

# **NOAA NESDIS CENTER for SATELLITE APPLICATIONS and RESEARCH**

## **NDE Vegetation Products System (NVPS) External Users Manual**

**Version 1.0 (DRAFT)**

# NOAA/NESDIS/STAR

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TITLE: NDE VEGETATION PRODUCTS SYSTEM EXTERNAL USERS MANUAL VERSION  
1.0

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APPROVAL SIGNATURES:

<hr/>	<u>June 20, 2017</u>
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NDE VI Project Lead	

## DOCUMENT HISTORY DOCUMENT REVISION LOG

The Document Revision Log identifies the series of revisions to this document since the baseline release. Please refer to the above page for version number information.

DOCUMENT TITLE: NVPS External Users Manual			
DOCUMENT CHANGE HISTORY			
Revision No.	Date	Revision Originator Project Group	CCR Approval # and Date

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## LIST OF CHANGES

Significant alterations made to this document are annotated in the List of Changes table.

<b>DOCUMENT TITLE: NVPS External Users Manual</b>					
<b>LIST OF CHANGE-AFFECTED PAGES/SECTIONS/APPENDICES</b>					
<b>Version Number</b>	<b>Date</b>	<b>Changed By</b>	<b>Page</b>	<b>Section</b>	<b>Description of Change(s)</b>

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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 Users 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 VI 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 1-1-1.

**Table 1-1 Product Team Members**

<b>Team Member</b>	<b>Organization</b>	<b>Role</b>	<b>Contact Information</b>
Marco Vargas	STAR	STAR Product Lead	5830 University Research Court Riverdale, MD. 20740 Phone: 301-683-3590



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TBD	TBD	Primary Maintenance Programmer	TBD
TBD	TBD	Secondary Maintenance Programmer	TBD
Donna McNamara	OSPO	Data Distribution	NSOF 1372 4231 Suitland Rd Suitland MD 20746 Phone: (301)817-3803 Email; <a href="mailto:donna.mcnamara@noaa.gov">donna.mcnamara@noaa.gov</a>

### 1.1.3. Product Description

The NVPS will continue generating 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

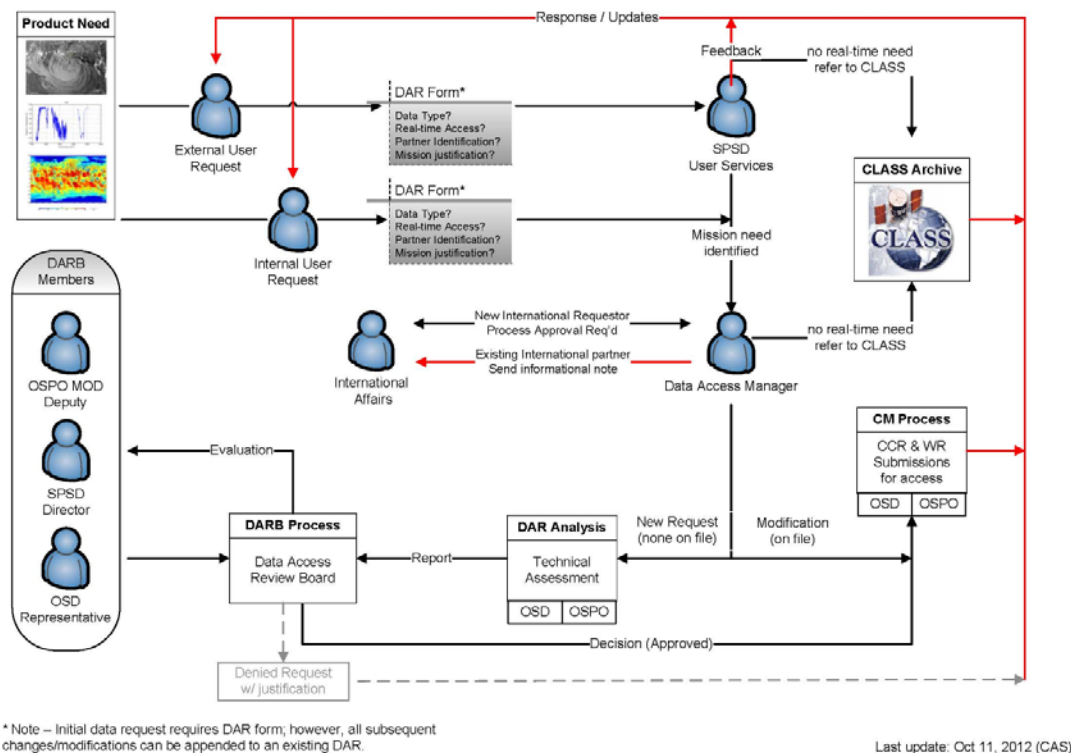
The NVPS is an upgrade to the S-NPP VIIRS GVF system that has been running operationally at NDE since February 2015. The S-NPP VIIRS GVF software system has been enhanced to generate along with the GVF products a gridded version (globally and regionally) of the VIIRS Vegetation Index (VI) EDR products 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](mailto: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 Data Distribution System currently distributing the ESPC data products and later by the Product Distribution and Access (PDA) system. The ESPC Data Distribution Manager, Donna McNamara ([donna.mcnamara@noaa.gov](mailto: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 needs 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](mailto: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

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SVI01	VI	TOA Reflectance at 640 nm	H5	IDPS
SVI02	VI	TOA Reflectance at 865 nm	H5	IDPS
JRR SR	GVF, VI	Surface Reflectance	netCDF4	NDE
JRR CM	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
VI-[DLY,WKL,BWKL]-REG _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 or 16]_c[YYYYMMDDhhmmsss].nc	This is the daily, weekly or biweekly regional VI product	netCDF4	Typical file 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

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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 2 KB
VI-[DLY,WKL,BWKL]-GLB _vxry_npp_s[YYYYMMDD1]_e[YYYYMMDD1,7 or 16]_c[YYYYMMDDhhmmsss]_stat.txt	Statistics file of the daily, weekly or biweekly global VI product for monitoring purposes	text	Typical file size 2 KB

**Table 1.5 NVPS output files standard name description**

Sequence	Description
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
hhmmss	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 VI product includes the following data fields:

- 1) Three VI Products: NDVI\_TOA, EVI\_TOC and NDVI\_TOC;
- 2) Five 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.

**Table 1-5 Data Fields of the NVPS VI Product**

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]

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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	10000	[-2,3]
I1_TOA	Top of Atmosphere Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-0.01,1.6]
I2_TOA	Top of Atmosphere Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-0.01,1.6]
I1_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-0.01,1.6]
I2_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-0.01,1.6]
M3_TOC	Top of Canopy Reflectance band	16-bit Integer	5000x10000 (Global) 10384x28889 (Regional)	-32768	10000	0	[-0.01,1.6]

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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]



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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] 130E->30E

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	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 = 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	1 = High	1

	<p>0 = Low</p> <p>NOTE: EVI quality is set to high (1) if ALL of these conditions are met:</p> <p>1) I1 Surface reflectance flag = available ; 2) I2 Surface reflectance flag = available</p> <p>3) M3 Surface reflectance flag = available;</p> <p>4) Cloud Confidence flag = confidently clear;</p> <p>5) Thin Cirrus flag = no thin cirrus; 6) Solar Zenith Angle &lt; 65 deg</p> <p>7) Sun glint (Geometry based) = none; 8) EVI range flag = in range</p> <p>9) No adjacency clouds; 10) No cloud shadows</p> <p>11) No snow/ice;</p> <p>12) Aerosol quantity = "low" or "medium" or "climatology"</p> <p>13) Cloud mask quality = "high" or "medium"</p>	
Overall TOC NDVI Quality	<p>1 = High</p> <p>0 = Low</p> <p>NOTE: TOC NDVI quality is set to high (1) if ALL of these conditions are met:</p> <p>1) I1 Surface reflectance flag = available ;</p> <p>2) I2 Surface reflectance flag = available</p> <p>3) Cloud Confidence flag = confidently clear;</p> <p>4) Thin Cirrus flag = no thin cirrus; 5) Solar Zenith Angle &lt; 65 deg</p> <p>6) Sun glint (Geometry based) = none</p> <p>7) No adjacency clouds</p> <p>8) No cloud shadows</p> <p>9) No snow/ice</p> <p>10) Aerosol quantity = "low" or "medium" or "climatology"</p> <p>11) Cloud mask quality = "high" or "medium"</p>	1
I1 TOA Reflectance	<p>1 = Not Available</p> <p>0 = Available</p>	1
I2 TOA Reflectance	<p>1 = Not Available</p> <p>0 = Available</p>	1
I1 Surface Reflectance	<p>1 = Not Available</p> <p>0 = Available</p>	1

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	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

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		1 = True (yes)	
	*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 overall Meta information of the NVPS VI Product is shown in Table 1-7.

**Table 1-7 Meta Information of the NVPS VI Product**

<p>Number of attributes = 29</p> <p>Conventions = CF-1.5</p> <p>Metadata_Conventions = CF-1.5, Unidata Dataset Discovery v1.0</p> <p>cdm_data_type = grid</p> <p>creator_email = yunyue.yu@noaa.gov/marco.vargas@noaa.gov</p> <p>creator_name = DOC/NOAA/NESDIS/STAR &gt; VI Team, Center for Satellite Applications and Research, NESDIS, NOAA, U.S. Department of Commerce</p> <p>creator_url = https://www.star.nesdis.noaa.gov/smcd/viirs_vi/Monitor.htm</p> <p>date_created = 2017-11-03T19:23:18Z</p> <p>geospatial_bounds = POLYGON((-180.0 90.0, 180.0 90.0, 180.0 -90.0, -180.0 -90.0, -180.0 90.0))</p> <p>geospatial_lat_resolution = 0.036</p>
--

geospatial\_lat\_units = degrees\_north  
geospatial\_lon\_resolution = 0.036  
geospatial\_lon\_units = degrees\_east  
history = Created by VI algorithm v1.0  
id = 51bfbb25-4be3-42cf-8932-68b26acfd5f  
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

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((130.0 90.0, 30.0 90.0, 30.0 -7.5, 130.0 -7.5, 130.0 90.0))  
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

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<pre>project = S-NPP Data Exploitation publisher_email = espcoperations@noaa.gov publisher_name = DOC/NOAA/NESDIS/NDE &gt; 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</pre>
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## 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](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](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
<b>M3</b>	<b>0.490</b>	<b>0.020</b>	<b>750</b>
M4	0.555	0.020	750
<b>I1</b>	<b>0.640</b>	<b>0.075</b>	<b>375</b>



M5	0.673	0.021	750
<b>I2</b>	<b>0.865</b>	<b>0.039</b>	<b>375</b>
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 NetCDF 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 ( $EVI_{\infty}$ ) 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  $EVI_{\infty}=0.6766$ , were empirically estimated, taken as the 5<sup>th</sup> and 95<sup>th</sup> percentiles from the probability distribution function of the weekly EVI maps.

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## 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

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

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 ( $0.003^\circ$ ). 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 VI 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 08/19/2015**

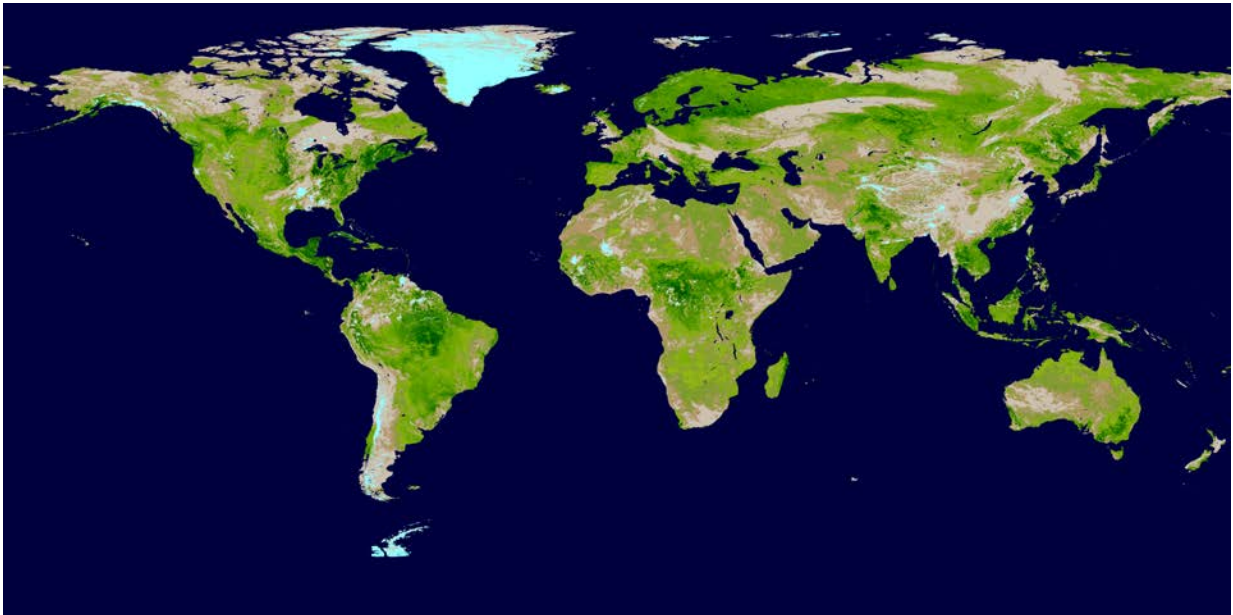
Area	ecosystem	lon_W	lon_E	lat_S	Lat_N	num_pixels	min_EVI	Max_EVI	Mean_EVI	Std_EVI	min_toandvi	Max_toanddvi	Mean_toandndvi	Std_toandvi	min_tocndvi	Max_tocnddvi	Mean_tocndndvi	Std_tocndvi
------	-----------	-------	-------	-------	-------	------------	---------	---------	----------	---------	-------------	--------------	----------------	-------------	-------------	--------------	----------------	-------------

Global	global	-180	180	-40	40	5841 920	-	0.463	1.002	0.176	0.206	-	0.749	0.827	0.242	0.167	-2.98	2.989	0.218	0.182
E-Sahara (LYBIA)	desert	23	24	28	29	841	0.115	0.125	0.12	0.002	0.149	0.166	0.155	0.002	0.119	0.135	0.125	0.003		
Great-Sandy (AUS)	semi-desert	125	126	-21	-20	841	0.077	0.147	0.128	0.009	0.201	0.262	0.233	0.01	0.163	0.235	0.204	0.01		
Colorado (USA)	steppe	-103	-102	36	37	841	0.07	0.57	0.238	0.08	0.105	0.586	0.3	0.087	0.077	0.597	0.287	0.095		
Illinois (USA)	crops	-89	-88	39	40	841	0.019	0.693	0.296	0.182	0.05	0.707	0.313	0.171	0.017	0.787	0.305	0.195		
Kentucky (USA)	broadleaf_forest	-85	-84	36	37	841	0.014	0.611	0.259	0.154	0.048	0.752	0.314	0.175	0.013	0.77	0.304	0.199		
Oregon (USA)	Coniferous_forest	-122	-123	43	44	841	0.078	0.447	0.297	0.073	0.055	0.736	0.631	0.1	0.161	0.726	0.605	0.115		
Amazon (BRAZIL)	Tropical_forest	-63	-62	-3	-2	812	0.113	0.454	0.38	0.06	0.215	0.719	0.611	0.108	0.197	0.764	0.643	0.129		

**Table 3-2 Example of regional VI statistics file for 08/19/2015**

Area	ecosystem	lon_W	lon_E	lat_S	Lat_N	num_pixels	min_EVI	Max_EVI	Mean_EVI	Std_EVI	min_toandvi	Max_toandvi	Mean_toandvi	Std_toandvi	min_tocndvi	Max_tocndvi	Mean_tocndvi	Std_tocndvi
E-Sahara (LYBIA)	desert	23	24	28	29	1254 4	0.113	0.128	0.12	0.003	0.148	0.168	0.155	0.002	0.117	0.137	0.125	0.003
Colorado (USA)	steppe	-103	-102	36	37	1265 6	0.02	0.887	0.228	0.114	0.066	0.769	0.321	0.135	0.035	1.036	0.312	0.156
Illinois (USA)	crops	-89	-88	39	40	1251 4	0.098	1.07	0.287	0.19	0.041	0.749	0.321	0.188	0.265	0.999	0.312	0.215
Kentucky (USA)	broadleaf_forest	-85	-84	36	37	1260 3	0.117	0.97	0.253	0.166	0.027	0.768	0.332	0.195	0.535	0.982	0.323	0.225
Oregon (USA)	coniferous_forest	-122	-123	43	44	1261 0	-0.19	0.527	0.297	0.083	0.297	0.774	0.631	0.114	-1	0.78	0.604	0.14
E-Sahara (LYBIA)	desert	23	24	28	29	1254 4	0.113	0.128	0.12	0.003	0.148	0.168	0.155	0.002	0.117	0.137	0.125	0.003

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.



**Figure 3-1** Example of global color-coded 0.036° EVI GeoTIFF produced for 08/19/2015.



**Figure 3-2** Example of regional color-coded 0.009° VI GeoTIFF produced for 08/19/2015

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 06/16/2013-06/22/2013**

Area	ecosystem	lon_W	lon_E	lat_S	Lat_N	num_pixels	min_gvf	Max_GV F	Mean_gvf	Std_gvf
Global	global	-180	180	-40	40	5874730	0	100	56.3	36.3
E-Sahara (LYBIA)	desert	23	24	28	29	841	13	17	14.6	0.7
Great-Sandy (AUS)	semi-desert	125	126	-21	-20	841	14	32	23.5	3.4
Colorado (USA)	steppe	-103	-102	36	37	841	24	100	52.9	22
Illinois (USA)	crops	-89	-88	39	40	841	82	100	95.9	3.7
Kentucky (USA)	broad_leaf_forest	-85	-84	36	37	841	98	100	100	0.1
Oregon (USA)	Coniferous_forest	-122	-123	43	44	841	78	100	88.5	4.1
Amazon (BRAZIL)	Tropical_forest	-63	-62	-3	-2	812	91	100	100	0.4

(Note: These statistics will be updated after the initial validation of the products is completed)

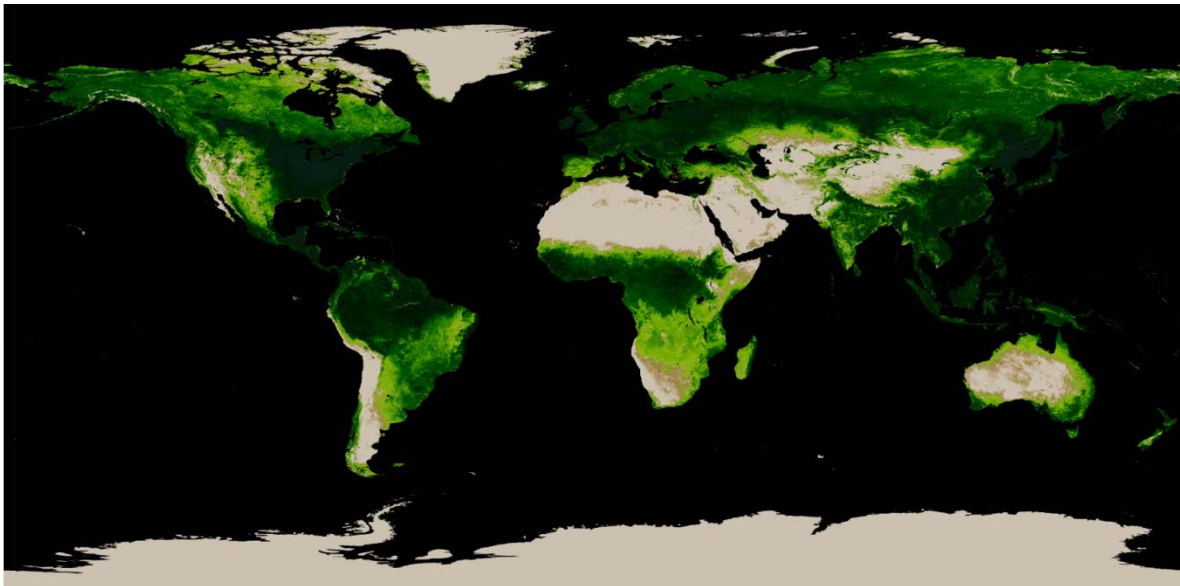
**Table 3-4 Example of regional GVF statistics file for the week 06/16/2013-06/22/2013**

Area	ecosystem	lon_W	lon_E	lat_S	Lat_N	num_pixels	min_gvf	Max_GV F	Mean_gvf	Std_gvf
E-Sahara (LYBIA)	desert	23	24	28	29	12544	12	18	14.5	0.8
Colorado (USA)	steppe	-103	-102	36	37	12656	20	100	51.9	24
Illinois (USA)	crops	-89	-88	39	40	12539	12	100	95.8	6.2
Kentucky (USA)	broad_leaf_forest	-85	-84	36	37	12643	52	100	100	1.5
Oregon (USA)	coniferous_forest	-122	-123	43	44	12538	46	100	88.5	7.3

(Note: These statistics will be updated after the initial validation of the products is completed)

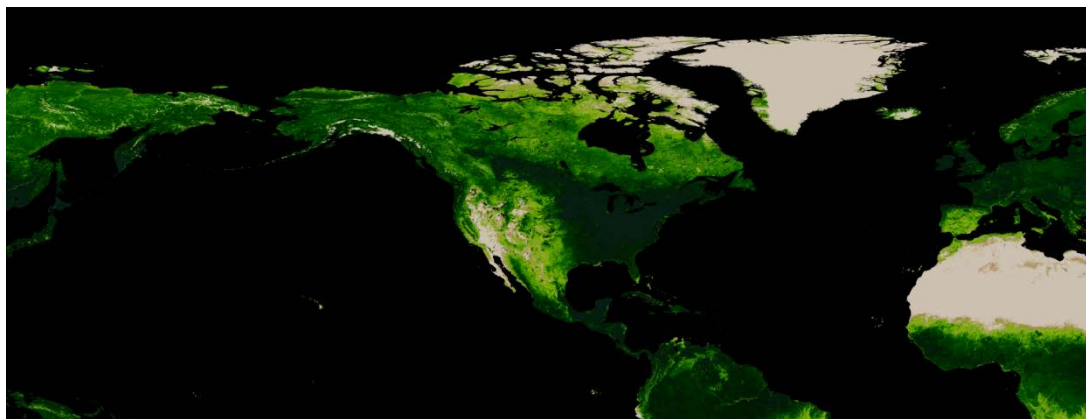
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For visual examination of product quality, color-coded GVF browse images in GeoTiff format for the global and regional GVF products are produced (Figures 3-3 and 3-4). The dimensions of the 0.036° resolution global GVF browse image are 10000 and 5000. 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 8/4/2013-8/10/2013.





**Figure 3-4** Example of regional color-coded **0.009°** GVF GeoTIFF produced from a weekly composited VIIRS data 8/4/2013-8/10/2013.

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	1

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		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"	
	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 Users 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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END OF DOCUMENT