Collection 2 Visible Infrared Imaging Radiometer Suite (VIIRS) 375-m Active Fire Product User's Guide

Version 1.0

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Document Change History

Version	Date	Description
1.0	5/2024	Original version adapted from C1 User’s Guide.

1. Introduction

This document describes the Visible Infrared Imaging Radiometer Suite (VIIRS) 375-m active fire product generated in NASA's Land Science Investigator Processing System (SIPS). The VIIRS sensor was first deployed on the Suomi National Polar-orbiting Partnership (S-NPP) VIIRS instrument in October 2011 and has since been complemented with additional VIIRS sensors on board the NOAA-20 and NOAA-21 satellites launched in 2017 and 2022, respectively. The first active fires detected with the VIIRS sensor occurred on 19 January 2012, when the inaugural instrument was fully commissioned.

The 375-m VIIRS active fire product is generated independently for each VIIRS sensor and is designated "VNP14IMG", "VJ114IMG", and "VJ214IMG" in reference to the S-NPP, NOAA-20, and NOAA-21 platforms, respectively. For the sake of brevity, we will hereafter use VNP14IMG to refer to all three products collectively, with platform-specific product caveats noted as necessary.

A complementary NASA VIIRS 750-m active fire product ("VNP14") is produced using an adaptation of the Collection-6 Moderate Resolution Imaging Spectroradiometer (MODIS) *Fire and Thermal Anomalies* (MOD14/MYD14) detection algorithm [Giglio *et al*., 2016]. Details of the 750-m VNP14 active fire product may be found in the separate *750-m Visible Infrared Imaging Radiometer Suite (VIIRS) Active Fire Product User's Guide* [Giglio *et al.*, 2024].

The VNP14IMG active fire product 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-band) 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 MODIS detection algorithm, several modifications were implemented to accommodate the unique characteristics of the 375-m VIIRS imagery [Schroeder *et al*., 2014].

Due to its higher spatial resolution, the VNP14IMG fire product provides much higher sensitivity to fires of relatively small size, as well as improved mapping of large fire perimeters. In comparison, the VNP14 product provides performance that is more comparable to the 1-km Aqua MODIS fire product (MYD14). Consequently, users should be aware of those differences and select the data set that is most appropriate for their own applications.

2. Summary of Collection 2 VNP14IMG algorithm and product changes

The Collection-2 VNP14IMG fire product incorporates the following improvements:

- The fire product is now produced using the significantly improved and much more robust Collection-2 NASA Level-1B VIIRS radiance and geolocation products. Among other advantages, these upstream inputs do not suffer from the frequent occurrence of spuriously calibrated "bad scans" that plagued the Science Data Record (SDR) Level-1B inputs used for Collection 1;
- the detection algorithm exploits new quality flags provided in the Collection-2 Level-1B product to virtually eliminate the spurious detections that were common for Collection 1;
- product files are significantly smaller due to better use of internal NetCDF compression.

3. VNP14IMG product suite

3.1 Level-2 (swath) VNP14IMG active fire product

3.1.1 Overview

A single Level 2 file (granule) comprises a 6-minute orbit segment spanning $N \approx 202$ scans, with each scan containing a fixed number of rows, with one row for each detector. VIIRS 375-m channels have 32 detectors per scan, and individual rows contain a total of 6400 samples (X axis). Consequently, 375-m VIIRS Level 2 fire product granules cover a total of $6400 \times N \times 32$ image elements, 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 the 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 and 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.

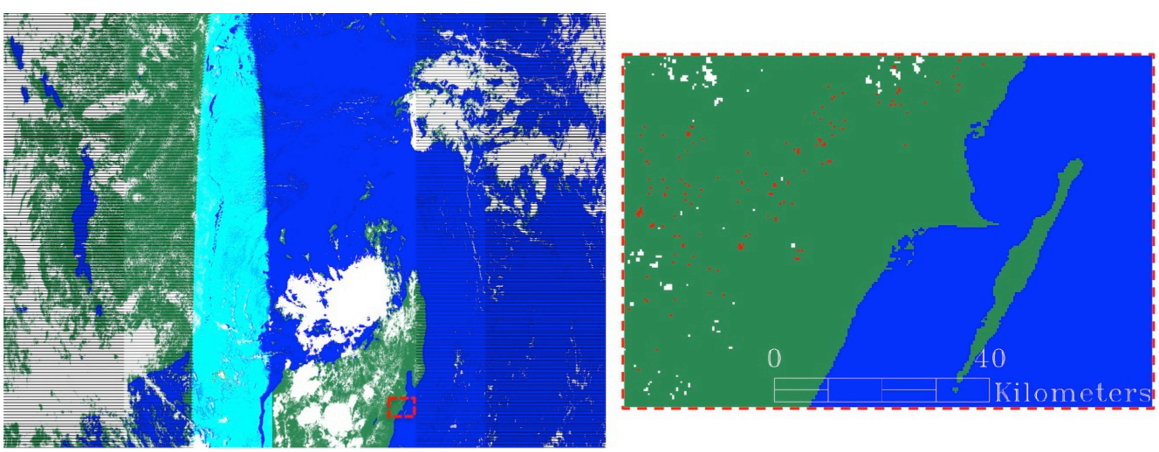


Figure 1: S-NPP VIIRS active fire detection classification SDS ('*fire mask*') derived from a single granule acquired on 22 November 2015 at ~10:35 UTC over parts of northern Madagascar and southeast Africa (left). Right panel shows a magnified subset containing land (green), water (blue), clouds (white) and fire (red) pixels. Glint (cyan- exclusive to 375-m fire product) and bow-tie deletion (black) pixels are also visible in the larger image.

3.1.2 Data layers

The VNP14IMG 8-bit '*fire mask*' SDS classes are similar to the heritage MOD14/MYD14 data (Table 1). Class 0 identifies pixels that could not 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* pixels are 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 residual *bowtie* data 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. Clouds, water 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 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 layer providing quality assurance information for every pixel processed. This SDS is stored as a 32-bit integer array 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 residual *bowtie* data, whereas bit 23-31 are reserved for future use.

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 $\Delta BT_{45} > 30$ K OR saturation/folding (day) $BT_4 > 300$ K AND $\Delta BT_{45} > 10$ K OR saturation/folding (night)
9	Bright pixel rejection (0 = false, 1 = true) $\rho_3 > 30\%$ AND $\rho_3 > \rho_2$ AND $\rho_2 > 25\%$ AND $BT_4 \leq 335$K
10	Candidate pixel (0 = false, 1 = true) $BT_4 > 325$ K AND $\Delta BT_{45} > 25$ K (daytime) $BT_4 > 295$ K AND $\Delta BT_{45} > 10$ K (nighttime)
11	Scene background (0 = false, 1 = true) $BT_4 > \mathrm{MIN}([330, BT_{4M}])$ (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 $\delta'_{4B} > 5$ K
16	Pixel saturation condition (0 = false, 1 = true) (day) $BT_5 \geq 325$ K OR $BT_4 = 367$ K OR $\Delta BT_{45} < 0$
17	Glint condition (0 = false, 1 = true) (day) $\Delta BT_{45} \leq 30$ K OR Glint $(\theta_g) < 15^o$
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 *bowtie* pixel (0 = false, 1 = true)
23-31	Reserved for future use

[1] https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_375m_ATBD.pdf

In addition to the '*fire mask*' and '*algorithm QA*' data layers above, sparse arrays provide numerous attributes of each 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 I4 brightness temperature	kelvin	float32	≈ 208 : 367	-
FP_T5	Fire pixel I5 brightness temperature	kelvin	float32	≈ 205 : 380	-
FP_MeanT4	Background I4 brightness temperature	kelvin	float32	≈ 270 : 340	0
FP_MeanT5	Background I5 brightness temperature	kelvin	float32	≈ 265 : 330	0
FP_MeanDT	Background 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	M13 radiance of fire pixel	W m^{-2} sr^{-1} μm^{-1}	float32	≈ > 0 : 400	0
FP_MeanRad13	M13 mean background radiance	W m^{-2} sr^{-1} μm^{-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	-

3.1.3 FRP retrieval

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. Such cases are rather infrequent.

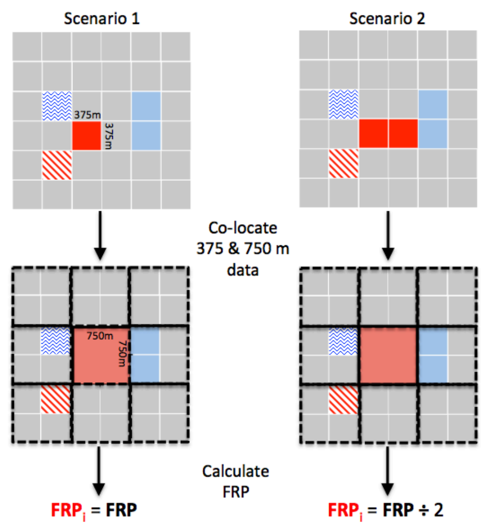


Figure 2: VNP14IMG FRP calculation using a combination of 375-m and 750-m data. The former is used to identify fire-affected (solid and dashed red), cloud (solid blue), water (dashed blue), and valid background pixels (gray; in this case representing fire-free land surface). Co-located 750-m M13 radiance coinciding with fire pixel (red shade) and valid background pixels 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.

3.2 VNP14IMGML monthly fire location product

Monthly fire-pixel locations and attributes are available in ASCII format mimicking the heritage MCD14ML product (*MODIS Collection 6 and Collection 6.1 Active Fire Product User's Guide* [2021]). Fire pixels are grouped into global monthly VNP14IMGML (S-NPP), VJ114IMGML (NOAA-20), and VJ214IMGML (NOAA-21) summary files, and carry essential fire detection information in comma-separated format that can be easily displayed on a map using common GIS software.

3.2.1 Naming convention

The monthly fire location product file naming convention is as follows:

`Vxx14IMGML.YYYMM.CC.VV.csv`

where

`XX`	= platform ("NP" = S-NPP, "J1" = NOAA-20, "J2" = NOAA-21)
`YYYYMM`	= year and month (1-12) of data acquisition
`CC`	= collection number (currently "02")
`VV`	= product version number (currently "02")

3.2.2 Product contents

Following a one-line header, each monthly fire location product file contains the following comma-separated fields:

YYYYMMDD	Detection date in year (YYYY), month (MM) and day (DD)
HHMM	UTC detection hour (HH) and minute (MM)
Line	VIIRS I-band image line number of fire pixel
Sample	VIIRS I-band image sample number of fire pixel (range 0-6399)
Lat	Fire pixel latitude (degrees)
Lon	Fire pixel longitude (degrees)
T4	Fire pixel brightness temperature on channel I4 (K)
T5	Fire pixel brightness temperature on channel I5 (K)
MeanT4	Background I4 brightness temperature (K)
MeanT5	Background I5 brightness temperature (K)
MeanDT	Background I4-I5 difference (K)
MADT4	Background T4 mean absolute deviation (K)
MADT5	Background T5 mean absolute deviation (K)
MADDT	Background DT mean absolute deviation (K)
FRP	Fire radiative power (MW)
Rad13	Fire pixel channel M13 radiance (W m^{-2} sr^{-1} μm^{-1})
Mean13	Background channel M13 radiance (W m^{-2} sr^{-1} μm^{-1})
AdjC	Number of adjacent cloud pixels (range 0-8)
AdjW	Number of adjacent water pixels (range 0-8)
WinS	Background window size (range 10-35)
Confidence	Confidence class ("L"=low, "N"=nominal, "H"=high)
DNFlag	Day/night flag ("D" or "N")
SZA	Fire pixel solar zenith angle (degrees)
SAA	Fire pixel solar azimuth angle (degrees)
VZA	Fire pixel view zenith angle (degrees)
VAA	Fire pixel view azimuth angle (degrees)
Glint	Glint angle (degrees)
Type	Type attributed to thermal anomaly: 0 = presumed vegetation fire, 1 = active volcano, 2 = other static land source, 3 = offshore detection (includes all detections over water)
PixArea	VIIRS I-band fire pixel area (km^2)

Warning: Creating ESRI shapefiles from VNP14IMGML CSV files is not recommended since the 2-GB size limit of the former will often be inadequate to contain the full contents of a VNP14IMGML product file. Instead, users are advised to employ ESRI layer files or consider alternative formats such as GeoJSON or ESRI file geodatabase if conversion from the CSV format is desired. These alternatives will help ensure the integrity of your data.

4. Data access

The first several hours of S-NPP/VIIRS data acquired after the nominal start of sensor operations on 19 January 2012 were characterized by the cooling of onboard calibration sources, with gradual improvement and stabilization of thermal emissive-band performance. For practical purposes, users should adopt 20 January 2012 as the effective start date of the VIIRS active fire data record.

4.1 Level-2 VNP14IMG (swath) NetCDF4/HDF5

The VNP14IMG and VJ114IMG Level-2 swath products are generated in NetCDF4/HDF5 format by NASA's Land-SIPS. These products can be accessed through NASA's Land Processes Distributed Active Archive Center (LP DAAC) at:

https://lpdaac.usgs.gov/products/vnp14imgv002/
https://lpdaac.usgs.gov/products/vj114imgv002/

In addition to the LP DAAC data access portal, these products are also available through the Level 1 and Atmosphere Archive Distribution System (LAADS Web) public web site:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5200/VNP14IMG/
https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5200/VJ114IMG/

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

V*xx*14IMG.A*YYYYDDD*.*HHMM*.*ccc*.*yyyydddhhmmss*.nc

where

xx	= platform ("NP" = S-NPP, "J1" = NOAA-20, "J2" = NOAA-21)
YYYYDDD	= year and Julian day (001-366) of data acquisition
HHMM	= hour and minute of data acquisition (approximate beginning time)
ccc	= collection number (currently "002")
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 files for additional metadata describing those granules.

4.2 VNP14IMGML fire location data

The VNP14IMGML product can be downloaded by connecting to an SFTP server at the University of Maryland. The login information is as follows:

```
server:    fuoco.geog.umd.edu
login:     fire
password:  burnt
directory: data/VIIRS/C2/VNP14IMGML
```

New VNP14IMGML files are created regularly and posted to the SFTP server above 1–2 months after all Level-2 granules for a given calendar month are generated by NASA.

For downloading product files, you can use the command-line `sftp` and `lftp` clients, or freely available GUI file transfer software such as FileZilla (https://filezilla-project.org) and Cyberduck (https://cyberduck.io/). SFTP-capable commercial software is also available and includes the examples listed below.

For Windows:

- SmartFTP (https://www.smartftp.com/)
- WinSCP (https://winscp.net)

For MacOS:

- ForkLift (https://binarynights.com/)
- Commander One (https://mac.eltima.com/file-manager.html)
- Transmit (https://panic.com/transmit/)
- Viper FTP (https://viperftp.com/)
- Flow (http://fivedetails.com/)

4.2.1 Example SFTP command-line session (abridged)

```
$ sftp fire@fuoco.geog.umd.edu
Password:
Connected to fuoco.geog.umd.edu.
sftp> cd data/VIIRS/C2/VNP14IMGML
sftp> progress
Progress meter disabled
sftp> get VNP14IMGML.2018*
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201801.C2.02.csv.gz to
VNP14IMGML.201801.C2.02.csv.gz
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201802.C2.02.csv.gz to
VNP14IMGML.201802.C2.02.csv.gz
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201803.C2.02.csv.gz to
VNP14IMGML.201803.C2.02.csv.gz
                                ⋮
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201810.C2.02.csv.gz to
VNP14IMGML.201810.C2.02.csv.gz
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201811.C2.02.csv.gz to
VNP14IMGML.201811.C2.02.csv.gz
Fetching /data/VIIRS/C1/VNP14IMGML/VNP14IMGML.201812.C2.02.csv.gz to
VNP14IMGML.201812.C2.02.csv.gz
sftp> bye
```

4.3 Near-real time fire data

In addition to the standard Level 2 NetCDF4/HDF5 and CSV formats, users can obtain near-real time (NRT) VNP14IMG and VNP14 data generated by NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE). The former is additionally 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. 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://firms.modaps.eosdis.nasa.gov/active_fire/

An online VIIRS NRT global data browser including VNP14IMG data visualization (Figure 3) is also available at:

https://earthdata.nasa.gov/labs/worldview/

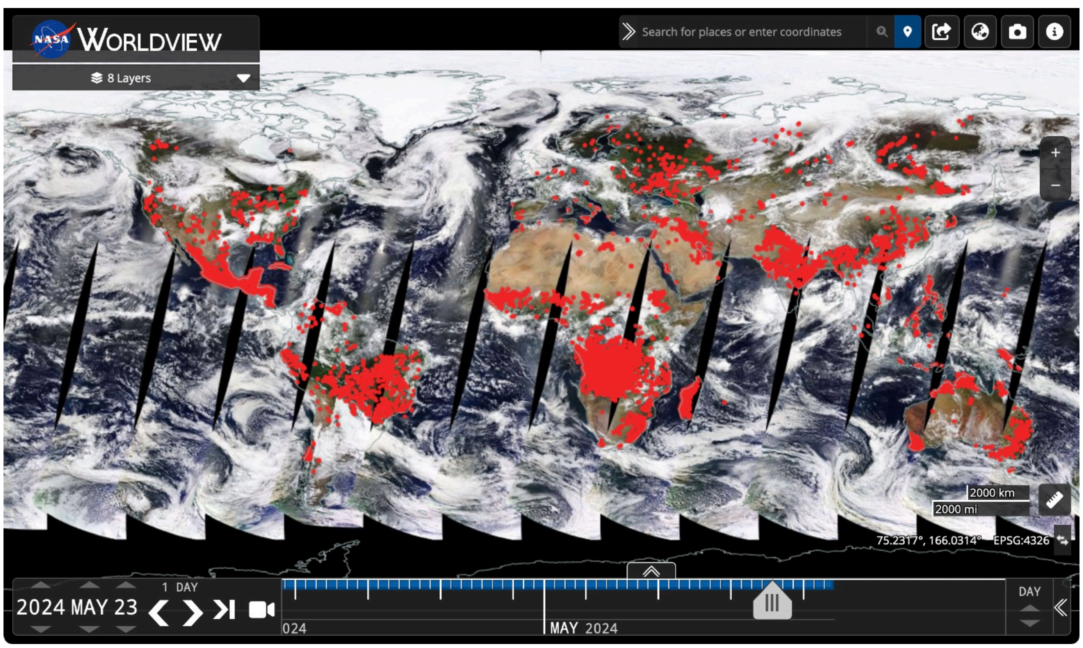


Figure 3: NASA's Worldview system showcasing VIIRS 375-m daytime global active fire detections for 23 May 2024.

5. Data handling

The Level 2 VNP14IMG product is compatible with the NetCDF4 and HDF5 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 provides a short IDL program that can be used to read the *'fire mask'*, *'FP_latitude'*, and *'FP_longitude'* variables contained in the Level 2 (swath) product files.

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
```

6. Frequently asked questions

Q: *What is the temporal frequency of the VIIRS fire data*?
A: The 3060-km VIIRS swath results in ≈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 1:30 pm and 1:30 am. Due to the S-NPP 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 enhanced ability to detect fires in general (compared to daytime detection) 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 one year (2021) of Collection-2 VNP14IMG and VNP14 product data for the entire globe, with the following results:

Daytime observations

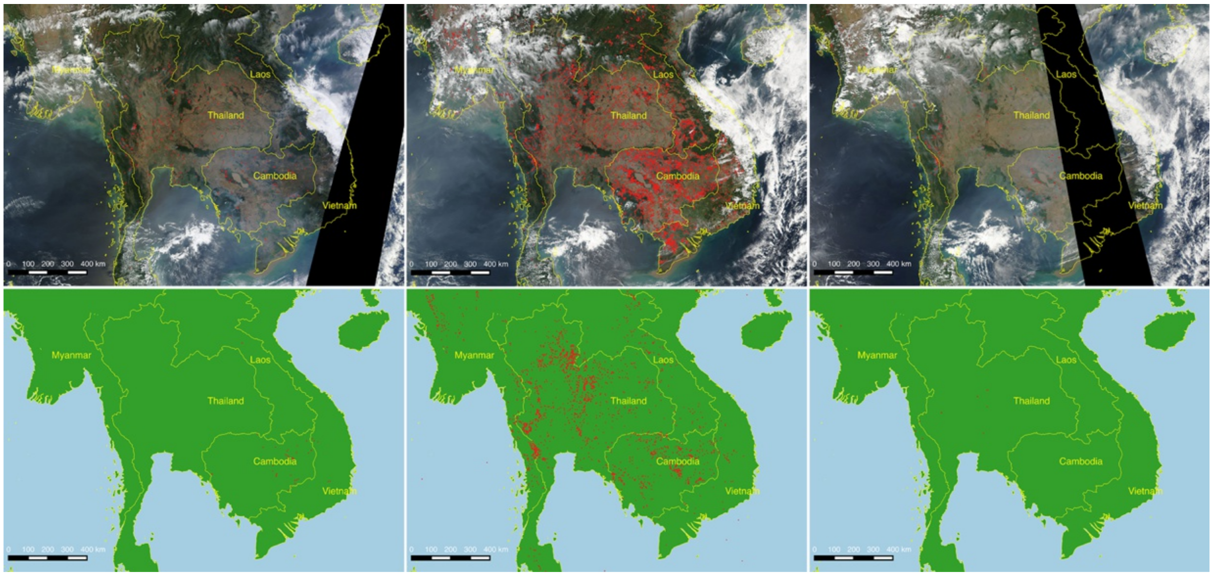
- The VNP14IMG product detected ~3× more daytime fire pixels (absolute) than the VNP14 product;
- 53% of the daytime VNP14IMG fire pixels had no match in the VNP14 product;
- 11% of the VNP14 daytime fire pixels had no match in the VNP14IMG product, with at least some of this surplus concentrated in sun glint areas due to the more conservative glint rejection tests used in the VNP14IMG algorithm.

Nighttime observations

- The VNP14IMG product detected ~17× more nighttime fire pixels (absolute) than the VNP14 product;
- 85% of the VNP14IMG fire pixels had no match in the VNP14 product, with a slightly larger proportion (19% versus 13%) of this subset residing in the non-vegetation-fire category compared to those nighttime VNP14IMG pixels that had a match in the VNP14 product;
- 0.8% of the VNP14 nighttime fire pixels had no match in the VNP14IMG product.

Note that these summary statistics are very broadly representative and will vary with the sample size and geographic area analyzed.

Differences between the 375-m VNP14IMG and 1-km Aqua MODIS fire products are further magnified due to MODIS coverage gaps along the tropics and the sampling characteristics (specifically, pixel enlargement away from nadir) of the MODIS sensor (Figure 4).



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 4: 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 1 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 that can be identified using the companion long-wave infrared (channel I5) signal. 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 on-board data aggregation resulting in spurious Level 1 radiances. Currently, there are no quality flags available in the input Level 1 data indicating these spurious radiance values. 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: A few VNP14IMG fire pixels were located outside the reported perimeter of a large wildfire. Was it an error? What data source should I trust?
A: In this circumstance users may need to look for additional clues when there is indication of potential commission error surrounding large wildfires. There have been a few instances involving

large and intense wildfires over which tall plumes carrying large volumes of hot material into the air were formed when the VNP14IMG product detected the surface fire along with part of the plume. Those occurrences typically share the following set of conditions:

(i) Nighttime detection. This is the period during which the VNP14IMG product is particularly responsive to heat sources thereby favoring plume detection;

(ii) Very large wildfires undergoing explosive growth and accompanied by rapid/vertically elongated plume development. Enough hot material must entrain the plume creating a distinguishable thermal signal (i.e., one that significantly exceeds the fire-free surface background);

(iii) High scan angle. This is what will ultimately produce the detections extending beyond the actual fire perimeter. The parallax effect causes the tall/super-heated plume detection pixel(s) to be displaced laterally when projected onto the surface. Displaced pixels will be located on the fire perimeter's side further away from the image center and closer to the swath's edge.

If those conditions apply, look for alternative observations (previous/next overpass) acquired closer to nadir and try and prioritize the use of the fire detection data accordingly. Unfortunately, the VNP14IMG detection algorithm is not currently able to distinguish nighttime surface fire pixels from the isolated plume detections due to strong similarities between their radiometric signatures.

Q: *Are these products still being refined*?
A: Yes. The Collection 2 reprocessing represents the second major release of NASA's VNP14IMG active fire product; 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.

7. References

Csiszar, I., Schroeder, W., Giglio, L., Ellicott, E., Vadrevu, K.P., Justice, C.O., and Wind, B. (2014). Active fires from the Suomi NPP Visible Infrared Imaging Radiometer Suite: Product Status and first evaluation results. J*ournal of Geophysical Research: Atmospheres*, doi: 10.1002/2013JD020453.

Giglio, L., Schroder, W., and Justice, C. (2016). The Collection 6 MODIS active fire detection algorithm and fire products. *Remote Sensing of Environment*, 178, 31-41.

Kaufman, Y.J., Justice, C.O., Flynn, L.P., Kendall, J.D., Prins, E.M., Giglio, L., Ward, D.E., Menzel, W.P., and Setzer, A.W. (1998). Potential global fire monitoring from EOS-MODIS. *Journal of Geophysical Research*, 103 (D24), 32,215-32,238.

MODIS Collection 6 and Collection 6.1 Active Fire Product User's Guide (2021). URL: http://modis-fire.umd.edu/files/MODIS_C6_C6.1_Fire_User_Guide_1.0.pdf

Schroeder, W., Oliva, P., Giglio, L., and Csiszar, I. (2014). The new VIIRS 375 m active fire detection data product: Algorithm description and initial assessment. *Remote Sensing of Environment*, 143, 85-96.

Wolfe, R.E., Lin, G., Nishihama, M., Tewari, K.P., Tilton, J.C., and Isaacman, A.R. (2013). Suomi NPP VIIRS prelaunch and on-orbit geometric calibration and characterization. *Journal of Geophysical Research: Atmospheres*, 118, doi:10.1002/jgrd.50873.