Visible Infrared Imaging Radiometer Suite (VIIRS)
375 m & 750 m Active Fire Detection Data Sets Based on
NASA VIIRS Land Science Investigator Processing System (SIPS)
Reprocessed Data - Version 1

Product User's Guide Version 1.1

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May 2017

Table of Contents

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1. Introduction

This document describes the Suomi National Polar-orbiting Partnership Visible Infrared Imaging Radiometer Suite (S-NPP/VIIRS) active fire detection products based on that instrument's 375 m (I-bands) and 750 m (M-bands) nominal resolution version 1 (V1) reprocessed data from the NASA Land Science Investigator Processing System (SIPS). The VIIRS instrument was first launched on 28 October 2011, and is to be superseded by other similar instruments on board the Joint Polar Satellite System (JPSS) to enter operations in 2017. The first active fires detected with the VIIRS sensor occurred on 19 January 2012, when the instrument was fully commissioned.

The NASA Land-SIPS VIIRS 750 m active fire product (hereafter referred to as VNP14) evolved from the original (baseline) active fire detection designed to provide continuity to the 1-km Earth Observing System Moderate Resolution Imaging Spectroradiometer (EOS/MODIS) active fire data record. The original version of the VIIRS 750 m active fire product was based on the MODIS *Fire and Thermal Anomalies* (MOD14/MYD14) Collection 4 algorithm [Giglio *et al*., 2003], although lacking some key output science data sets found in the MODIS product such as the 2D image classification product (fire mask), and sub-pixel fire radiative power retrievals (FRP)[Csiszar *et al*., 2014]. That product was later replaced with the latest version (Collection 6) of the MODIS active fire algorithm equivalent [Giglio *et al*., 2016], incorporating all the missing output science data layers. NASA's Land-SIPS adopted the "VNP14" nomenclature for that version of the product.

The NASA-Land SIPS VIIRS 375 m active fire product (hereafter referred to as VNP14IMG) was proposed during the early post-launch period following the successful application of the 375 m data for active fire detection. This new application constituted a repurposing of the VIIRS 375 m (I) channels, as none of these channels were originally designed for active fire detection. Most importantly, abnormal radiometric conditions involving different pixel saturation scenarios are frequently observed in the primary mid-infrared (I4) channel, thereby requiring special handling of the data. Building on the MOD14/MYD14 algorithm, several modifications were implemented to accommodate the unique characteristics associated with the VIIRS 375 m data [Schroeder *et al*., 2014]. As a new application, the VNP14IMG data set is deemed *experimental* – the product's status is expected to change in the near future as provisions are added to the VIIRS program.

Due to its higher spatial resolution, the VNP14IMG active fire product provides greater response over fires of relatively small areas, as well as improved mapping of large fire perimeters. In comparison, the VNP14 fire data set provides rather similar performance relative to the MYD14 1-km product. Consequently, users should be aware of those differences and select the data set that is most appropriate for their own applications.

Currently, both VNP14 and VNP14IMG algorithms are in production although availability varies depending on the data processing environment. Users should consult Section 3 of this document for more information.

2. Fire Product Format

The VIIRS active fire data products were intentionally designed after the MOD14/MYD14 MODIS products in order to support data continuity between those two major satellite programs and their corresponding environmental data records. Data processing is divided primarily among the following levels:

- Level 2: swath data projection similar to input L1 data. No data resampling or other corrections are applied;
- Level 3: tiled data sets: spatial resampling performed using pre-determined projection type (e.g., sinusoidal) and fixed pixel size (e.g., 500 m) along with some temporal aggregation (e.g., files containing an 8-day data stack)
- Level 4: gridded data sets: spatial resampling performed in order to conform to Climate Modeling Grid (CMG) products (e.g., $0.25^o \times 0.25^o$ gridded data). Gridded data are corrected for cloud obscuration and sampling frequency, which will vary as a function of latitude.

Product nomenclature may vary according to data processing level and environment. Currently, only the Level 2 VNP14 and VNP14IMG active fire data sets are available.

2.1. Generic VIIRS Active Fire Product Level 2 Format

A single Level 2 file (granule) comprises a ≈6-min orbit segment spanning multiple scans (N), with each individual scan containing a fixed number of rows, with one row for each detector. VIIRS 375 m and 750 m channels have 32 and 16 detectors per scan, respectively. Individual rows contain a total of 6400 and 3200 samples (X axis) in the 375 m and 750 m data. Consequently, VIIRS Level 2 fire product granules will cover a total of $6400 \times N \times 32$ and $3200 \times N \times 16$ image elements in the 375 m and 750 m data, respectively, both describing a ground swath of approximately 3060 km wide.

Several global attributes are included in the Level 2 file providing comprehensive information about individual granules. Those attributes describe summary statistics detailing the number of fire, land, and water pixels, day/night flag, and the granule's beginning/ending times and bounding geographic coordinates, among others. Information about granule attributes can be accessed using NetCDF-enabled software.

The 8-bit image classification product ('*fire mask*') is the primary science data set (SDS) consisting of a two-dimensional array with same [x, y] dimensions as the input data driving the respective fire detection algorithms (Figure 1). The '*fire mask*' SDS consists of 10 different pixel classes that build on the heritage EOS/MODIS active fire product. Three of those classes are used to flag fire pixels along with their detection confidence. A quality assurance ('*algorithm QA*') SDS of same dimensions as the companion '*fire mask*' SDS provides complementary information for all pixels processed, and can be used to partially reconstruct the observation conditions pertinent to each case. In addition to the data above, sparse array SDSs are used to store several parameters for all fire pixels detected in each granule, including key information such as center pixel latitude and longitude, brightness temperatures on relevant channels, and FRP retrievals, among others (see Tables 3 & 6). The number of fire pixels detected in each granule is stored in the global attribute '*FirePix*'. That parameter is set to 0 and sparse array SDSs are empty when no fire pixels are detected in a granule.

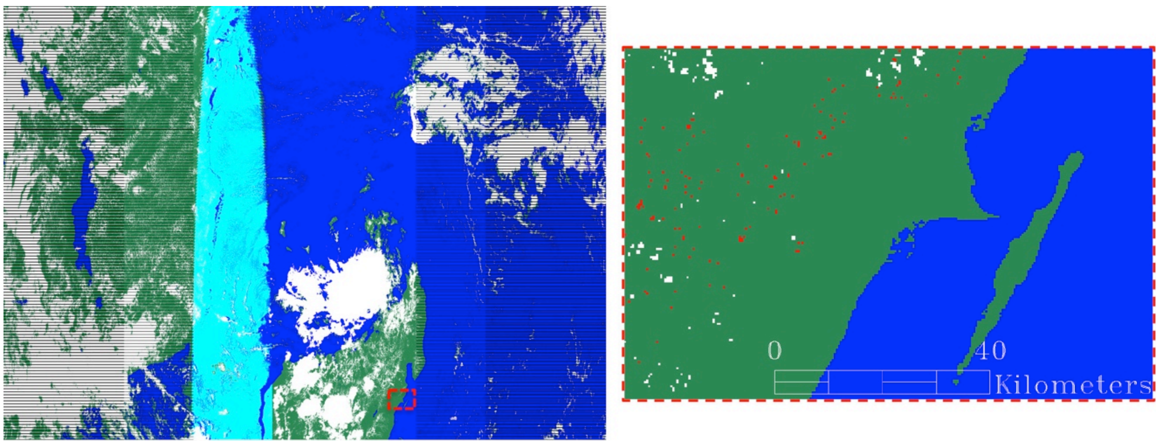


Figure 1: S-NPP/VIIRS active fire detection classification SDS ('*fire mask*') derived from single granule acquired on 22 November 2015 at ~1035UTC over parts of northern Madagascar and southeast Africa (left). Right panel shows magnified subset containing land (green), water (blue), clouds (white) and fire (red) pixels. Glint (cyan- exclusive to 375 m fire product) and bow-tie deletion (black) pixels are also visible in the large image.

2.2. The VNP4IMG Active Fire Data Set

The VNP14IMG 8-bit '*fire mask*' SDS classes are similar to the heritage MOD14/MYD14 data (Table 1). Class 0 identifies pixels that couldn't be processed due to missing or poor quality data in one or more of the input data layers. Class 1 is used to mark *bowtie* pixels corresponding to redundant data elements towards the edge of the swath that are deleted prior to relay to the ground stations in order to reduce downlink bandwidth [Wolfe *et al.*, 2013]. It is important to note that residual *bowtie* is still present in the regular input files. The fire algorithm will handle those redundant data as part of the regular processing sequence. Fire pixels identified as a residual *bowtie* are output to the VNP14IMG '*fire mask*' SDS (classes 7-9) and sparse array SDSs (Table 3), and marked up with a unique flag in the '*algorithm QA*' SDS (Table 2, bit 22). The latter should be used when emissions estimates based on FRP data are calculated, thereby avoiding potential double-counting of redundant FRP values.

Class 2 is used to mark areas potentially affected by Sun glint where pixels are processed although algorithm performance is normally reduced. Water, clouds and land pixels (classes 3-5) are classified using internal tests included in the algorithm along with a static land-water mask. Unclassified pixels (class 6) coincide with those cases when the analysis of individual pixels was prevented due to insufficient background information.

Low confidence (class 7) daytime fire pixels are typically associated with areas of Sun glint or water pixels, and lower relative temperature anomaly (<15K) in the mid-infrared channel I4. In order to minimize confusion among data users, low confidence pixels occurring over water or otherwise associated with the South Atlantic magnetic anomaly (see Schroeder *et al*. [2014] for details) are marked up with unique quality flags in the '*algorithm QA*' SDS (Table 2, bits 18-21). Those occurrences are predominantly linked to spurious detections although some verifiable fires may be mixed in. In order to prevent contamination of fire data displays, those pixels are assigned a corresponding *land* or *water* class in the '*fire mask*' SDS and removed from the sparse array SDSs (Table 3) describing the fire pixels detected.

Nominal confidence (class 8) pixels are those pixels free of potential Sun glint contamination during the day, and marked by strong (>15K) temperature anomaly in either day or nighttime data. Finally, high confidence (class 9) fire pixels are associated with day or nighttime saturated pixels, including nominal saturation and digital number (DN) folding (i.e., pixels that greatly exceed the saturation temperature causing the DN value to fold over; see Schroeder *et al*., [2014] for details).

Table 1: VNP14IMG '***fire mask***' SDS classes.

Pixel Class	Definition
0	Not processed
1	Bow-tie deletion
2	Sun glint
3	Water
4	Cloud
5	Land
6	Unclassified
7	Low confidence fire pixel
8	Nominal confidence fire pixel
9	High confidence fire pixel

A two-dimensional '*algorithm QA*' SDS complements the fire mask output providing quality assurance information for every pixel processed. The '*algorithm QA*' SDS is stored in 32-bit integer format populated with several fields that together can be used to reconstruct some of the key observation conditions pertinent to each pixel analyzed. Bits 0-6 describe the overall (nominal/non-nominal) quality of all input files used, followed by bits 7-18 describing primary and secondary fire detection tests (see Algorithm Theoretical Basis Document [ATBD][1] for details). Bits 19-22 are used to mark pixels associated with detection over water (persistence test) and/or *bowtie* conditions, whereas bit 23-31 are reserved for future use.

[1] VNP14IMG ATBD available at:
https://viirsland.gsfc.nasa.gov/PDF/ATBD_VIIRS_375m_activefire_algorithm.pdf

Table 2: VNP14IMG '*algorithm QA*' SDS bits and definition.

Bit	Description
0	Channel I1 quality (0 = nominal (or nighttime), 1 = non-nominal)
1	Channel I2 quality (0 = nominal (or nighttime), 1 = non-nominal)
2	Channel I3 quality (0 = nominal (or nighttime), 1 = non-nominal)
3	Channel I4 quality (0 = nominal, 1 = non-nominal)
4	Channel I5 quality (0 = nominal, 1 = non-nominal)
5	Geolocation data quality (0 = nominal, 1 = non-nominal)
6	Channel M13 quality (0 = nominal, 1 = non-nominal)
7	Unambiguous fire (0 = false, 1 = true [night only])
8	Background pixel (0 = false, 1 = true) BT_4 > 335 K AND ΔBT_{45} > 30 K OR saturation/folding (day) BT_4 > 300 K AND ΔBT_{45} > 10 K OR saturation/folding (night)
9	Bright pixel rejection (0 = false, 1 = true) ρ_3 > 30% AND $\rho_3 > \rho_2$ AND ρ_2 > 25% AND $BT_4 \leq$ 335K
10	Candidate pixel (0 = false, 1 = true) BT_4 > 325 K AND ΔBT_{45} > 25 K (daytime) BT_4 > 295 K AND ΔBT_{45} > 10 K (nighttime)
11	Scene background (0 = false, 1 = true) BT_4 > MIN([330, BT_{4M}]) (day)
12	Test 1 (0 = false, 1 = true) $\Delta BT_{45} > \Delta BT_{45B} + 2\times\delta_{45B}$ (day) $\Delta BT_{45} > \Delta BT_{45B} + 3\times\delta_{45B}$ (night)
13	Test 2 (0 = false, 1 = true) $\Delta BT_{45} > \Delta BT_{45B}$ +10 K (day) $\Delta BT_{45} > \Delta BT_{45B}$ +9 K (night)
14	Test 3 (0 = false, 1 = true) $BT_4 > BT_{4B} + 3.5\times\delta_{4B}$ (day) $BT_4 > BT_{4B} + 3\times\delta_{4B}$ (night)
15	Test 4 (0 = false, 1 = true) (day) $BT_5 > BT_{5B} + \delta_{5B}$ – 4 K OR δ'_{4B} > 5 K
16	Pixel saturation condition (0 = false, 1 = true) (day) $BT_5 \geq$ 325 K OR BT_4 = 367 K OR ΔBT_{45} < 0
17	Glint condition (0 = false, 1 = true) (day) $\Delta BT_{45} \leq$ 30 K OR Glint (θ_g) < 15°
18	Potential South Atlantic magnetic anomaly pixel (0 = false, 1 = true)
19	Fire pixel over water (0 = false, 1 = true)
20	Persistence test (0 = false, 1 = true) BT_{13}-MAX[BT_{13B}] < 2.5 K
21	Persistence test (0 = false, 1 = true) Number of previous co-located detections < 3
22	Residual *bow-tie* pixel (0 = false, 1 = true)
23-31	Reserved for future use

In addition to the '*fire mask*' and '*algorithm QA*' data layers above, sparse arrays provide several parameters for each individual fire pixel detected in the granule as described in Table 3.

Table 3: Complementary VNP14IMG SDSs. Individual data sets contain *n* entries each corresponding to *n* fire pixels detected. *N* is the number of scans in a granule. "≈" describes typical dynamic range (approximate).

Data set	Description	Units	Type	Range	Fill Value
FP_line	Fire pixel line	-	uint16	0 : (32×*N*)-1	-
FP_sample	Fire pixel sample	-	uint16	0 : 6399	-
FP_latitude	Fire pixel latitude	degrees	float32	-90 : +90	-
FP_longitude	Fire pixel longitude	degrees	float32	-180 : +180	-
FP_T4	Fire pixel channel I4 brightness temperature	kelvin	float32	≈ 208 : 367	-
FP_T5	Fire pixel channel I5 brightness temperature	kelvin	float32	≈ 205 : 380	-
FP_MeanT4	Background channel I4 brightness temperature	kelvin	float32	≈ 270 : 340	0
FP_MeanT5	Background channel I5 brightness temperature	kelvin	float32	≈ 265 : 330	0
FP_MeanDT	Background channel I4-I5 brightness temperature difference	kelvin	float32	≈ -10 : 50	0
FP_MAD_T4	Mean absolute deviation (channel I4 background)	kelvin	float32	≈ >0 : 20	0
FP_MAD_T5	Mean absolute deviation (channel I5 background)	kelvin	float32	≈ > 0 : 20	0
FP_MAD_DT	Mean absolute deviation (background channel I4-I5 temperature difference)	kelvin	float32	≈ > 0 : 20	0
FP_power	Fire radiative power	megawatts	float32	≈ > 0 : 1500	0
FP_Rad13	Channel M13 radiance of fire pixel	$W.m^{-2}.sr^{-1}.\mu m^{-1}$	float32	≈ > 0 : 400	0
FP_MeanRad13	Channel M13 mean background radiance	$W.m^{-2}.sr^{-1}.\mu m^{-1}$	float32	≈ > 0 : 10	0
FP_AdjCloud	Number of adjacent cloud pixels	-	uint16	0 : 8	-
FP_AdjWater	Number of adjacent water pixels	-	uint16	0 : 8	-
FP_WinSize	Window size (contextual analysis)	-	uint16	10 : 35	0
FP_confidence	Fire detection confidence (7=low, 8=nominal, 9 = high)	-	byte8	7 : 9	-
FP_day	Day/night flag	-	byte8	0 : 1	-
FP_SolZenAng	Fire pixel solar zenith angle	degrees	float32	0 : 180	-
FP_SolAzAng	Fire pixel solar azimuth angle	degrees	float32	-180 : 180	-
FP_ViewZenAng	Fire pixel view zenith angle	degrees	float32	0 : 70	-
FP_ViewAzAng	Fire pixel view azimuth angle	degrees	float32	-180 : 180	-

As a result of the FRP calculation method employed (see VNP14IMG ATBD for details), 375 m fire pixels co-located with a single 750 m pixel used in the retrieval will share the same fractional FRP value in MW (Figure 2). Users should be aware of this characteristic, which serves as an alternative solution to the frequent saturation of the mid-infrared I4 channel. Despite being extremely rare, M13 pixel saturation can occur over very large and intense active fires. In that event, 375 m fire pixels may still be detected and output (provided the algorithm is able to resolve those fires using the available data) whereas their FRP retrievals will be set to zero. Other situations involving challenging FRP retrieval (e.g., insufficient background data) may also result in fire pixels accompanied by null FRP values. We note that such cases are rather infrequent.

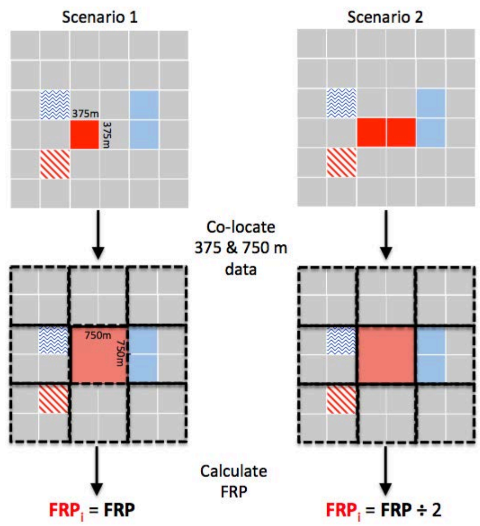


Figure 4: VNP14IMG FRP calculation using a combination of VIIRS 375 m and 750 m data. The former is used to identify fire-affected (solid and dashed red), cloud (solid blue), water (dashed blue), and valid background pixels (gray; in this case representing fire-free land surface). Co-located M13 channel radiance data (750 m) coinciding with fire pixel (red shade) and valid background pixels (gray-only) are used in the FRP calculation. In scenario 1, the single 750 m retrieval (center pixel; **FRP**) is assigned to the single coincident 375 m fire pixel (solid red; **FRP$_i$**, where *i* is the 375 m fire-affected sub-pixel index). In scenario 2, the single 750 m FRP retrieval is split between the two coincident 375 m fire-affected sub-pixels, so that **FRP$_i$** = **FRP**÷2.

2.3. The VNP14 Active Fire Data Set

The VNP14 '*fire mask*' pixel classes are essentially the same as in the MOD14/MYD14 product (Table 4). Pixel class 0 describes all pixels that could not be processed due to missing data (e.g., instrument is not pointing at the Earth) or poor quality data. *Bowtie* pixels discarded by the on-board trim procedure are designated as class 1. Class 3 is associated with water pixels identified with the ancillary land-water mask used in the algorithm, while class 4 is assigned to cloud-covered pixels that are classified using the algorithm's internal cloud detection tests. Class 5 refers to fire-free land pixels, and class 6 is reserved for pixels having insufficient background information for the detection algorithm to function. Classes 7-9 denote low, nominal, high confidence fire pixels, respectively, based on a heuristic measure of confidence [Giglio *et al.*, 2016].

Table 4: VNP14 '***fire mask***' data set classes.

Pixel Class	**Definition**
0	Not processed (no data or poor quality data)
1	Not processed (*bowtie* deletion)
2	Unused
3	Water
4	Cloud
5	Land
6	Unclassified
7	Low confidence fire pixel
8	Nominal confidence fire pixel
9	High confidence fire pixel

Like the '*fire mask*' data layer, the VNP14 quality assurance science data set ('*algorithm QA*') mimics the MOD14/MYD14 product. It consists of a 32-bit unsigned integer array containing additional information describing the observation conditions and analyses results for every pixel in the Level 2 data granule (Table 5).

Table 5: VNP14 '*algorithm QA*' data set bits and definition.

Bit	**Description**
0-1	land/water state (00 = water, 01 = coast, 10 = land, 11 = unused)
2	EDR ground trim zone (0= false, 1 = true)
3	atmospheric correction performed (0 = no, 1 = yes)
4	day/night algorithm (0 = night, 1 = day)
5	potential fire pixel (0 = false, 1 = true)
6	spare (set to 0)
7-10	background window size parameter
11-16	individual detection test flags (0 = fail, 1 = pass)
17-19	spare (set to 0)
20	adjacent cloud pixel (0 = no, 1 = yes)
21	adjacent water pixel (0 = no, 1 = yes)
22-23	Sun glint level (0-3)
24-28	individual rejection test flags (0 = false, 1 = true)
29-31	spare (set to 0)

Sparse arrays provide information for all fire pixels detected in the Level 2 granule as described in Table 6. Additional Climate Modeling Grid (CMG) layers are also found among the SDSs. Those CMG layers describe intermediate products used for the generation of Level 4 products by the VIIRS Science Team. Therefore, its description is beyond the scope of this document.

Table 6: Complementary VNP14 science data sets. Individual data sets contain *n* entries each corresponding to *n* fire pixels detected. *N* is the number of scans in a granule. "≈" describes typical dynamic range (approximate)

Data set	Description	Units	Type	Range	Fill Value
FP_line	Fire pixel line	-	uint16	0 : (16×N)-1	-
FP_sample	Fire pixel sample	-	uint16	0 : 3199	-
FP_latitude	Fire pixel latitude	degrees	float32	-90 : 90	-
FP_longitude	Fire pixel longitude	degrees	float32	-180 : 180	-
FP_R7	M7 reflectance of fire pixel	-	float32	≈ > 0: 0.35	-1
FP_T13	M13 brightness temperature of fire pixel	kelvin	float32	≈ 300 : 634	-
FP_T15	M15 brightness temperature of fire pixel	kelvin	float32	≈ 265 : 330	-
FP_MeanT13	M13 brightness temperature of background	kelvin	float32	≈ 260 : 340	0
FP_MeanT15	M15 brightness temperature of background	kelvin	float32	≈ 265 : 330	0
FP_MeanDT	Mean background M13-M15 brightness temperature difference	kelvin	float32	≈ -10 : 40	0
FP_MAD_T13	Background M13 brightness temperature mean absolute deviation	kelvin	float32	≈ > 0 : 20	0
FP_MAD_T15	Background M15 brightness temperature mean absolute deviation	kelvin	float32	≈ > 0 : 20	0
FP_MAD_DT	Background M13-M15 brightness temperature difference mean absolute deviation	kelvin	float32	≈ > 0 : 20	0
FP_power	Fire radiative power	megawatts	float32	≈ >0 : 5000	0
FP_AdjCloud	Number of adjacent cloud pixels	-	uint16	0 : 8	-
FP_AdjWater	Number of adjacent water pixels	-	uint16	0 : 8	-
FP_WinSize	Background window size (contextual analysis)	-	uint16	5 : 21	-
FP_NumValid	Number of valid background pixels	-	uint16		
FP_confidence	Detection confidence	-	uint8	0 : 100	-
FP_land	Land pixel flag	-	uint8		
FP_MeanR7	Background M7 reflectance	-	float32	≈ >0 : 0.6	-1
FP_MAD_R7	Background M7 reflectance mean absolute deviation	-	byte8	≈ >0 : 0.2	-1
FP_ViewZenAng	View zenith angle of fire pixel	degrees	float32	≈ 0 : 70	-
FP_SolZenAng	Solar zenith angle of fire pixel	degrees	float32	0: 180	-
FP_RelAzAng	Relative azimuth angle of fire pixel	degrees	float32	-180 : 180	-

2.4. ASCII PRODUCTS

Some online data outlets (e.g., NASA-LANCE Fire Information for Resource Management System [FIRMS]) may provide ASCII files containing summary data describing the geographic location of fire pixels (longitude and latitude of the pixel's centroid) along with other basic information such as acquisition time, fire radiative power, the pixel's brightness temperature in the primary mid- and long wave-infrared channels, detection confidence, among others. The format and content of those files may vary among data providers. Those ASCII data and their derivatives (e.g., shapefiles and KML files) are formatted for easy of use and quick display using common GIS software. Users seeking more detailed fire detection information (e.g., identifying areas of cloud coverage where fire pixels may be obscured) are encouraged to download the Level 2 data files and access the available science data sets and metadata.

3. DATA ACCESS

Currently, both VNP14IMG and VNP14 Level 2 products in NetCDF/HDF5 format are being generated by NASA's Land SIPS using the V1 reprocessed Level 1 data. The VNP14 product set can be accessed through NASA's Land Processes Distributed Active Archive Center (LP DAAC) at:
https://lpdaac.usgs.gov/

In addition to the LP DAAC data access portal, the VNP14IMG and VNP14 products are available through the Level 1 and Atmosphere Archive Distribution System (LAADS Web) public FTP site. For command line data transfer, users should login anonymously to the ladsweb FTP server and navigate to the following folder:

```
ftp ladsweb.nascom.nasa.gov
login: anonymous
password: guest    (any password will work)
cd allData/5000/VNP14IMG/
cd allData/5000/VNP14/
```

Users can also access the content of those folders by simply pointing their web browsers to the following links:
ftp://ladsweb.nascom.nasa.gov/allData/5000/VNP14IMG/
ftp://ladsweb.nascom.nasa.gov/allData/5000/VNP14/

Individual data files describe ≈6-min orbit segments. The filename convention (standard across Land SIPS products) is as follows:

VNP14IMG.A*YYYYDDD*.*HHMM*.vvv.*yyyydddhhmmss*.nc
VNP14.A*YYYYDDD*.*HHMM*.vvv.*yyyydddhhmmss*.nc

Where:

YYYYDDD	= year and Julian day (001-366) of data acquisition
HHMM	= hour and minute of data acquisition (approximate beginning time)
vvv	= version number
yyyyddd	= year and Julian day of data processing
hhmmss	= hour, minute, and second of data processing

Users are encouraged to consult the global attributes in the VNP14IMG and VNP14 files for additional metadata information describing those granules.

In addition to the standard Level 2 NetCDF/HDF5 file output, users can find links to near real-time (NRT) VNP14IMG data generated by NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) and distributed in GIS-friendly (e.g., ASCII, shapefile) formats. The VIIRS NRT active fire data are primarily meant for use in support of fire management applications requiring low-latency data access. Users are warned about possible coverage gaps resulting from temporary interruptions in the NRT data processing chain. In response to users' demand, only VNP14IMG data are produced and distributed in near real-time. Latency-insensitive applications demanding higher consistency (e.g., scientific studies) should favor the non-NRT VNP14IMG and VNP14 data stream serving the LP DAAC and LAADS Web archives.

The VIIRS NRT VNP14IMG product can be accessed through the NASA FIRMS portals:
https://earthdata.nasa.gov/viirs-fire-data
https://firms2.modaps.eosdis.nasa.gov/active_fire/viirs/

An online VIIRS NRT global data browser including VNP14IMG data visualization (Figure 6) is also available at:
https://earthdata.nasa.gov/labs/worldview/

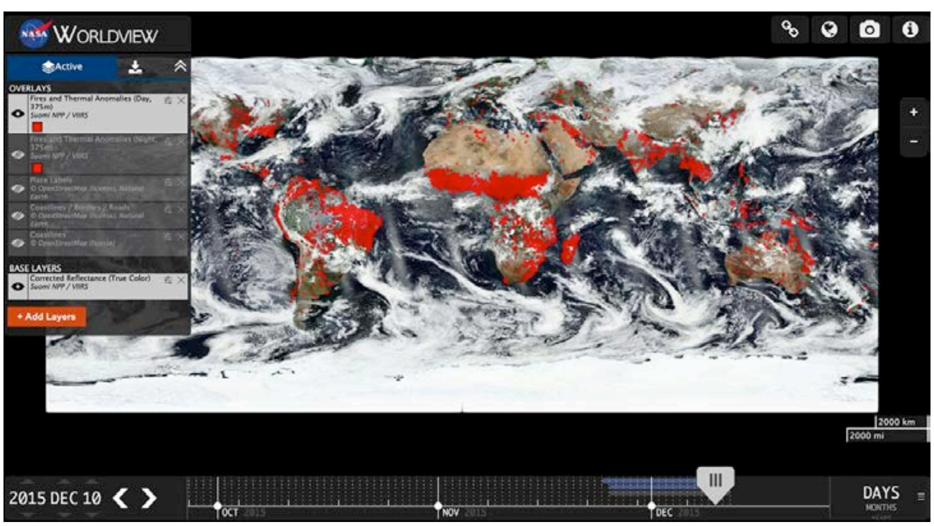


Figure 6: NASA's Worldview data display system showcasing VIIRS 375 m daytime global active fire detections for 10 December 2015.

4. DATA HANDLING

The Level 2 NetCDF VNP14IMG and VNP14 data sets are compatible with HDF5 and NetCDF4 libraries and can be read/handled using commercial off-the-shelf (e.g., ENVI/IDL) as well as publicly available software (e.g., HDFView). Example 1 describes a short IDL program that can be used to read the *'fire mask'*, *'FP_latitude'*, and *'FP_longitude'* science data sets contained in the NetCDF files. Due to the similarities between the VNP14IMG and VNP14 active fire product files, the code can be used interchangeably to read both products.

The Level 2 NetCDF output files are available in the satellite (swath) projection. A data reprojection tool can be downloaded from the VIIRS Land Science portal at: http://viirsland.gsfc.nasa.gov/Tools.html. The swath-to-grid tool allows users to convert the fire mask swath data into standard geo-referenced output files (e.g., GeoTIFF). The VIIRS geolocation data are needed to perform the transformation; users are referred to the tool's documentation for additional details. Example 2 demonstrates the use of the tool applied to a single VNP14IMG data file.

Example 1: IDL code designed to read VNP14IMG m or VNP14 active fire masks (2D array) and fire pixel latitude, longitude, and FRP vectors.

```
PRO read_viirs_fire_nc,input_file

      ;input_file = input VIIRS fire data file (string)
      ;example: '/data/VNP14IMG.A2016001.1200.001.2016001230000.nc'
      ;code will also work with VIIRS 750 m fire data (VNP14*.nc)

      ;Open file to read
      file_id = H5F_OPEN(input_file)
      ;Read fire mask data set (2D array)
      sd_id   = H5D_OPEN(file_id,'fire mask')
      fire_mask = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      ;Read global attribute containing number of fire pixels
      attr_id = H5A_OPEN_NAME(file_id,'FirePix')
      firepix = H5A_READ(attr_id)
      H5A_CLOSE,attr_id
      ;Read fire pixel info included among sparse arrays
      IF (firepix GT 0) THEN BEGIN
      ;Read fire pixel latitude data set (vector)
      sd_id   = H5D_OPEN(file_id,'FP_latitude')
      fp_latitude = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      ;Read fire pixel longitude data set (vector)
      sd_id   = H5D_OPEN(file_id,'FP_longitude')
      fp_longitude = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      ;Read fire pixel FRP data set (vector)
      sd_id   = H5D_OPEN(file_id,'FP_power')
      fp_power = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      ENDIF
      ;Close file
      H5F_CLOSE,file_id

END
```

Example 2: IDL code designed to read and resample VNP14IMG or VNP14 active fire masks (2D array) using the VIIRS reprojection tool, creating a 'resampled_data.tif' output file.

```
PRO resample_viirs_fire,input_fire,input_geo

      ;input_fire = input VIIRS fire data file
      ;example: '/data/VNP14IMG.A2016001.1200.001.2016001230000.nc'
      ;input_geo = input VIIRS geolocation data
      ;example: '/data/VNP03IMG.A2016001.1200.001.2016001230000.nc'
      ;code will also work with VIIRS 750 m data (VNP14*.nc and VNP03MOD*.nc)

      ;Read fire mask
      file_id = H5F_OPEN(input_fire)
      sd_id   = H5D_OPEN(file_id,'fire mask')
      fire_mask = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      H5F_CLOSE,file_id
      ;Read latitude and longitude
      file_id = H5F_OPEN(input_geo)
      dataset = STRCOMPRESS('/geolocation_data/latitude',/REMOVE_ALL)
      sd_id   = H5D_OPEN(file_id,dataset)
      latitude = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      dataset = STRCOMPRESS('/geolocation_data/longitude',/REMOVE_ALL)
      sd_id   = H5D_OPEN(file_id,dataset)
      longitude = H5D_READ(sd_id)
      H5D_CLOSE,sd_id
      H5F_CLOSE,file_id
      ;Create temporary EOS.hdf file containing mask, lat/lon layers
      dims = SIZE(fire_mask,/DIMENSIONS)
      fid = EOS_SW_OPEN('EOS.hdf', /CREATE)
      swathID = EOS_SW_CREATE(fid, "VIIRS_Swath")
      status = EOS_SW_DEFDIM(swathID, "Along_Scan", dims[0])
      status = EOS_SW_DEFDIM(swathID, "Along_Track",dims[1])
      status = EOS_SW_DEFGEOFIELD(swathID, "Latitude","Along_Scan,Along_Track", 5)
      status = EOS_SW_WRITEFIELD(swathID,"Latitude", latitude)
      status = EOS_SW_DEFGEOFIELD(swathID, "Longitude","Along_Scan,Along_Track", 5)
      status = EOS_SW_WRITEFIELD(swathID,"Longitude", longitude)
      status = EOS_SW_DEFDATAFIELD(swathID,"MASK","Along_Scan,Along_Track", 20)
      status = EOS_SW_WRITEFIELD(swathID,"MASK", fire_mask)
      status = EOS_SW_DETACH(swathID)
      status = EOS_SW_CLOSE(fid)
      ;Create temporary parameter file (customizable - see tool documentation)
      OPENW,lun,'file.prm',/GET_LUN
      PRINTF,lun,'NUM_RUNS = 1'
      PRINTF,lun,'BEGIN'
      PRINTF,lun,'INPUT_FILENAME = EOS.hdf'
      PRINTF,lun,'FIELD_NAME = MASK|'
      PRINTF,lun,'BAND_NUMBER = 1'
      PRINTF,lun,'INPUT_SWATH_FILLVALUE = 1'
      PRINTF,lun,'OUTPUT_PROJECTION_TYPE = GEO'
      PRINTF,lun,'OUTPUT_GRID_FILLVALUE = 0'
      ;Define custom parameters depending on input_fire data (VNP14 or VNP14IMG)
      IF dims[0] EQ 6400 THEN BEGIN
      PRINTF,lun,'OUTPUT_PIXEL_SIZE_X = 0.0035'  ;approx VNP14IMG resolution in degrees
      PRINTF,lun,'OUTPUT_PIXEL_SIZE_Y = 0.0035'  ;approx VNP14IMG resolution in degrees
      ENDIF ELSE BEGIN
      PRINTF,lun,'OUTPUT_PIXEL_SIZE_X = 0.007'   ;approx VNP14 resolution in degrees
      PRINTF,lun,'OUTPUT_PIXEL_SIZE_Y = 0.007'   ;approx VNP14 resolution in degrees
      ENDELSE
      PRINTF,lun,'MAXIMUM_WEIGHT_MODE = 1'
      PRINTF,lun,'WEIGHT_DISTANCE_MAX = 1.2'
      PRINTF,lun,'OUTPUT_FILENAME =  resampled_data.tif'
      PRINTF,lun,'OUTPUT_TYPE = GEO'
      PRINTF,lun,'END'
      FREE_LUN,lun
      FILE_DELETE,'resampled_data.tif',/QUIET ;del previous file to allow tool to write output
      ;Run reprojection tool (path must be updated to reflect location of the executable)
      SPAWN,'/home/Reproj_Tool/VIIRS_SwathToGrid -p file.prm',log_rep
      ;Delete temporary files
      FILE_DELETE,'file.prm','EOS.hdf','VIIRS_SwathToGrid.log',/QUIET
END
```

5. Frequently Asked Questions

Q: *Where can I find additional information on VIIRS active fire products*?
A: A dedicated website containing additional VIIRS fire data information is available at: http://viirsfire.geog.umd.edu/

Q: *Does the experimental status of the VNP14IMG mean lower data quality?*
A: No, the VNP14IMG algorithm underwent the same rigorous development process as the companion VNP14 data set including extensive testing and quality assessment. The *experimental* status is merely a formality associated with the applicable science data production and distribution rules at NASA. The VNP14IMG data set development was completed after the initial set of VIIRS land product suite had been proposed, thereby provisions for data archival were not in place. We expect the VNP14IMG product to be included in the next iteration of the VIIRS land product suite, after which its status shall be upgraded.

Q: *What is the temporal frequency of the VIIRS fire data*?
A: The 3060 km VIIRS swath enables ≈15% image overlap between consecutive orbits at the equator, thereby providing full global coverage every 12h. The nominal (equator-crossing) overpass times for S-NPP are 1:30pm and 1:30am. Thanks to its polar orbit, mid-latitudes will experience 3-4 looks a day.

Q: *What is the main difference between the VNP14IMG and VNP14 active fire data*?
A: The two data products use similar methodologies to detect active fire pixels although differences in the spectral characteristics of the VIIRS channels used in each case led to unique algorithms. Because of its improved spatial resolution, the VNP14IMG product will usually detect more fire pixels compared to VNP14. That difference is particularly pronounced during the nighttime part of the orbit when the occurrence of smaller/cooler fires will favor the VNP14IMG product.

Q: *Will the VNP14IMG fire product always outperform the lower resolution VNP14 product*?
A: Generally speaking, the higher spatial resolution product will achieve higher probability of fire detection in both day and nighttime scenes. Summary statistics were calculated using 90 consecutive days of coincident VNP14IMG and VNP14 product data for the entire globe resulting in the following:

<u>Daytime data</u>:

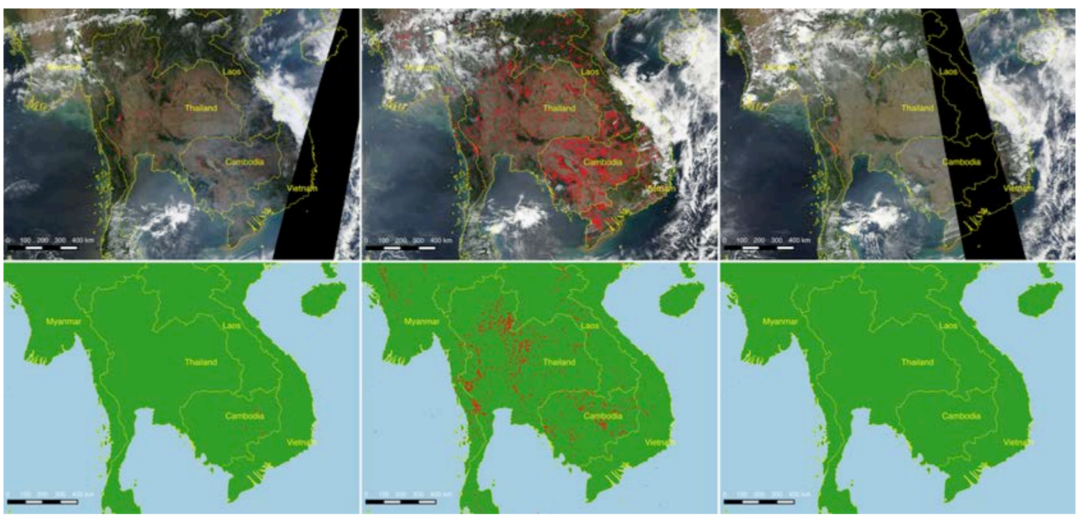
- VNP14IMG product detected up +3x more fire pixels (absolute difference) than the VNP14
- ≈45% of the daytime VNP14IMG fire pixels had no match in the VNP14 product
- ≈4% of the VNP14 daytime fire pixels had no match in the VNP14IMG product (concentrated occurrence in Sun glint areas due to more

conservative tests used in the VNP14IMG product. Other reasons vary, spatial mismatch/point spread function help explain part of it)

<u>Nighttime data</u>:

- VNP14IMG product picked up +20x more fire pixels (absolute difference) than the VNP14
- ≈80% of the VNP14IMG pixels had no match in the VNP14 product
- Rare/negligible occurrence of VNP14 fire pixels with no match in the VNP14IMG product (usually associated with areas of missing/poor-quality data in the VNP14IMG algorithm input)

The summary statistics above are meant for illustration purposes only and may vary based on sample size and geographic area analyzed. Differences between VNP14IMG m and MODIS 1 km fire detection performance are further magnified due to coverage gaps along the tropics and sampling characteristics (pixel enlargement away from nadir) impacting the MODIS data (Figure 7).



Daytime			Nighttime		
Terra/MODIS (04:05 UTC)	S-NPP/VIIRS (06:20 UTC)	Aqua/MODIS (07:10 UTC)	Terra/MODIS (14:55 UTC)	S-NPP/VIIRS (18:55 UTC)	Aqua/MODIS (19:20 UTC)
606	9,643	361	58	4,608	22

Figure 7: Fire detection maps and statistics for the Lower Mekong region in southeast Asia derived from Terra/MODIS (MOD14) (left panels), S-NPP/VIIRS (VNP14IMG) (center panels), and Aqua/MODIS (MYD14) (right panels) data acquired on 01 March 2016. Top panels show daytime fire pixels (red dots) overlaid on the corresponding true color RGB composite, whereas bottom panels show nighttime fire pixels overlaid on plain map. Blank sections on Terra and Aqua/MODIS RGB composites describe coverage gaps typically found across tropical regions. Identical fire pixel representation (size, form) was used in each panel.

Q: *How often do fire pixels saturate the 375 m mid-infrared (I4) channel*?
A: Quite often. There are three main scenarios associated with saturated pixels in the I4 mid-infrared channel used in the VNP14IMG active fire detection algorithm. First there is the typical saturation condition in which the pixel is assigned the

nominal saturation temperature of 367 K. The second scenario involves the more extreme case when the fire signal will greatly exceed the dynamic range of channel I4. In that case, the pixel's digital number will fold over and show an abnormally low temperature which can be confronted by the companion long-wave infrared channel (I5) data. The third and last scenario is the more challenging one. It represents those cases when native pixels that reach saturation are mixed with other non-saturated pixels during onboard data aggregation resulting in corrupted Level 1 radiances. Currently, there are no quality flags available in the input Level 1 data indicating those anomalies. The different saturation scenarios above are believed to have small/negligible effect on the fire detection performance. However, their occurrence is a major factor limiting the retrieval of sub-pixel fire characteristics (FRP) using the I4 channel.

Q: *Are the VIIRS active fire data science-ready*?
A: The VIIRS active fire data have been extensively tested since routine production of the mission's data record started in 19 January 2012. Numerous bad scan episodes (i.e., pixel clusters containing spurious radiances and incorrectly classified as fire extending across the swath) were found in the Level 1 input data during the initial 18-24 months of the time series [Csiszar *et al*., 2014]. Those anomalies were gradually addressed by the VIIRS calibration team and their occurrence have significantly dropped, though not completely eliminated, with the implementation of revised Level 1 data processing packages in 2015. Consequently, the Land-SIPS V1 reprocessed data may still show few isolated granules affected by those anomalies. Those granules may be removed from the archive in cases when corrective measures are exhausted.

Initial assessment of both VNP14IMG and VNP14 data was implemented over a few experimental sites indicating consistent fire detection and characterization performance (e.g., Dickinson *et al*. [2015]). Additional data comparison analyses were implemented using near coincident Aqua/MODIS and TET-1 (German Aerospace Center) active fire data, which again showed consistent performance of the VIIRS active fire products across different observation conditions [Rucker *et al*., 2016]. Consequently, we consider the current data of good enough quality for use in fire management applications and scientific studies. However, users must be aware of the quality limitations involving the publicly available data record. Make sure to consult the online documentation describing the primary data archives at http://viirsfire.geog.umd.edu/.

Q: *Is this product still being refined*?
A: Absolutely. The current suite represents the second release of the VNP14IMG and VNP14 active fire algorithms; data imperfections can – and likely will – occur. As with other satellite data products, the VIIRS active fire algorithm development undergoes routine quality control during which data issues such as omission errors, false alarms and other anomalies are investigated and addressed. New versions of the products will be released once algorithm revisions are implemented and tested. Users are encouraged to report back to the science team when encountering potential data discrepancies.

6. References

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