NASA VIIRS Land Science Investigator Processing System (SIPS)
Visible Infrared Imaging Radiometer Suite (VIIRS)
375 m & 750 m Active Fire Products

Product User's Guide Version 1.4.1

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Written by:

Wilfrid Schroeder
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)
Email: wilfrid.schroeder@noaa.gov

Louis Giglio
Department of Geographical Sciences
University of Maryland
Email: lgiglio@umd.edu

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 Collection 1 (C1) 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 The VIIRS instrument was first launched on 28 October 2011, and is to be superseded by other similar instruments on board the Joint Polar Satellite System (JPSS). 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 baseline algorithm implementation designed to provide continuity to the 1-km Earth Observing System Moderate Resolution Imaging Spectroradiometer (EOS/MODIS) active fire data record [Csiszar *et al*., 2014]. 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, Level 2 VNP14IMG, and Level 3 VNP14A1 active fire data sets are available.

2.1. Generic VIIRS Active Fire Product Level 2 (Swath) 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.

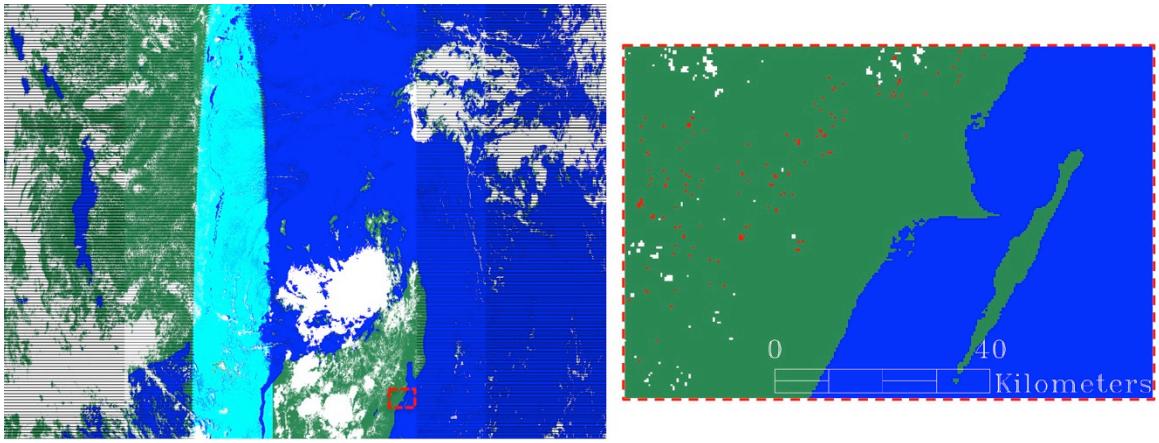


Figure 1: S-NPP/VIIRS active fire detection classification SDS ('*fire mask*') derived from single granule acquired on 22 November 2015 at ~1035UTC over parts of northern Madagascar and southeast Africa (left). Right panel shows magnified subset containing land (green), water (blue), clouds (white) and 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 VNP14IMG Active Fire Product

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 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 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 residual *bowtie* data, whereas bit 23-31 are reserved for future use.

[1] VNP14IMG ATBD available at:
https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_375m_ATBD.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 $\Delta BT_{45} > 30$ 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 (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 : $(32\times N)-1$	-
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.

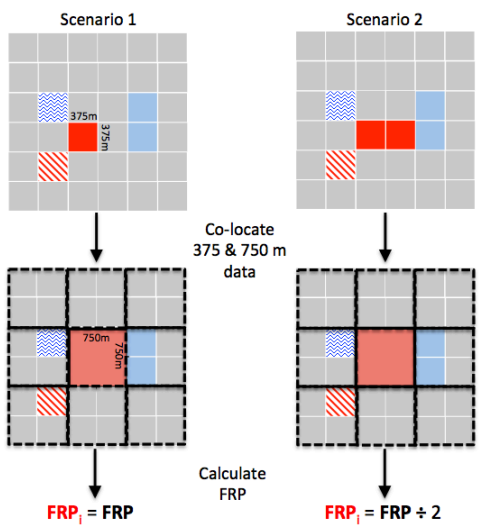


Figure 2: VNP14IMG FRP calculation using a combination of VIIRS 375 m and 750 m data. The former is used to identify fire-affected (solid and dashed red), cloud (solid blue), water (dashed blue), and valid background pixels (gray; in this case representing fire-free land surface). Co-located M13 channel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

The VNP14 '*fire mask*' pixel classes are essentially the same as in the MOD14/MYD14 product (Table 4)(see VNP14 ATBD[2] for details). 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

[2] VNP14 ATBD available at:
https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_750m_ATBD.pdf

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 contain information used for the forthcoming generation of Level 3 products by the VIIRS Science Team.

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. THE VNP14A1 LEVEL 3 DAILY FIRE PRODUCT

The VNP14A1 daily Level 3 fire product is tile based, with each product file spanning a single 1,200 × 1,200 km sinusoidal tile[3]. The product is a 1-km gridded composite of 750-m VNP14 fire pixels detected in each grid cell over each daily (24-hour) compositing period; the 1-km grid was adopted for compatibility with the existing 1-km MODIS MOD14A1 and MYD14A1 data records.

2.4.1. DATA LAYERS

The product contains four data layers (*FireMask*, *MaxFRP*, *QA*, and *sample*), each stored as a separate NetCDF variable.

FireMask: The fire mask is stored as a 1200 × 1200, 8-bit unsigned integer array. This mask is essentially a maximum value composite of the Level 2 VNP14 fire product pixel classes (Table 4) for those swaths overlapping the corresponding sinusoidal tile during the 24-h product period. As with the predecessor MOD14A1 and MYD14A1 products, the "maximum value" compositing scheme has been slightly modified to prevent cloud-obscured water grid cells from having precedence over cloud-free water grid cells.

MaxFRP: The maximum FRP of all fire pixels falling within each 1 km grid cell is provided on a daily basis in the "MaxFRP" variable. Here the FRP values have been scaled by a factor of 10 and stored as a 32-bit signed integer. Multiply these scaled values by 0.1 to retrieve the maximum FRP in MW.

QA: This quality assurance layer is a 1200 × 1200 8-bit unsigned integer array. Only seven unique QA values are possible, ranging from 0 through 6, with the meaning shown in the table below. Note that for missing-data grid cells (bit pattern 11 in bits 0-1), bit 2 will always be clear.

Bit(s)	Meaning
0-1	land/water state (00 = water, 01 = coast, 10 = land, 11 = missing data)
2	day/night flag (0 = night, 1 = day)

sample: For all grid cells assigned one of the VNP14 fire pixel classes (values 7, 8, or 9), the position of the fire pixel within the scan is recorded on a daily basis in a 1200 × 1200 16-bit signed integer SDS named "sample". Sample values have a range of 0 to 3199. All grid cells assigned one of the non-fire classes in the "FireMask" variable will be filled with a value of -1.

2.4.2. METADATA

The VNP14A1 products contains HDFEOS geo-referencing metadata, with additional product-specific metadata stored as NetCDF file attributes (Table 7).

[3] Sinusoidal tile grid: https://modis-land.gsfc.nasa.gov/MODLAND_grid.html

Table 7: VNP14A1 fire product metadata stored as standard NetCDF file attributes.

Name	Description
VNP14GD_input_file	VNP14GD input pointer
VNP14GN_input_file	VNP14GN input pointer
tile	MODIS/VIIRS sinusoidal tile descriptor (e.g., “h08v05”)
InstrumentShortname	“VIIRS”
ShortName	“VNP14A1”
CodeVersion	Software version string (e.g., “1.1.1”)
TileID	Long form of sinusoidal tile descriptor (e.g., “51008005”)
StartTime	ISO-format start date/time (e.g., “2018-01-01 00:00:00”)
EndTime	ISO-format end date/time (e.g., “2018-01-01 23:59:59”)
FireCells	Number of 1-km grid cells of class *fire* (unsigned integer)
NorthBoundingCoord	Northern-most bounding latitude (decimal degrees)
SouthBoundingCoord	Southern-most bounding latitude (decimal degrees)
EastBoundingCoord	Eastern-most bounding longitude (decimal degrees)
WestBoundingCoord	Western-most bounding longitude (decimal degrees)

3. Data Access

The current Collection 1 reprocessed time series builds on the VIIRS Science Data Record (SDR). The first several hours of S-NPP/VIIRS data acquired after the nominal start of sensor operations on 19 Jan 2012 were characterized by the cooling of onboard calibration sources, with gradual improvement and stabilization of the thermal emissive bands' performance. For practical purposes, users should adopt 20 Jan 2012 as the effective start date of the VIIRS active fire data record.

Additional intermittent data calibration anomalies affecting the SDR granules used as input to the VNP14IMG algorithm resulted in 468 output files containing empty fire masks and another 114 files showing lines of spurious detections in the fire product during the Jan 2012-Oct 2017 period (Figure 3). Similarly, anomalous SDR input data serving the VNP14 algorithm resulted in lines of spurious fire pixels impacting 188 files during the Jan 2012-Oct 2017 period (Figure 3). The frequency of those SDR data anomalies was found to be higher during the first year of the time series (2012), then gradually decreasing with time.

Outstanding data anomalies are being addressed by the VIIRS calibration team therefore future VIIRS Collections are expected to be free of those artifacts resulting in a more complete data record. An updated list of VNP14IMG and VNP14 files affected by the SDR anomalies will be posted to the dedicated VIIRS directory under the "*fuoco*" ftp server at the University of Maryland (see section 3.2 below). The filenames containing those lists will be clearly marked and maintained regularly with the most up-to-date information. Users should consult those lists and take appropriate steps to avoid the spurious fire pixels.

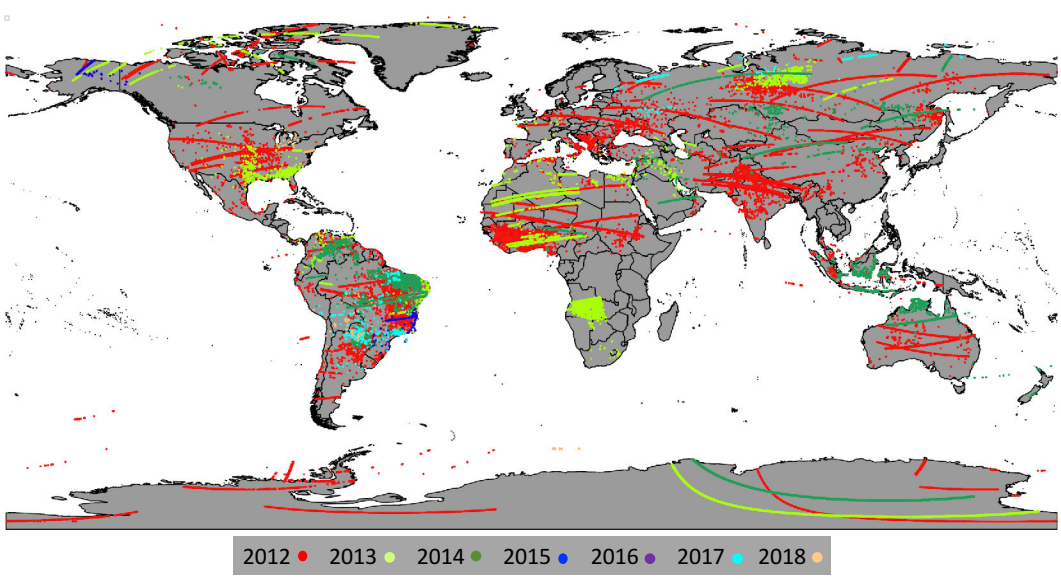


Figure 3: Annual global distribution of spurious VNP14IMG fire pixels associated with poorly-calibrated SDR input data acquired between Jan 2012- Jun 2018. Map shows data from 112 separate granules.

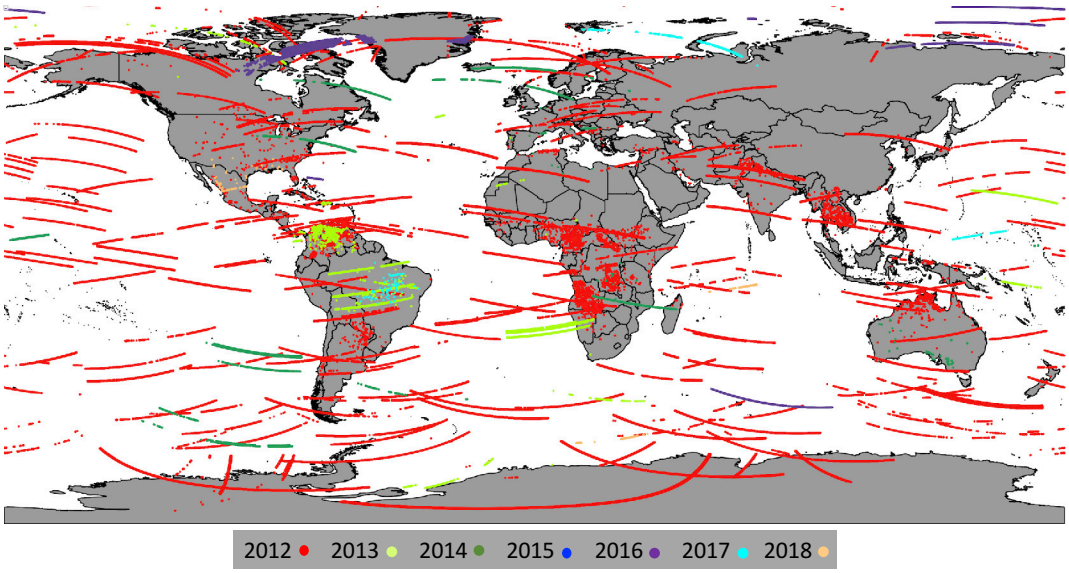


Figure 3 (continued): Annual global distribution of spurious VNP14 fire pixels associated with poorly-calibrated SDR input data acquired between Jan 2012- Jun 2018. Map shows data from 187 separate granules.

3.1. Level 2 (Swath) NetCDF4/HDF5

Currently, both VNP14IMG and VNP14 Level 2 swath products are being generated in NetCDF4/HDF5 format by NASA's Land-SIPS using the V1 reprocessed Level 1 data. The VNP14 product 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 web site using the following links:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5000/VNP14IMG/
https://ladsweb.modaps.eosdis.nasa.gov/archive/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.

3.2. ASCII Fire Location Data

VNP14IMGML and VNP14ML data are available in ASCII format mimicking the heritage MCD14ML product (see MODIS Collection 6 Active Fire Product User's Guide [2015]). The ASCII data are grouped into global monthly summary files, and carry essential fire detection information in comma-separated format that can be easily displayed on a map using common GIS software. Data granules containing spurious fire pixels (Section 3/figure 3) are excluded from VNP14IMGML and VNP14ML files. Those files are labeled as follows:

VNP14IMGML.YYYMM.CC.VV.txt || *VNP14ML.YYYMM.CC.VV.txt*

Where:

YYYYMM = year and month (01-12) of data acquisition
CC = collection number
VV = version number

The VNP14IMGML data file contains 12 separate fields with the following information:

YYYYMMDD Detection date in year (YYYY), month (MM) and day (DD)
HHMM Detection time (UTC) in hour (HH) and minutes (MM)
Sat Satellite descriptor (three letters). Example: Suomi-NPP (VNP)
Lat Fire pixel latitude (degrees)
Lon Fire pixel longitude (degrees)
T_I4 Fire pixel brightness temperature on channel I4 (Kelvin)
T_I5 Fire pixel brightness temperature on channel I5 (Kelvin)
Sample VIIRS I-band image sample number of fire pixel (range 0-6399)
Pixarea VIIRS I-band fire pixel area (km^2)
FRP Fire radiative power (MW)
Conf Confidence class (low, nominal, high)
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)

Similarly, the VNP14GML data file contains 12 separate fields with the following information:

YYYYMMDD Detection date in year (YYYY), month (MM) and day (DD)
HHMM Detection time (UTC) in hour (HH) and minutes (MM)
Sat Satellite descriptor (three letters). Example: Suomi-NPP (VNP)
Lat Fire pixel latitude (degrees)
Lon Fire pixel longitude (degrees)
T_M13 Fire pixel brightness temperature on channel M13 (Kelvin)
T_M15 Fire pixel brightness temperature on channel M15 (Kelvin)
Sample VIIRS M-band image sample number of fire pixel (range 0-3199)
Pixarea VIIRS M-band fire pixel area (km^2)

FRP Fire radiative power (MW)
Conf Confidence class (0-100%)
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)

Users can download the VNP14IMGML and VNP14ML data sets by connecting to an ftp server at the University of Maryland using:

```
server:     fuoco.geog.umd.edu
login:      fire
password:   burnt
directory (VNP14IMGML): /VIIRS/VNP14IMGML
directory (VNP14ML): /VIIRS/VNP14ML
```

New VNP14IMGML and VNP14ML files are created regularly and posted to the ftp server above shortly after all data for a given month becomes available.

In addition to the standard Level 2 NetCDF4/HDF5 and ASCII data formats, 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 4) is also available at:
https://earthdata.nasa.gov/labs/worldview/

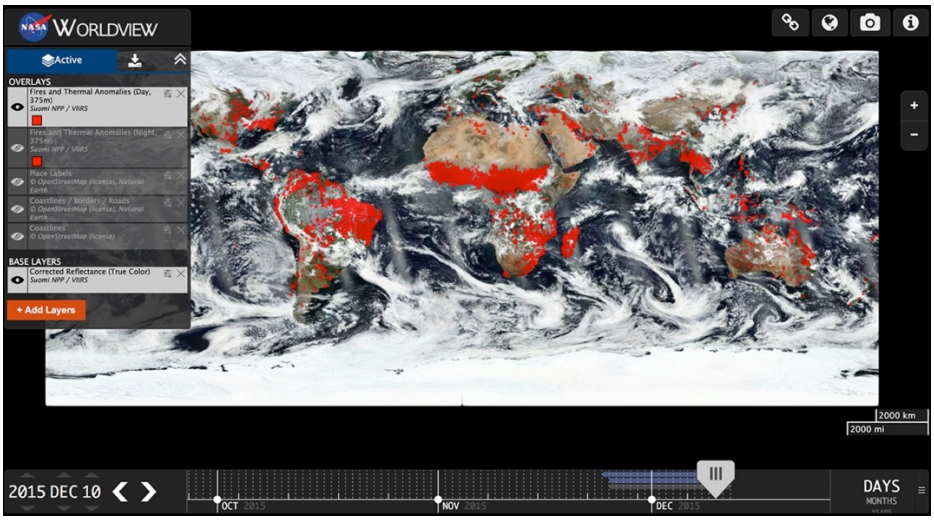


Figure 4: NASA's Worldview data display system showcasing VIIRS 375 m daytime global active fire detections for 10 December 2015.

3.3. Level 3 VNP14A1 Product

The Level 3 tiled VNP14A1 product is generated in NetCDF4/HDF5 format by NASA's Land SIPS, and is distributed from the LP-DAAC (https://lpdaac.usgs.gov/).

4. Data Handling

The Level 2 VNP14IMG and VNP14 and Level 3 VNP14A1 products are compatible with 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 describes 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. 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. The HDF-EOS to GeoTIFF (HEG) data conversion tool can be downloaded from:

https://newsroom.gsfc.nasa.gov/sdptoolkit/HEG/HEGDownload.html

The HEG 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 (available at the link above) for additional details. Currently, only VNP14 files are supported by HEG.

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
```

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: *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:

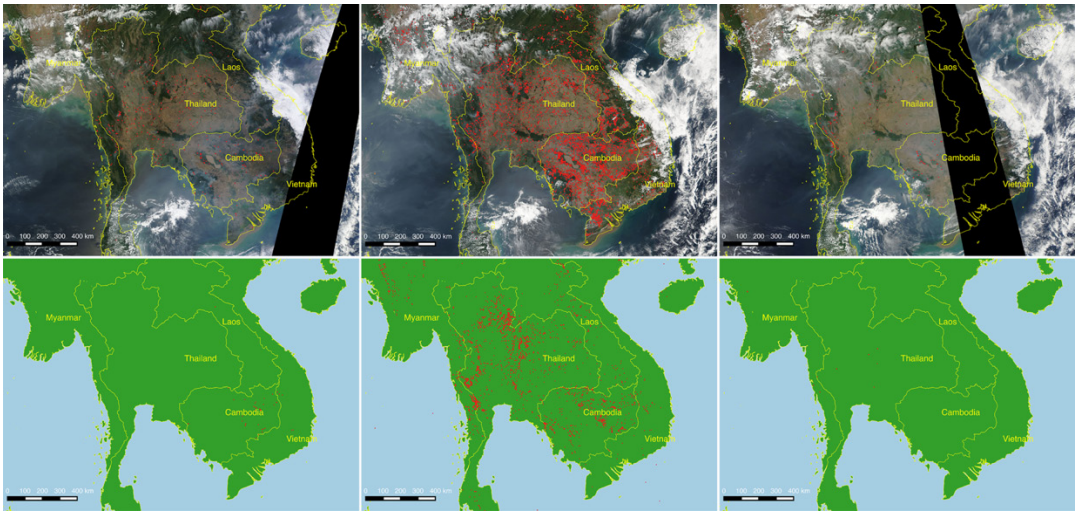
<u>*Daytime data*</u>:

- 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 5).



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 5: 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: 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 those circumstances 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 isn't currently able to distinguish nighttime surface fire pixels from the isolated plume detections due to strong similarities between their radiometric signatures.

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. Corrupted SDR data were still found in the Collection 1 reprocessed data (Figure 3). Those anomalies are being addressed by the VIIRS calibration team and their occurrence have significantly reduced, though not completely eliminated. Consequently, the reprocessed data show isolated granules affected by those anomalies. Those granules have been removed from the Collection 1 VNP14IMG and VNP14 public archives.

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 intrinsic quality limitations involving the various publicly available data records. Make sure to consult the online documentation describing the primary data archives at http://viirsfire.geog.umd.edu/.

Q: *Are these products 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.

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