VI-TOC-EVI-[DLY,WKL,BWKL]-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOC EVI daily, weekly or biweekly regional VI product	Geotiff	Typical file size 45 MB
VI-TOC-EVI-[DLY,WKL,BWKL]-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss].tif	Browse image of the TOC EVI daily, weekly or biweekly global VI product	Geotiff	Typical file size 7 MB
VI-[DLY,WKL,BWKL]-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 OR 16]_c[YYYYMMDDhhmmsss]_stat.txt	Statistics file of the daily, weekly or biweekly regional VI product for monitoring purposes	text	Typical file size 4 KB
VI-[DLY,WKL,BWKL]-GLB	Statistics file of the	text	Typical file

_vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 or 16]_c[YYYYMMDDhhmmsss]_stat.txt	daily, weekly or biweekly global VI product for monitoring purposes		size 4 KB

Table 1.5 NVPS output files standard name description

Sequence	Description
GVF	Green Vegetation Fraction
VI	Vegetation Indices (NDVI, EVI)
NDVI	Normal Difference Vegetation Index
EVI	Enhanced Vegetation Index
DLY	Daily (1-day temporal scale)
WKL	Weekly (7-day temporal resolution)
BWKL	Biweekly (16-day temporal resolution, in term of conventions)
GLB	Global (spatial resolution: 4-km)
REG	Regional (spatial resolution:1-km)
TOA	Top of Atmosphere
TOC	Top of Canopy
vxry	Version (e.g., v1r0)
npp	Indicates the observations from S-NPP
s	start (data observation time)
e	end (data observation time)
c	current (data processing time)
YYYYMMDD	4-digit year, 2-digit month, and 2-digit day
hhmmsss	2-digit hour, 2-digit minute, 2-digit second, and 1-digit fractional second
.nc	netCDF4 file
.tif	GeoTiff image file
stat.txt	Text file stored statistics analysis results

1.4. Data Structure of the Product

The GVF product includes the following data fields:

1) GVF;
2) Number of Pixels;
3) Geospatial Coordinates: latitude, longitude

The description of these data fields are listed in Table 1-5(a).

The VI product includes the following data fields:

1) Three VI Products: NDVI_TOA, EVI_TOC and NDVI_TOC;
2) Five aggregated reflectance bands: I1_TOA, I2_TOA, I1_TOC,I2_TOC, and M3_TOC
3) Geometry Information: RAA: Relative Azimuth Angle, SZA: Solar Zenith Angle, and VZA: Viewing Zenith Angle;
4) Four Quality Flags (QFs).
5) Geospatial Coordinates: latitude, longitude

The description of these data fields are listed in Table 1-5(b).

Table 1-5 (a) Data Fields of the NVPS GVF Products

Data Name	Data Description	Data Type	Dimension	Fill Value	Scale	offset	Data Range
GVF	Green Vegetation Fraction	8-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-128	100	0	[0,100]
Number_Of_ Pixels	Number of Pixels	8-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	255	1	0	[0,255]
Latitude	Geospatial coordinate	32-bit float	5000x1 (Global) 10384x1 (Regional)	-999.0	1	0	[-90º,90º] [-7.5º,90º]
Longitude	Geospatial coordinate	32-bit float	10000x1 (Global) 28889x1 (Regional)	-999.0	1	0	[-180º,180º] [-230º,30º]

Table 1-5 (b) Data Fields of the NVPS VI Products

Data Name	Data Description	Data Type	Dimension	Fill Value	Scale	offset	Data Range
NDVI_TOA	Top of Atmosphere Normalized Difference Vegetation Index	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-1,1]
NDVI_TOC	Top of Canopy Normalized Difference Vegetation Index	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-1,1]
EVI_TOC	Top of Canopy Enhanced Vegetation Index	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-1,1]
I1_TOA	Top of Atmosphere Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[0,1]
I2_TOA	Top of Atmosphere Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[0,1]

I1_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[0,1]
I2_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[0,1]
M3_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[0,1]
SZA	Solar Zenith Angle	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	100	0	[0,90]
VZA	Viewing Zenith Angle	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	100	0	[0,90]
RAA	Relative Azimuth Angle	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	100	0	[-180,180]
QF1	Quality Flag Byte 0 (See Table 3-5)	8-bit unsigned character	5000x10000 (Global) 10384x28889 (Regional)	255	1	0	[0, 255]

QF2	Quality Flag Byte 1 (See Table 3-5)	8-bit unsigned character	5000x10000 (Global) 10384x28889 (Regional)	2	1	0	[0, 255]
QF3	Quality Flag Byte 2 (See Table 3-5)	8-bit unsigned character	5000x10000 (Global) 10384x28889 (Regional)	0	1	0	[0, 255]
QF4	Quality Flag Byte 3 (See Table 3-5)	8-bit unsigned character	5000x10000 (Global) 10384x28889 (Regional)	0	1	0	[0, 255]
Latitude	Geospatial coordinate	32-bit float	5000x1 (Global) 10384x1 (Regional)	-999.0	1	0	[-90°,90°] [-7.5°,90°]
Longitude	Geospatial coordinate	32-bit float	10000x1 (Global) 28889x1 (Regional)	-999.0	1	0	[-180°,180°] [-230°,30°]

The details of the bit layout of the four quality flags are listed in Table 1-6.

Table 1-6 Bit Layout of the Four QFs in NVPS VI Product

Byte	VIIRS VI Flag	Result	Bits
0	Overall TOA NDVI Quality	0 = High 1 = Low NOTE: TOA NDVI quality is set to high (0) if ALL of these conditions are met: 1) I1 TOA reflectance flag = available; 2) I2 TOA reflectance flag = available 3) Cloud Confidence flag = confidently clear 4) Thin Cirrus flag = no thin cirrus; 5) Solar Zenith Angle < 65 deg 6) Sun glint (Geometry based) = none; 7) No adjacency clouds 8) No cloud shadows; 9) No snow/ice 10) Aerosol quantity =“low” or “medium” or “climatology” 11) Cloud mask quality = “high” or “medium”	1
	Overall TOC EVI Quality	0 = High 1 = Low NOTE: EVI quality is set to high (0) if ALL of these conditions are met: 1) I1 Surface reflectance flag = available ; 2) I2 Surface reflectance flag = available 3) M3 Surface reflectance flag = available; 4) Cloud Confidence flag = confidently clear; 5) Thin Cirrus flag = no thin cirrus; 6) Solar Zenith Angle < 65 degree 7) Sun glint (Geometry based) = none; 8) EVI range flag = in range 9) No adjacency clouds; 10) No cloud shadows 11) No snow/ice; 12) Aerosol quantity =“low” or “medium” or “climatology” 13) Cloud mask quality = “high” or “medium”	1
	Overall TOC NDVI Quality	0 = High 1 = Low NOTE: TOC NDVI quality is set to high (0) if ALL of these conditions are met: 1) I1 Surface reflectance flag = available ; 2) I2 Surface reflectance flag = available 3) Cloud Confidence flag = confidently clear;	1

		4) Thin Cirrus flag = no thin cirrus; 5) Solar Zenith Angle < 65 degree 6) Sun glint (Geometry based) = none 7) No adjacency clouds 8) No cloud shadows 9) No snow/ice 10) Aerosol quantity =“low” or “medium” or “climatology” 11) Cloud mask quality = “high” or “medium”	
	I1 TOA Reflectance	1 = Not Available 0 = Available	1
	I2 TOA Reflectance	1 = Not Available 0 = Available	1
	I1 Surface Reflectance	1 = Not Available 0 = Available	1
	I2 Surface Reflectance	1 = Not Available 0 = Available	1
	M3 Surface Reflectance	1 = Not Available 0 = Available	1
1	EVI Range	1 = Out of Range 0 = In Range	1
	*Land/Water	001= deep ocean (1) 010= shallow water (2) 011= land (3) 100= snow (4) 101= arctic (5) 110= Antarctic + Greenland (6) 111= desert (7)	3
	*Cloud Confidence	11 = Confidently Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confidently Clear	2
	*Sun Glint	11 = Geometry & Wind 10 = Wind Speed Based	2

		01 = Geometry Based 00 = None	
2	*Thin Cirrus (reflective)	1 = Cloud 0 = No Cloud	1
	Stratification – Solar Zenith Angle	1 = 65 Degrees <= SZA <= 85 Degrees 0 = SZA < 65 Degrees or SZA > 85 Degrees	1
	*Excl – AOT > 1.0	1 = AOT > 1.0 0 = AOT <= 1.0	1
	Excl – Solar Zenith Angle > 85 Deg	1 = SZA > 85 degrees 0 = SZA <= 85 degrees	1
	*Snow/Ice	0 = False (no) 1 = True (yes)	1
	*Adjacent to Clouds	0 = False (no) 1 = True (yes)	1
3	*Aerosol Quantity	00 = Climatology 01 = Low 10 = Average 11 = High	2
	*Cloud Shadows	0 = False (no) 1 = True (yes)	1
	**Aerosol Optical Thickness Quality	00 = High Quality 01 = Degraded Quality 10 = Excluded Quality 11 = Not Produced	2
	*Cloud Mask Quality	00 = Poor 01 = Low 10 = Medium 11 = High	2
	Spare Bits	Initialized to 0	3

The overall Meta information of the NVPS VI Product is shown in Table 1-7.

Table 1-7 Meta Information of the NVPS VI Product

Number of attributes = 29
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Conventions = CF-1.5 Metadata_Conventions = CF-1.5, Unidata Dataset Discovery v1.0

```
cdm_data_type = grid
creator_email = yunyue.yu@noaa.gov/marco.vargas@noaa.gov
creator_name = DOC/NOAA/NESDIS/STAR > VI Team, Center for Satellite Applications and
               Research, NESDIS, NOAA, U.S. Department of Commerce
creator_url = https://www.star.nesdis.noaa.gov/smcd/viirs_vi/Monitor.htm
date_created = 2017-11-03T20:19:53Z
geospatial_bounds = POLYGON((-230.0 90.0, 30.0 90.0, 30.0 -7.5, -230.0  -7.5))
geospatial_lat_resolution = 0.0090
geospatial_lat_units = degrees_north
geospatial_lon_resolution = 0.0090
geospatial_lon_units = degrees_east
history = Created by VI algorithm v1.0
id = a43c72a3-1f14-4edf-8dbe-06b97a7bcb49
 institution = DOC/NOAA/NESDIS/NDE > S-NPP Data Exploitation, NESDIS, NOAA, U.S.
               Department of Commerce
instrument_name = VIIRS
naming_authority = gov.noaa.nesdis.nde
platform_name = NPP
process_level = NOAA Level 3
project = S-NPP Data Exploitation
publisher_email = espcoperations@noaa.gov
publisher_name = DOC/NOAA/NESDIS/NDE > S-NPP Data Exploitation, NESDIS, NOAA, U.S.
                 Department of Commerce
publisher_url = http://projects.osd.noaa.gov/NDE
source = GITCO, JRR-AOD, JRR-CloudMask, SR, SVI01, SVI02
standard_name_vocabulary = CF Standard Name Table (version 17, 24 March 2011)
summary = TOA NDVI, TOC NDVI and TOC EVI in each pixel derived on a daily basis from
          VIIRS observations
time_coverage_end = 2017-10-20T24:00:00Z
time_coverage_start = 2017-10-20T00:00:00Z
title = VIIRS_VI
```

2. ALGORITHM

2.1. Algorithm Overview

The NVPS is to produce GVF and the Vegetation Indices TOA NDVI, TOC NDVI and TOC EVI.

2.1.1. GVF Algorithm

The NVPS will produce daily rolling weekly Green Vegetation Fraction from S-NPP VIIRS granule data. The GVF output files include a 0.009° (1-km) GVF regional file, and a 0.036° (4-km) GVF global file, both in NetCDF4 format. The NetCDF4 output will be converted to GRIB2 at NDE using a standalone conversion tool. The daily rolling weekly production scheme means that the GVF products are derived from VIIRS input data from the past 7 days, but the output is generated every day. Seven major steps are required to generate the GVF products (global and regional): (1) identification of VIIRS granules to be gridded for each tile, (2) gridding at 0.003° spatial resolution of daily VIIRS observations for I1, I2, and M3 bands, (3) compositing of the gridded daily observations of the past 7 days into a weekly composite, (4) EVI calculation from weekly composite, (5) EVI gap filling and smoothing based on an EVI time series, (6) GVF computation at 0.003° , (7) GVF aggregation to 0.009° for the regional product and to 0.036° for the global product. The GVF product is smooth and therefore no quality flags are provided in the output file. For detailed information about the GVF algorithm, see the GVF Algorithm Theoretical Basis Document (https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_GVF_v2.1.pdf).

2.1.2. VI Algorithm

In addition to the GVF products, the NVPS is to produce the following VI products: TOA NDVI, TOC NDVI and TOC EVI. The VI products will be generated at three different temporal resolutions; these are daily, weekly (7-day) and bi-weekly (16-day). The VI composited products (weekly and bi-weekly) are generated every day. All VI products are estimated from S-NPP VIIRS granule data. The final VI data product files include a 0.009° (1-km) VI regional file, and a 0.036° (4-km) global file, both in NetCDF4 format. Six major steps are required to generate the VI products; (1) identification of VIIRS granules to be gridded for each tile, (2) gridding at 0.003° spatial resolution of daily VIIRS observations for I1, I2, and M3 bands, (3) compositing of the gridded daily observation of the past 7 days or 16 days into weekly or bi-weekly composites, (4) reflectance aggregation from 0.003° to 0.009° for the regional products and to 0.036° for the global products, (5) VI calculation at global or regional grids; (6) quality assurance for the VI products. For detailed information about the VI algorithm, see the JPSS VIIRS Vegetation Index Algorithm Theoretical Basis Document (https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/D0001-M01-S01-025_JPSS_ATBD_VIIRS-Vegetation-Index_A.pdf).

2.2. Input Satellite Data

2.2.1. Satellite Instruments

NVPS is a product system operated within the NDE DHS by OSPO. NVPS uses data from the VIIRS instrument onboard the S-NPP satellite. VIIRS will be included on the future JPSS satellites (JPSS-1, JPSS-2, JPSS-3 and JPSS-4).

VIIRS is one of five instruments onboard the SNPP satellite that launched on Oct. 28, 2011. The VIIRS instrument has high spatial resolution with controlled growth off nadir and a sufficient number of spectral bands to satisfy the requirements for generating accurate operational and scientific products. Calibration is performed onboard using a solar diffuser for short wavelengths and a blackbody source and deep space view for thermal wavelengths. The nominal altitude for the S-NPP satellite is 824 km. The VIIRS scan will therefore extend to 56 degrees on either side of nadir.

The positioning of the VIIRS Visible/Near Infrared (VNIR) and Short Wave Infrared (SWIR) spectral bands is summarized in table 2-1. There are nine moderate (M) resolution bands and three imagery (I) resolution bands in the VNIR and SWIR spectral region. The nadir resolutions for the M and I bands are 750 m and 375 m, respectively. The VI algorithm uses the VIIRS bands I1, I2 and M3 as input data.

Table 2-1 Summary of VIIRS VNIR and SWIR Spectral Band Characteristics

Band Name	Center	Width* (microns)	Resolution (m)
M1	0.415	0.020	750
M2	0.445	0.020	750
M3	**0.490**	**0.020**	**750**
M4	0.555	0.020	750
I1	**0.640**	**0.075**	**375**
M5	0.673	0.021	750
I2	**0.865**	**0.039**	**375**
M7	0.865	0.039	750
M8	1.240	0.020	750

I3	1.610	0.060	375
M10	1.610	0.060	750
M11	2.250	0.050	750

*Full width half maximum (FWHM)

2.2.2. Pre-Processing Steps

The VIIRS instrument Raw Data Records (RDR) packet data are transmitted from the satellite to the ground stations and are then sent to the Interface Data Processing Segment (IDPS) at the NOAA Satellite Operations Facility (NSOF). The IDPS applies the instrument calibration and geolocation to generate the geolocation files and Sensor Data Records (SDR) files, including TOA I1 and I2 bands. The Surface Reflectance (SR), Aerosol Optical Thickness (AOT) and Cloud Mask (CM) files required by the VI system are generated in NetCDF4 format at NDE from the SDR files. When NDE has all the inputs required to process the VI algorithm (based on the VI production rules), including GITCO and SVI01/SVI02 from IDPS and SR, AOT and CM from NDE, it executes the job to produce the output files described in this document.

2.3. Input Ancillary Data

2.3.1. Global Maximum and Minimum EVI Vegetation Index

The global maximum EVI (EVI_{∞}) is a theoretical EVI value for dense vegetation where GVF=1 and the global minimum EVI (EVI_0) is a theoretical EVI value for bare soils where GVF=0. Both are global constants, independent of vegetation and soil types. Based on the SNPP VIIRS weekly composite EVI data in a year from Aug 2012 to July 2013, the global values, EVI_0=0.0900 and EVI_{∞}=0.6766, were empirically estimated, taken as the 5^{th} and 95^{th} percentiles from the probability distribution function of the weekly EVI maps.

2.3.2. Soil Adjustment factor L

The compositing procedure used in the NVPS system is different from the traditional maximum value compositing (MVC). It is well documented that MVC based on NDVI favors observations in the forward scatter direction, creating a bias and resulting in low red and NIR reflectances because of shadowing effect. To reduce the bias, the soil-adjusted vegetation index (SAVI) is used in compositing. The SAVI with L=0.05 was found to be the

optimal vegetation index used in compositing to minimize the bias between the two directions

$$SAVI = (1+L)\frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red} + L} \quad (2.1)$$

2.3.3. Coefficients C_1 and C_2 for Compositing

Sensor zenith angles should be taken into account in compositing such that observations close to the nadir view are given a priority and observations at off-nadir view should be selected only if nadir view observations are cloudy. So, in compositing, SAVI should be adjusted according to the sensor zenith angle for each observation. The view-angle adjusted SAVI (VA-SAVI) is

$$\text{VA-SAVI} = \text{SAVI} - C \times SZ^2 \quad (2.2)$$

where SZ is the sensor zenith angle in degrees and C is a coefficient that accounts for the view angle variation of SAVI. C is a function of vegetation density, which can be estimated by the maximum SAVI ($SAVI_{max}$) in a compositing period for a pixel.

$$C = C_1 - C_2(SAVI_{max} - 0.5)^2 \quad (2.3)$$

C_1=0.00008 and C_2=0.0002 are used in compositing.

2.3.4. Water Mask

The Moderate Resolution Imaging Spectroradiometer (MODIS) 250-m land-water mask (MOD44W) was reprojected to the lat/lon projection and resampled to the NVPS grid resolution (0.003°). The land-water mask is used as a static input of the VIP system to mask water pixels.

2.3.5. Weekly EVI from Previous 14 Weeks for GVF Smoothing

The VIIRS GVF products are smooth. The EVI smoothing unit SVI requires an input of 15-week weekly EVI data, equivalent to EVI derived from VIIRS surface reflectance of 105 days. EVI from the current week along with EVI data from the previous 14 weeks are needed as input ancillary data.

2.3.6. GVF Climatology

There is no VIIRS reflectance data at high latitudes during winter because there is no sun light, resulting in gaps in VIIRS GVF. To fill the gaps in winter, a yearly evergreen tree fraction map was created from MODIS Vegetation Continuous Field product and MODIS Land Cover product. Both MODIS products are produced yearly, at nominally 250m and 500m resolutions respectively. From the year 2010 land cover product, pixels with the evergreen needle-leaf, evergreen broad-leaf, and mixed forest land cover types were identified. The tree fraction data were retrieved from the MODIS Vegetation Continuous Field product. By combining these two products, the fractions of evergreen needle-leaf, evergreen broad-leaf trees in each pixel were calculated. For mixed forests pixels, 50% of the tree fraction is assumed to be evergreen tree fraction. In theory, evergreen tree fraction is the GVF for cold regions where there is no other evergreen vegetation. Monthly GVF climatology data were derived from VIIRS monthly composite EVI data between 8/1/2012 and 8/31/2013 and gaps of the monthly GVF climatology in high latitude area in winter are filled by the evergreen tree fraction map.

3. PERFORMANCE

3.1. Product Testing

3.1.1. Test Data

Description of all NVPS test data (input, output, and intermediate) used in unit and system tests is provided in the NVPS Algorithm Readiness Review Document (NESDIS/STAR, 2017). These are available by contacting the NVPS Product Area Lead (PAL) at OSPO.

3.1.2. Test Plans

Description of all NVPS test plans used in unit and system tests is provided in the NVPS System Readiness Document. These are available by contacting the Product Area Lead (PAL) at OSPO.

3.2. Product Accuracy

3.2.1. Test Results

Description of all NVPS test results from the unit and system tests is provided in the NVPS System Readiness Document. These are available by contacting the Product Area Lead (PAL) at OSPO.

3.2.2. Product Accuracy

The NVPS validation is in progress at the current stage of this project. The VI Team has not received yet the enterprise input dataset (2.5 months of ESR, ECM, EAOT at different seasons) to perform the initial validation of the products. Results of the initial validation results (beta maturity) will be presented at the System Readiness Review in September 2017. When this occurs, all testing documents will be updated and made available through the PAL.

3.3. Product Quality

Statistics (maximum VI, minimum VI, mean and standard deviation of the VI global and regional product) for selected areas are computed and output into a text file for OSPO to monitor the production process. Tables 3-1 and 3-2 are examples of statistics files for the global and regional VI products, respectively. For the global VI product, seven areas representing different ecosystems and the global area are selected to calculate the VI statistics (Table 3-1). The ranges of the longitude and latitude and the number of land pixels for each area are also described in the statistic file. For the regional VI product, the VI statistics over five areas are listed in the regional statistics file (Table 3-2).

Table 3-1 Example of global VI statistic file for 01/04/2018

Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_evi	min_evi	max_evi	mean_evi	std_evi
global	-180	180	-40	40	5276054	-0.381	0.975	0.135	0.118
desert	23	24	28	29	841	0.084	0.14	0.116	0.004
semi-desert	125	126	-21	-20	841	0.039	0.165		0.022
steppe	-103	-102	36	37	841	0.058	0.302	0.132	0.044
crops	-89	-88	39	40	841	-0.018	0.169	0.071	0.048
broad_leaf_forest	-85	-84	36	37	841	-0.005	0.217	0.065	0.03
coniferous_forest	-123	-122	43	44	841	-0.05	0.17	0.062	0.031
tropical_forest	-63	-62	-3	-2	812	0.009	0.482	0.196	0.115

Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_toandvi	min_toandvi	max_toandvi	mean_toandvi	std_toandvi
global	-180	180	-40	40	5276054	-0.716	0.869	0.22	0.158
desert	23	24	28	29	841	0.112	0.167	0.149	0.004
semi-desert	125	126	-21	-20	841	0.065	0.255	0.178	0.04
steppe	-103	-102	36	37	841	0.132	0.379	0.216	0.044
crops	-89	-88	39	40	841	0.04	0.3	0.138	0.067
broad_leaf_forest	-85	-84	36	37	841	0.091	0.312	0.141	0.039
coniferous_forest	-123	-122	43	44	841	0.007	0.361	0.135	0.051
tropical_forest	-63	-62	-3	-2	812	0.033	0.726	0.28	0.166

Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_tocndvi	min_tocndvi	max_tocndvi	mean_tocndvi	std_tocndvi
global	-180	180	-40	40	5276054	-1	0.971	0.187	0.17
desert	23	24	28	29	841	0.088	0.13	0.116	0.004
semi-desert	125	126	-21	-20	841	0.037	0.229	0.149	0.04
steppe	-103	-102	36	37	841	0.089	0.347	0.172	0.048
crops	-89	-88	39	40	841	-0.022	0.232	0.081	0.062
broad_leaf_forest	-85	-84	36	37	841	-0.009	0.255	0.073	0.035
coniferous_forest	-123	-122	43	44	841	-0.15	0.29	0.08	0.048
tropical_forest	-63	-62	-3	-2	812	0.009	0.747	0.265	0.179

Table 3-2 Example of regional VI statistics file for 01/04/2018

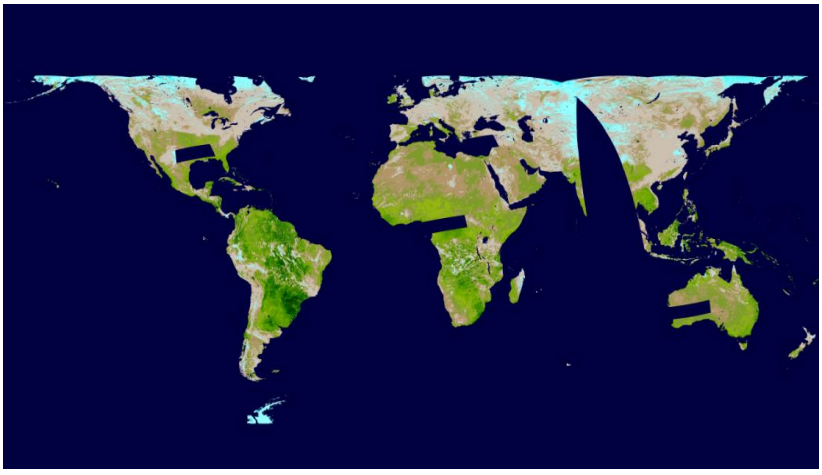
Area	Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_evi	min_evi	max_evi	mean_evi
E-Sahara(LYBIA)	desert	23	24	28	29	12544	0.013	0.188	0.115
Colorado(USA)	steppe	-103	-102	36	37	12656	0.033	0.546	0.13
Illinois(USA)	crops	-89	-88	39	40	12508	-0.031	0.27	0.072
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	12600	-0.106	0.335	0.063
Oregon(USA)	coniferous_forest	-123	-122	43	44	12579	-0.08	0.401	0.062

Area	Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_toandvi	min_toandvi	max_toandvi	mean_toandvi
E-Sahara(LYBIA)	desert	23	24	28	29	12544	0.072	0.169	0.149
Colorado(USA)	steppe	-103	-102	36	37	12656	0.121	0.594	0.215
Illinois(USA)	crops	-89	-88	39	40	12508	0.025	0.352	0.14
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	12600	0.008	0.428	0.143
Oregon(USA)	coniferous_forest	-123	-122	43	44	12579	-0.078	0.625	0.139

Area	Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	N_pixel_tocndvi	min_tocndvi	max_tocndvi	mean_tocndvi
E-Sahara(LYBIA)	desert	23	24	28	29	12544	0.021	0.17	0.116
Colorado(USA)	steppe	-103	-102	36	37	12656	0.061	0.574	0.17
Illinois(USA)	crops	-89	-88	39	40	12508	-0.036	0.311	0.083
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	12600	-0.414	0.501	0.074
Oregon(USA)	coniferous_forest	-123	-122	43	44	12579	-0.261	0.589	0.082

For visual examination of product quality, color-coded VI browse images in GeoTiff format for the global and regional VI products are produced (Figures 3-1 and 3-2). The dimensions of the 0.036° resolution global VI browse image are 10000 and 5000. The dimensions of the 0.009° resolution regional VI browse image are 28889 and 10834.

(a) Global Daily EVI_TOC on 01/04/2018



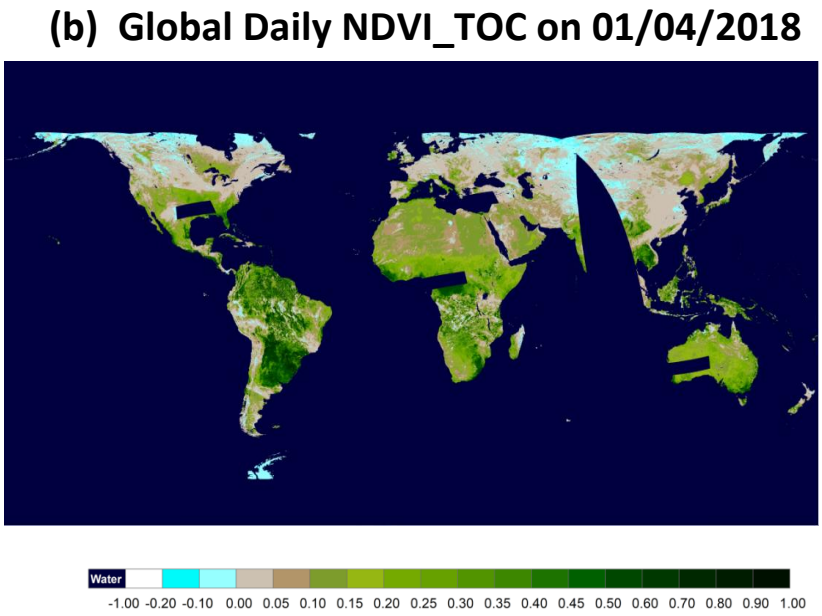
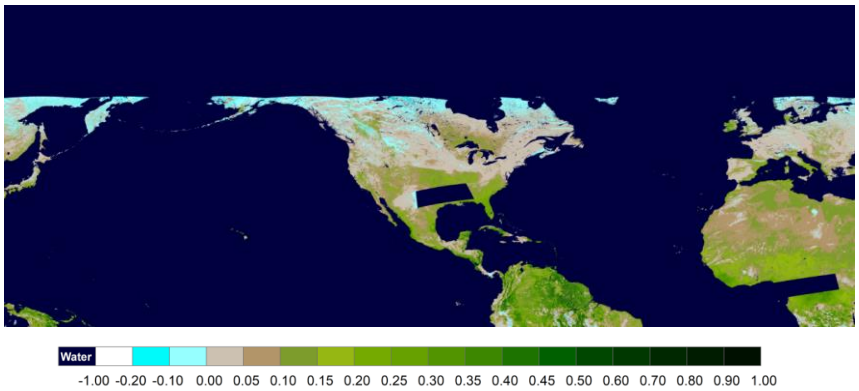
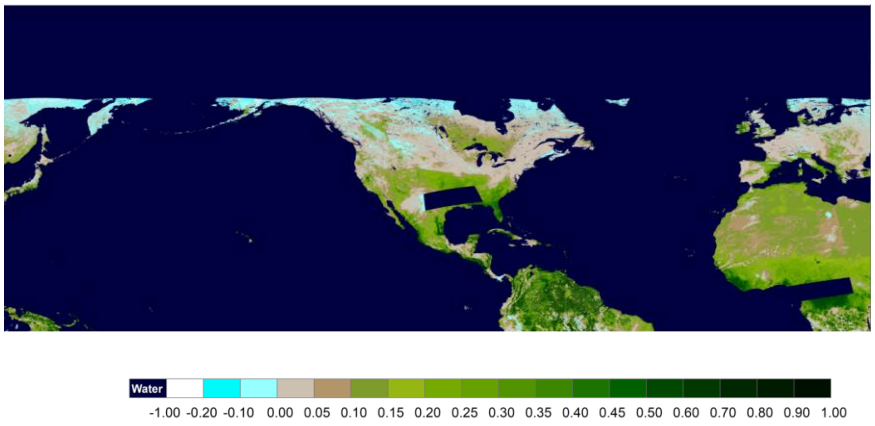


Figure 3-1 (a,b,c) Examples of global color-coded 0.036° EVI_TOC, NDVI_TOC and NDVI_TOA GeoTIFF produced for 01/04/2018.

(a) Regional Daily EVI_TOC on 01/04/2018



(b) Regional Daily NDVI_TOC on 01/04/2018



(c) Regional Daily NDVI_TOA on 01/04/2018

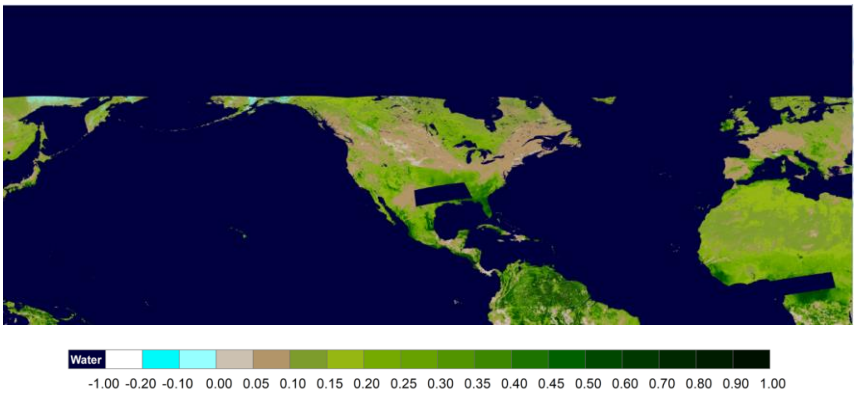


Figure 3-2 (a.b,c) Examples of regional color-coded 0.009° EVI_TOC,NDVI_TOC, NDVI_TOA GeoTIFF produced for 01/04/2018

Statistics (maximum GVF, minimum GVF, mean and standard deviation of the GVF global GVF product) for selected areas are computed and output into a text file for OSPO to monitor the production process. Tables 3-3 and 3-4 are examples of statistics files for the global and regional GVF products, respectively. For the global GVF product, seven areas representing different ecosystems and the global area are selected to calculate the GVF statistics (Table 3-1). The ranges of the longitude and latitude and the number of land pixels for each area are also described in the statistic file. For the regional GVF product, the GVF statistics over five areas are listed in the regional statistics file (Table 3-2).

Table 3-3 Example of global GVF statistics file for the week 01/03/2018-01/09/2018

Area	Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	Num_pixels	min_gvf	max_gvf	mean_gvf	std_gvf
Global	global	-180	180	-40	40	5819957	1	100	30.5	33.9
E-Sahara(LYBIA)	desert	23	24	28	29	841	1	7	3.8	1.8
Great-Sandy(AUS)	semi-desert	125	126	-21	-20	841	1	15	5.6	4.1
Colorado(USA)	steppe	-103	-102	36	37	841	7	75	22.3	12.2
Illinois(USA)	crops	-89	-88	39	40	841	5	43	21.1	7.8
Kentucky(USA)	broad_leaf_forest	-85	-84	36	37	840	6	51	29	6.2
Oregon(USA)	coniferous_forest	-123	-122	43	44	838	18	100	70	12.3
Amazon(BRAZIL)	tropical_forest	-63	-62	-3	-2	812	65	100	93.1	5.3

Table 3-4 Example of regional GVF statistics file for the week 01/03/2018-01/09/2018

Area	Ecosystem	lon_W(deg.)	lon_E(deg.)	lat_S(deg.)	lat_N(deg.)	Num_pixels	min_gvf	max_gvf	mean_gvf	std_gvf
Global	global	-180	180	-40	40	5819957	1	100	30.5	33.9
E-Sahara(LYBIA)	desert	23	24	28	29	841	1	7	3.8	1.8
Great-Sandy(AUS)	semi-desert	125	126	-21	-20	841	1	15	5.6	4.1
Colorado(USA)	steppe	-103	-102	36	37	841	7	75	22.3	12.2
Illinois(USA)	crops	-89	-88	39	40	841	5	43	21.1	7.8
Kentucky(USA)	broad_leaf_fores	-85	-84	36	37	840	6	51	29	6.2
Oregon(USA)	coniferous_forest	-123	-122	43	44	838	18	100	70	12.3
Amazon(BRAZIL)	tropical_forest	-63	-62	-3	-2	812	65	100	93.1	5.3

For visual examination of product quality, color-coded GVF browse images in GeoTiff format for the global and regional GVF products are produced (Figures 3-3 and 3-4). The dimensions of the 0.036° resolution global GVF browse image are 10000 and 5000. The dimensions of the 0.009° resolution regional GVF browse image are 28889 and 10834.

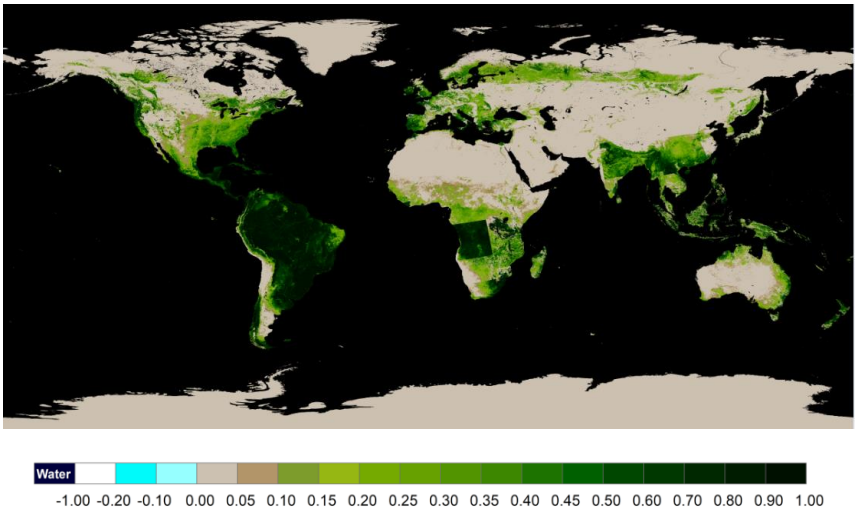


Figure 3-3 Example of global color-coded 0.036° GVF GeoTIFF produced from a weekly composited VIIRS data 01/03/2018-01/09/2018.

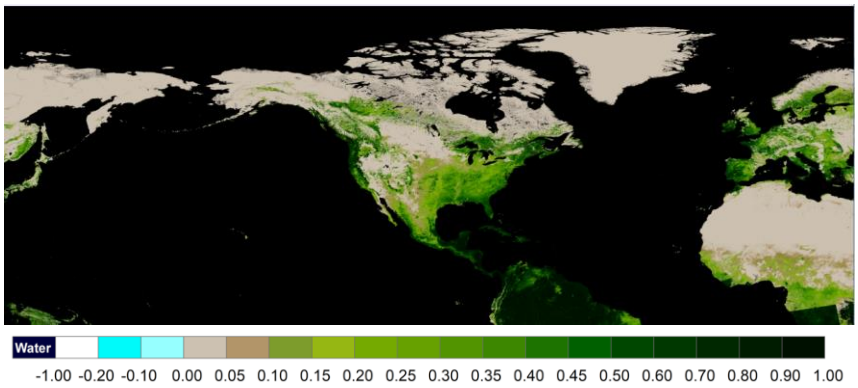


Figure 3-4 Example of regional color-coded **0.009**° GVF GeoTIFF produced from a weekly composited VIIRS data 01/03/2018-01/09/2018.

There are four quality flags in the VIIRS vegetation index output files, listed as QF1 through QF4. These fields are bit-mapped quality fields for the inputs and outputs of the algorithm. These are listed in Tables 3-5.

Table 3-5 Bit Layout of the four QFs in the NVPS VI Product

Byte	VIIRS VI Flag	Result	Bits
0	Overall TOA NDVI Quality	1 = High 0 = Low NOTE: TOA NDVI quality is set to high (1) if ALL of these conditions are met: 1) I1 TOA reflectance flag = avail ; 2) I2 TOA reflectance flag = avail 3) Cloud Confidence flag = confidently clear 4) Thin Cirrus flag = no thin cirrus; 5) Solar Zenith Angle < 65 deg 6) Sun glint (Geometry based) = none; 7) No adjacency clouds 8) No cloud shadows; 9) No snow/ice 10) Aerosol quantity =“low” or “medium” or “climatology” 11) Cloud mask quality = “high” or “medium”	1
	Overall TOC EVI Quality	1 = High 0 = Low NOTE: EVI quality is set to high (1) if ALL of these conditions are met: 1) I1 Surface reflectance flag = avail ; 2) I2 Surface reflectance flag = avail 3) M3 Surface reflectance flag = avail; 4) Cloud Confidence flag = confidently clear; 5) Thin Cirrus flag = no thin cirrus; 6) Solar Zenith Angle < 65 deg 7) Sun glint (Geometry based) = none; 8) EVI range flag = in range 9) No adjacency clouds; 10) No cloud shadows 11) No snow/ice;	1

		12) Aerosol quantity =“low” or “medium” or “climatology” 13) Cloud mask quality = “high” or “medium”	
	Overall TOC NDVI Quality	1 = High 0 = Low NOTE: TOC NDVI quality is set to high (1) if ALL of these conditions are met: 1) I1 Surface reflectance flag = avail ; 2) I2 Surface reflectance flag = avail 3) Cloud Confidence flag = confidently clear; 4) Thin Cirrus flag = no thin cirrus; 5) Solar Zenith Angle < 65 deg 6) Sun glint (Geometry based) = none 7) No adjacency clouds 8) No cloud shadows 9) No snow/ice 10) Aerosol quantity =“low” or “medium” or “climatology” 11) Cloud mask quality = “high” or “medium”	1
	I1 TOA Reflectance	1 = Not Available 0 = Available	1
	I2 TOA Reflectance	1 = Not Available 0 = Available	1
	I1 Surface Reflectance	1 = Not Available 0 = Available	1
	I2 Surface Reflectance	1 = Not Available 0 = Available	1
	M3 Surface Reflectance	1 = Not Available 0 = Available	1
1	EVI Range	1 = Out of Range 0 = In Range	1
	*Land/Water	001= deep ocean (1) 010= shallow water (2) 011= land (3) 100= snow (4) 101= arctic (5) 110= Antarctic + Greenland (6) 111= desert (7)	3
	*Cloud Confidence	11 = Confidently Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confidently Clear	2
	*Sun Glint	11 = Geometry & Wind 10 = Wind Speed Based 01 = Geometry Based 00 = None	2
2	*Thin Cirrus (reflective)	1 = Cloud 0 = No Cloud	1
	Stratification – Solar Zenith Angle	1 = 65 Degrees <= SZA <= 85 Degrees 0 = SZA < 65 Degrees or SZA > 85 Degrees	1
	*Excl – AOT > 1.0	1 = AOT > 1.0 0 = AOT <= 1.0	1
	Excl – Solar Zenith Angle > 85 Deg	1 = SZA > 85 degrees 0 = SZA <= 85 degrees	1
	*Snow/Ice	0 = False (no) 1 = True (yes)	1
	*Adjacent to Clouds	0 = False (no) 1 = True (yes)	1

	*Aerosol Quantity	00 = Climatology 01 = Low 10 = Average 11 = High	2
3	*Cloud Shadows	0 = False (no) 1 = True (yes)	1
	**Aerosol Optical Thickness Quality	00 = High Quality 01 = Degraded Quality 10 = Excluded Quality 11 = Not Produced	2
	*Cloud Mask Quality	00 = Poor 01 = Low 10 = Medium 11 = High	2
	Spare Bits	Initialized to 0	3

The GVF output files do not contain quality flags because the GVF is a smooth product.

3.4. Analysis Tools

No external product tools are supplied. The NVPS output file format is netCDF4. External users can choose their own tools to display and analyze these output files.

4. PRODUCT STATUS

4.1. Operations Documentation

Please see the NVPS System Maintenance Manual, Section 4 “Normal Operations” for detailed information about operational procedures. A set of SPSRB required documentation is available for the NVPS, including the External User Manual (this document), the Algorithm Theoretical Basis Document, and the System Maintenance Manual. These documents are available upon request from the PAL.

4.2. Maintenance History

Please see the NVPS System Maintenance Manual, Section 5 “Monitoring and Maintenance” for detailed information about monitoring and maintenance support.

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