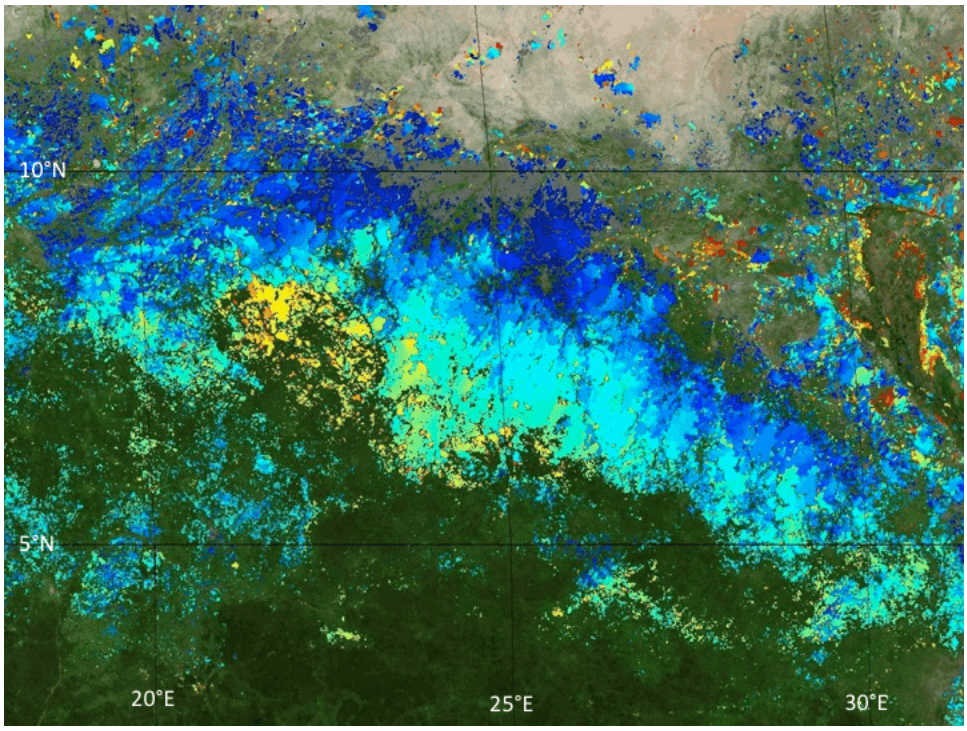
Collection 6 MODIS Burned Area Product User's Guide
Version 1.2



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Abbreviations and Acronyms

BA	Burned Area
CMG	Climate Modeling Grid
EOS	Earth Observing System
EOSDIS	EOS Data Information System
GeoTIFF	Georeferenced Tagged Image File Format
HDF	Hierarchical Data Format
LP-DAAC	Land Processes Distributed Active Archive Center
MODIS	Moderate Resolution Imaging Spectrometer
SDS	Science Data Set
QA	Quality Assessment

Title page image: MCD64A1 cumulative area burned in the Central African Republic and South Sudan during the 2004–2005 burning season.

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1 Introduction

This document contains the most current information about the Collection 6 Moderate Resolution Imaging Spectrometer (MODIS) Burned Area product suite. It is intended to provide the end user with practical information regarding the use (and misuse) of the products, and to explain some of the more obscure and potentially confusing aspects of the burned area products and MODIS products in general.

1.1 Summary of Collection 6 Algorithm and Product Changes

1. The product is now generated using an improved version of the Giglio et al. (2009) MCD64 burned area mapping algorithm (i.e., MCD64A1 will be adopted as the standard MODIS burned area product for Collection 6). The MCD45A1 product will not be generated beyond Collection 5.1.
2. The product is generated using Collection 6 (versus Collection 5) surface reflectance and active fire input data.
3. General improvement (reduced omission error) in burned area detection.
4. Significantly better detection of small burns.
5. Modest reduction in burn-date temporal uncertainty.
6. Significant reduction in the occurrence of unclassified grid cells due to algorithm changes and refinements in the upstream Collection 6 input data.
7. Product coverage expanded from 219 to 268 MODIS tiles.
8. Expanded per-pixel quality assurance (QA) product layer.
9. MCD64A1 *Burn Date* layer now uniquely flags missing-data versus water grid cells.

1.2 Terminology

Before proceeding with a description of the MCD64 burned area products, we briefly define the terms *granule*, *tile*, *climate modelling grid*, and *collection* in the context of these products.

1.2.1 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.

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 $\times$ 21600 pixels at 1 km, and 172800 $\times$ 86400 pixels at 250 m), they are divided into fixed tiles approximately $10^\circ \times 10^\circ$ 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).

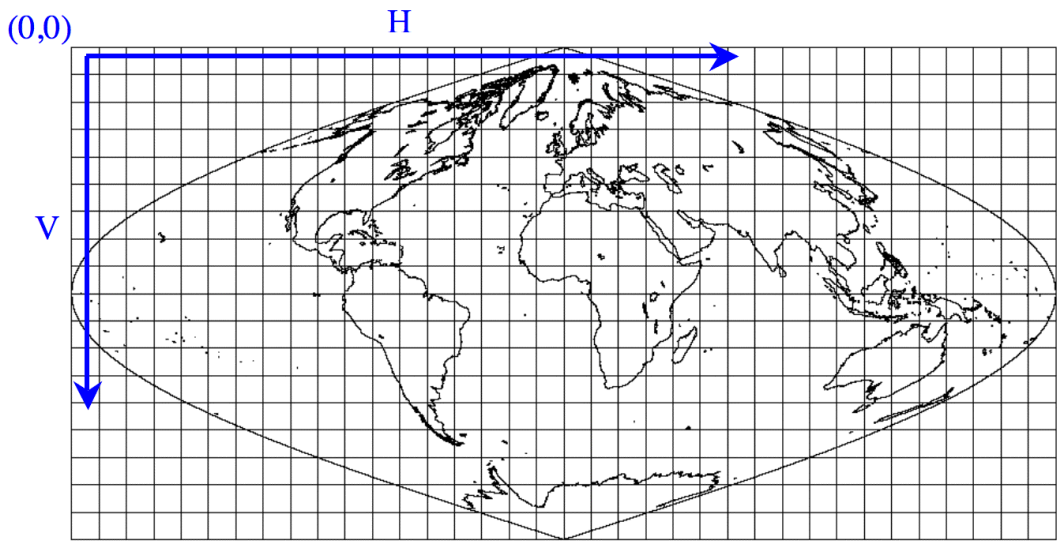

Figure 1: MODIS tiling scheme.

Note that 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. The exact cell sizes are shown in Table 1.

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

1.2.3 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.

1.2.4 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.

Neither the MCD45A1 nor MCD64A1 MODIS burned area product were produced in Collections 1 through 4. Both products were produced for the first time as part of Collection 5. For Collection 6, only the MCD64A1 product is available.

2 MCD64A1 Algorithm Summary

The MCD64 burned-area mapping approach employs 500-m MODIS imagery coupled with 1-km MODIS active fire observations. The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index (VI) derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. The VI is defined as

$$\mathrm{VI} = \frac{\rho_5 - \rho_7}{\rho_5 + \rho_7},$$

where ρ_5 and ρ_7 are respectively the band 5 and band 7 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.

The mapping algorithm ultimately identifies the date of burn, to the nearest day, for 500-m grid cells within the individual MODIS 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 burned (range 1-366), with a value of 0 for unburned land pixels 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 MCD64 Product Suite

Three different versions of the MODIS burned area product are available:

- The official MCD64A1 product in HDF-EOS format, which is available as part of the MODIS suite of global land products.
- The re-projected monthly GeoTIFF version available from the University of Maryland.
- The re-projected monthly Shapefile version available from the University of Maryland.

3.1 Level 3 Monthly Tiled Product: MCD64A1

The MCD64A1 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 has been adopted by all standard MODIS products, is as follows:

`MCD64A1.AYYYYDDD.hHHvVV.006.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 sinusoidal grid

`VV` = vertical tile coordinate on MODIS sinusoidal grid
`PPPPPPPPPPPPP` = production date[1]

Example: The product file `MCD64A1.A2006244.h31v10.006.2016091211913.hdf` contains the September 2006 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 MCD64 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).

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 and unmapped 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.

3.1.3 Metadata

As with standard MODIS products, the MCD64A1 product contains global metadata stored in the ECS *CoreMetadata.0* and *ArchiveMetadata.0* global attributes. For convenience, a subset of these metadata as well as additional metadata are stored as standard HDF global attributes (Table 3).

Table 3: MCD64A1 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 MCD64A1 product.

```
mcd64a1_file = 'MCD64A1.A2006213.h20v11.006.2016091211241.hdf'

sd_id = HDF_SD_START(mcd64a1_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      =        91474
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 MCD64A1 product.

```
import gdal
import numpy as np

in_file = "MCD64A1.A2006244.h31v10.006.2016091211913.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 MCD64A1 "Burn Date" SDS using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
mcd64a1_file = 'MCD64A1.A2006213.h20v11.006.2016091211241.hdf'

% read burn date layer in one shot
burn_date = hdfread(mod14a2_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 MCD64A1 "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.)

```
mcd64a1_file = 'MCD64A1.A2006244.h31v10.006.2016091211913.hdf'

sd_id = hdfsd('start', mcd64a1_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');
```

Example 5: C code for reading MCD64A1 burn date layer using HDF library functions.

```
#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 = "MCD64A1.A2006244.h31v10.006.2016091211913.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: MCD64monthly

A user-friendly GeoTIFF version of the MCD64 product is derived from the standard MCD64A1 HDF version by University of Maryland. 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.

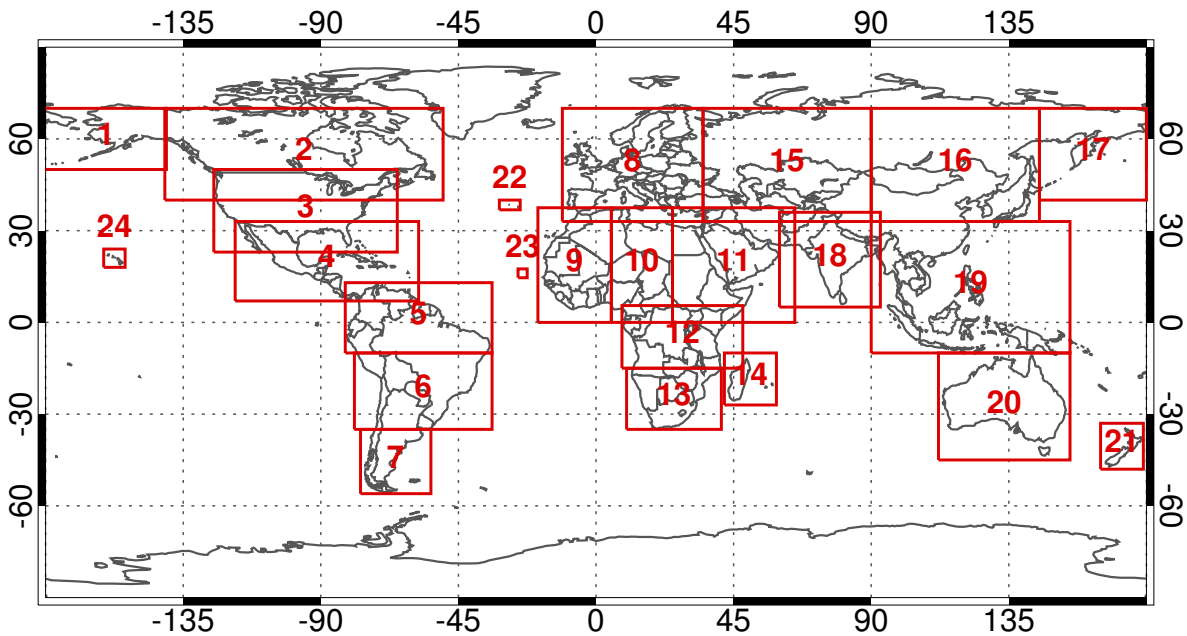

Figure 2: Coverage of the GeoTIFF subsets. A table of bounding coordinates is available in Appendix A.

3.2.1 Naming Convention

The GeoTIFF files follow a naming convention similar to the official MCD64A1 product. However, as the GeoTIFF files are obtained by mosaicing, resampling, and reprojecting several tiles of the original product, the processing time is not available. Example product file names are:

```
MCD64monthly.A2000306.Win01.006.burndate.tif
MCD64monthly.A2000306.Win01.006.ba_qa.tif
```

where

`MCD64monthly` = monthly GeoTIFF version of MCD64A1
`A2000306` = year and Julian date of the starting day of the month covered by the product: 306 is the Julian date of Nov 1, hence 2000306 means that the product covers November 2000.
`Win01` = spatial extent: the file covers window 1 (Alaska)
`006` = version identifier (Collection 6)
`burndate/ba_qa` = file content: unlike HDF, GeoTIFF files contain a single layer. Currently, two layers of the original product are available as GeoTIFF files: “Burn Date” and “QA”.

3.2.2 Example Code

Example 6: IDL code to read the GeoTIFF MCD64monthly "Burn Date" product. Although not shown in this example, the IDL `QUERY_TIFF` function can be used to determine information about the GeoTIFF image without having to read it into memory.

```
infile = 'MCD64monthly.A2016183.Win13.006.burndate.tif'

; read entire image
burn_date = read_tiff(infile, GEOTIFF=geo)

; now read just a spatial subset
burn_date_subset = read_tiff(infile, SUB_RECT = [1000, 1000, 400, 400])

help, burn_date
help, burn_date_subset
help, geo, /STRUCT
```

The code produces the following output:

```
BURN_DATE       INT       = Array[7055, 4552]
BURN_DATE_SUBSET
                INT       = Array[400, 400]
** Structure <18147a8>, 10 tags, length=120, data length=114, refs=1:
   MODELPIXELSCALETAG
                   DOUBLE    Array[3]
   MODELTIEPOINTTAG
                   DOUBLE    Array[6, 1]
   GTMODELTYPEGEOKEY
                   INT              2
   GTRASTERTYPEGEOKEY
                   INT              2
   GTCITATIONGEOKEY
                   STRING    'Geographic (Longitude, Latitude) Unspe'...
   GEOGRAPHICTYPEGEOKEY
                   INT          32767
   GEOGGEODETICDATUMGEOKEY
                   INT          32767
   GEOGANGULARUNITSGEOKEY
                   INT           9102
   GEOGSEMIMAJORAXISGEOKEY
                   DOUBLE           0.0000000
   GEOGSEMIMINORAXISGEOKEY
                   DOUBLE           0.0000000
```

3.3 Shapefile subset for GIS visualization and analysis: MCD64monthly

Shapefiles of the MCD64A1 *Burn Date* layer are derived from the monthly GeoTIFF files by the University of Maryland. The shapefiles are available with the same projection (Plate-Carrée) and geographic extent used for the GeoTIFF sub-continental windows (Figure 2).

3.3.1 Naming Convention

The shapefile naming convention is identical to the GeoTIFF naming convention. Each shapefile consists of multiple files which must remain in the same subdirectory. For convenience, shapefiles are distributed as a zipped tar archive file (".tar.gz") containing the four shapefile elements. MCD64monthly shapefile archives are named as follows:

`MCD64monthly.A2000306.Win01.006.burndate.shapefiles.tar.gz`

which in turn contains the following files:

```
MCD64monthly.A2000306.Win01.006.burndate.shp
MCD64monthly.A2000306.Win01.006.burndate.shx
MCD64monthly.A2000306.Win01.006.burndate.prj
MCD64monthly.A2000306.Win01.006.burndate.dbf
```

where

`MCD64monthly` = monthly shapefile version of MCD64A1
`A2000306` = year and Julian date of the starting day of the calendar month covered by the product (here November 2000).
`Win01` = spatial extent: the file covers window 1 (Alaska)
`006` = version identifier (Collection 6)
`burndate` = file content.

3.4 MCD64CMQ Climate Modeling Grid Burned Area Product

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

3.4.1 Naming Convention

The MCD64CMQ monthly product files follow the standard MODIS product naming convention. Examples:

`MCD64CMQ.A2003213.006.2017283041945.hdf`	*August 2003 product file*
`MCD64CMQ.A2003214.006.2017283041945.hdf`	*August 2004 product file*

3.4.2 Global Grid

Each data layer has 720 rows and 1440 columns comprising a global 0.25° grid. The center of the upper left grid cell is located at longitude 179.875°W, 89.875°N. One data layer has an additional dimension (i.e., it is three dimensional) as described below.

3.4.3 Data Layers

Each product file nominally contains four data layers (*BurnedArea*, *QA*, *UnmappedFraction*, and *LandCoverDist*), each stored as a separate HDF4 Scientific Data Set (SDS). Note that the *LandCoverDist* SDS will be absent from the most recent MCD64CMQ product files due to the ∼1-year forward production lag in the MCD12Q1 annual land cover product used to populate this layer. Such incomplete MCD64CMQ product files have a global string attribute named *LandCoverNote* and will be reprocessed when the relevant annual MCD12Q1 product becomes available.

BurnedArea: Monthly area burned. The scaled values stored in this SDS must be multiplied by a factor of 0.01 to obtain burned area in hectares.

QA: 8-bit quality assurance bit field. 0 = water, 1 = unprocessed land, 2 = processed land.

UnmappedFraction: Combined spatial and temporal fraction of the unmapped land area within each grid cell [percent]. Specifically, this quantity is the average number of days that could be mapped during the one-month product period over all 500-m land grid cells falling within each 0.25° bin, divided by the number of days in the product calendar month. The resulting proportion is expressed as a percentage.

Note that the unmapped fraction does not merely tally those 500-m grid cells in the MCD64A1 product classified as *unmapped* (such grid cells have a value of -1 in the MCD64A1 *Burn Date* SDS), for which the number of days mapped is zero. Rather, the quantity represents an average over *all* 500-m land grid cells, whether they are entirely unmapped, partially mapped due to a shortened mapping period (bit 2 set in the MCD64A1 *QA* SDS), or fully mapped during the product period.

Unprocessed land grid cells (see *QA* layer above) will have an unmapped fraction of 100%.

LandCoverDist: A breakdown (to the nearest percent) of the area burned in each grid cell by the 17 different UMD land cover classes available in the Collection 6 MCD12Q1 land cover product. These classes, which have been slightly modified for Collection 6, are shown below. The number in each row is the index into the specific plane of the three-dimensional *LandCoverDist* array that contains the percentage of the area burned for the corresponding land cover type.

0	water	9	savannas
1	evergreen needleleaf forests	10	grasslands
2	evergreen broadleaf forests	11	permanent wetlands
3	deciduous needleleaf forests	12	croplands
4	deciduous broadleaf forests	13	urban and built-up
5	mixed forests	14	cropland/natural vegetation mosaics
6	closed shrublands	15	barren
7	open shrublands	16	unclassified
8	woody savannas		

3.4.4 Metadata

File-level metadata are stored as global attributes in the HDF product files (Table 4).

Table 4: MCD64CMQ metadata stored as standard global HDF attributes.

Attribute Name	Description
ShortName	Short name of product ("MCD64CMQ").
Instrument	Instrument name ("MODIS").
BinSize	Global grid bin size in degrees (0.25).
StartDate	Start date of monthly product to nearest second.
EndDate	End date of monthly product to nearest second.
NumInputBA	Number of MCD64A1 input files (nominally 268).
InputPointerBA	Comma-separated list of MCD64A1 input file names.
NumInputLC	Number of MCD12Q1 input files.
InputPointerLC	Comma-separated list of MCD12Q1 input file names.
LandCoverNote	String attribute present only in product files lacking the *LandCoverDist* SDS. Example value: "2018 MCD12Q1 product not available at time of processing".

3.4.5 Example Code

Example 7: IDL code to read the MCD64CMQ *BurnedArea* SDS.

```
pro cmg_demo
     COMPILE_OPT STRICTARR, STRICTARRSUBS

     mcd64cmq_file = 'MCD64CMQ.A2018001.006.2018149165520.hdf'

     sd_id = HDF_SD_START(mcd64cmq_file, /READ)

     index = HDF_SD_NAMETOINDEX(sd_id, 'BurnedArea')
     sds_id = HDF_SD_SELECT(sd_id, index)

     ; read SDS scale factor attribute
     attr_index = HDF_SD_ATTRFIND(sds_id, 'scale_factor')
     HDF_SD_ATTRINFO, sds_id, attr_index, DATA=scale_factor
     ; IDL returns scalar numeric attributes as a 1-element vector
     ; next line will convert it to a scalar
     scale_factor = scale_factor[0]

     ; read SDS units attribute
     attr_index = HDF_SD_ATTRFIND(sds_id, 'units')
     HDF_SD_ATTRINFO, sds_id, attr_index, DATA=units

     ; read scaled data
     HDF_SD_GETDATA, sds_id, ScaledAburn
     HDF_SD_ENDACCESS, sds_id

     HDF_SD_END, sd_id

     help, ScaledAburn, scale_factor, units

     Aburn = scale_factor * temporary(ScaledAburn)
     help, Aburn

     ; calculate total area burned worldwide
     Atotal = total(Aburn, /DOUBLE)     ; ha

     print, Atotal/1.0e6, FORMAT='("Total burned area is",F6.2," Mha")
end
```

The code produces the following output:

```
SCALEDABURN     LONG      = Array[1440, 720]
SCALE_FACTOR    FLOAT     =     0.0100000
UNITS           STRING    = 'hectares'
ABURN           FLOAT     = Array[1440, 720]
Total burned area is 26.91 Mha
```

Example 8: IDL code to generate vectors containing the the latitude and longitude at the center of each 0.25° grid cell.

```
pro cmg_nav
     COMPILE_OPT STRICTARR, STRICTARRSUBS

     XGRID = 1440
     YGRID = 720
     bin_size = 0.25          ; degrees

     lat = (90.0 - bin_size/2) - bin_size * indgen(YGRID)     ; degrees
     lon = (-180.0 + bin_size/2) + bin_size * indgen(XGRID)   ; degrees

     ; print center latitude and longitude of first 24 rows/columns of grid

     help, lat
     print, lat[0:23], FORMAT='(8F9.3)'

     help, lon
     print, lon[0:23], FORMAT='(8F9.3)'
end
```

The code produces the following output:

```
LAT             FLOAT     = Array[720]
   89.875   89.625   89.375   89.125   88.875   88.625   88.375   88.125
   87.875   87.625   87.375   87.125   86.875   86.625   86.375   86.125
   85.875   85.625   85.375   85.125   84.875   84.625   84.375   84.125
LON             FLOAT     = Array[1440]
 -179.875 -179.625 -179.375 -179.125 -178.875 -178.625 -178.375 -178.125
 -177.875 -177.625 -177.375 -177.125 -176.875 -176.625 -176.375 -176.125
 -175.875 -175.625 -175.375 -175.125 -174.875 -174.625 -174.375 -174.125
```

4 Obtaining the MODIS Burned Area Products

All MODIS products are available free of charge. The MODIS Burned Area Product is available for ordering from the Land Processes Distributed Active Archive Center (LP-DAAC).[2] Additionally, two ftp servers are 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 ba1 FTP server

The MODIS burned area product is available for download in either HDF, GeoTIFF, or Shapefile format from the University of Maryland `ba1` ftp server. Connect using the following information:

Server: `ba1.geog.umd.edu`
Login name: `user`
Password: `burnt_data`

For downloading the product files, you can use your current web browser such as Firefox or Internet Explorer, or the command-line `ftp` and `lftp` utilities. For those desiring more flexibility, we recommend using special FTP software when downloading large amounts of data. You can use freely available software such as FileZillaClient[3] or SmartFTP[4], both of which allow you to schedule the download to start at a later time. Whichever program you use, you will need to connect to the ftp server `ftp://ba1.geog.umd.edu`.

4.1.1 HDF Files

The file system on the ftp server is structured to organize the data hierarchically by year and by month. All the product files for a given calendar month are located in the subdirectory named `/C6/HDF/YYYY/DDD/`, where `YYYY` is the year and `DDD` is the julian day of the beginning of the calendar month. For example, the directory `/C6/HDF/2001/182` contains all of the July 2001 Collection 6 product files for all tiles.

4.1.2 GeoTIFF files and Shapefiles

The file system on the ftp server is structured to organize the data hierarchically by window, and then by year. All the data for the same window from the same year is located (for GeoTIFF files and shapefiles, respectively) in a the directories `/C6/TIF/WinXX/YYYY/` and `/C6/SHP/WinXX/YYYY/`, where `XX` is the number of the window (Figure 2) and `YYYY` is the year. For example, the directory `/C6/TIF/Win01/2001` contains all of the GeoTIFF files for the year 2001 for window 01 (Alaska).

[2] `https://lpdaac.usgs.gov/`
[3] `http://filezilla-project.org/download.php`
[4] `http://www.smartftp.com/`

4.2 Downloading the products from the fuoco FTP server

The MCD64A1 HDF product is also available from the `fuoco` FTP server used to distribute various other fire data sets from the University of Maryland (including the MCD64CMQ Climate Modeling Grid product derived from MCD64A1). 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:

```
.
|-- MCD64A1
|   |-- C5
|   `-- C6
|       |-- docs
|       |-- h01v10
|       |-- h03v06
|              .
|              .
|              .
|       |-- h33v11
|       `-- h34v10
|-- MCD64CMQ
|   `-- C6
```

As can be seen from the directory tree, the file system on this server is structured to organize the MCD64A1 product hierarchically by tile. Specifically, all MCD64A1 product files for a given tile are located in the directory `MCD64A1/C6/hHHvVV`, where `HH` is the horizontal tile coordinate and `VV` is the vertical tile coordinate. For example, the Collection 6 MCD64A1 HDF files for MODIS tile h08v05 will be found in the directory `MCD64A1/C6/h08v05`.

5 Working with the product in ENVI 4.8

5.1 MCD64A1 (HDF)

HDF MODIS 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.

5.2 MCD64monthly (GeoTIFF)

The GeoTIFF files are fully compatible with ENVI. To open them, simply go through the *File → Open Image File* menu.

5.3 MCD64monthly (Shapefile)

Shapefiles are not directly supported in ENVI, rather they are converted to the ENVI Vector File (".evf") format during ingest. To load a shapefile, select *Vector → Open Vector File* and choose the Shapefile wildcard filter setting ("*.shp"). When prompted to set "Import Vector Files Parameters", set the desired layer name and output file location and select "OK". Do not adjust the projection information; the default values correspond to the Plate-Carrée projection used by the GeoTIFF files. Use the "Available Vectors List" (*Vector → Available Vectors List*) to overlay the vectors on an existing display, or display them in a new window.

6 Working with the product in ArcGIS

Handling HDF-EOS files is not straightforward in ArcGIS. We recommend that users of the standard HDF-EOS product perform any scientific analysis in other software packages (e.g., ENVI) and then export their output to ArcGIS in a different format such as GeoTIFF.

6.1 MCD64monthly (GeoTIFF)

The MCD64 GeoTIFF files can be directly loaded into ArcGIS through *Add Layer*. In order to display the burned areas only, under *Layer Properties → Unique Values → Symbology* set the color to "No Color" for the following Values:

- 0 - unburned
- -1 - missing data
- -2 - water

ArcGIS will display the burned area in Julian days of the given month in either individual colors or in the same color depending on your settings. An example is shown in Figure 3.

6.1.1 Area of Interest (AoI)

In order to reduce the file size of the regional GeoTIFF and focus on a specific region, an "area of interest (AoI)" spatial subset can be extracted.

1. Display desired AoI
2. Right mouse click data layer
3. *Data → Export Data*

The "Export Raster Data" window will open (Figure 4). Check both data frames options to *Current* and choose TIFF in the *Format* field.

6.2 MCD64monthly (Shapefile)

The Shapefiles can directly be loaded into ArcGIS via *Add Layer*. To change the appearance of the file, select *Layer Properties → Symbology → Graduated Colors*. Optionally, to remove the outlines of the data, right click a symbol in the *Graduated Colors* panel and select "Properties For All Symbols", then set "Outline Color" to "No Color". An example is shown in shown in Figure 5.

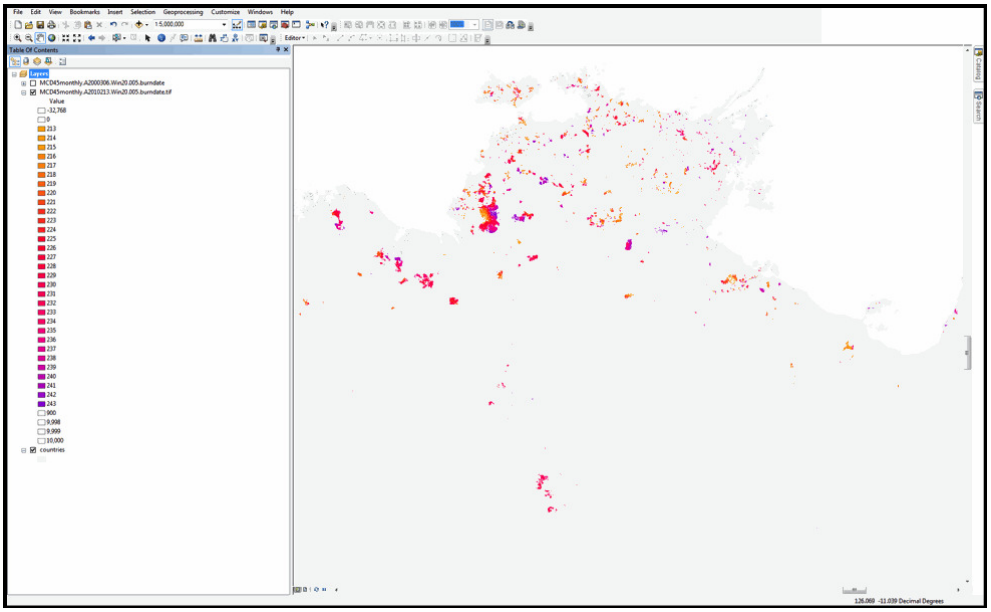

Figure 3: Display of GeoTIFF from August 2010, Window 20. Each burn day of the month is shown in a different color.

7 Known Problems

7.1 Data Outages

The monthly products for August 2000 and June 2001 are heavily degraded due to extended MODIS outages.

7.2 Cropland Burning

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

8 Frequently Asked Questions

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.

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[5], or perform the calculation as described in Appendix B.

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

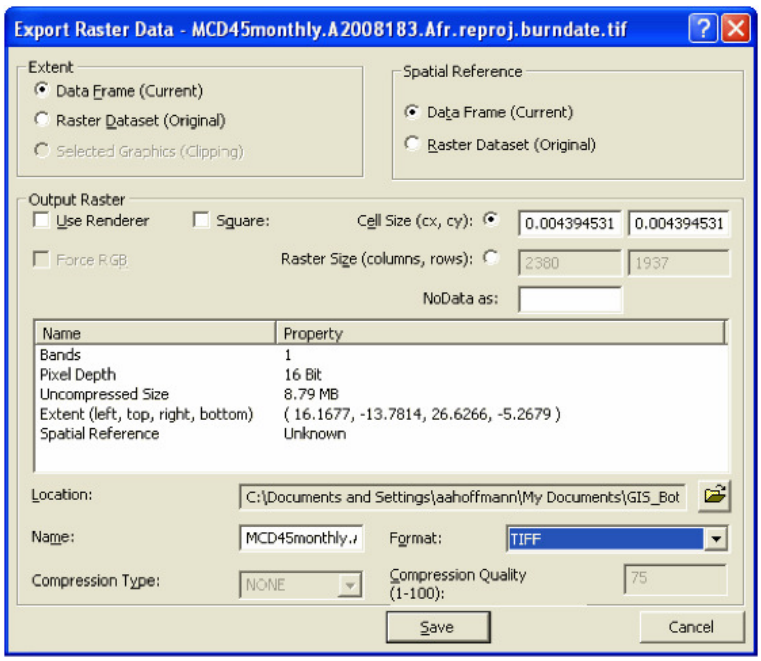

Figure 4: ArcGIS export raster window.

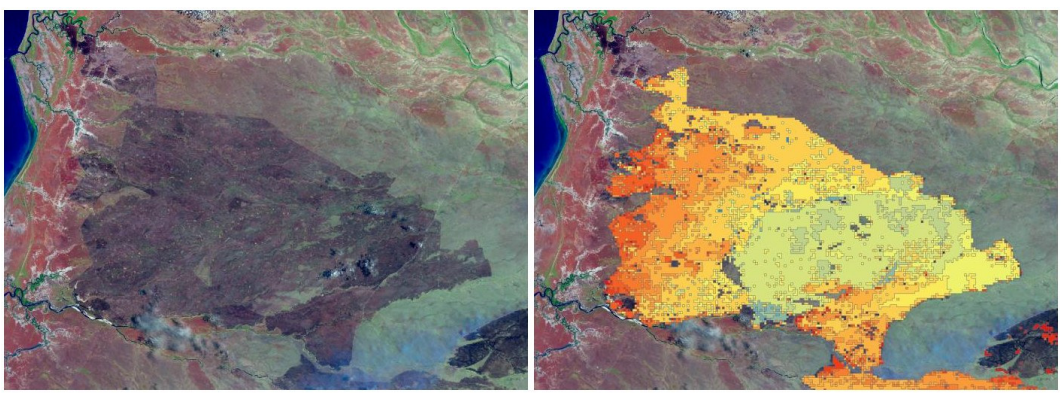

Figure 5: Left: True-color (R, G, B) Landsat 7 scene acquired 20 October 2002 at path 98, row 71. Right: MCD64monthly October Shapefile superimposed over the burned area. Older burned areas are shown in blue tones, newer burns are shown in red tones.

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.

9 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*, in press.

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.

Roy, D. P., Giglio, L., Kendall, J. D., and Justice, C. O., 1999, A multitemporal active-fire based burn scar detection algorithm. *International Journal of Remote Sensing*, 20, 1031-1038.

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`
- **NASA Earthdata Search**: The 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`

Appendix A Coverage of the GeoTIFF subsets

Table 5: 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:

$$x = R\lambda\cos\phi \tag{1}$$
$$y = R\phi. \tag{2}$$

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):

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

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

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

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:

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

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 $0 \leq i \leq 4799$ and $0 \leq j \leq 4799$.

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 $0 \leq i \leq 1199$ and $0 \leq j \leq 1199$.