MODIS Collection 6 Active Fire Product User's Guide
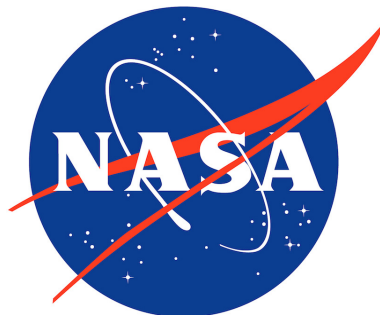## Revision B

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Document Change History

Revision	Date	Description
A	3/2015	Original version.
B	12/2018	Documented changes to version-2 MCD14ML product. Updated URLs and description of LP-DAAC ordering interface. Updated references. Minor typographical corrections.

Contents

List of Tables

1   Introduction

This document contains the most current information about the Collection 6 Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) fire products. It is intended to provide the end user with practical information regarding their use and misuse, and to explain some of the more obscure and potentially confusing aspects of the fire products and MODIS products in general.

2   Summary of Collection 6 Algorithm and Product Changes

1. Processing has been extended to oceans and other large water bodies to detect offshore gas flaring.

2. Reduced incidence of false alarms caused by small forest clearings.

3. Improved detection of small fires.

4. Expanded sun-glint rejection.

5. Slightly improved cloud masking.

6. Slight adjustment of detection confidence calculation.

7. FRP retrieval now performed using Wooster et al. (2003) approach.

8. Expanded fire pixel table in Level 2 product.

9. Additional granule-level metadata in Level 2 product.

10. Simplified layer date information in 1-km Level 3 daily fire product.

11. Simplified QA layer in 1-km Level 3 8-day and daily fire products.

12. 0.25° CMG products (available late 2018).

13. Improved elimination of static hot-spot sources from CMG products.

14. New hot-spot *type* attribute and day/night flag in MCD14ML fire location product.

3 Overview of the MODIS Active Fire Products

Here we provide a general overview of the MODIS active fire products. More detailed descriptions of these products and example ingest code can be found in Section 4.

3.1 Terminology

Before proceeding with a description of the MODIS fire products, we briefly define the terms *granule*, *tile*, and *collection*, and *climate modelling grid* in the context of these products.

3.1.1 Granules

A *granule* is an unprojected segment of the MODIS orbital swath containing about 5 minutes of data. MODIS Level 0, Level 1, and Level 2 products are granule-based.

3.1.2 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).
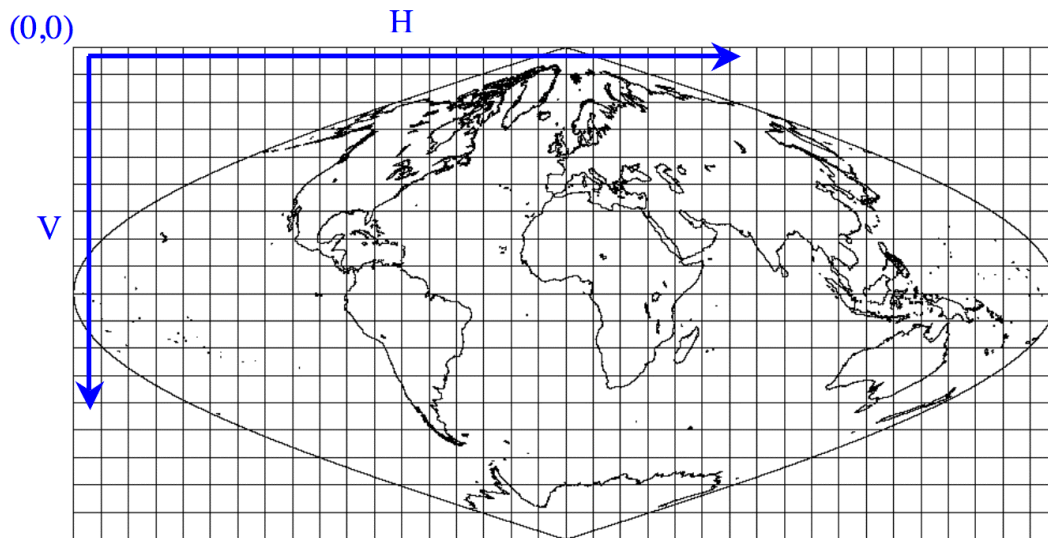
Figure 1: MODIS tiling scheme.

3.1.3 Climate Modeling Grid (CMG)

MODIS Level 3 and Level 4 products can also be defined on a coarser-resolution *climate modelling grid* (CMG). The objective is to provide the MODIS land products at consistent low resolution spatial and temporal scales suitable for global modeling. In practice, there is a fair amount of variation in the spatial and temporal gridding conventions used among the MODIS land CMG products.

3.1.4 Collections

Reprocessing of the entire MODIS data archive is periodically performed to incorporate better calibration, algorithm refinements, and improved upstream data into all MODIS products. The updated MODIS data archive resulting from each reprocessing is referred to as a *collection*. Later collections supersede all earlier collections.

For the Terra MODIS, Collection 1 consisted of the first products generated following launch. Terra MODIS data were reprocessed for the first time in June 2001 to produce Collection 3. (Note that this first reprocessing was numbered Collection 3 rather than, as one would expect, Collection 2.) Collection 3 was also the first version produced for the Aqua MODIS products. Collection 4 reprocessing began in December 2002 and was terminated in December 2006. Production of the Collection 5 products, which commenced in mid-2006, will continue until the Collection 6 reprocessing is complete. Production of the "Tier-1" Collection 6 MODIS products, which includes the active fire products, commenced in February 2015.

3.2 Level 2 Fire Products: MOD14 (Terra) and MYD14 (Aqua)

This is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. The Level 2 product is defined in the MODIS orbit geometry covering an area of approximately 2340×2030 km in the along-scan and along-track directions, respectively. It is used to generate all of the higher-level fire products, and contains the following components:

- An active fire mask that flags fires and other relevant pixels (Figure 2);

- a pixel-level quality assurance (QA) image that includes 19 bits of QA information about each pixel;

- a fire-pixel table which provides 27 separate pieces of radiometric and internal-algorithm information about each fire pixel detected within a granule;

- extensive mandatory and product-specific metadata;

- a grid-related data layer to simplify production of the Climate Modeling Grid (CMG) fire product (Section 3.6).

Product-specific metadata within the Level 2 fire product includes the number of cloud, water, non-fire, fire, unknown, and other pixels occurring within a granule to simplify identification of granules containing fire activity.
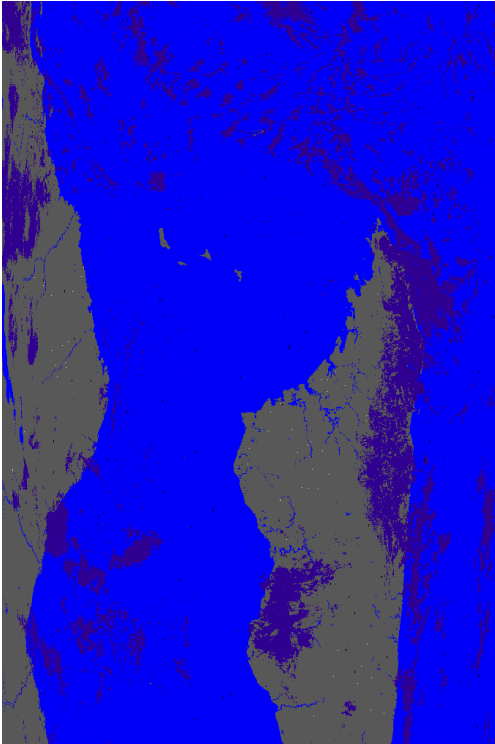
Figure 2: Example MOD14 (Terra MODIS) swath-level fire mask for granule acquired 5 September 2002 at 07:20 UTC, with water shown in blue, clouds in purple, non-fire land pixels in grey, and fire pixels in white. The along-track direction points toward the bottom of the page. The large land mass on the right is Madagascar.

3.3 Level 2G Daytime and Nighttime Fire Products: MOD14GD/MOD14GN (Terra) and MYD14GD/MYD14GN (Aqua)

The Level 2 active fire products sensed over daytime and nighttime periods are binned without resampling into an intermediate data format referred to as *Level 2G*. The Level 2G format provides a convenient geocoded data structure for storing granules and enables the flexibility for subsequent temporal compositing and reprojection. The Level 2G fire products are a temporary, intermediate data source used solely for producing the Level 3 fire products and are consequently not available from the permanent MODIS data archive.

3.4 Level 3 8-Day Daily Composite Fire Products: MOD14A1 (Terra) and MYD14A1 (Aqua)

The MODIS daily Level 3 fire product is tile based, with each product file spanning one of the 460 MODIS tiles, 326 of which contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each daily (24-hour) compositing period. For convenience, eight days of data are packaged into a single file.

Figure 3 shows the Terra fire mask for day 7 (4 September 2001) of the 29 August–5 September 2001 daily Level 3 fire product. The tile is located in Northern Australia (h31v10).

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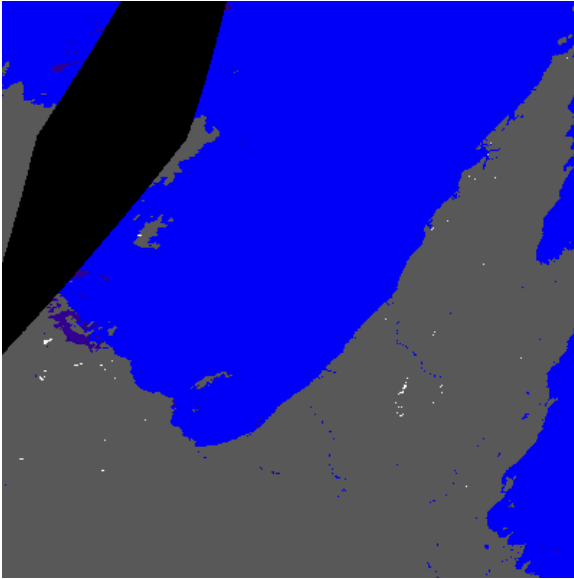
Figure 3: Example of 4 September 2001 Collection 6 MOD14A1 daily fire mask for tile h31v10, located in Northern Australia. Water is shown in blue, clouds in violet, non-fire land grid cells in grey, and fire grid cells in white. Grid cells lacking data are shown in black.

3.5   Level 3 8-Day Summary Fire Products: MOD14A2 (Terra) and MYD14A2 (Aqua)

The MODIS daily Level 3 8-day summary fire product is tile-based, with each product file spanning one of the 460 MODIS tiles, of which 326 contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell during the 8-day compositing period.

Figure 4 shows the 8-day summary fire mask from the 8-day Level 3 Terra fire product spanning 29 August–5 September 2001. As in the previous example, the tile is located in Northern Australia (h31v10). The 8-day composite is the maximum value of the individual Level 2 pixel classes that fell into each 1-km grid cell over the entire 8-day compositing period.
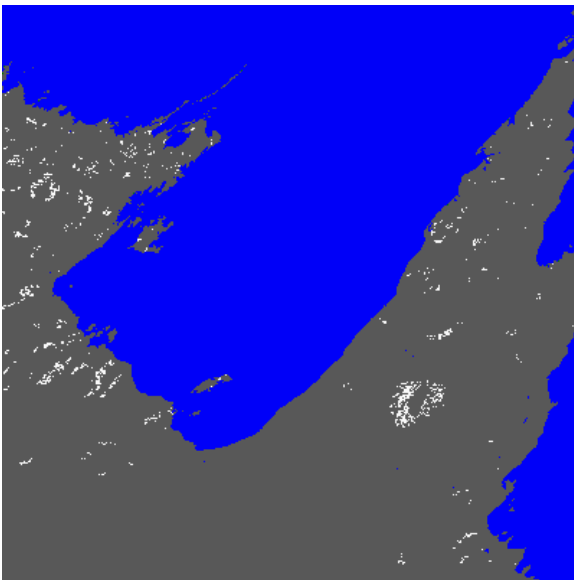
Figure 4: Example of 8-day MOD14A2 summary fire mask for MODIS tile h31v10 spanning 29 August–5 September 2001. The color scale is the same as that of Figure 3.

3.6 Climate Modeling Grid Fire Products (MOD14CMQ, MYD14CMQ, etc.)

The CMG fire products are gridded statistical summaries of fire pixel information intended for use in regional and global modeling. The products are now generated at 0.25° spatial resolution for time periods of one calendar month (MOD14CMQ and MYD14CMQ) and eight days (MOD14C8Q and MYD14C8Q). An example of the corrected fire pixel count layer of the product is shown in Figure 5.
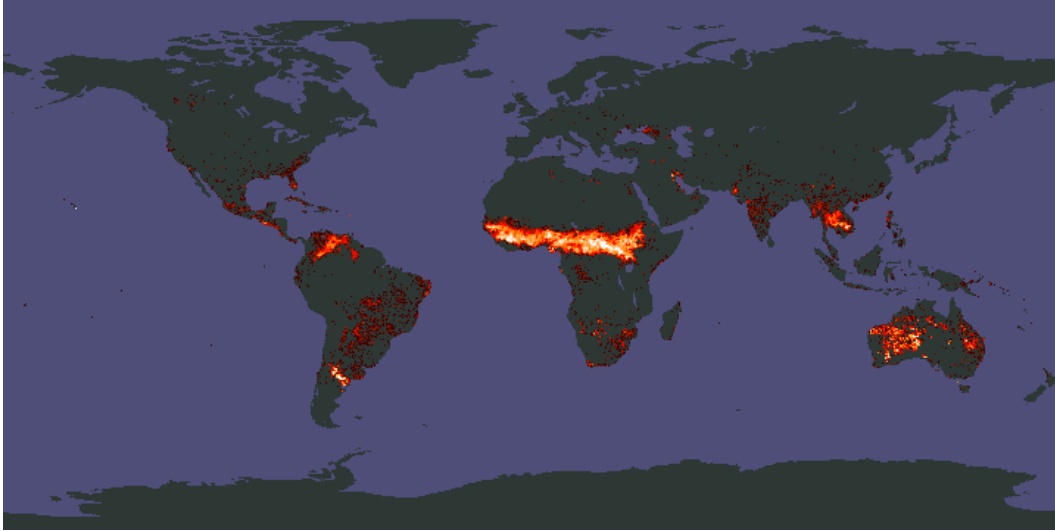
Figure 5: Example of the corrected fire pixel count data layer from the January 2001 Terra MODIS monthly CMG fire product.

3.7 Global Monthly Fire Location Product (MCD14ML)

For some applications it is necessary to have the geographic coordinates of individual fire pixels. New for Collection 5 is the global monthly fire location product (MCD14ML), which contains this information for all Terra and Aqua MODIS fire pixels in a single monthly ASCII file.

3.8 Near Real-Time MODIS Imagery and Fire Products

The Land Atmosphere Near Real-time Capability for EOS (LANCE) Rapid Response System produces near-real time global imagery including true- and false-color corrected reflectance superimposed with fire locations (Figure 6), Normalized Difference Vegetation Index (NDVI), and land surface temperature. Near-real time locations of Terra and Aqua MODIS fire pixels are also available as text files.
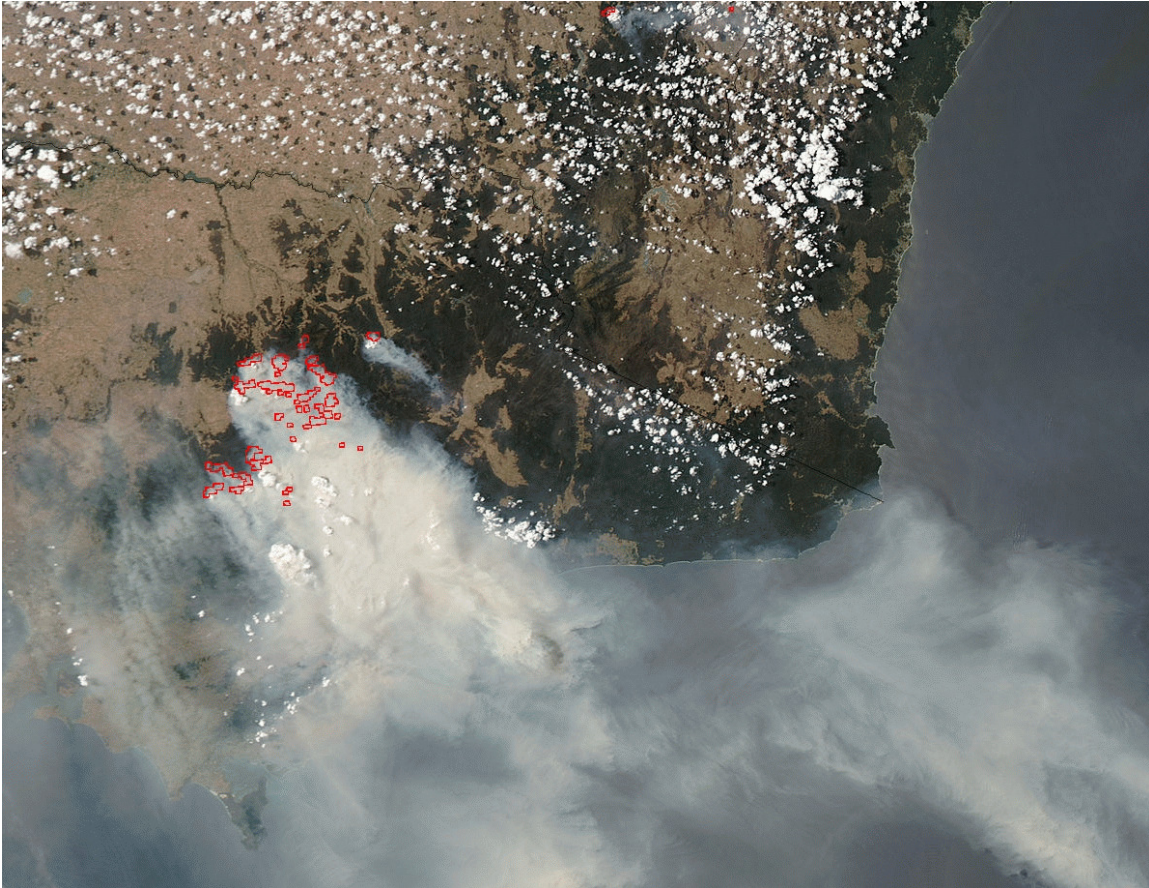
Figure 6: MODIS Rapid Response true color imagery of fires and smoke in southeast Australia (10 December 2006, 03:45 UTC).

3.9 LDOPE Global Browse Imagery

The MODIS Land Data Operational Product Evaluation (LDOPE) provides interactive daily global browse imagery of many MODIS land products from the MODIS Land Global Browse Images web site[1] in near-real time (Figure 7). For most products (including the fire products) the browse imagery is generated using only the daytime overpasses. The site allows you to arbitrarily zoom into any region of the globe and examine features of interest in more detail.
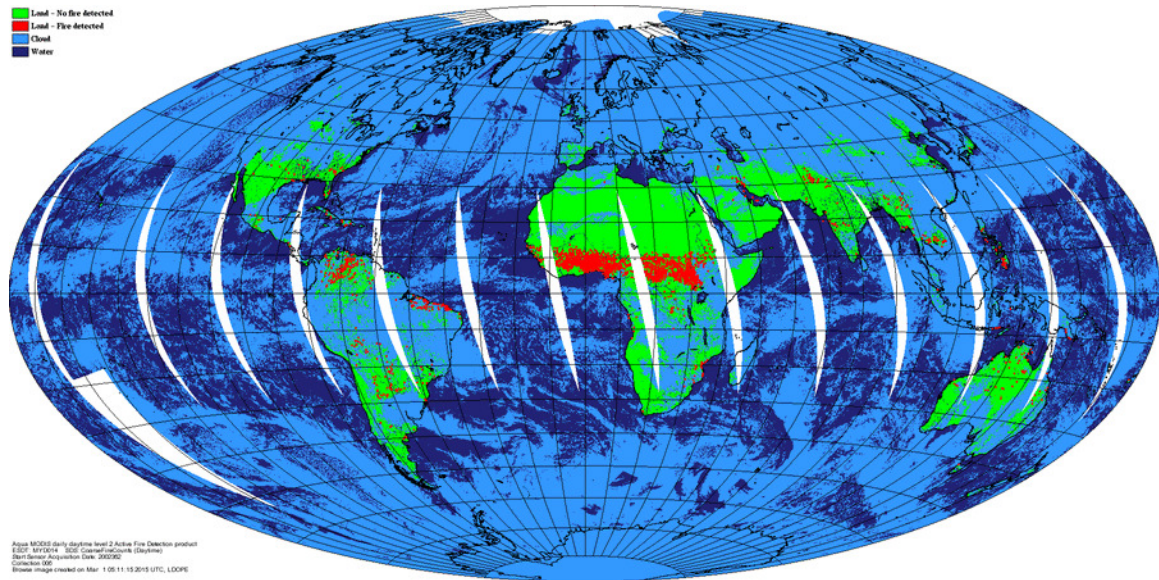
Figure 7: Example Collection-6 Aqua MODIS active fire global browse image for 28 December 2002 showing all daytime overpasses. Fire pixels are shown in red, cloud pixels are shown in light blue, and areas lacking data are shown in white. Browse image courtesy of the LDOPE.

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[1] http://landweb.nascom.nasa.gov/cgi-bin/browse/browse.cgi

4   Obtaining the MODIS Active Fire Products

All MODIS products are available to users free of charge through several different sources (Table 1). Not all products are available from each source.

Table 1: MODIS fire product availability.

Product	Source
Level 2 and Level 3 fire products: MOD14, MYD14 MOD14A1, MYD14A1 MOD14A2, MYD14A2	LAADS (Section 4.1) and LP-DAAC (Section 4.2)
CMG fire products: MOD14CMQ, MYD14CMQ MOD14C8Q, MYD14C8Q	University of Maryland (Section 4.3)
Global fire location product: MCD14ML	University of Maryland (Section 4.3)
Near real-time fire and corrected reflectance imagery.	LANCE Worldview and Rapid Response (Section 4.4)
Geographic subsets of near real-time active fire locations in various GIS-compatible formats.	LANCE FIRMS (Section 4.5)

4.1   LAADS

The MODIS Level 1, atmosphere, and land products may be obtained from the Level 1 and Atmosphere Archive and Distribution System (LAADS), available here:

```
http://ladsweb.nascom.nasa.gov/index.html
```

4.2   LP-DAAC

Most of the MODIS land products may be obtained from the Land Processes Distributed Active Archive Center (LP-DAAC), available here:

```
https://lpdaac.usgs.gov/
```

4.3 University of Maryland ftp Server

At present the active-fire CMG products and the MCD14ML product are distributed from an ftp server at the University of Maryland. Log in using the following information:

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

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

```
.
|-- db
|    `-- MCD64A1
|-- gfed -> gfed4
|-- gfed3
|    `-- monthly
|         `-- hdf
|-- gfed4
|    |-- daily
|    `-- monthly
|-- modis
|    |-- C4
|    |-- C5
|    |    |-- cmg
|    |    |    |-- 8day
|    |    |    |    |-- fits
|    |    |    |    `-- hdf
|    |    |    `-- monthly
|    |    |         |-- fits
|    |    |         `-- hdf
|    |    `-- mcd14ml
|    |-- C6
|    |    |-- cmg
|    |    |    |-- 8day
|    |    |    |    |-- fits
|    |    |    |    `-- hdf
|    |    |    `-- monthly
|    |    |         |-- fits
|    |    |         `-- hdf
|    |    `-- mcd14ml
|    `-- docs
`-- virs
     `-- monthly
```

4.3.1 MODIS CMG Active-Fire Products

The current MODIS CMG fire products are located in the directory `modis/C6/cmg`. For convenience, these products are distributed in multiple, standard data formats. Currently HDF and Flexible Image Transport System (FITS) files are available; additional formats may be produced in the future.

4.3.2 MODIS Monthly Fire Location Product

The current MCD14ML product is located in the directory `modis/C6/mcd14ml`.

4.3.3 Documentation

The most recent version of the *Active Fire Product User's Guide* for each Collection is archived in the directory `modis/docs`.

4.3.4 Pre-Collection 6 Products

To help ensure traceability and replicability the server provides an archive of the older Collection 4 and Collection 5 CMG fire products in the directories `modis/C4` and `modis/C5`, respectively. *These products are obsolete and should not be used for new research or analyses.*

4.3.5 VIRS Monthly Fire Product

Although unrelated to MODIS, the ftp server also hosts an archive of the 0.5° Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS) monthly fire product in the directory `virs/monthly`. See the documentation in the directory `virs` for details.

4.4 LANCE Worldview and Rapid Response

Near real-time fire and corrected reflectance imagery are available from the NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) Worldview and Rapid Response systems, located here:

$$\texttt{https://earthdata.nasa.gov/lance}$$

Note: In general, the near real-time MODIS products should not be used for time series analyses or long-term studies.

4.5 LANCE FIRMS

Near real-time MODIS fire locations are available in a variety of formats (ASCII, shapefile, KML, or WMS) from the LANCE Fire Information for Resource Management System (FIRMS):

$$\texttt{https://earthdata.nasa.gov/data/near-real-time-data/firms}$$

Note: In general, the near real-time MODIS fire locations should not be used for time series analyses or long-term studies; for such purposes the standard MCD14ML product is more appropriate. By special request, FIRMS will distribute spatial subsets of MODIS fire locations extracted from the standard MCD14ML product via the *Archive Download Tool*.

5 Detailed Product Descriptions

5.1 MOD14 and MYD14

MOD14/MYD14 is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. The Level 2 product is defined in the MODIS orbit geometry covering an area of approximately 2340 by 2030 km in the across- and along-track directions, respectively. It is used to generate all of the higher-level fire products.

5.1.1 Fire Mask

The fire mask is the principle component of the Level 2 MODIS fire product, and is stored as an 8-bit unsigned integer Scientific Data Set (SDS) named "fire mask". In it, individual 1-km pixels are assigned one of nine classes. The meaning of each class is listed in Table 2.

Table 2: MOD14/MYD14 fire mask pixel classes.

Class	Meaning
0	not processed (missing input data)
1	not processed (obsolete; not used since Collection 1)
2	not processed (other reason)
3	non-fire water pixel
4	cloud (land or water)
5	non-fire land pixel
6	unknown (land or water)
7	fire (low confidence, land or water)
8	fire (nominal confidence, land or water)
9	fire (high confidence, land or water)

5.1.2 Collection 6 Water Processing

For Collection 6, oceans and other large water bodies are now processed to detect offshore gas flaring. As such, the *cloud*, *unknown*, and *fire* pixel classes can now occur over water. While it was safe to use the fire mask as a rudimentary land/water mask prior to Collection 6, users must now appeal to bits 0–1 of the pixel-level algorithm QA layer (Section 5.1.4) to unambiguously discriminate land from water pixels.

5.1.3 Detection Confidence

A detection confidence intended to help users gauge the quality of individual fire pixels is included in the Level 2 fire product. This confidence estimate, which ranges between 0% and 100%, is used to assign one of the three fire classes (*low-confidence fire*, *nominal-confidence fire*, or *high-confidence fire*) to all fire pixels within the fire mask.

In some applications errors of commission (or *false alarms*) are particularly undesirable, and for these applications one might be willing to trade a lower detection rate to gain a lower false alarm rate. Conversely, for other applications missing any fire might be especially undesirable, and one

might then be willing to tolerate a higher false alarm rate to ensure that fewer true fires are missed. Users requiring fewer false alarms may wish to retain only nominal- and high-confidence fire pixels, and treat low-confidence fire pixels as clear, non-fire, land pixels. Users requiring maximum fire detectability who are able to tolerate a higher incidence of false alarms should consider all three classes of fire pixels.

5.1.4 Algorithm Quality Assessment Bits

Pixel-level QA is stored in a 32-bit unsigned integer SDS named "algorithm QA", with individual fields stored in specific bits (Table 3). For details, please see the MODIS Level 2 Fire Product file specification.

Table 3: Summary of Level-2 fire product pixel-level QA bits.

Bit(s)	Meaning
0-1	land/water state (00 = water, 01 = coast, 10 = land, 11 = unused)
2	3.9 μm high-gain flag (0 = band 21, 1 = band 22)
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)

5.1.5 Fire Pixel Table

The fire pixel table is simply a collection of SDSs containing relevant information about individual fire pixels detected within a granule. Due to HDF file format and library limitations, the Fire Pixel Table is stored as 27 separate SDSs. A brief summary of these SDSs is provided in Table 3.

Table 4: Collection 6 Level 2 fire product SDSs comprising the "fire pixel table". MAD = "mean absolute deviation".

SDS Name	Data Type	Units	Description
FP_line	int16	-	Granule line of fire pixel.
FP_sample	int16	-	Granule sample of fire pixel.
FP_latitude	float32	degrees	Latitude at center of fire pixel.
FP_longitude	float32	degrees	Longitude at center of fire pixel.
FP_R2	float32	-	Near-IR (band 2) reflectance of fire pixel (daytime only).
FP_T21	float32	K	Channel 21/22 brightness temperature of fire pixel.
FP_T31	float32	K	Channel 31 brightness temperature of fire pixel.
FP_MeanT21	float32	K	Background channel 21/22 brightness temperature.
FP_MeanT31	float32	K	Background channel 31 brightness temperature.
FP_MeanDT	float32	K	Background brightness temperature difference.
FP_MAD_T21	float32	K	
FP_MAD_T31	float32	K	
FP_MAD_DT	float32	K	
FP_power	float32	MW	Fire radiative power.
FP_AdjCloud	uint8	-	Number of adjacent cloud pixels.
FP_AdjWater	uint8	-	Number of adjacent water pixels.
FP_WinSize	uint8	-	Background window size.
FP_NumValid	int16	-	Number of valid background pixels.
FP_confidence	uint8	%	Detection confidence estimate.
FP_land	uint8	-	Land flag (0 = water pixel, 1 = land pixel).
FP_MeanR2	float32	-	Background channel 2 reflectance.
FP_MAD_R2	float32	-	Background channel 2 reflectance MAD.
FP_ViewZenAng	float32	degrees	View zenith angle.
FP_SolZenAng	float32	degrees	Solar zenith angle.
FP_RelAzAng	float32	degrees	Relative azimuth angle.
FP_CMG_row	int16	-	CMG row.
FP_CMG_col	int16	-	CMG column.

5.1.6 Metadata

Every MODIS product carries with it ECS-mandated metadata stored in the HDF global attributes *CoreMetadata.0* and *ArchiveMetadata.0*. Each attribute is an enormous string of ASCII characters encoding many separate metadata fields in Parameter Value Language (PVL). Among other information, the *ArchiveMetadata.0* attribute usually contains product-specific metadata included at the discretion of the PI. However, since the PVL is awkard to read and tedious to parse, we have stored many of the product-specific metadata fields as standard HDF global attributes. These are summarized in Table 5. Descriptions of the product-specific metadata stored in the ECS *ArchiveMetadata.0* attribute may be found in the MOD14/MYD14 Fire Product file specification (see Section 10).

Table 5: MODIS Level 2 fire product metadata stored as standard global HDF attributes.

Attribute Name	Description
FirePix	Number of fire pixels detected in granule.
MissingPix	Number of pixels in granule lacking valid data for processing.
LandPix	Number of land pixels in granule.
WaterPix	Number of water pixels in granule.
CoastPix	Number of coast pixels in granule.
WaterAdjacentFirePix	Number of fire pixels that are adjacent to one or more water pixels.
CloudAdjacentFirePix	Number of fire pixels that are adjacent to one or more cloud pixels.
UnknownLandPix	Number of land pixels assigned a class of *unknown*.
UnknownWaterPix	Number of water pixels assigned a class of *unknown*.
LandCloudPix	Number of land pixels obscured by cloud in granule.
WaterCloudPix	Number of water pixels obscured by cloud in granule.
GlintPix	Number of pixels in granule contaminated with sun glint.
GlintRejectedPix	Number of tentative fire pixels that were rejected due to apparent sun glint contamination.
CoastRejectedPix	Number of tentative fire pixels that were rejected due to apparent water contamination of the contextual neighborhood.
HotSurfRejectedPix	Number of tentative fire pixels that were rejected as apparent hot desert surfaces.
ClearingRejectedPix	Number of tentative fire pixels rejected as apparent forest clearings.
CoastRejectedWaterPix	Number of tentative fire pixels rejected due to apparent land contamination of contextual background.
DayPix	Number of daytime pixels in granule.
NightPix	Number of nighttime pixels in granule.
Satellite	Name of satellite ("Terra" or "Aqua").
ProcessVersionNumber	Production code version string (e.g. "6.2.3").
MOD021KM input file	File name of MOD021KM (Terra) or MYD021KM (Aqua) Level 1B radiance input granule.
MOD03 input file	File name of MOD03 (Terra) or MYD03 (Aqua) geolocation input granule.

5.1.7 Example Code

Example 1: IDL code for reading the "fire mask" SDS in the MODIS Level 2 fire product.

```
mod14_file = 'MOD14.A2002177.1830.005.2008192223417.hdf'

; open the HDF file for reading
sd_id = HDF_SD_START(mod14_file, /READ)

; find the SDS index to the MOD14 fire mask
index = HDF_SD_NAMETOINDEX(sd_id, 'fire mask')

; select and read the entire fire mask SDS
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, fire_mask

; finished with SDS
HDF_SD_ENDACCESS, sds_id

; finished with HDF file
HDF_SD_END, sd_id
```

5.2 MOD14A1 and MYD14A1

The MOD14A1 and MYD14A1 daily Level 3 fire products are tile-based, with each product file spanning one of the 460 MODIS tiles, of which 326 contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each daily (24-hour) compositing period. For convenience, eight days of data are packaged into a single file.

5.2.1 Fire Mask

The fire mask is stored as an 8 (or less) $\times$ 1200 $\times$ 1200, 8-bit unsigned integer SDS named "Fire-Mask". (For historical reasons this layer was named "most confident detected fire" prior to Collection 5.) The SDS contains eight successive daily fire masks for a specific MODIS tile. Each of these daily masks is essentially a maximum value composite[2] of the Level 2 fire product pixel classes (Table 2) for those swaths overlapping the MODIS tile during that day. Product files containing less than eight days of data will occasionally be encountered during time periods of missing data and should be handled in ingest software.

5.2.2 QA

Each of the daily fire masks has a corresponding simple QA layer. Each layer is a 1200 $\times$ 1200 8-bit unsigned integer array. Only seven unique QA values are possible, with the meanings shown in Table 6. Note that for missing-data grid cells (bit pattern 11 in bits 0-1), bit 2 will always be clear.

Table 6: QA values in the Collection 6 MODIS Level 3 tiled active fire products.

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

5.2.3 Maximum FRP

The maximum fire radiative power of all fire pixels falling within each grid cell is provided on a daily basis in the "MaxFRP" SDS. 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.

5.2.4 Scan Sample

For all grid cells assigned one of the 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 $\times$ 1200 16-bit unsigned integer SDS named "sample". Sample values have a range of 0 to 1353. All grid cells assigned one of the non-fire classes in the "FireMask" SDS will be filled with a sample value of 0.

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[2]Due to the introduction of water processing in Collection 6, the original maximum value compositing scheme had to be modified slightly to prevent cloud-obscured water grid cells from having precedence over cloud-free water grid cells.

5.2.5 Metadata

As with the Level 2 fire products, the MOD14A1 and MYD14A1 products contain global metadata stored in the ECS *CoreMetadata.0* and *ArchiveMetadata.0* global attributes. Also like the Level 2 products, a subset of these metadata are written as standard HDF global attributes for convenience (see Table 7). Here are example values for the product file "MOD14A1.A2002297.h31v10.006.2015058030918.hdf", listed using `ncdump` (see Section 8.8.4):

```
:FirePix = 482, 319, 329, 386, 660, 739, 1096, 477 ;
:CloudPix = 76933, 83531, 61942, 67212, 36943, 6980, 46727,
            15949 ;
:UnknownPix = 450, 168, 113, 96, 711, 190, 192, 225 ;
:MissingPix = 53920, 155798, 4, 163180, 0, 163250, 0, 149596 ;
:Dates = "2002-10-24 2002-10-25 2002-10-26 2002-10-27
          2002-10-28 2002-10-29 2002-10-30 2002-10-31" ;
:MaxT21 = 425.2746f ;
:ProcessVersionNumber = "6.0.1" ;
:StartDate = "2002-10-24" ;
:EndDate = "2002-10-31" ;
:HorizontalTileNumber = 31s ;
:VerticalTileNumber = 10s ;
```

Notice that the first four fields (`FirePix`, `CloudPix`, `UnknownPix`, and `MissingPix`) are one-dimensional arrays (or vectors) nominally having eight elements. Each element corresponds to a single day in the 8-day time period covered by the product. Note that the Scientific Data Sets in the product file ("FireMask", "MaxFRP", etc.) will contain fewer than eight planes when there are no valid MODIS observations during one or more days spanned by the product. In such cases, the vector metadata fields will have fewer than eight elements.

Table 7: MOD14A1 and MYD14A1 fire product metadata stored as standard global HDF attributes.

Attribute Name	Description
FirePix	Number of 1-km tile cells containing fires (8-element array).
CloudPix	Number of 1-km tile cells assigned a class of *cloud* after compositing (8-element array).
UnknownPix	Number of 1-km tile cells assigned a class of *unknown* after compositing (8-element array).
MissingPix	Number of 1-km tile cells lacking valid data (8-element array).
Dates	Date of each plane in three-dimensional fire mask array.
MaxT21	Maximum band 21 brightness temperature (K) of all fire pixels in tile.
ProcessVersionNumber	Production code version string (e.g. "6.0.1").
StartDate	Start date of 8-day time period spanned by product (YYYY-MM-DD).
EndDate	End date of 8-day time period spanned by product (YYYY-MM-DD).
HorizontalTileNumber	Horizontal tile coordinate (H).
VerticalTileNumber	Vertical tile coordinate (V).

5.2.6 Level 3 Tile Navigation

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;

$w = T/1200 = 926.62543305$ m, the actual size of a "1-km" MODIS sinusoidal grid cell.

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:

$$
\begin{align}
x &= R\lambda\cos\phi \tag{1}\\
y &= R\phi. \tag{2}
\end{align}
$$

Next compute the horizontal (H) and vertical (V) tile coordinates, where $0 \leq H \leq 35$ and $0 \leq V \leq 17$ (Section 3.1.2):

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

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

$$
\begin{align}
i &= \left\lfloor \frac{(y_{\max} - y) \bmod T}{w} - 0.5 \right\rfloor \tag{5}\\
j &= \left\lfloor \frac{(x - x_{\min}) \bmod T}{w} - 0.5 \right\rfloor. \tag{6}
\end{align}
$$

Note that for the 1-km MOD14A1 and MYD14A1 products (indeed, all 1-km MODIS products on the sinusoidal grid) $0 \leq i \leq 1199$ and $0 \leq j \leq 1199$.

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:

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

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

$$
\begin{aligned}
\phi &= \frac{y}{R} \quad &(9)\\
\lambda &= \frac{x}{R\cos\phi}. \quad &(10)
\end{aligned}
$$

Applicability to 250-m and 500-m 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 $0 \le j \le 4799$.

500-m grid: Set $w = T/2400$ = 463.31271653 m, the actual size of a "500-m" MODIS sinusoidal grid cell. For 500-m grid cells $0 \le i \le 2399$ and $0 \le j \le 2399$.

5.2.7 Example Code

Example 2: MATLAB code to read the Level 3 MODIS daily fire mask, using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
mod14a1_file = 'MOD14A1.A2008281.h31v10.005.2008292070548.hdf'

% read entire "FireMask" SDS in one shot
fire_mask = hdfread(mod14a1_file, 'FireMask');

% display fire mask for the first day in MOD14A1/MYD14A1
% note how image is transposed so that North appears on top
imagesc(fire_mask(:,:,1)');
```

Example 3: IDL code to read some of the global attributes and SDSs in the Level 3 daily fire product.

```
mod14a1_file = 'MOD14A1.A2007241.h08v05.005.2007251120334.hdf'

sd_id = HDF_SD_START(mod14a1_file, /READ)

; read "FirePix" and "MaxT21" attributes
attr_index = HDF_SD_ATTRFIND(sd_id, 'FirePix')
HDF_SD_ATTRINFO, sd_id, attr_index, DATA=FirePix
attr_index = HDF_SD_ATTRFIND(sd_id, 'MaxT21')
HDF_SD_ATTRINFO, sd_id, attr_index, DATA=MaxT21

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

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

HDF_SD_END, sd_id

help, FirePix
print, FirePix, format = '(8I8)'
print, MaxT21, format = '("MaxT21:",F6.1," K")'
help, FireMask, MaxFRP
```

The code produces the following output:

```
FIREPIX           LONG      = Array[8]
      18        48        19         1        18        11       100        32
MaxT21: 468.1 K
FIREMASK          BYTE      = Array[1200, 1200, 8]
MAXFRP            LONG      = Array[1200, 1200, 8]
```

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5.3 MOD14A2 and MYD14A2

The MOD14A2 (Terra) and MYD14A2 (Aqua) daily Level 3 8-day summary fire products are tile-based, with each product file spanning one of the 460 MODIS tiles, 326 of which contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each 8-day compositing period.

5.3.1 Fire Mask

The fire mask is stored as a 1200 × 1200 8-bit unsigned integer SDS named "FireMask". (For historical reasons this layer was named "most confident detected fire" prior to Collection 5.) This summary fire mask is essentially a maximum value composite of the Level 2 fire product pixel classes (Table 2) for those swaths overlapping the MODIS tile during the eight-day compositing period.

5.3.2 QA

The QA layer contains pixel-level quality assessment information stored in a 1200 × 1200 8-bit unsigned integer image. The possible QA values are the same as those for the MOD14A1 and MYD14A1 products (see Table 6).

5.3.3 Level 3 Tile Navigation

Forward and inverse mapping of the MODIS sinusoidal tile grid used for the MOD14A2 and MYD14A2 products is the same as for the MOD14A1 and MYD14A1 products. See Section 5.2.6 for details.

5.3.4 Example Code

Example 4: MATLAB code to read the Level 3 MODIS 8-day fire mask, using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
mod14a2_file = 'MYD14A2.A2004193.h08v08.005.2007207151726.hdf'

% read entire "FireMask" SDS in one shot
fire_mask = hdfread(mod14a2_file, 'FireMask');

% display fire mask (transposed so that North appears on top)
imagesc(fire_mask');
```

Example 5: Longer version of MATLAB code to read the Level 3 MODIS 8-day fire mask. This is probably the better approach to use if multiple subsets of an SDS will be read in sequence 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.)

```
mod14a2_file = 'MYD14A2.A2004193.h08v08.005.2007207151726.hdf'

sd_id = hdfsd('start', mod14a2_file, 'DFACC_RDONLY');

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

% prepare to read entire SDS (always 1200 x 1200 pixels in size)
start = [0,0];
edges = [1200,1200];

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

status = hdfsd('end', sd_id);


% display fire mask (transposed so that North appears on top)
imagesc(fire_mask');
```

Example 6: C code for reading Level 3 MODIS 8-day fire mask using HDF library functions.

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

#define ROWS 1200
#define COLS 1200

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 nfire;
        uint8 fire_mask[ROWS][COLS];


        infile = "MOD14A2.A2008265.h31v10.005.2008275132911.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, "FireMask")) == 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_UINT8) exit(6);

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

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


        /* simple example: count grid cells containing fires */
        nfire = 0;
        for (i = 0; i < ROWS; i++) {
                for (j = 0; j < COLS; j++)
                        if (fire_mask[i][j] >= 7) nfire++;
                }

        printf("%d grid cells containing fires.\n", nfire);

        exit(0);
}
```

5.4 CMG Fire Products (MOD14CMQ, MYD14CMQ, etc.)

The CMG fire products are gridded statistical summaries of fire pixel information intended for use in regional and global modeling, and other large scale studies. For Collection 6, the products are generated at 0.25° spatial resolution for time periods of one calendar month (MOD14CMQ/MYD14CMQ) and eight days (MOD14C8Q/MYD14C8Q).

At present the CMG products are distributed from the University of Maryland via anonymous ftp (see Section 4.3). For convenience, these products are distributed in multiple, standard data formats. Currently, HDF and Flexible Image Transport System (FITS) files are available.

5.4.1 CMG Naming Convention

Monthly CMG fire products. The file names of the monthly CMG product files have the structure `M?D14CM?.YYYYMM.CCC.VV.XXX`, where `M?D14CM?` is a prefix[3] encoding the satellite and product spatial resolution (see Figure 8), `YYYY` is the four-digit product year, `MM` is the two-digit calendar month, `CCC` denotes the Collection (see Section 3.1.4), `VV` denotes the product version within a Collection, and `XXX` is a suffix indicating the file format.

Eight-day CMG fire products. The file names of the 8-day CMG product files have the structure `M?D14C8?.YYYYDDD.CCC.VV.XXX`, where `M?D14C8?` is a prefix encoding the satellite and product spatial resolution (see Figure 8), `YYYY` is the four-digit product year, `DDD` is the two-digit calendar month, `CCC` denotes the Collection (see Section 3.1.4), `VV` denotes the product version within a Collection, and `XXX` is a suffix indicating the file format.

```
                 ┌─────────────────────────────┐
                 │         Satellite           │
                 │  'O' = Terra                │
                 │  'Y' = Aqua                 │
                 │  'C' = combined Terra/Aqua  │
                 └─────────────────────────────┘
                              │
                              ▼

                      M?D14C??

          ┌──────────────────────┐  ┌──────────────────────┐
          │ Temporal Resolution  │  │  Spatial Resolution  │
          │  'M' = monthly       │  │  'H' = 0.5°          │
          │  '8' = 8 days        │  │  'Q' = 0.25°         │
          └──────────────────────┘  └──────────────────────┘
```
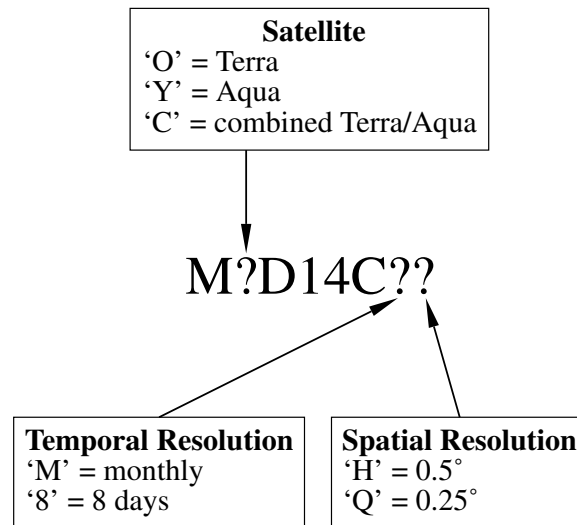
Figure 8: MODIS CMG fire product naming prefix (ESDT) convention.

---

[3]In MODIS-speak this prefix is usually referred to as an *Earth Science Data Type* (ESDT).

5.4.2 Data Layers

The CMG fire products contain eight separate data layers summarized in Table 8. For the 0.25° products each layer is a 1440 × 720 numeric array.

Table 8: Summary of data layers in the CMG fire products.

Layer Name	Data Type	Units	Description
CorrFirePix	int16	-	Corrected number of fire pixels.
CloudCorrFirePix	int16	-	Corrected number of fire pixels, with an additional correction for cloud cover.
MeanCloudFraction	int8	-	Mean cloud fraction.
RawFirePix	int16	-	Uncorrected count of fire pixels.
CloudPix	int32	-	Number of cloud pixels.
TotalPix	int32	-	Total number of pixels.
MeanFRP	float32	MW	Mean fire radiative power.
NumPixFRP	int16	-	Number of fire pixels used to compute mean FRP.

5.4.3 Global Metadata

Global metadata are stored as global attributes in the HDF product files, and primary-HDU keywords in the FITS product files.

5.4.4 Climate Modeling Grid Navigation

Forward navigation. Given the latitude and longitude (in degrees) of a point on the Earth's surface, the image coordinates (x,y) of the 0.25° CMG grid cell containing this point are computed as follows:

```
y = floor((90.0 - latitude) / 0.25)

x = floor((longitude + 180.0) / 0.25),
```

where `floor` is the floor function, e.g., `floor`(2.2) = 2. These equations yield image coordinates satisfying the inequalities $0 \leq x \leq 1439$, $0 \leq y \leq 719$, which are appropriate for programming languages using zero-based array indexing such as C and IDL; for languages using one-based array indexing (e.g. Fortran, MATLAB) add 1.

Inverse navigation. Given coordinates (x,y) of a particular grid cell in the 0.25° CMG fire products, the latitude and longitude (in degrees) of the center of the grid cell may be computed as follows:

```
latitude = 89.875 - 0.25 × y

longitude = -179.875 + 0.25 × x
```

Here, x and y are again zero-based image coordinates; for one-based image coordinates first subtract 1 from both x and y.

5.4.5 Example Code

Example 7: IDL code for reading the cloud-corrected fire pixel layer within the Collection 6 MODIS CMG monthly and 8-day fire products (HDF4 format).

```
; read "CloudCorrFirePix" array in CMG product (HDF4 format)
cmg_file = 'MYD14CMQ.200412.006.01.hdf'

sd_id = HDF_SD_START(cmg_file, /READ)
index = HDF_SD_NAMETOINDEX(sd_id, 'CloudCorrFirePix')
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, CloudCorrFirePix
HDF_SD_ENDACCESS, sds_id
HDF_SD_END, sd_id
```

Example 8: IDL code for reading the cloud-corrected fire pixel layer within the Collection 6 MODIS CMG monthly and 8-day fire products (FITS format).

```
; read "CloudCorrFirePix" array in CMG product (FITS format)
cmg_file = 'MYD14CMQ.200412.006.01.fits'

FITS_OPEN, cmg_file, fcb
ihdu = FITS_FIND_HDU(fcb, 'CloudCorrFirePix')
FITS_READ_ARRAY, fcb, ihdu, CloudCorrFirePix, ndims, dims
FITS_CLOSE, fcb
```

5.5 Global Monthly Fire Location Product (MCD14ML)

The monthly fire location product contains the geographic location, date, and some additional information for each fire pixel detected by the Terra and Aqua MODIS sensors on a monthly basis. For convenience, the product is distributed as a plain ASCII (text) file with fixed-width fields delimited with spaces. The first line of each file is a header containing the abbreviated names of each column (field). As an example, here are the first ten lines of the December 2008 product file:

```
YYYYMMDD HHMM sat lat lon T21 T31 sample FRP conf type dn
20081201 0051 T -12.0288  143.0191 321.6 289.6  681    11.5  53   0 D
20081201 0051 T -12.0301  143.0282 317.8 287.9  682     7.8  42   0 D
20081201 0051 T -12.0391  143.0269 356.8 289.1  682    67.4   0   0 D
20081201 0051 T -12.0481  143.0255 346.6 286.7  682    46.2   0   0 D
20081201 0051 T -12.0552  141.9690 320.8 291.4  571    11.3  38   0 D
20081201 0051 T -12.9809  143.4871 330.7 301.2  752    16.8  80   0 D
20081201 0051 T -12.9999  143.4275 339.1 300.0  746    31.6  88   0 D
20081201 0051 T -13.0012  143.4368 327.6 300.5  747    14.0  76   0 D
20081201 0051 T -13.0079  143.4203 345.0 298.5  746    42.8  92   0 D
```

A brief description of each data column is provided in Table 9.

Table 9: Summary of columns in the MCD14ML fire location product.

Column	Name	Units	Description
1	YYYYMMDD	-	UTC year (YYYY), month (MM), and day (DD).
2	HHMM	-	UTC hour (HH) and minute (MM).
3	sat	-	Satellite: Terra (T) or Aqua (A).
4	lat	degrees	Latitude at center of fire pixel.
5	lon	degrees	Longitude at center of fire pixel.
6	T21	K	Band 21 brightness temperature of fire pixel.
7	T31	K	Band 31 brightness temperature of fire pixel.
8	sample	-	Sample number (range 0-1353).
9	FRP	MW	Fire radiative power (FRP).
10	conf	%	Detection confidence (range 0-100).
11	type	-	Inferred hot spot type:
			0 = presumed vegetation fire
			1 = active volcano
			2 = other static land source
			3 = offshore
12	dn	-	Day/night algorithm flag: day (D) or night (N).

Hot-spot types 0–2 are reserved exclusively for land pixels; hot spots detected over water (presumably offshore gas flares) will always be assigned a type of 3.

5.5.1 Naming Convention

The names of the MCD14ML product files have the structure `MCD14ML.YYYYMM.CCC.VV.txt`, where `YYYY` is the four-digit product year, `MM` is the two-digit calendar month, `CCC` denotes the Col-

lection (see Section 3.1.4), and `VV` denotes the product version (currently "`02`") within a Collection.

5.5.2 Versions

The version 2 MCD14ML product has an additional digit of precision in the latitude and longitude fields, and a new column indicating the day/night state of each fire pixel.

Version 2:

```
YYYYMMDD HHMM sat lat lon T21 T31 sample FRP conf type dn
20081201 0051 T -12.0288  143.0191 321.6 289.6  681    11.5  53  0 D
```

Version 1:

```
YYYYMMDD HHMM sat lat lon T21 T31 sample FRP conf type
20081201 0051 T -12.029  143.019 321.8 289.6  681    15.1   0  1
```

5.5.3 Example Code

Example 9: IDL code for reading a single monthly fire location product file while still compressed (note the COMPRESS keyword when the file is opened).

```
infile = 'MCD14ML.200904.006.02.txt.gz'

header = ''
year = 0
month = 0B
day = 0B
hour = 0B & minute = 0B
sat = ''
lat = 0.0 & lon = 0.0
T21 = 0.0 & T31 = 0.0
sample = 0
FRP = 0.0
confidence = 0B
type = 0B
dnstr = ''

fmt = '(I4.4,2I2,1X,2I2,1X,A1,F9.4,F10.4,2F6.1,I5,F8.1,I4,I3,1X,A1)'

openr, 2, infile, /COMPRESS

; skip header
readf, 2, header

while ~EOF(2) do begin
        readf, 2, year, month, day, hour, minute, sat, $
                lat, lon, T21, T31, sample, FRP, confidence, type, $
                dnstr, FORMAT = fmt

        ; do something with values here
endwhile

close, 2
```

Example 10: R/S-Plus code for reading a single monthly fire location product file and plotting separate histograms of band 21 brightness temperature for Terra and Aqua fire pixels.

```
# comment.char argument is not necessary but makes the read.table()
# call somewhat faster
z <- read.table("MCD14ML.200711.006.02.txt.gz", header=TRUE,
        comment.char="")

# two plots on page
par(mfrow=c(2,1))

xstr <- "Band 21 Brightness Temperature"

# Terra fire pixels
hist(z$T21[z$sat == "T"], xlab = xstr)

# Aqua fire pixels
hist(z$T21[z$sat == "A"], xlab = xstr)
```

6 Validation of the MODIS Active Fire Products

In this section we provide a brief overview of the validation status of the MODIS active fire products. A more detailed overview may be found in the active fire section of the MODIS Land Team Validation web site[4].

6.1 Validation Based on ASTER Imagery

Validation of the Terra MODIS active fire product has primarily been performed using coincident, high resolution fire masks derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery. See Morisette et al. (2005a,b), Csiszar et al. (2006), and Schroeder et al. (2008) for details. A very brief (though now somewhat obsolete) discussion of the general validation procedure, with some early results, can be found in Justice et al. (2002). For information about the methodology for producing the ASTER fire masks, see Giglio et al. (2008).

More recent work described has achieved Stage 3 validation of the Level 2 Terra MODIS fire product using 2500 ASTER scenes distributed globally and acquired from 2001 through 2006 (Figure 9). See Giglio et al. (2016) for details.
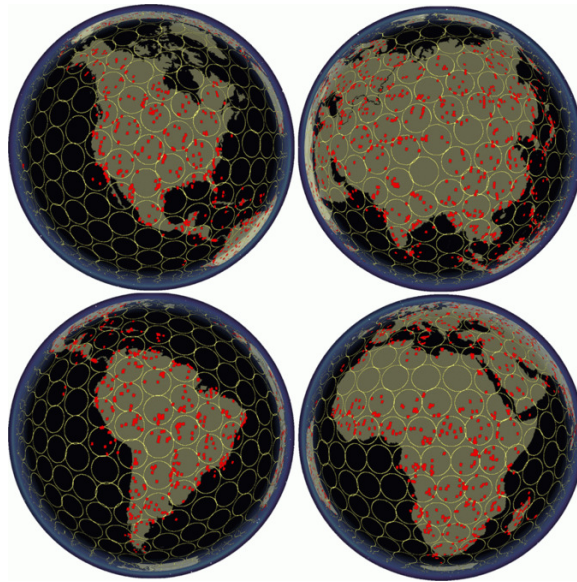
Figure 9: Spatial coverage and distribution of ASTER scenes (red patches) used in the Stage 3 validation of MOD14.

6.2 Other Validation

Independent validation of the Collection 5 Terra and Aqua MODIS active fire products without ASTER has been performed by de Klerk (2008) and Hawbaker et al. (2008). These approaches have at least two advantages over ASTER-based methods: 1) They can be applied to both MODIS sensors (not just the Terra MODIS), and 2) they are not restricted to the near-nadir portion of the MODIS swath.

---

[4]http://landval.gsfc.nasa.gov/ProductStatus.php?ProductID=MOD14

7 Caveats and Known Problems

7.1 Caveats

7.1.1 Fire Pixel Locations vs. Gridded Fire Products

We urge caution in using fire pixel locations in lieu of the 1-km gridded MODIS fire products. The former includes no information about cloud cover or missing data and, depending on the sort of analysis that is being performed, it is sometimes possible to derive misleading (or even incorrect) results by not accounting for these other types of pixels. It is also possible to grossly misuse fire pixel locations, even for regions and time periods in which cloud cover and missing observations are negligible. Some caveats to keep in mind when using MODIS fire pixel locations:

- The fire pixel location files allow users to temporally and spatially bin fire counts arbitrarily. However, severe temporal and spatial biases may arise in any MODIS fire time series analysis employing time intervals shorter than about eight days.

- Known fires for which no entries occur in the fire-pixel location files are not necessarily missed by the detection algorithm. Cloud obscuration, a lack of coverage, or a misclassification in the land/sea mask may instead be responsible, but with only the information provided in the fire location files this will be impossible to determine.

7.2 Collection 6 Known Problems

7.2.1 Pre-November 2000 Data Quality

Prior to November 2000, the Terra MODIS instrument suffered from several hardware problems that adversely affected all of the MODIS fire products. In particular, some detectors were rendered dead or otherwise unusable in an effort to reduce unexpected crosstalk between many of the 500 m and 1 km bands. The dead detectors are known to introduce at least three specific artifacts in the pre-November 2000 fire products: striping, undetected small fires, and undetected large fires. In some very rare instances severe miscalibration of band-21 in the first weeks of the MODIS data archive (February and March 2000) will cause entire scan lines to be identified as fire.

7.2.2 Detection Confidence

A detection confidence intended to help users gauge the quality of individual fire pixels is included in the Level 2 fire product. This confidence estimate, which ranges between 0% and 100%, is used to assign one of the three fire classes (*low-confidence fire*, *nominal-confidence fire*, or *high-confidence fire*) to all fire pixels within the fire mask. In the Collection 4 fire product this confidence estimate did not adequately identify highly questionable, low confidence fire pixels. Such pixels, which by design should have a confidence close to 0%, were too often assigned much higher confidence estimates of 50% or higher. While an adjustment implemented in the Collection 5 code partially mitigated this problem, some highly questionable fire pixels are still classified as nominal-confidence fires. A second minor adjustment was implemented for Collection 6 to help correct this problem.

7.2.3 Flagging of Static Sources

Some obvious, non-fire static hot-spot sources (both industrial and volcanic) are not properly flagged as such in the *type* field of the MCD14ML product. This problem will be corrected in a forthcoming reprocessed version of the product.

7.3 Collection 5 Known Problems

The frequency of certain problems known to affect the Collection 5 MODIS fire products was reduced for Collection 6. Two such problems are described here.

7.3.1 False Alarms in Small Forest Clearings

Extensive validation of the Collection-5 Level-2 Terra MODIS fire product by Schroeder et al. (2008) found that small clearings within rainforest were a source of persistent false alarms in the Amazon. An example is shown in Figure 10. For Collection 6, the frequency of this type false alarm was reduced using an additional rejection test.
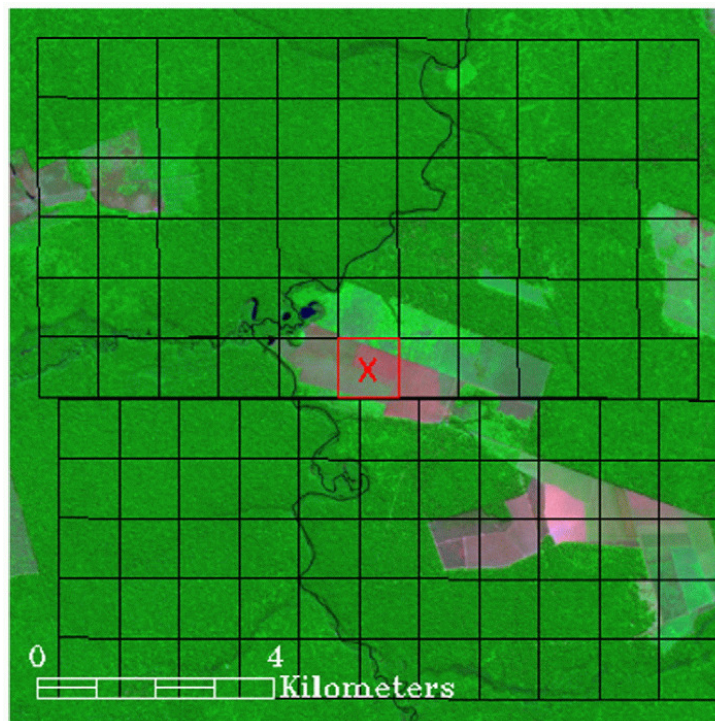
Figure 10: Example false alarm (red square with cross) in the Collection 5 product from 23 May 2002 (14:03 UTC) in an Amazonian rainforest clearing, with approximate edges of 1-km MODIS pixels (black grid) superimposed on a high resolution ASTER image. Source: Schroeder et al. (2008).

7.3.2   False Alarms During Calibration Maneuvers

A bug in the Collection-5 Level 1B calibrated-radiance production code occasionally produced spurious radiance values in the thermal bands during lunar roll calibration maneuvers. This in turn produced spurious stripes of fire pixels across the entire swath in up to ∼20 scans during these periods. The bug caused similar striping in several other MODIS products, in particular the cloud mask.

While most of the affected Level 2 granules were deleted from the Collection 5 archive, a small number were missed during quality assurance and subsequently propagated "arcs" of fire pixels into the Collection 5 CMG and MCD14ML fire products. An example for the Aqua MODIS is shown in Figure 11. The bug was fixed in late 2009, and the corrected Level 1B production code is now being used for the Collection 6 reprocessing.
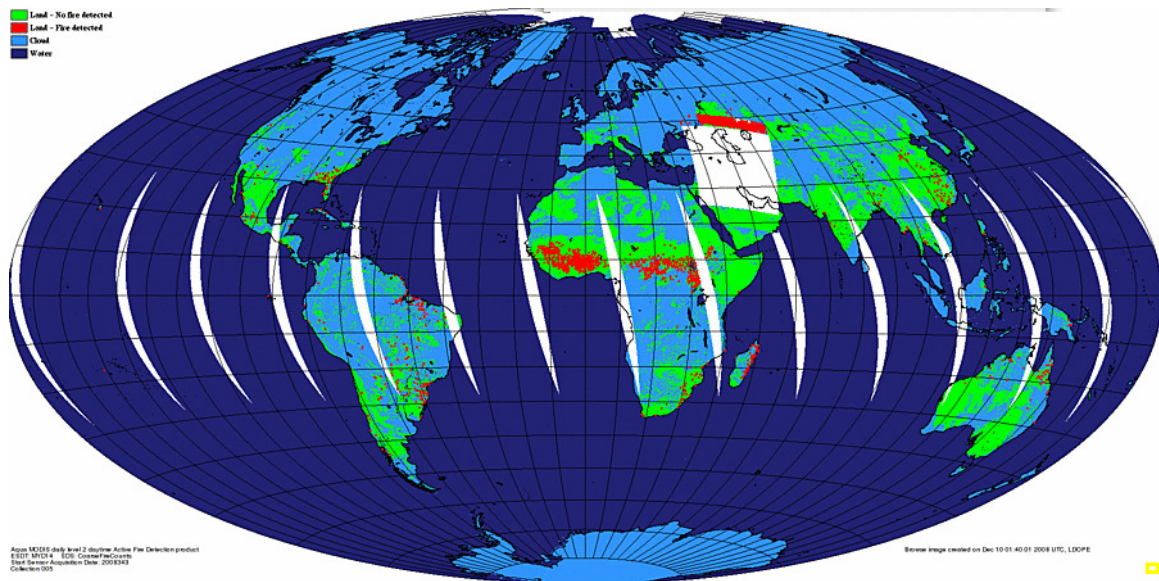
Figure 11: Example of a spurious arc of false fire pixels (red dots) in the Collection-5 8 December 2008 Aqua daily global browse imagery caused by spurious mid-infrared radiance values in the Level 1B input data during a lunar calibration maneuver at 22:35 UTC. Cloud pixels are shown in light blue, and areas lacking data are shown in white. Browse image courtesy of the LDOPE.

8   Frequently Asked Questions

8.1   Terra and Aqua Satellites

8.1.1   Where can I find general information about the Terra and Aqua satellites?

See NASA's Terra and Aqua web sites for a start:

```
http://terra.nasa.gov/
http://aqua.nasa.gov/
```

8.1.2   When were the Terra and Aqua satellites launched?

18 December 1999 and 4 May 2002, respectively.

8.1.3   How can I determine overpass times of the Terra and Aqua satellites for a particular location?

Both historical and predicted orbit tracks for Terra and Aqua are available from the University of Wisconsin-Madison Space Science and Engineering Center (SSEC)[5].

8.2   General MODIS Questions

8.2.1   Where can I find Algorithm Technical Basis Documents (ATBDs) for the MODIS land products?

ATBDs for all of the MODIS land products are available from MODARCH[6]. Note that some are not up to date and predate the launch of both the Terra and Aqua satellites.

8.2.2   Do the MODIS sensors have direct broadcast capability?

Yes, and there is a large community of MODIS direct broadcast data users. More information is available from the NASA Direct Readout Laboratory[7].

8.3   General Fire Product Questions

8.3.1   How are the fires and other thermal anomalies identified in the MODIS fire products detected?

Fire detection is performed using a contextual algorithm (*Giglio et al.*, 2003; *Giglio et al.*, 2016) that exploits the strong emission of mid-infrared radiation from fires (*Dozier*, 1981; *Matson and Dozier*, 1981). The algorithm examines each pixel of the MODIS swath, and ultimately assigns to each one of the following classes: *missing data*, *cloud*, *water*, *non-fire*, *fire*, or *unknown*.

Pixels lacking valid data are immediately classified as *missing data* and excluded from further consideration. Cloud and water pixels are identified using cloud and water masks, and are assigned the classes *cloud* and *water*, respectively. Processing continues on the remaining clear land pixels.

---

[5]`http://www.ssec.wisc.edu/datacenter/`
[6]`http://modarch.gsfc.nasa.gov/data/atbd/`
[7]`http://directreadout.sci.gsfc.nasa.gov/`

A preliminary classification is used to eliminate obvious non-fire pixels. For those potential fire pixels that remain, an attempt is made to use the neighboring pixels to estimate the radiometric signal of the potential fire pixel in the absence of fire. Valid neighboring pixels in a window centered on the potential fire pixel are identified and are used to estimate a background value. If the background characterization was successful, a series of contextual threshold tests are used to perform a relative fire detection. These look for the characteristic signature of an active fire in which both 4 μm brightness temperature and the 4 and 11 μm brightness temperature difference depart substantially from that of the non-fire background. Relative thresholds are adjusted based on the natural variability of the background. Additional specialized tests are used to eliminate false detections caused by sun glint, desert boundaries, errors in the water mask, and small forest clearings. Candidate fire pixels that are not rejected in the course of applying these tests are assigned a class of *fire*. Pixels for which the background characterization could not be performed, i.e. those having an insufficient number of valid pixels, are assigned a class of *unknown*.

See *Giglio et al.* (2016) for a detailed description of the Collection 6 detection algorithm.

8.3.2 What is the smallest fire size that can be detected with MODIS? What about the largest?

MODIS can routinely detect both flaming and smoldering fires $\sim$1000 m^2 in size. Under very good observing conditions (e.g. near nadir, little or no smoke, relatively homogeneous land surface, etc.) flaming fires one tenth this size can be detected. Under pristine (and extremely rare) observing conditions even smaller flaming fires $\sim$50 m^2 can be detected.

Unlike most contextual fire detection algorithms designed for satellite sensors that were never intended for fire monitoring (e.g. AVHRR, VIRS, ATSR), there is no upper limit to the largest and/or hottest fire that can be detected with MODIS.

8.3.3 Why didn't MODIS detect a particular fire?

This can happen for any number of reasons. The fire may have started and ended in between satellite overpasses. The fire may be too small or too cool to be detected in the 1 km^2 MODIS footprint. Cloud cover, heavy smoke, or tree canopy may completely obscure a fire. Occasionally the MODIS instruments are inoperable for extended periods of time (e.g. the Terra MODIS in September 2000) and can of course observe nothing during these times.

8.3.4 How well can MODIS detect understory burns?

The likelihood of detection beneath a tree canopy is unknown but probably very low. Understory fires are usually small, which already makes MODIS less likely to detect them, but with the addition of a tree canopy to obstruct the view of a fire, detection becomes very unlikely.

8.3.5 Can MODIS detect fires in unexposed coal seams?

In general, no. The detection algorithm is not tuned to look for the subtle temperature changes in the overlying soil that is characteristic of such fires.

8.3.6 How do I obtain the MODIS fire products?

See Section 4.

8.3.7　What validation of the MODIS active fire products has been performed?

Validation of the Terra MODIS active fire product has primarily been performed using coincident, high resolution fire masks derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery. See Section 6.

8.3.8　I don't want to bother with strange file formats and/or an unfamiliar ordering interface and/or very large data files. Can't you just give me the locations of fire pixels in plain ASCII files and I'll bin them myself?

You can use the MCD14ML monthly fire location product, or obtain MODIS fire pixel locations via the Web Fire Mapper, but this doesn't necessarily mean that fire pixel locations are the most appropriate source of fire-related information. The fire pixel location files include no information about cloud cover or missing data, and depending on the sort of analysis you are performing, it is sometimes possible to derive misleading (or even incorrect) results by effectively ignoring these other types of pixels. In many cases it is more appropriate to use one of the 1-km Level 3 or CMG fire products. See Section 7.1.1 for more information about this issue.

8.3.9　I want to estimate burned area using active fire data. What effective area burned should I assume for each fire pixel?

Pulling this off to an acceptable degree of accuracy is generally not possible due to nontrivial spatial and temporal sampling issues. For some applications, however, acceptable accuracy can be achieved, although the effective area burned per fire pixel is not simply a constant, but rather varies with respect to several different vegetation- and fire-related variables. See Giglio et al. (2006b) for more information.

8.3.10　Why are some of the MODIS fire products not available prior to November 2000?

Although the Terra MODIS first began acquiring data in February 2000, crosstalk and calibration remained problematic until early November 2000 (see Section 7.2.1). Among other problems, this compromises the integrity and consistency of the earliest MODIS fire products, in particular the CMG fire products which are almost always used for time series analyses. For this reason we do not distribute those products (specifically, the CMG and fire-location products) which were rendered particularly inconsistent during the pre-November 2000 time period.

8.3.11　Why then are the Level 2 swath and Level 3 tiled fire products available before November 2000?

Because these products are not totally useless despite the early calibration problems. In addition, these products are less often used for time series analysis, where a lack of consistency is likely to be more problematic.

8.4　Level 2 Fire Products

8.4.1　Why do the Level 2 product files vary in size?

Level 2 granules can contain slightly different numbers of scans. More importantly, internal HDF compression is used to reduce the size of the files.

8.4.2 How should the different fire detection confidence classes be used?

Three classes of fire pixels (low confidence, nominal confidence, high confidence) are provided in the fire masks of the MODIS Level 2 and Level 3 fire products. Users requiring fewer false alarms may wish to consider only nominal- and high-confidence fire pixels, and treat low-confidence fire pixels as clear, non-fire, land pixels. Users requiring maximum fire detectability, who are able to tolerate a higher incidence of false alarms, should consider all three classes of fire pixels.

8.4.3 How are the confidence values in the "FP_confidence" SDS related to the confidence classes assigned to fire pixels?

The confidence class assigned to a fire pixel (*low*, *nominal*, or *high*) is determined by thresholding the confidence value (C) calculated for the fire pixel. These thresholds are listed in Table 10.

Table 10: Fire-pixel confidence classes associated with the confidence level C computed for each fire pixel.

Range	Confidence Class
$0\% \leq C < 30\%$	low
$30\% \leq C < 80\%$	nominal
$80\% \leq C \leq 100\%$	high

8.4.4 How can I take data from the fire-pixel-table SDSs (i.e., the one-dimensional SDSs with the prefix "FP_") and place the values in the proper locations of a two-dimensional array that matches the swath-based "fire mask" and "algorithm QA" SDSs?

1. Open a MOD14/MYD14 Level 2 granule for reading using your favorite programming language.

2. Determine the number of fire pixels in the granule. The easiest way to do this is to read the global HDF attribute "FirePix". (If you are a masochist you can read and parse the ECS *CoreMetadata.0* string for the product specific attribute `FIREPIXELS` instead.) If the number of fire pixels is zero, all of the "FP_" SDSs will have length zero, and there's nothing left to process, so close the file and go on to whatever else you'd like to do.

3. Find the number of lines in the granule. Call this number `nlines`. In the product this quantity corresponds to the dimension `number_of_scan_lines`. Since it is difficult to determine the value of a named dimension directly with the HDF library, you must instead determine the dimensions of an SDS for which the named dimension applies. You can use either the "fire mask" or "algorithm QA" SDSs for this as they both have dimensions `number_of_scan_lines` by `pixels_per_scan_line`. The HDF library function SDgetinfo returns this information (in IDL use `HDF_SD_GETINFO`). You can determine the number of samples as well (`pixels_per_scan_line`), if you like, but the value of this dimension will always be 1354.

4. Read the the "FP_line" and "FP_sample" SDSs in their entirety. These arrays contain pixel coordinates within the granule for all of the quantities in the other "FP_" SDSs. Hereafter we'll

assume these have been read and stored in internal arrays named `FP_line` and `FP_sample`, respectively.

5. Create a 2-D array to hold whatever "FP_" quantity it is that you'd like to use. Assuming you want the band 21/22 brightness temperature ("FP_T21"), then in IDL you could do this:

```
T21 = fltarr(nlines, 1354)
```

6. Read the entire "FP_" SDS that you'd like to use. In the above example this is "FP_T21". Following our earlier convention, we'll assume this SDS is read into an internal array named `FP_T21`.

7. Populate pixels in the T21 array by indexing it with `FP_line` and `FP_sample`. In IDL you would do this in one shot:

```
T21 = FP_T21[FP_line, FP_sample]
```

In non-vector-based languages you'd have to write an explicit loop. In C, for example, do this:

```
for (i = 0; i < num_fire_pixels; i++)
    T21[FP_line[i]][FP_sample[i]] = FP_T21[i];
```

Note that the coordinates in "FP_line" and "FP_sample" are zero-based. In a language like Fortran (with the first array element numbered 1) you'd have to add 1 to all values in `FP_line` and `FP_sample`.

8. Do whatever you want with the 2-D `T21` array – it can now be indexed just like the fire mask and QA SDSs would be if you had read them from the file. Note, though, that the newly created `T21` array will only contain data in those pixels where fires were detected. This is true for 2-D arrays created from any of the other "FP_" SDSs as well.

9. Go back to step 4 for the remaining "FP_" quantities you want to use.

10. Close the HDF file.

8.4.5 Why are the values of the fire radiative power (FRP) in the Collection 4 Level 2 product inconsistent with those in the Collection 5 Level 2 product?

The "FP_power" SDS in the Collection 4 Level 2 product actually contained radiative power per unit area, despite the fact that the `units` attribute of this SDS is assigned a value of "megawatts" (this is an error). These values had to be multiplied by the appropriate pixel area (at the surface of the Earth) to obtain the FRP, like this:

FRP (MW) = power values stored in the Collection 4 Level 2 product $\times$ pixel area (km^2)

Note that the area of a MODIS pixel varies with its position in the MODIS scan; see the next question for details. Note also that starting with Collection 5 the Level 2 products have this multiplication performed during processing and therefore contain the correct FRP.

8.4.6 What is the area of a MODIS pixel at the Earth's surface?

The area of a MODIS pixel is nominally 1 km^2 but grows away from nadir. To find the approximate pixel area, calculate the along-scan and along-track pixel dimensions (ΔS and ΔT, respectively). The pixel area is then the product $\Delta S \times \Delta T$. General formulas for the pixel dimensions (in km) can be found in Ichoku and Kaufman (2005) and are reproduced here:

$$\Delta S = R_{\mathrm{e}}s\left(\frac{\cos\theta}{\sqrt{(R_{\mathrm{e}}/r)^2 - \sin^2\theta}} - 1\right) \tag{11}$$

$$\Delta T = rs\left(\cos\theta - \sqrt{(R_{\mathrm{e}}/r)^2 - \sin^2\theta}\right), \tag{12}$$

where $R_{\mathrm{e}} = 6378.137$ km (Earth radius), $r = R_{\mathrm{e}}+h$, $h = 705$ km (satellite altitude), $s = 0.0014184397$, and θ is the scan angle. The scan angle (in radians) can be calculated from the granule sample SDS ("FP_sample") included in the Level 2 fire product as follows:

$$\theta = s \times (\mathrm{sample} - 676.5) \tag{13}$$

Note that the errors in the above approximations are smaller than the error entailed by treating the pixel as having sharp edges.

8.4.7 Can I use cloud pixels identified in the Level 2 fire product as a general-purpose cloud mask for other applications?

Cloud pixels are identified in the Level 2 fire products using simple, fixed brightness-temperature and reflectance thresholds. While adequate for identifying optically thick cloud cover, this scheme often fails to identify cloud edges and thin cirrus. It is also likely to misclassify snow and sometimes desert as cloud. While adequate for the fire detection algorithm, which can tolerate these limitations but cannot tolerate fires being mislabeled as cloud, these characteristics probably render the internal cloud mask inadequate for most other applications.

8.5 Level 3 Tiled Fire Products

8.5.1 Why do coastlines in the tile-based Level 3 products looked so warped?

The tile-based Level 3 products are defined on a global sinusoidal grid which preserves areas but greatly distorts the shape of land masses at longitudes far from the prime meridian.

8.5.2 Is there an existing tool I can use to reproject the tiled MODIS products into a different projection?

The *MODIS Reprojection Tool* (MRT) can reproject the tiled MODIS products into many different projections; see Section 10.

8.5.3 Why do some MOD14A1 and MYD14A1 product files have fewer than eight daily data layers?

Days for which no MODIS data was acquired *at all* will not have a "plane" in the three-dimensional Scientific Data Sets included in the MOD14A1 and MYD14A1 products.

8.5.4 How can I determine the date associated with each daily composite in the MOD14A1 and MYD14A1 products when fewer than eight days of data are present?

There are two ways to do this. Let the number of days of valid data (nominally 8) in the product be N_{days}.

Method 1: Using the product-specific `Dates` global attribute.

The `Dates` attribute (a string) will contain the date for each plane of the three-dimensional SDS, with each of the N_{days} dates encoded as 10-character substring (format YYYY-MM-DD), separated by a space. Here's an example for the normal case of $N_{\text{days}} = 8$:

```
"2002-10-24 2002-10-25 2002-10-26 2002-10-27 2002-10-28 2002-10-29 2002-10-30 2002-10-31"
```

Method 2: Using the ECS *ArchiveMetadata.0* global attribute.

You may alternatively search the *ArchiveMetadata.0* global attribute for the DAYSOFYEAR entry. This field will contain exactly N_{days} dates, with each date corresponding to the date of each plane in the three-dimensional Scientific Data Sets. For example, a time period having no days of 100% missing data will contain eight dates in the DAYSOFYEAR entry, like this:

```
"   OBJECT              = DAYSOFYEAR\n",
"     NUM_VAL           = 1\n",
"     VALUE             = \"2009-08-29, 2009-08-30, 2009-08-31,
                           2009-09-01, 2009-09-02, 2009-09-03,
                           2009-09-04, 2009-09-05\"\n",
"   END_OBJECT          = DAYSOFYEAR\n",
```

And here's an example when only six days of data are present:

```
"  OBJECT                   = DAYSOFYEAR\n",
"    NUM_VAL                = 1\n",
"    VALUE                  = \"2001-06-10, 2001-06-11, 2001-06-12,
                              2001-06-13, 2001-06-14,
                              2001-06-15\"\n",
"  END_OBJECT               = DAYSOFYEAR\n",
```

8.5.5 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[8], or perform the calculation as described in Section 5.2.6.

8.5.6 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[8], or perform the calculation as described in Section 5.2.6.

8.5.7 What size are the grid cells of Level 3 MODIS sinusoidal grid?

The Level 3 MODIS products generated on the MODIS sinusoidal grid are colloquially referred to as having "1 km", "500 m", and "250 m" grid cells, but the actual cell sizes are shown in Table 11.

Table 11: 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

---

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

8.6 Level 3 CMG Fire Products

8.6.1 I need to reduce the resolution of the 0.25° CMG fire product to grid cells that are a multiple of 0.25° in size. How do I go about doing this?

For all pixel-count data layers simply sum the values of the 0.25° grid cells that lie within the larger grid cells. Be sure to handle grid cells flagged with the missing data value of -1. At the very least this entails excluding the negative missing data values from the resulting sum, but, depending upon the application, it may be more appropriate to flag the coarser grid cell as lacking valid data entirely. When coarsening the mean fire radiative power layer (MeanPower) you should weight the individual 0.25° mean FRP values by the corrected fire pixel counts (CorrFirePix), handling (by at least excluding) missing FRP values of 0 in the process. A few examples are shown in the following figures:
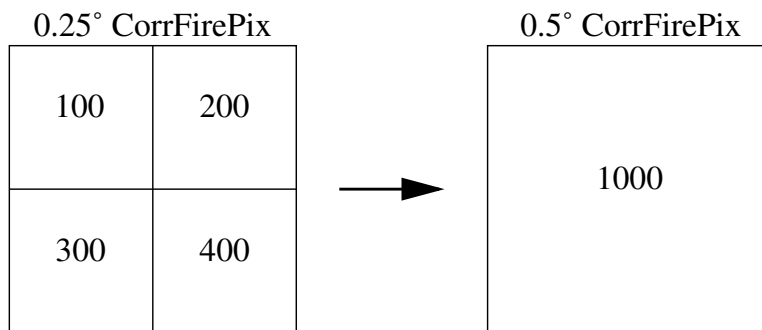
Rebinning corrected fire pixel counts from 0.25° grid cells (left) to a 0.5° grid cell (right). The result is simply the sum of the pixel counts of the four 0.25° grid cells (100 + 200 + 300 + 400 = 1000 fire pixels) nested within the 0.5° grid cell.

0.25° CorrFirePix   0.5° CorrFirePix

-1	-1
300	400

→

-1
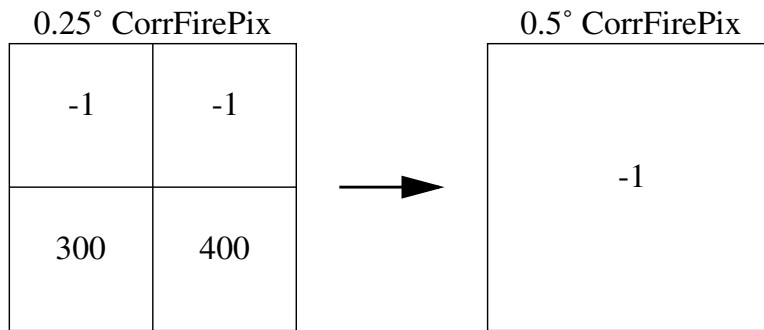
Rebinning corrected fire pixel counts from 0.25° grid cells (left) to a 0.5° grid cell (right) when missing data values of -1 are present. In this case we flag the entire 0.5° grid cell as lacking valid data which is appropriate when, for example, we are going to compare independent gridded fire products that won't generally have missing data values in exactly the same grid cells. For other applications it would be sufficient to simply exclude the missing values from the sum, yielding a result of 300 + 400 = 700 fire pixels in the 0.5° grid cell.

0.25° MeanPower (MW)   0.5° MeanPower (MW)

10	20
30	40

→

30
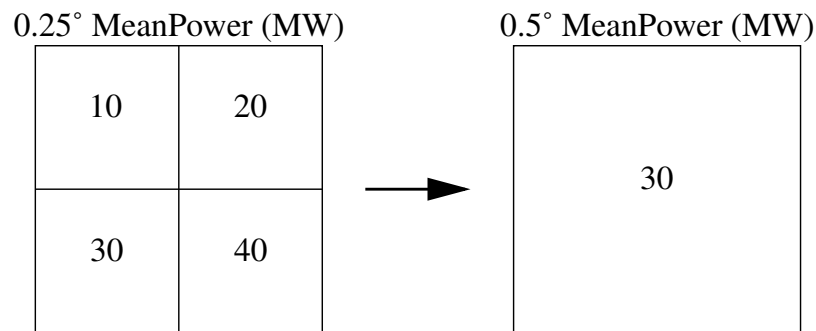
Rebinning the mean FRP from 0.25° grid cells (left) to a 0.5° grid cell (right). The result is the average of the FRP in the four 0.25° grid cells nested within the 0.5° grid cell, weighted by their individual corrected fire pixel counts. Using the corrected fire pixel counts from the first example (above) this yields:

$$\frac{10\,\mathrm{MW}\times100 \; + \; 20\,\mathrm{MW}\times200 \; + \; 30\,\mathrm{MW}\times300 \; + \; 40\,\mathrm{MW}\times400}{100 \; + \; 200 \; + \; 300 \; + \; 400} = 30\,\mathrm{MW}$$

8.6.2 Why don't you distribute a daily CMG fire product?

Because a MODIS product at daily temporal resolution will be plagued by extremely large sampling bias errors. At most latitudes a single MODIS instrument simply does not sample the Earth's surface adequately in time periods shorter than about 8 days to "average out" most of the sampling bias.

8.6.3 Why don't you distribute the CMG fire products as plain binary (or ASCII) files?

1) The number of files one must deal with balloons since most users request that individual data layers be written to separate files; 2) it is difficult to include useful metadata without writing separate header files, increasing the total number of files to handle even further; 3) it is possible for data and its accompanying metadata to become separated; and 4) production, ingest, and analysis software is much more likely to break when changes are made to the product.

8.6.4 Where can I find information about the FITS file format?

Extensive information about FITS is available from NASA's FITS Support Office[9]. For a more general overview see the FITS entry on Wikipedia[10]. You may also find the *TRMM VIRS Monthly Fire Product User's Guide* (*Giglio and Kendall*, 2003) helpful, particularly Appendix 2.

8.6.5 What software libraries are available for reading FITS files?

An extensive list, which includes packages for C, Fortran, IDL, Java, Perl, Python, and R, is maintained by the FITS Support Office[11].

8.6.6 How can I display images in FITS files?

Two good choices are *SAOimage*[12] (Figure 12) and *DS9*[13] (Figure 13). Use the "`-ul`" switch with SAOimage and the "`-orient y`" switch with DS9 to orient North upwards, otherwise the grid will appear upside down. If you're willing to tolerate an upside-down orientation (i.e., South on top), then *Fv*[14] (Figure 14) is another good choice.

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[9] http://fits.gsfc.nasa.gov/
[10] http://en.wikipedia.org/wiki/FITS
[11] http://fits.gsfc.nasa.gov/fits_libraries.html
[12] http://tdc-www.harvard.edu/software/saoimage.html
[13] http://hea-www.harvard.edu/RD/ds9/
[14] http://heasarc.nasa.gov/docs/software/ftools/fv/
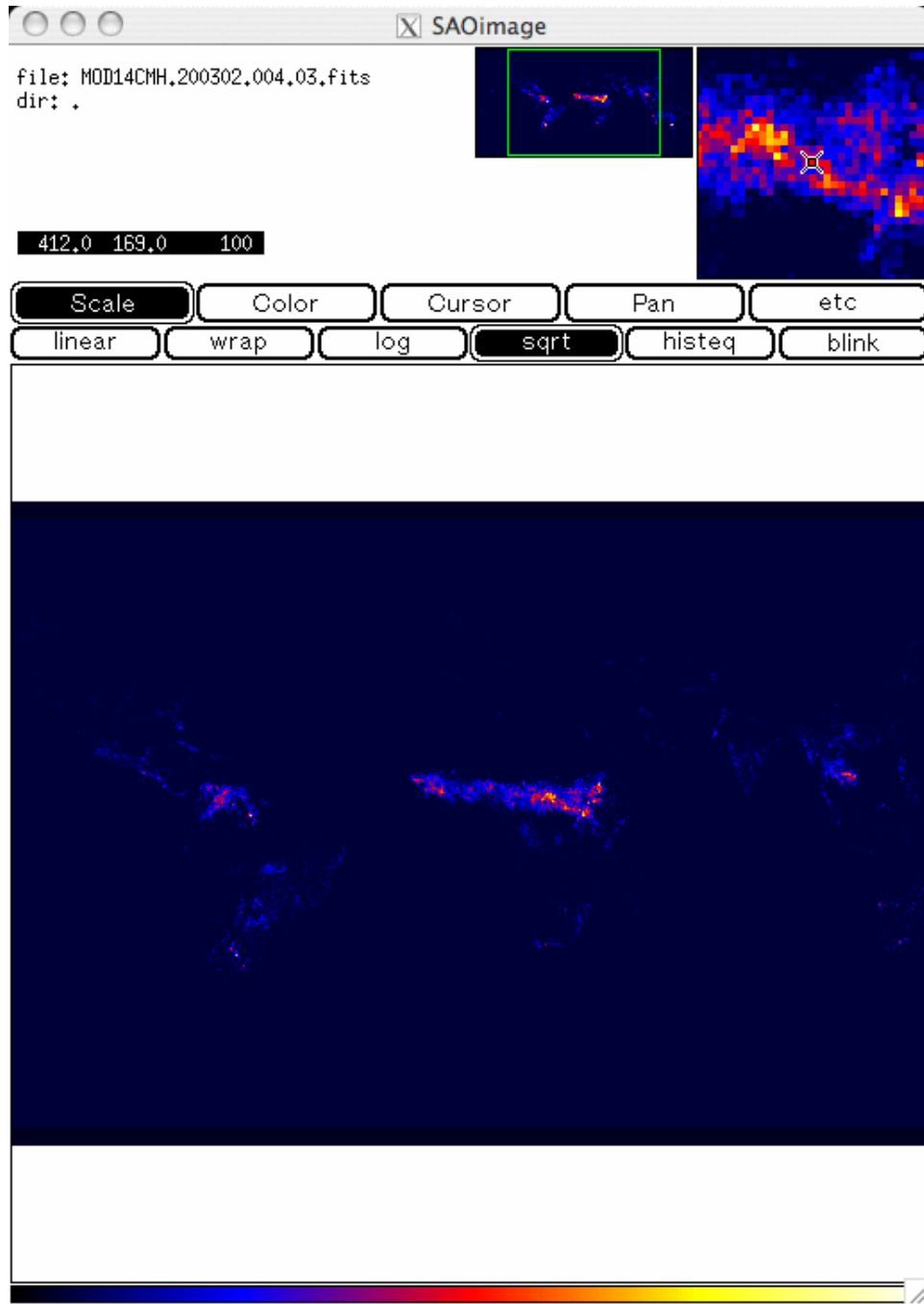
Figure 12: SAOimage displaying the `CorrFirePix` data layer in the February 2003 Collection 5 MOD14CMH product.
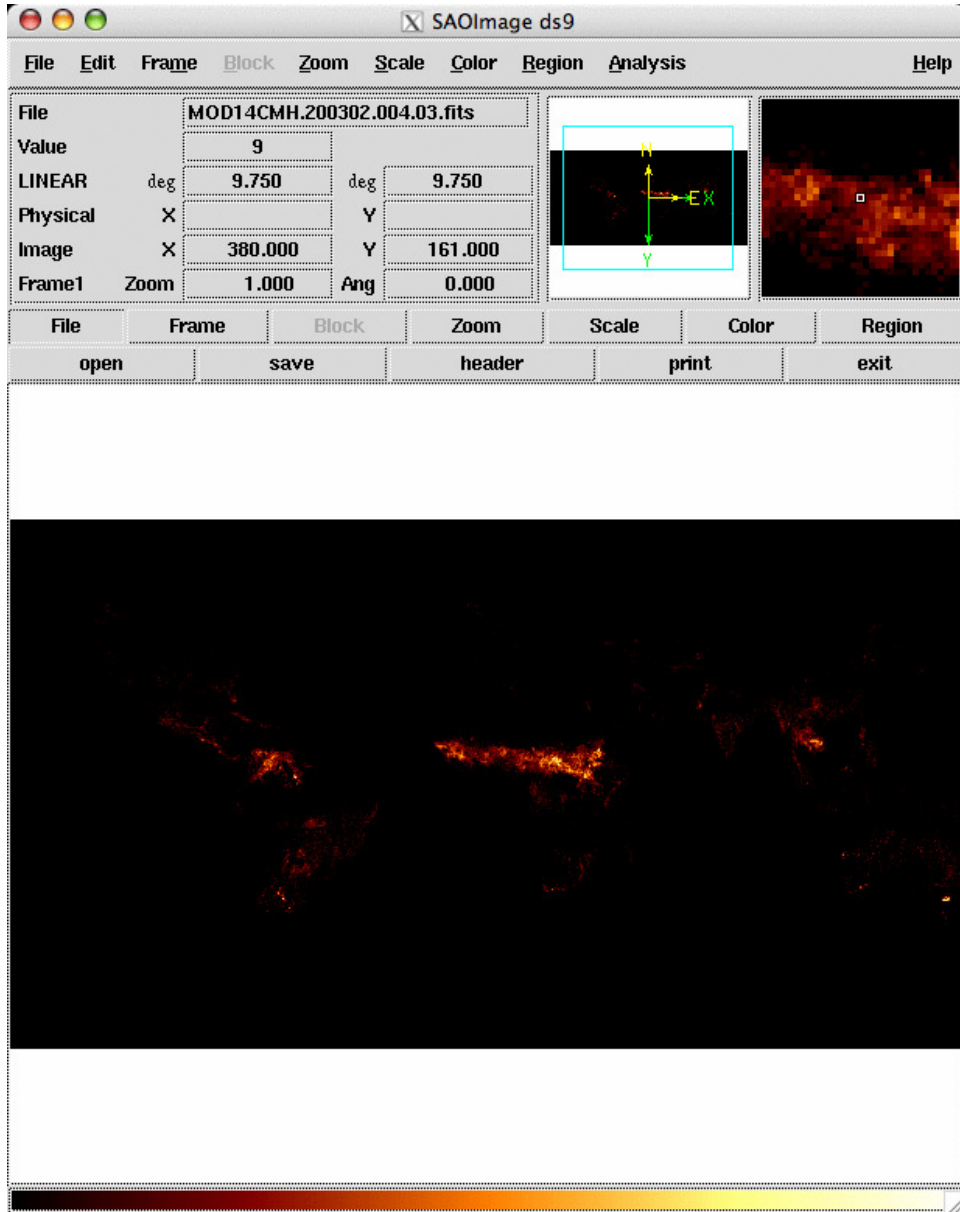
Figure 13: DS9 displaying the `CorrFirePix` data layer in the February 2003 Collection 5 MOD14CMH product. The longitude and latitude, respectively, at the center of the pixel beneath the cursor is shown in the upper left hand corner of the window, in the two numeric fields to the right of the word "LINEAR".
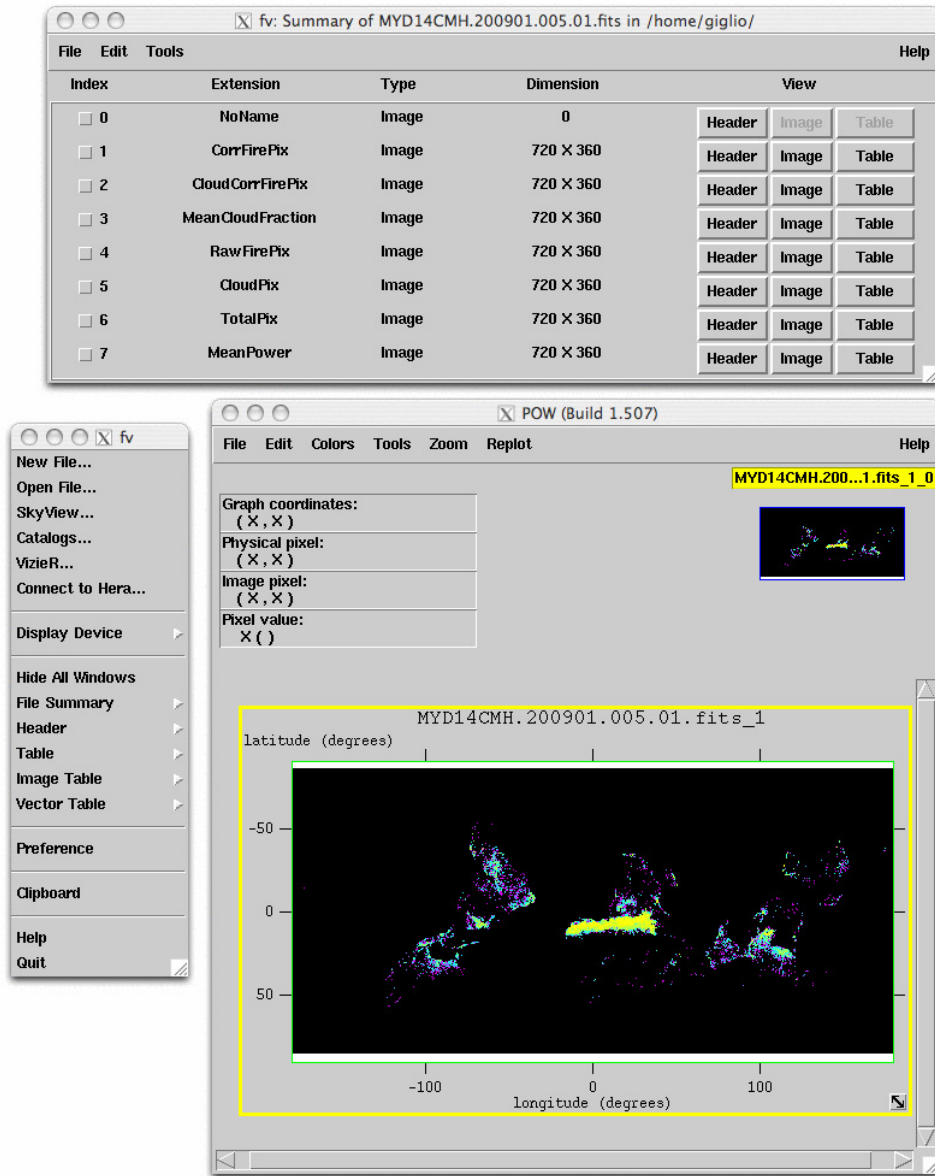
Figure 14: Fv displaying the `CorrFirePix` data layer in the January 2009 Collection 5 MYD14CMH product. Note the "upside down" orientation of the global image.

8.6.7 Does the last 8-day CMG product for each calendar year include data from the first few days of the following calendar year?

Yes. The last 8-day CMG product for each calendar year, which begins on day 361, includes the first three days (two days for leap years) of the following calendar year. For example, the 8-day Aqua MODIS CMG product `MYD14C8Q.2004361.006.01.hdf` is produced using observations from days 361–366 of 2004 and days 1–2 of 2005.

8.6.8 Where can I find details about the different corrections performed on some of the data layers in the CMG fire products?

See Giglio et al. (2006a).

8.6.9 Are persistent hot spots filtered out of the MODIS CMG fire products?

Yes, static, persistent hot spots are excluded during production of the CMG fire products (Figure 15). See Giglio et al. (2006a) for details. For Collection 6, the static source database will be updated bi-annually since the Terra MODIS data record now spans more than 15 years in duration.
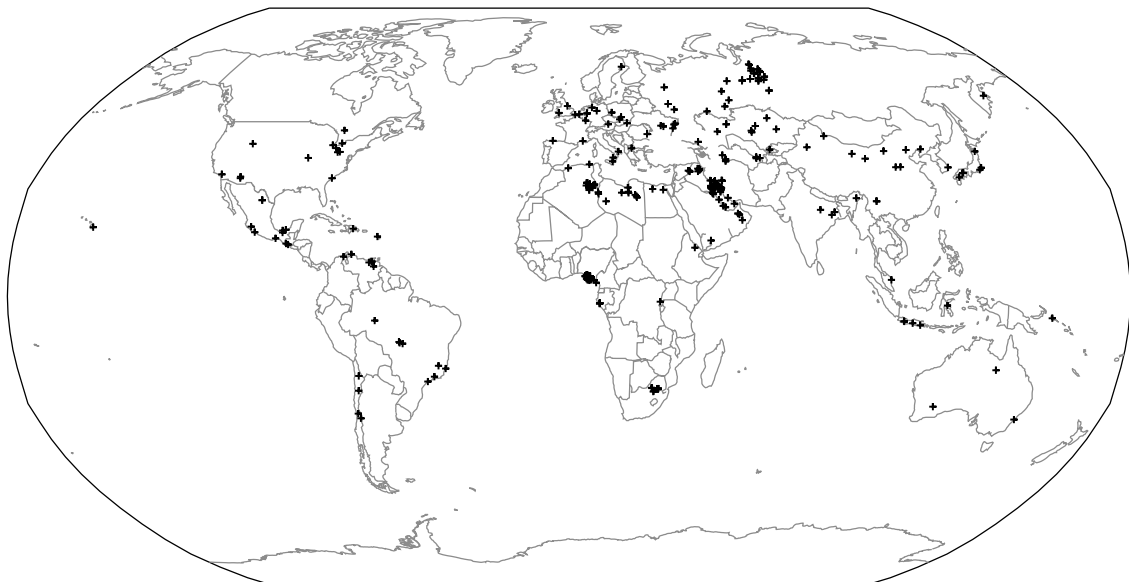

Figure 15: Locations of static hot spots excluded from the Collection 5 CMG fire products.

8.6.10 Is there an easy way to convert a calendar date into the ordinal dates (day-of-year) used in the file names of the 8-day fire products?

Yes. Try the Unix (or Linux) `cal` command (with the `-j` switch), or use Table 12.

Table 12: Calendar dates (month/day) corresponding to the day-of-year (DOY) beginning each 8-day time period for which the 8-day fire products are generated. Dates for non-leap years and leap years are shown separately.

DOY	Non-Leap Date	Leap Date	DOY	Non-Leap Date	Leap Date
1	01/01	01/01	185	07/04	07/03
9	01/09	01/09	193	07/12	07/11
17	01/17	01/17	201	07/20	07/19
25	01/25	01/25	209	07/28	07/27
33	02/02	02/02	217	08/05	08/04
41	02/10	02/10	225	08/13	08/12
49	02/18	02/18	233	08/21	08/20
57	02/26	02/26	241	08/29	08/28
65	03/06	03/05	249	09/06	09/05
73	03/14	03/13	257	09/14	09/13
81	03/22	03/21	265	09/22	09/21
89	03/30	03/29	273	09/30	09/29
97	04/07	04/06	281	10/08	10/07
105	04/15	04/14	289	10/16	10/15
113	04/23	04/22	297	10/24	10/23
121	05/01	04/30	305	11/01	10/31
129	05/09	05/08	313	11/09	11/08
137	05/17	05/16	321	11/17	11/16
145	05/25	05/24	329	11/25	11/24
153	06/02	06/01	337	12/03	12/02
161	06/10	06/09	345	12/11	12/10
169	06/18	06/17	353	12/19	12/18
177	06/26	06/25	361	12/27	12/26

8.7 Global Monthly Fire Location Product

8.7.1 Can I use the MCD14ML fire location product to make my own gridded fire data set?

Yes, but please see the caveats in Section 7.1.1 first. If done carelessly you may end up with severe temporal and spatial biases in your gridded data.

8.7.2 How many lines are in each MCD14ML product file?

This size of each product file depends on the number of fire pixels detected each month but typically varies between 200,000 and 500,000 lines.

8.7.3 Are persistent hot spots filtered out of the fire location product?

No. Unlike the CMG fire product, static, persistent hot spots are not removed from the MCD14ML product. For Collection 6, you can use the new *type* attribute to identify such fire pixels in the MCD14ML product.

8.7.4 The MCD14ML ASCII product files have fixed-width, space-delimited fields. Is there an easy way to convert these to comma-separated values (CSV) files?

Yes. In Unix, Linux, or Mac OS-X you can use the `tr` command to do this. Here's an example:

```
tr -s ' ' , < MCD14ML.200805.006.01.txt > MCD14ML.200805.006.01.csv
```

8.7.5 How can I compute the scan angle given the sample number in the MCD14ML product?

The scan angle θ (in radians) can be calculated from the value in the `sample` column as follows:

$$\theta = s \times (\text{sample} - 676.5), \tag{14}$$

where $s = 0.0014184397$. (See section 8.4.6 if you are also interested in the approximate size of the pixel at the Earth's surface.)

8.8 Hierarchical Data Format (HDF)

8.8.1 What are HDF files?

The Hierarchical Data Format (HDF), developed at the National Center for Supercomputing, is one of various file formats used to portably archive and distribute scientific data. HDF files are more or less "self-describing" in that they can include extensive metadata about the data stored within the file. Note that there are two *incompatible* flavors of HDF in use: HDF4, the format in which all MODIS products are stored, and HDF5, which is actually a completely different file format that is not backwards-compatible with HDF4. See the NCSA HDF web site for more information[15].

8.8.2 How do I read HDF4 files?

If you are writing your own software in a "traditional" programming language such as C or Fortran, you will need obtain the HDF4 library from NCSA[16]. Some commercial software packages, however, including MATLAB, IDL, and ENVI, have the HDF library built-in, in which case you will not need to install the library.

8.8.3 Can't I just skip over the HDF header and read the data directly?

Put any thought of reading or writing HDF files without the HDF library out of your head. HDF was intended to be not so much a physical file format, but instead an "application interface". As such, the format is fairly complicated (and has in fact changed over time) and it would be very time consuming (and risky) to roll your own HDF ingest code. The physical file format is nothing like the typical header-followed-by-data common to many other formats, and it is not easy to simply skip over the metadata fragments in an HDF file.

8.8.4 How can I list the contents of HDF4 files?

The NCSA HDF4 Library includes a utility named `ncdump` which will do this. Be sure to use the switch `-h` otherwise you will be inundated with ASCII dumps of all numeric arrays in the file.

8.8.5 How can I display images in HDF4 files?

Commercial software packages that can display the data layers in most MODIS products (which are generally stored as HDF4 "Scientific Data Sets") include ENVI[17] and ERDAS Imagine[18].
Freely available display software includes *HDFView*[19] and the older *HDFLook*[20] (pre-compiled binaries only).

---

[15]`http://hdf.ncsa.uiuc.edu/`
[16]`http://hdf.ncsa.uiuc.edu/hdf4.html`
[17]`http://www.ittvis.com/ProductServices/ENVI.aspx`
[18]`http://www.erdas.com/`
[19]`http://www.hdfgroup.org/hdf-java-html/hdfview/`
[20]`http://www-loa.univ-lille1.fr/Hdflook/hdflook_gb.html`

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10 Relevant Web and FTP Sites

- **MODIS Fire and Thermal Anomalies**: General information about the MODIS Fire (Thermal Anomalies) and Burned Area products.
  `http://modis-fire.umd.edu/`

- **MODIS File Specifications**: Detailed file descriptions of all MODIS land products.
  `ftp://modular.nascom.nasa.gov/pub/LatestFilespecs/collection5`

- **MODIS Land Team Validation**: Information concerning the validation status of all MODIS land products.
  `http://landval.gsfc.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.
  `https://lpdaac.usgs.gov/tools/ldope_tools`

- **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`

- **LANCE FIRMS Web Fire Mapper**: The Fire Information for Resource Management System (FIRMS) Web Fire Mapper generates custom maps of active fires detected by the Terra and Aqua MODIS instruments. Users can also active fire locations in ESRI shape file and ARC/INFO formats.
  `http://firms.modaps.eosdis.nasa.gov/firemap/`

- **LANCE Rapid Response System**: Access to near-real time Terra and Aqua MODIS reflectance, fire, vegetation index, and land surface temperature imagery. Includes a multi-year archive.
  `http://earthdata.nasa.gov/data/near-real-time-data/rapid-response`

- **NASA Earthdata Search**: The current primary distribution site for most MODIS products. Formerly Reverb, and before that the Warehouse Inventory Search Tool (WIST), and before that the EOS Data Gateway (EDG).
  `https://search.earthdata.nasa.gov/`

- **MODIS Land Product Quality Assessment**: Product quality-assessment (QA) related information, including a very complete archive of known land-product issues with descriptions and examples.
  `http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/newPage.cgi`

- **NASA Direct Readout Laboratory**: Free information and software to acquire, process, and analyze MODIS Direct Broadcast data.
  `http://directreadout.sci.gsfc.nasa.gov/`

- **SSEC Terra and Aqua Orbit Tracks**: Orbit tracks for various polar orbiting satellites, including Terra and Aqua, from the University of Wisconsin-Madison Space Science and Engineering Center (SSEC).
  `https://www.ssec.wisc.edu/datacenter/orbit_tracks.html`