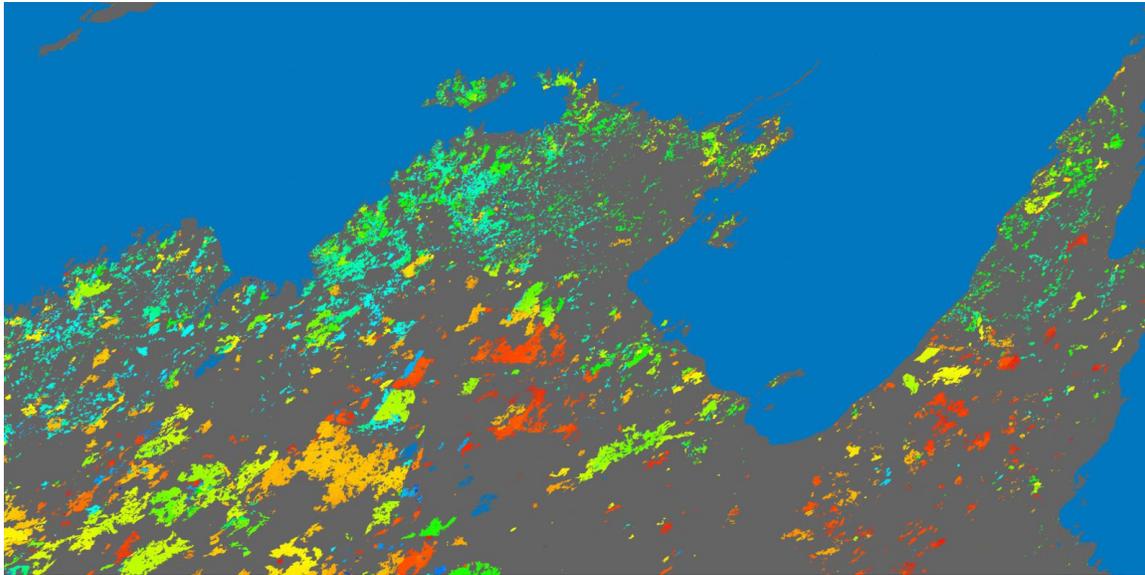# Collection 1 VIIRS Burned Area Product User's Guide
Version 1.0

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Abbreviations and Acronyms

CMG	Climate Modeling Grid
EOS	Earth Observing System
GeoTIFF	Georeferenced Tagged Image File Format
HDF	Hierarchical Data Format
JPSS	Joint Polar Satellite System
LP-DAAC	Land Processes Distributed Active Archive Center
MODIS	Moderate Resolution Imaging Spectroradiometer
SDS	Science Data Set
S-NPP	Suomi National Polar-orbiting Partnership
QA	Quality Assessment
VIIRS	Visible Infrared Imaging Radiometer Suite

Document Change History

Revision	Date	Description
1.0	10/2019	Original version.

Title page image: 2017 VNP64A1 cumulative area burned in northern Australia.

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1   Introduction

This document contains the most current information about the NASA Visible Infrared Imaging Radiometer Suite (VIIRS) Collection 1 VNP64A1 Burned Area product family. It is intended to provide the end user with practical information about the use of these products, and to explain potentially confusing aspects of the products themselves as well as the VIIRS sensor in general.

1.1   Product Rationale and Legacy

The VIIRS burned area product (VNP64A1) is intended as a successor to the MODIS burned area product used widely within the global modeling and fire applications communities. The mapping approach is based on the existing MODIS Collection 6 MCD64A1 burned-area mapping algorithm, with an emphasis on data consistency and continuity. The VNP64A1 product continues the 19-year MODIS record into the S-NPP and JPSS era, facilitating the development of a multi-sensor burned area climate data record suitable for long-term monitoring and research.

1.2   Terminology

1.2.1   Granules

A *granule* is an unprojected segment of the VIIRS orbital swath containing about 6 minutes of data. VIIRS Level 0, Level 1, and Level 2 products are granule-based.

1.2.2   Tiles

MODIS Level 2G, Level 3, and Level 4 products are defined on a global 250-m, 500-m, or 1-km sinusoidal grid (the particular spatial resolution is product-dependent). Because these grids are unmanageably large in their entirety (43200×21600 pixels at 1 km, and 172800×86400 pixels at 250 m), they are divided into fixed tiles approximately $10° \times 10°$ in size. Each tile is assigned a horizontal (H) and vertical (V) coordinate, ranging from 0 to 35 and 0 to 17, respectively (Figure 1). The tile in the upper left (i.e. northernmost and westernmost) corner is numbered (0,0).

  Note that the Level 3 VIIRS (and MODIS) products generated on the MODIS sinusoidal grid are colloquially referred to as having "1 km", "500 m", and "250 m" grid cells. The exact cell sizes are shown in Table 1.

1.2.3   Climate Modeling Grid (CMG)

VIIRS Level 3 and Level 4 products can also be defined on a coarser-resolution *climate modelling grid* (CMG). The objective is to provide the VIIRS land products at consistent low resolution spatial and temporal scales suitable for global modeling.

1.2.4   Collections

As with NASA's MODIS product suite, reprocessing of the entire VIIRS data archive is periodically performed to incorporate better calibration, algorithm refinements, and improved upstream data into all VIIRS products. The updated data archive resulting from each reprocessing is referred to as a *collection*. Later collections supersede all earlier collections.
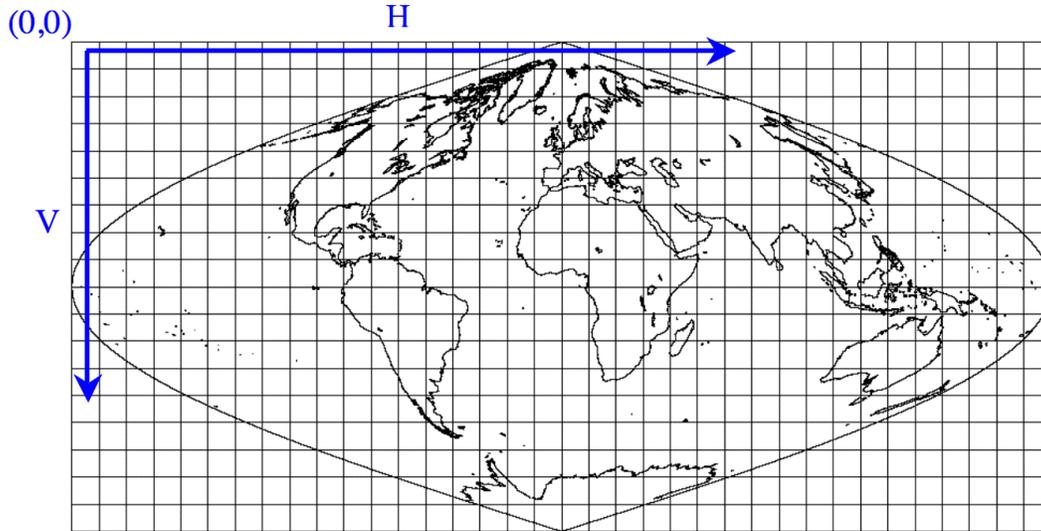
Figure 1: MODIS tiling scheme.

Table 1: Sizes of grid cells in Level 3 tiled MODIS sinusoidal grid.

Colloquial Size	Actual Size (m)
"1 km"	926.62543305
"500 m"	463.31271653
"250 m"	231.65635826

2 VNP64A1 Algorithm Summary

The VNP64A1 product is generated using the existing Collection 6 MODIS MCD64A1 burned area mapping algorithm (Giglio et al., 2018), with minor modifications to accomodate the different characteristics of the VIIRS sensor.

The adapted VNP64 approach employs 750-m S-NPP VIIRS imagery coupled with 750-m S-NPP VIIRS active fire observations. The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index (VI) derived from VIIRS short-wave infrared channels 8 and 11, and a measure of temporal texture. The VI is defined as

$$\text{VI} = \frac{\rho_8 - \rho_{11}}{\rho_8 + \rho_{11}},$$

where ρ_8 and ρ_{11} are respectively the band 8 and band 11 atmospherically corrected surface reflectance. Cumulative active fire maps are used to guide the selection of burned and unburned training samples and to guide the specification of prior probabilities. The combined use of active-fire and reflectance data enables the algorithm to adapt regionally over a wide range of pre- and post-burn conditions and across multiple ecosystems. See Giglio et al. (2018) for a complete description of the algorithm.

While the native spatial resolution of the VIIRS M bands used to generate the VNP64A1 product is somewhat coarser than the 500-m MODIS imagery used to generate the legacy MCD64A1 product, the VNP64A1 product is generated on the same 500-m MCD64A1 sinusoidal grid for compatability.

The mapping algorithm ultimately identifies the date of burn, to the nearest day, for 500-m grid cells within the individual tile being processed. The date is encoded in a single data layer of the output product as the ordinal day of the calendar year on which the grid cell burned (range 1-366), with a value of 0 for unburned land grid cells and additional special values reserved for missing-data and water grid cells. The output product contains additional data layers for diagnostic purposes and to facilitate uncertainty propagation into downstream products derived from the burned area maps, such as emissions estimates.

3   VNP64 Product Suite

At present, only the first of three planned VIIRS burned area products is available:

- The official VNP64A1 product in HDF4-EOS format, which is available as part of NASA's suite of standard VIIRS global land products. As a cost saving measure, the VNP64A1 product is initially being generated in the older HDF4 format used for the precursor MODIS MCD64A1 burned area product. Eventually the VNP64A1 product will be regenerated in the HDF5/netCDF4 format compatible with most other NASA VIIRS products.

Re-projected monthly GeoTIFF and monthly Shapefiles will be made available from the University of Maryland in the near future.

3.1 Level 3 Monthly Tiled Product: VNP64A1

The VNP64A1 burned area product is a monthly, Level-3 gridded 500-m product containing per-pixel burning and quality information, and tile-level metadata.

3.1.1 Naming Convention

The file naming convention, which matches that used for all standard NASA MODIS products, is as follows:

`VNP64A1.AYYYYDDD.hHHvVV.001.PPPPPPPPPPPPP.hdf`

where

`YYYY` = year mapped
`DDD` = start day-of-year (Julian day) of calendar month in which burns have been mapped (Table 2)
`HH` = horizontal tile coordinate on MODIS/VIIRS sinusoidal grid
`VV` = vertical tile coordinate on MODIS/VIIRS sinusoidal grid
`PPPPPPPPPPPPP` = production date[1]

Example: The product file `VNP64A1.A2017244.h31v10.001.2019091211913.hdf` contains the September 2017 burned area map for MODIS tile h31v10, located in northern Australia.

Table 2: Day-of-year (DOY) of the first day of each calendar month. The `DDD` field (see above) in the file names of the VNP64 products will always have one of the 22 unique values shown here.

Month	Non-Leap Year Start DOY	Leap Year Start DOY
January	1	1
February	32	32
March	60	61
April	91	92
May	121	122
June	152	153
July	182	183
August	213	214
September	244	245
October	274	275
November	305	306
December	335	336

---

[1]This naming convention ensures that files always have a unique name: if a tile is reprocessed the last number, indicating the day and time in which the file was processed, will be different, thus avoiding any confusion with obsolete data.

3.1.2 Data Layers

The product contains five data layers (*Burn Date*, *Burn Date Uncertainty*, *QA*, *First Day*, and *Last Day*), each stored as a separate HDF4 Scientific Data Set (SDS). These layers exactly correspond to those of the legacy MCD64A1 product.

Burn Date: Ordinal day of burn (1-366) for each 500-m grid cell, with 0 = unburned land, -1 = unmapped due to insufficient data, and -2 = water.

Burn Date Uncertainty: Estimated uncertainty in date of burn, in days. Unburned, unmapped, and water grid cells will always have a value of 0 in this layer.

QA: 8-bit quality assurance bit field.

    bit 0: 0 = water grid cell, 1 = land grid cell.

    bit 1: Valid data flag (0 = false, 1 = true). A value of 1 indicates that there was sufficient valid data in the reflectance time series for the grid cell to be processed. (NB. Water grid cells will always have this bit clear.)

    bit 2: Shortened mapping period (0 = false, 1 = true). This flag indicates that the period of reliable mapping does not encompass the full one-month product period, i.e., burns could not be reliably mapped over the full calendar month.

    bit 3: Grid cell was relabeled during the contextual relabeling phase of the algorithm (0 = false, 1 = true).

    bit 4: Spare bit set to 0.

    bits 5–7: Special condition code reserved for unburned grid cells. This code provides an explanation for any grid cells that were summarily classified as *unburned* by the detection algorithm due to special circumstances.

        0: None or not applicable (i.e., burned, unmapped, or water grid cell).

        1: Valid observations spaced too sparsely in time.

        2: Too few training observations or insufficient spectral separability between burned and unburned classes.

        3: Apparent burn date at limits of time series.

        4: Apparent water contamination.

        5: Persistent hot spot.

        6: Reserved for future use.

        7: Reserved for future use.

First Day and **Last Day:** The *First Day* and *Last Day* SDSs indicate the first and last days, respectively, on which changes could be reliably detected within the time series, on a per-grid-cell basis. Note that during periods of persistent cloud cover or frequent data loss, these dates will often lie within the calendar month that was mapped, indicating that reliable mapping could not be achieved over the full month. As with the *Burn Date* SDS, unmapped and water grid cells in these layers are flagged with values of -1 and -2, respectively.

3.1.3 Metadata

As with the legacy MCD64A1 product, various metadata are stored as standard HDF global attributes (Table 3). For compatability with the MODIS Reprojection Tool, the VNP64A1 product also contains a subset of global metadata stored in the ECS *CoreMetadata.0* global attribute.

Table 3: VNP64A1 metadata stored as standard global HDF attributes.

Attribute Name	Description
BurnedCells	Number of burned 500-m land grid cells during product month.
MissingCells	Number of 500-m land grid cells during product month having too few valid observations for algorithm to function.
LandCells	Number of 500-m land grid cells in tile.
ValidLandCells	Number of 500-m land grid cells for which mapping could be performed.
ProductStartDay	Julian start day of product calendar month (range 1 – 336).
ProductEndDay	Julian end day of product calendar month (range 31 – 366).
year	Product year.
tile	Six-character tile descriptor, e.g., "h20v11".

3.1.4   Example Code

Example 1: IDL code to read a global attribute and two SDSs in the VNP64A1 product.

```
vnp64a1_file = 'VNP64A1.A2018001.h20v08.001.2019179171745.hdf'

sd_id = HDF_SD_START(vnp64a1_file, /READ)

; read "BurnedCells" attribute
attr_index = HDF_SD_ATTRFIND(sd_id, 'BurnedCells')
HDF_SD_ATTRINFO, sd_id, attr_index, DATA=burned_cells

; convert 1-element vector to scalar
burned_cells = burned_cells[0]

index = HDF_SD_NAMETOINDEX(sd_id, 'Burn Date')
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, burn_date
HDF_SD_ENDACCESS, sds_id

index = HDF_SD_NAMETOINDEX(sd_id, 'QA')
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, QA
HDF_SD_ENDACCESS, sds_id

HDF_SD_END, sd_id

help, burned_cells, burn_date, QA
```

The code produces the following output:

```
BURNED_CELLS    LONG      =        278877
BURN_DATE       INT       = Array[2400, 2400]
QA              BYTE      = Array[2400, 2400]
```

Example 2: Python code to read the "Burn Date" and "QA" SDSs in the VNP64A1 product.

```python
import gdal
import numpy as np

in_file = "VNP64A1.A2018001.h20v08.001.2019179171745.hdf"

hdf_handle = gdal.Open(in_file)

# Print a list of all of the datasets within the hdf file
sds_list = hdf_handle.GetSubDatasets()
for sds in sds_list:
    print(sds)

# Open a subdataset "N" as an array with sds_list[N][0], values of N are:
# 0 = 'Burn Date', 1 = 'Burn Date Uncertainty', 2 = 'QA',
# 3 = 'First Day', 4 = 'Last Day'
burndate_handle = gdal.Open(sds_list[0][0])
burndate_data = burndate_handle.ReadAsArray()

qa_handle = gdal.Open(sds_list[2][0])
qa_data = qa_handle.ReadAsArray()

# Array can be handled with Numpy now
print(np.shape(burndate_data))
print(qa_data.dtype)

# Clean up when done
del qa_data, qa_handle, burndate_data, burndate_handle
```

Example 3: MATLAB code to read the VNP64A1 "Burn Date" SDS using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
vnp64a1_file = 'VNP64A1.A2018274.h13v11.001.2019073192514.hdf'

% read burn date layer in one shot
burn_date = hdfread(vnp64a1_file, 'Burn Date');

% display burn date (transposed so that North appears on top)
imagesc(burn_date.');
```

Example 4: Longer version of MATLAB code to read the VNP64A1 "Burn Date" layer. This is probably the better approach to use if multiple SDSs or multiple spatial subsets of an SDS will be read since the HDF file will be opened and closed only once. (The shorter approach using `hdfread` requires that the file be opened and closed for each read.)

```
vnp64a1_file = 'VNP64A1.A2016245.h31v10.001.2019091211913.hdf'

sd_id = hdfsd('start', vnp64a1_file, 'DFACC_RDONLY');

sds_index = hdfsd('nametoindex', sd_id, 'Burn Date');
sds_id = hdfsd('select', sd_id, sds_index);

% prepare to read entire SDS (always 2400 x 2400 pixels in size)
start = [0,0];
edges = [2400,2400];

[burn_date, status] = hdfsd('readdata', sds_id, start, [], edges);
status = hdfsd('endaccess', sds_id);

status = hdfsd('end', sd_id);

% display burn date (transposed so that North appears on top)
imagesc(burn_date.');
```

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Example 5: C code for reading the VNP64A1 burn date layer using HDF4 library functions.

```c
#include <stdio.h>
#include <stdlib.h>
#include "mfhdf.h"

#define ROWS 2400
#define COLS 2400

main(int argc, char **argv)
{
        int32 sd_id, sds_index, sds_id;
        int32 rank, data_type, nattr, dim_sizes[MAX_VAR_DIMS];
        int32 start[2], int32 edges[2];

        char *infile;
        int i, j;
        long nburn;
        uint16 burn_date[ROWS][COLS];


        infile = "VNP64A1.A2016245.h31v10.001.2019091211913.hdf";

        if ((sd_id = SDstart(infile, DFACC_READ)) == FAIL) exit(1);

        start[0] = start[1] = 0;
        edges[0] = ROWS;
        edges[1] = COLS;

        if ((sds_index = SDnametoindex(sd_id, "Burn Date")) == FAIL) exit(2);
        if ((sds_id = SDselect(sd_id, sds_index)) == FAIL) exit(3);
        if (SDgetinfo(sds_id, (char *) NULL, &rank, dim_sizes, &data_type,
                &nattr) == FAIL) exit(4);

        /* check rank and data type */
        if (rank != 2) exit(5);
        if (data_type != DFNT_UINT16) exit(6);

        if (SDreaddata(sds_id, start, NULL, edges,
                (void *) burn_date) == FAIL) exit(7);

        if (SDendaccess(sds_id) == FAIL) exit(8);
        if (SDend(sd_id) == FAIL) exit(9);


        /* simple example: count burned grid cells */
        nburn = 0L;
        for (i = 0; i < ROWS; i++) {
                for (j = 0; j < COLS; j++)
                        if (burn_date[i][j] > 0) nburn++;
                }

        printf("%d burned grid cells.\n", nburn);

        exit(0);
}
```

3.2 GeoTIFF subset for GIS visualization and analysis: VNP64monthly

A user-friendly GeoTIFF version of the VNP64 product will be derived from the standard VNP64A1 HDF version by the University of Maryland. As with the existing MODIS MCD64monthly product, the GeoTIFF files are reprojected in Plate-Carrée projection and cover a set of sub-continental windows (Figure 2). A table containing the regions covered and bounding coordinates of the 24 windows is available in Appendix A.
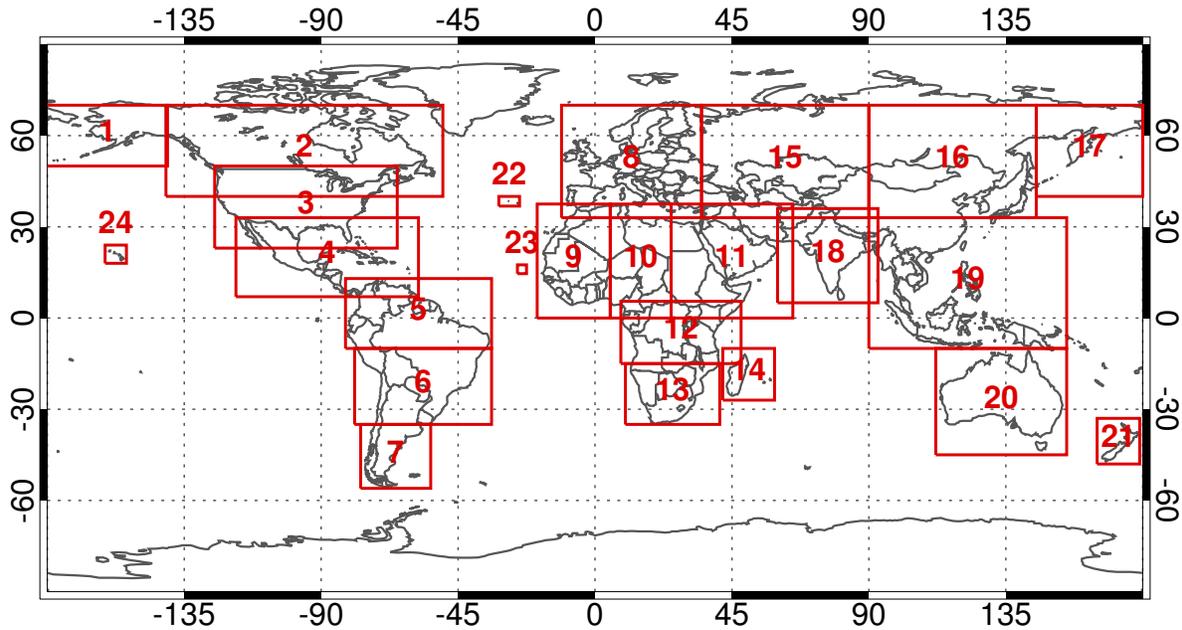

Figure 2: Coverage of the GeoTIFF subsets. A table of bounding coordinates is available in Appendix A.

3.3 VNP64CMQ Climate Modeling Grid Burned Area Product

The CMG burned area product is a gridded summary intended for use in regional and global modeling.

4   Obtaining the VIIRS Burned Area Product

Note: The instructions that follow will apply to the VNP64A1 product once it has been publicly released. At the time of this writing a full release of the burned area product has been postponed due to the downstream impacts of spatial artifacts present in the upstream Collection 1 VIIRS cloud mask product. To differing degrees these artifacts propagate into many of the Collection-1 Level 2 and Level 3 NASA VIIRS land products. In the interim, a sample of the C1 VNP64A1 product for a limited number of tiles will be made available. See Section 6.1 for more information.

All NASA VIIRS products are available free of charge. The VIIRS Burned Area Product is available for ordering from the Land Processes Distributed Active Archive Center (LP-DAAC).[2] Additionally, an ftp server[3] is maintained by the University of Maryland, primarily to assist science users who need to regularly download large volumes of data.

4.1   Downloading the products from the fuoco FTP server

The VNP64A1 HDF product is available from the `fuoco` FTP server used to distribute various fire data sets from the University of Maryland. Connect using the following information:

Server: `fuoco.geog.umd.edu`
Login name: `fire`
Password: `burnt`

Once connected, you will have access to the following abridged directory tree:

```
.
|-- VNP64A1
|   `-- C1
|       |-- docs
|       |-- h01v10
|       |-- h03v06
|              .
|              .
|              .
|       |-- h33v11
|       `-- h34v10
|-- VNP64CMQ
|   `-- C1
```

As can be seen from the directory tree, the file system on this server is structured to organize the VNP64A1 product hierarchically by tile. Specifically, all VNP64A1 product files for a given tile are located in the directory `VNP64A1/C1/hHHvVV`, where `HH` is the horizontal tile coordinate and `VV` is the vertical tile coordinate. For example, the Collection 1 VNP64A1 HDF files for MODIS tile h08v05 will be found in the directory `VNP64A1/C1/h08v05`.

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[2] `https://lpdaac.usgs.gov/`
[3] A second ftp server, "ba1", is currently also maintained but will be discontinued in the near future to accommodate more stringent campus IT security policies.

5 Working with the product in ENVI 4.8

5.1 VNP64A1 (HDF)

HDF-EOS products are only partially supported in ENVI. To open them, select *File → Open External Files → Generic Formats → HDF*. Opened as a generic HDF file, all geographic information is lost. To restore this information the projection parameters must be entered manually.

6 Known Problems

6.1 VIIRS Cloud Mask Artifacts

The C1 Land SIPS implementation of the 750-m VIIRS Cloud Mask product (VNP35) uses as an input a 0.05° gridded top-of-canopy NDVI climatology, and as a result a subset of the internal VNP35 cloud mask threshold tests are performed at this much coarser spatial resolution. The final cloud state (e.g., *confident clear*, *probably clear*, *probably cloudy*, etc.) assigned to each 750-m pixel is consequently sometimes quantized to the low resolution NDVI grid, in turn causing 0.05° (∼5-km) "blocks" to appear in downstream products, in particular the VIIRS daily surface reflectance product, which is a critical input to the VNP64 mapping algorithm (Figure 3).

The effect of the artifacts on the VNP64A1 product is to induce commission errors (i.e., grid cells falsely identified as *burned*) along the edges of the artificial 0.05° grid cell boundaries. The cloud mask artifacts, and consequently the resulting VNP64A1 commission errors, mainly occur along the edges of inland water bodies and at high latitudes.
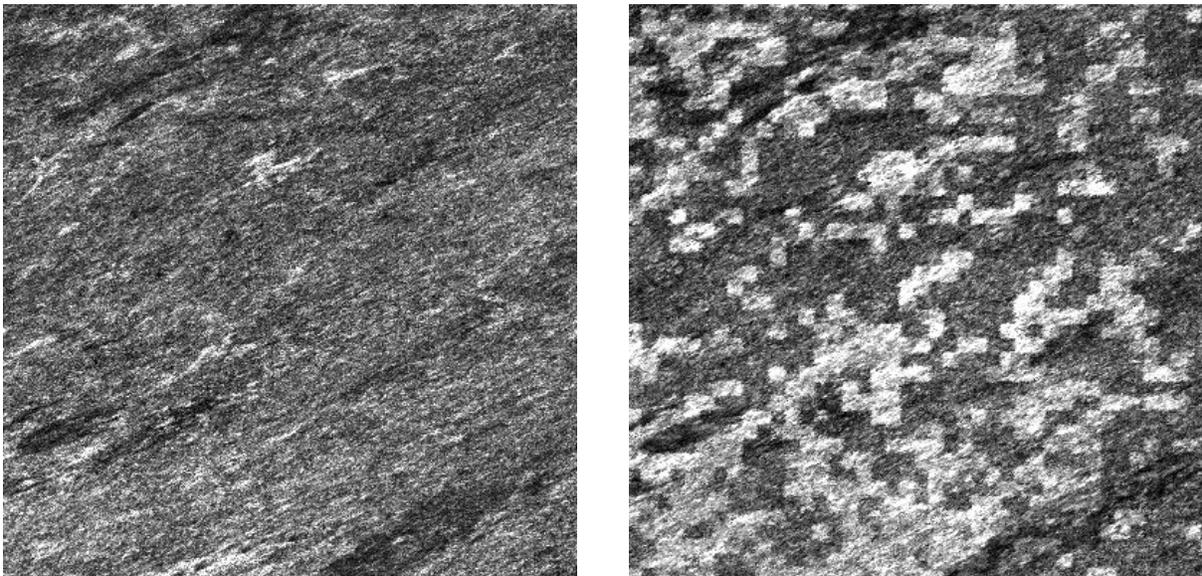
Figure 3: July 2016 vegetation-index change composite derived from the MODIS (left) and S-NPP VIIRS (right) surface reflectance time series used to generate the respective MODIS MCD64A1 and VIIRS VNP64A1 monthly burned area products. Square artifacts of the 0.05° NDVI climatology employed in the upstream VIIRS cloud mask are clearly evident in the VIIRS composite. Both images span the same 200 km × 200 km area in within MODIS tile h12v03 located over central Canada to the east of Hudson Bay.

6.2 Cropland Burning

Burned areas in cropland should generally be treated as low confidence due to the inherent difficulty in mapping agricultural burning reliably.

7 Frequently Asked Questions

Is there an existing tool I can use to remap the VNP64A1 product into a different projection?

The VNP64A1 HDF4 file structure is virtually identical to that of the precursor MODIS MCD64A1 burned area product, hence the existing *MODIS Reprojection Tool* (MRT) can be use to remap the VNP64A1 product into many different projections; see Section 9.

How do I calculate the latitude and longitude of a grid cell in the Level 3 products?

You can use the online MODLAND Tile Calculator[4], or perform the calculation as described in Appendix B.

How do I calculate the tile and grid cell coordinates of a specific geographic location (latitude and longitude)?

You can use the online MODLAND Tile Calculator, or perform the calculation as described in Appendix B.

8 References

Giglio, L., Boschetti, L., Roy, D. P., Humber, M. L., and Justice, C. O., 2018, The Collection 6 MODIS burned area mapping algorithm and product. *Remote Sensing of Environment*, 217, 72-85.

Giglio, L., Loboda, T., Roy, D. P., Quayle, B., and Justice, C. O., 2009, An active-fire based burned area mapping algorithm for the MODIS sensor. *Remote Sensing of Environment*, 113, 408-420.

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[4]`http://landweb.nascom.nasa.gov/cgi-bin/developer/tilemap.cgi`

9   Relevant Web and FTP Sites

- **VIIRS Land Product Quality Assessment**: Product quality-assessment (QA) related information, including a very complete archive of known land-product issues with descriptions and examples.
  `https://landweb.modaps.eosdis.nasa.gov/NPP_QA/`

- **VIIRS Land Validation**: Information concerning the validation status of all NASA VIIRS land products.
  `https://viirsland.gsfc.nasa.gov/Val_overview.html`

- **NASA Earthdata Search**: The primary distribution site for most NASA VIIRS land products.
  `https://search.earthdata.nasa.gov/`

- **MODIS LDOPE Tools**: A collection of programs, written by members of the Land Data Operational Product Evaluation (LDOPE) group, to assist in the analysis and quality assessment of MODIS Land (MODLAND) products. Many of these tools will work with the VNP64A1 product.
  `https://lpdaac.usgs.gov/tools/ldope/`

- **MODIS Reprojection Tool (MRT), Release 4.1**: Software for reprojecting tiled MODIS Level 3 products into many different projections.
  `https://lpdaac.usgs.gov/tools/modis_reprojection_tool`

- **MODLAND Tile Calculator**: Online tool for performing forward and inverse mapping of MODIS sinusoidal tiles.
  `http://landweb.nascom.nasa.gov/cgi-bin/developer/tilemap.cgi`

Appendix A Coverage of the GeoTIFF subsets

Table 4: Regions and bounding coordinates of the GeoTIFF subsets.

Window	Coverage	Min. Lon.	Max. Lon.	Min. Lat.	Max. Lat.
1	Alaska	-180	-140.5	50	70
2	Canada	-141	-50	40	70
3	USA (Conterminous)	-125	-65	23	50
4	Central America	-118	-58	7	33
5	South America (North)	-82	-34	-10	13
6	South America (Central)	-79	-34	-35	-10
7	South America (South)	-77	-54	-56	-35
8	Europe	-11	35	33	70
9	West and North Africa	-19	5	0	37.5
10	Central and North Africa	5	25	0	37.5
11	East Africa and Arabian Peninsula	25	65	0	37.5
12	Southern Africa (North)	8.5	48	-15	5.5
13	Southern Africa (South)	10	41	-35	-15
14	Madagascar	42	59	-27	-10
15	Russia and Central Asia 1	35	90	33	70
16	Russia and Central Asia 2	90	145	33	70
17	Russia (Kamachatka)	145	180	40	70
18	South Asia	60	93	5	36
19	South East Asia	90	155	-10	33
20	Australia	112	155	-45	-10
21	New Zealand	165	179	-48	-33
22	Azores	-31.6	-24.8	36.8	40
23	Cape Verde Island	-25.5	-22.5	14.6	17.5
24	Hawaii	-161	-154	18	24

Appendix B   Coordinate conversion for the MODIS sinusoidal projection

Navigation of the tiled MODIS products in the sinusoidal projection can be performed using the forward and inverse mapping transformations described here. We'll first need to define a few constants:

$R = 6371007.181$ m, the radius of the idealized sphere representing the Earth;

$T = 1111950$ m, the height and width of each MODIS tile in the projection plane;

$x_{\min} = $ -20015109 m, the western limit of the projection plane;

$y_{\max} = 10007555$ m, the northern limit of the projection plane;

$w = T/2400 = 463.31271653$ m, the actual size of a "500-m" MODIS sinusoidal grid cell.

B.1   Forward Mapping

Denote the latitude and longitude of the location (in radians) as ϕ and λ, respectively. First compute the position of the point on the global sinusoidal grid:

$$
\begin{aligned}
x &= R\lambda\cos\phi & (1) \\
y &= R\phi. & (2)
\end{aligned}
$$

Next compute the horizontal (H) and vertical (V) tile coordinates, where $0 \leq H \leq 35$ and $0 \leq V \leq 17$ (Section 1.2.2):

$$
\begin{aligned}
H &= \left\lfloor \frac{x - x_{\min}}{T} \right\rfloor & (3) \\
V &= \left\lfloor \frac{y_{\max} - y}{T} \right\rfloor, & (4)
\end{aligned}
$$

where $\lfloor\ \rfloor$ is the floor function. Finally, compute the row (i) and column (j) coordinates of the grid cell within the MODIS tile:

$$
\begin{aligned}
i &= \left\lfloor \frac{(y_{\max} - y) \bmod T}{w} \right\rfloor & (5) \\
j &= \left\lfloor \frac{(x - x_{\min}) \bmod T}{w} \right\rfloor. & (6)
\end{aligned}
$$

Note that for all 500-m MODIS products on the sinusoidal grid $0 \leq i \leq 2399$ and $0 \leq j \leq 2399$.

B.2   Inverse Mapping

Here we are given the row (i) and column (j) in MODIS tile H, V. First compute the position of the center of the grid cell on the global sinusoidal grid:

$$
\begin{aligned}
x &= (j + 0.5)w + HT + x_{\min} & (7) \\
y &= y_{\max} - (i + 0.5)w - VT & (8)
\end{aligned}
$$

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Next compute the latitude ϕ and longitude λ at the center of the grid cell (in radians):

$$\phi = \frac{y}{R} \tag{9}$$

$$\lambda = \frac{x}{R \cos \phi}. \tag{10}$$

B.3 Applicability to 250-m and 1-km MODIS Products

With the following minor changes the above formulas are also applicable to the higher resolution 250-m and 500-m MODIS tiled sinusoidal products.

250-m grid: Set $w = T/4800 = 231.65635826$ m, the actual size of a "250-m" MODIS sinusoidal grid cell. For 250-m grid cells $0 \le i \le 4799$ and $0 \le j \le 4799$.

1-km grid: Set $w = T/1200 = 926.62543305$ m, the actual size of a "1-km" MODIS sinusoidal grid cell. For 1-km grid cells $0 \le i \le 1199$ and $0 \le j \le 1199$.