LDOPE QA Tools

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Introduction

- MODIS Land HDF-EOS Product format
  - Metadata stored as global attributes
    - Core metadata
    - Archive metadata
    - HDF-EOS Structural metadata
    - Product specific attributes (in some products)
  - Science Data Sets
    - Science Parameter datasets
      - “500m Surface Reflectance Band 1”, . . . in MOD09A1, “1 km 16 days NDVI” . . . in MOD13A2
    - QA datasets
      - “500m Surface Reflectance Data State” and “500m Surface Reflectance Band Quality” in MOD09A1
      - “1 km 16 days VI Quality” in MOD13A2

Introduction

- QA tools are developed with feedback from the MODIS Land ST
- Incorporate the scientific knowledge, experience and insights gained during the substantial MODLAND product development period
- QA Tools are generic and can be applied to any MODIS Land products
- Tools run at command line and use unix-like command syntax
- Output of the tools are HDF files or text files
- Tools are compatible with C4 and C5 data
- A subset of these tools are being distributed to the public from LPDAAC (*http://edcdaac.usgs.gov/landdaac/tools/ldope/index.asp*)
  - Available for following operating systems – Irix/Linux/Solaris/Windows
  - Documentation available on installation and usage

Summary of LDOPE QA Tools

Tool Name	Description
comp_sds_hist	Print the histogram of SDS values (frequency and values), excluding no-data and missing values, of specified SDSs in any MODIS Land HDF-EOS data product.
comp_sds_range	Print the observed range, excluding no-data and missing values, of specified SDSs in a MODIS Land HDF-EOS data product.
comp_sds_stat	Print summary statistics (mean, standard deviation, minimum, maximum and number of observations) of any SDS, excluding no-data and missing values, of a MODIS Land HDF-EOS data product.
comp_sds_values	Print the unique values found in specified SDSs of a MODIS Land HDF-EOS data product. This tool is most useful for summarizing the data distribution of SDSs that have only a small number of values (e.g., the MODIS Land HDF-EOS snow and fire products).
convert_l1b_data	Convert MODIS L1B data to Top of Atmosphere (TOA) reflectance for the MODIS reflective bands and TOA radiance for the MODIS emissive bands and write these to 2D HDF SDS(s) that can be read by commercial of the shelf (COTS) software. The conversion is performed using the scale and off-sets defined in the MODIS L1B product metadata.
cp_proj_param	Copy projection metadata into an HDF file that is defined in the MODIS Land Integerized Sinusoidal projection or Sinusoidal projection. The HDF file may then be reprojected using the EDC reprojection tool. This allows reprojection of MODIS Land L2G/L3/L4 HDF-EOS data product SDS(s) filtered or masked by LDOPE QA tools or other software.
create_mask	Apply relational and logical operators to one or more SDS in one or more MODIS Land HDF-EOS data products to create an output 2D HDF SDS that can be read by conventional COTS. For example, create a binary SDS that shows the pixel locations where only good quality, non-cloudy, 16-day vegetation index values with a land cover type = 3 are present.
create_sds_ts_stat	Create a summary statistic HDF file containing one or more output 2D SDS that describe the mean, standard deviation, minimum, maximum, sum, and number of observations, computed on pixel wise basis from a time series of input MODIS Land HDF-EOS data products.
enlarge_sds	The inverse of companion tool *reduce_sds*. Simulate finer resolution data by pixel replication.
geolocation	Compute the geographic latitude and longitude of a MODIS Land L2G/L3/L4 pixel coordinate.
mask_sds	Mask one of more SDS of a MODIS Land HDF-EOS data product file and output the SDS values at pixels where the mask criteria are met and output fill values elsewhere.
math_sds	Perform simple arithmetic on two input SDSs of the same or different MODIS Land HDF-EOS data products and output the results to a 2D SDS.
mosaic_sds	Create a spatial mosaic of SDSs from different L3/L4 MODIS Land HDF-EOS data products. Specified SDSs are spatially arranged based either on their geolocation or in a user specified manner.

Summary of LDOPE QA Tools

read_l2g	The MODIS Land L2G HDF-EOS data products store one or more L2 observations for each L2G pixel in a series of layers (that reflect the MODIS orbit overpass and swath sensing geometry) in a compressed run length encoded format. This tool reads the L2G format and writes user specified layers to output 2D HDF Science Data Sets (SDSs) that can be read by conventional COTS.
read_meta	Print the ECS core and archive metadata and SDS attributes of any MODIS Land HDF-EOS data product.
read_pixvals	Read MODIS Land HDF-EOS data product values at specified pixel locations.
read_proj_param	Read the projection parameter information of a L2G/L3/L4 MODIS Land HDF-EOS data product. This information is needed to project non-MODLAND data into registration with a geolocated MODIS Land HDF-EOS data product.
read_sds_attributes	Print the attributes of one or more SDS of MODIS Land HDF-EOS data products.
reduce_sds	Generate reduced spatial resolution MODIS Land HDF-EOS data product SDSs by sub-sampling or averaging. Handle the MODLAND product no-data and missing values. This may be used to reduce data volumes, and to quickly enable analysis of the different MODIS Land HDF-EOS data product spatial resolutions (250m, 500m, 1km), or to enable comparison with other coarser spatial resolution data sets.
reduce_sds_rank	Several MODIS Land HDF-EOS data products (e.g., MOD43) and related MODIS products (e.g., MOD35) contain multidimensional SDSs. This tool converts multidimensional (3D or 4D) SDS to a series of 2D HDF SDSs that can be read by conventional COTS.
sds2bin	Convert an SDS of any MODIS Land HDF-EOS data product to a flat binary image format.
subset_sds	Create spatial subset SDS(s) from one or more SDS of a MODIS Land HDF-EOS data product.
tile_id	Compute the MODIS Land L2G/L3/L4 tile id for a given latitude and longitude. This tool identifies the MODIS Land tile that corresponds to a known geographic location.
transpose_sds	Transpose one or more SDS in a MODIS Land HDF-EOS data product by rotating the SDS 180 degree in clockwise direction This tool enables qualitative comparison of MODIS Aqua and Terra Level 2 or Level 1 granules.
unpack_sds_bits	The MODIS Land HDF-EOS data product per-pixel QA information and other information such as the land-sea mask, logical criteria used by the algorithm, and cloud state are stored in an efficient bit encoded manner. This tool decodes requested bit fields and writes them to 2D HDF SDSs that can be read by conventional COTS.

Command Line Syntax

- A tool consists of a command name followed by one or more arguments of these type
  - arguments indicating certain processing parameters
  - arguments that are input filenames.
  - Command Format
    - command_name -argument_name=argument_value filename(s)
- Common arguments and meaning
  - -help Print help message for the command.
  - -help filename Print valid values for the various command line arguments of this command.
  - -sds Input SDS names.
  - -of Output filename.
  - -meta Copy metadata from the input file to the output file.
  - -bit Bit numbers.
  - -xy Pixel location in sample and line number.
  - -bn band numbers.

Example: Reading Metadata

read_meta –core MOD11A2.A2001065.h20v10.005.2007002071908.hdf

read_meta –arch MOD11A2.A2001065.h20v10.005.2007002071908.hdf

read_meta –qa MOD09A1.A2000305.h19v10.005.2006330133549.hdf

```
Started process meta_read
Metadata from hdf file: MOD11A2.A2001065.h20v10.005.2007002071908.hdf
--------------------------------------------------------------
LOCALGRANULEID = "MOD11A2.A2001065.h20v10.005.2007002071908.hdf"
PRODUCTIONDATETIME = "2007-01-02T07:19:08.000Z"
```

```
Started process meta_read
Metadata from hdf file: MOD09A1.A2000305.h19v10.005.2006330133549.hdf
--------------------------------------------------------------
SCIENCEQUALITYFLAG = "Not Investigated"
AUTOMATICQUALITYFLAGEXPLANATION = "Always Passed"
QUALITYCLASSPERCENTAGE500MBAND3 = (100, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)
QUALITYCLASSPERCENTAGE500MBAND4 = (100, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)
QUALITYCLASSPERCENTAGE500MBAND5 = (90, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 5, 5, 0)
QUALITYCLASSPERCENTAGE500MBAND6 = (100, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)
QUALITYCLASSPERCENTAGE500MBAND7 = (100, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)
QUALITYCLASSPERCENTAGE500MBAND1 = (95, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 5, 0, 0)
QUALITYCLASSPERCENTAGE500MBAND2 = (92, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 0, 0)
```

```
Started process meta_read
Metadata from hdf file: MOD11A2.A2001065.h20v10.005.2007002071908.hdf
PGEVERSION = "5.0.3"
ASSOCIATEDSENSORSHORTNAME = "MODIS"
ASSOCIATEDPLATFORMSHORTNAME = "Terra"
ASSOCIATEDINSTRUMENTSHORTNAME = "MODIS"
QAPERCENTGOODQUALITY = "28"
QAPERCENTOTHERQUALITY = "40"
QAPERCENTNOTPRODUCEDCLOUD = "32"
QAPERCENTNOTPRODUCEDOTHER = "00"
CLOUD_CONTAMINATED_LST_SCREENED = "YES"
HORIZONTALTILENUMBER = "20"
VERTICALTILENUMBER = "10"
TileID = "51020010"
```

```
Started process meta_read
Metadata from hdf file: MOD09A1.A2000305.h20v10.005.2006330041025.hdf
--------------------------------------------------------------
PGEVERSION      "5.0.6"
INPUTPOINTER    ("MOD09GQ.A2000305.h20v10.005.2006320050445.hdf", "MOD09GQ.A2000306.h20v10.005.2006320135156.hdf", "MOD09GQ.A2000307.h20v10.005.2006320231311.hdf", "MOD09GQ.A2000308.h20v10.005.2006321081726.hdf", "MOD09GQ.A2000309.h20v10.005.2006321213219.hdf", "MOD09GQ.A2000310.h20v10.005.2006322175040.hdf", "MOD09GQ.A2000311.h20v10.005.2006323032529.hdf", "MOD09GQ.A2000312.h20v10.005.2006323151117.hdf", "MOD09GA.A2000305.h20v10.005.2006320050445.hdf", "MOD09GA.A2000306.h20v10.005.2006320135156.hdf", "MOD09GA.A2000307.h20v10.005.2006320231310.hdf", "MOD09GA.A2000308.h20v10.005.2006321081725.hdf", "MOD09GA.A2000309.h20v10.005.2006321213219.hdf", "MOD09GA.A2000310.h20v10.005.2006322175040.hdf", "MOD09GA.A2000311.h20v10.005.2006323032529.hdf", "MOD09GA.A2000312.h20v10.005.2006323151116.hdf")
```

Example: Reading SDS Attributes

read_sds_attributes MOD11A2.A2001065.h20v10.005.2007002071908.hdf

read_sds_attributes -sds="1 km 16 days VI Quality" MOD13A2.A200305.h20v10.005.2006330041025.hdf

```
SDS : 1 km 16 days VI Quality
  Attribute        Data Type           Value
------------------+-----------+-----------------------------------
long_name          STRING     1 km 16 days VI Quality
units              STRING     bit field
valid_range        UINT16     0, 65534
_FillValue         UINT16     65535
Legend             STRING
Value =
         Bit Fields Description (Right to Left):
        [0-1] : MODLAND_QA [2 bit range]
                 00: VI produced, good quality
                 01: VI produced, but check other QA
                 10: Pixel produced, but most probably cloudy
                 11: Pixel not produced due to other reasons than clouds
        [2-5] : VI usefulness [4 bit range]
                 0000: Highest quality
                 0001: Lower quality
                 0010..1010: Decreasing quality
                 1100: Lowest quality
                 1101: Quality so low that it is not useful
                 1110: L1B data faulty
                 1111: Not useful for any other reason/not processed
        [6-7] : Aerosol quantity [2 bit range]
                 00: Climatology
                 01: Low
                 10: Average
                 11: High (11)
        [8] : Adjacent cloud detected; [1 bit range]
                 1: Yes
                 0: No
        [9] : Atmosphere BRDF correction performed [1 bit range]
                 1: Yes
                 0: No
        [10] : Mixed clouds  [1 bit range]
                 1: Yes
                 0: No
        [11-13] : Land/Water Flag [3 bit range]
                 000: Shallow ocean
                 001: Land (Nothing else but land)
                 010: Ocean coastlines and lake shorelines
                 011: Shallow inland water
                 100: Ephemeral water
                 101: Deep inland water
                 110: Moderate or continental ocean
                 111: Deep ocean
        [14] : Possible snow/ice [1 bit range]
                 1: Yes
                 0: No
        [15] : Possible shadow [1 bit range]
                 1: Yes
                 0: No
```

Example: Reading L2G

Task: Read one or more layers from a L2G compact format file

Tool: read_l2g

Input: L2G HDF file

Output: HDF file containing user requested layers from the input HDF file.

Example: Read the first two layers of surface reflectance for bands 1, 3, and 4 from the input L2G compact format file MOD09GHK.A2007001.h17v07.005.2007007183940.hdf

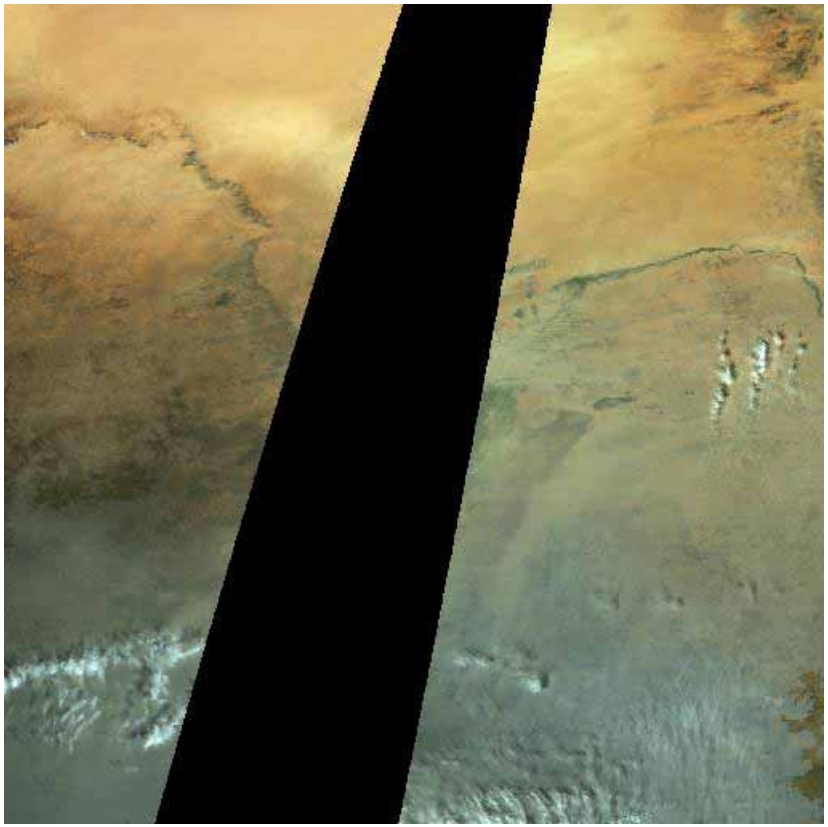
Command: read_l2g –layer=1,2 –sds=sur_refl_b01,sur_refl_b03,sur_refl_b04
–of=Layers.MOD09GHK.A2007001.h17v07.005.2007007183940.hdf
MOD09GHK.A2007001.h17v07.005.2007007183940.hdf

Result: Output HDF file will contain six SDS

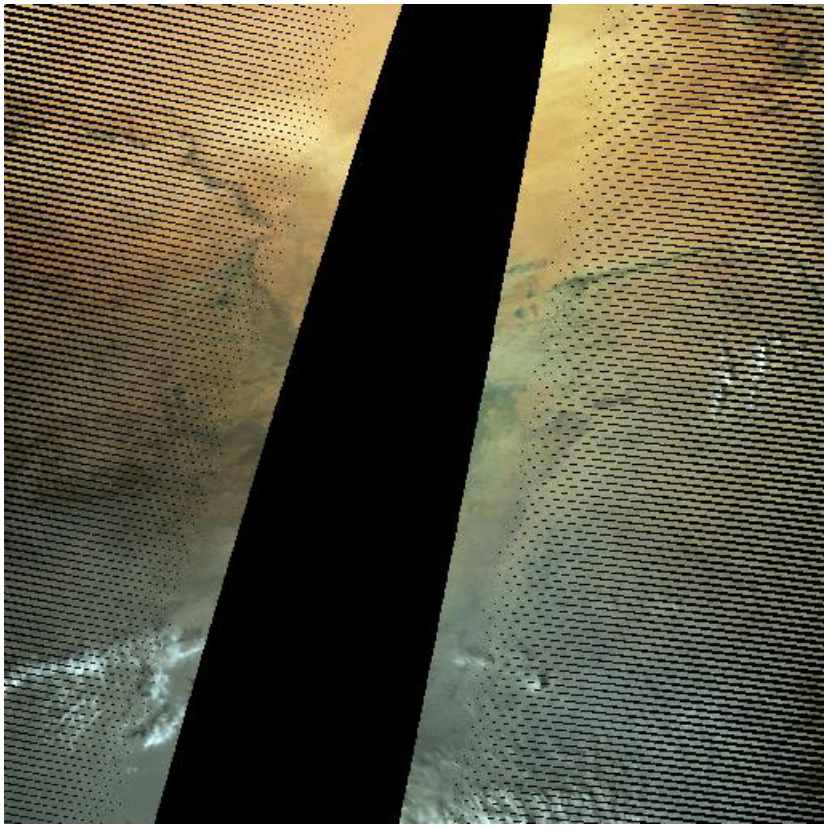
sur_refl_b01_layer1
sur_refl_b02_layer1
sur_refl_b03_layer1
sur_refl_b01_layer2
sur_refl_b02_layer2
sur_refl_b03_layer2

Example: Reading L2G

Layers.MOD09GHK.A2007001.h17v07.005.2007007183940.hdf



RGB Composite of surface reflectance from bands 1, 3 and 4 – Layer 1



RGB Composite of surface reflectance from bands 1, 3 and 4 – Layer 2

Example: Reading L2G

Task: Read one or more granules from a L2G compact format file

Tool: read_l2g

Input: L2G HDF file (and the pointer file in case of C4)

Output: HDF file containing user requested layers from the input HDF file.

Example: Read surface reflectance for bands 1, 3, and 4 for all the granules in the input L2G compact format file MOD09GHK.A2007001.h17v07.005.2007007183940.hdf

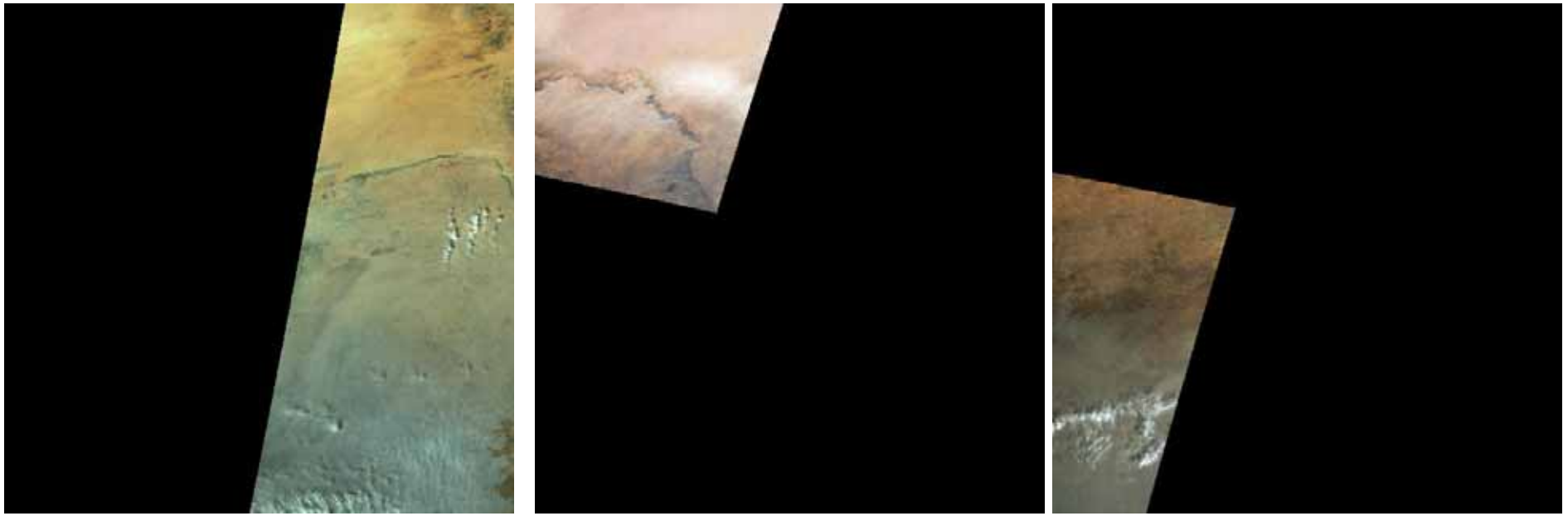
Command: read_l2g –gpidx –sds=sur_refl_b01,sur_refl_b03,sur_refl_b04
–of=Granules.MOD09GHK.A2007001.h17v07.005.2007007183940.hdf
-ptr=MODPTHKM.A2007001.h17v07.005.2007007180905.hdf
MOD09GHK.A2007001.h17v07.005.2007007183940.hdf

Result: Output HDF file will contain 9 SDS (for this example)

sur_refl_b01_gpnt1	sur_refl_b01_gnpt2	sur_refl_b01_gnpt3
sur_refl_b02_gpnt1	sur_refl_b01_gnpt2	sur_refl_b01_gnpt3
sur_refl_b03_gpnt1	sur_refl_b01_gnpt2	sur_refl_b01_gnpt3

Example: Reading L2G

Granules.MOD09GHK.A2007001.h17v07.005.2007007183940.hdf



Granule 1 Granule 2 Granule 3

RGB Composite of surface reflectance from bands 1, 3 and 4

Example: Reading QA Information

Task: Decode the pixel level QA

Tool: unpack_sds_bits

Input: HDF file containing the QA SDS

Output: HDF file containing one or more SDS where each SDS corresponds to an user requested qa flag

Example: Decode the “aerosol flag”, “internal cloud mask”, “MOD35 cloud mask” and the “land water mask” from MOD09A

Command: Unpack_sds_bits –sds=sur_refl_state_500m –bit=0-1,3-5,6-7,10 –of= QA_MOD09A1.A2000305.h20v10.005.2006330041025.hdf MOD09A1.A2000305.h20v10.005.2006330041025.hdf

Result: Output HDF file will contain four SDS

bit_0-1_sur_refl_state_500m

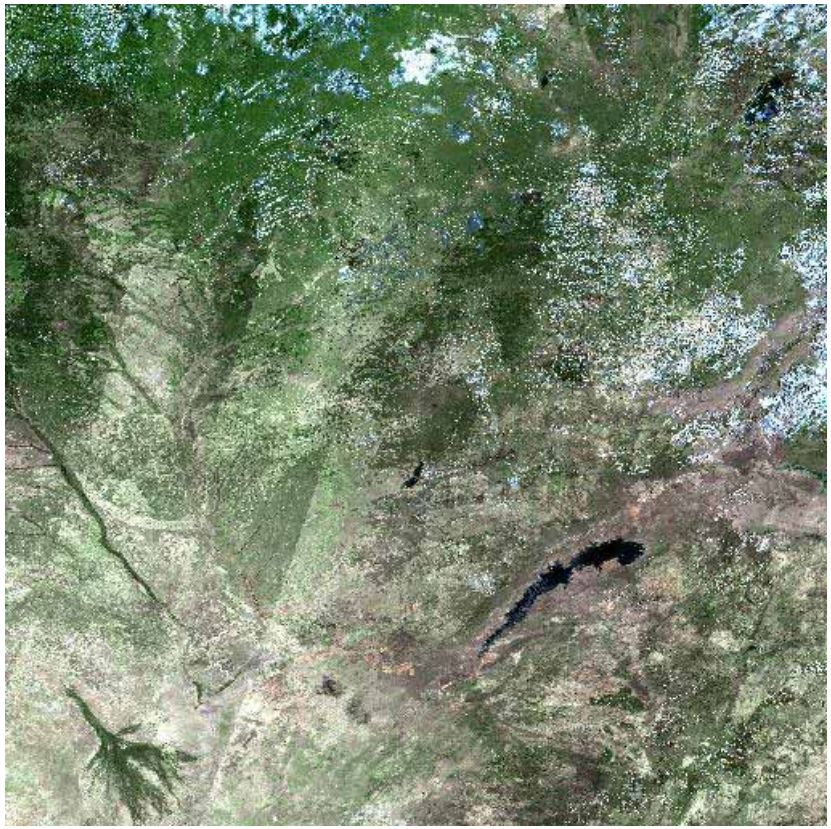
bit_3-5_sur_refl_state_500m

bit_6-7_sur_refl_state_500m

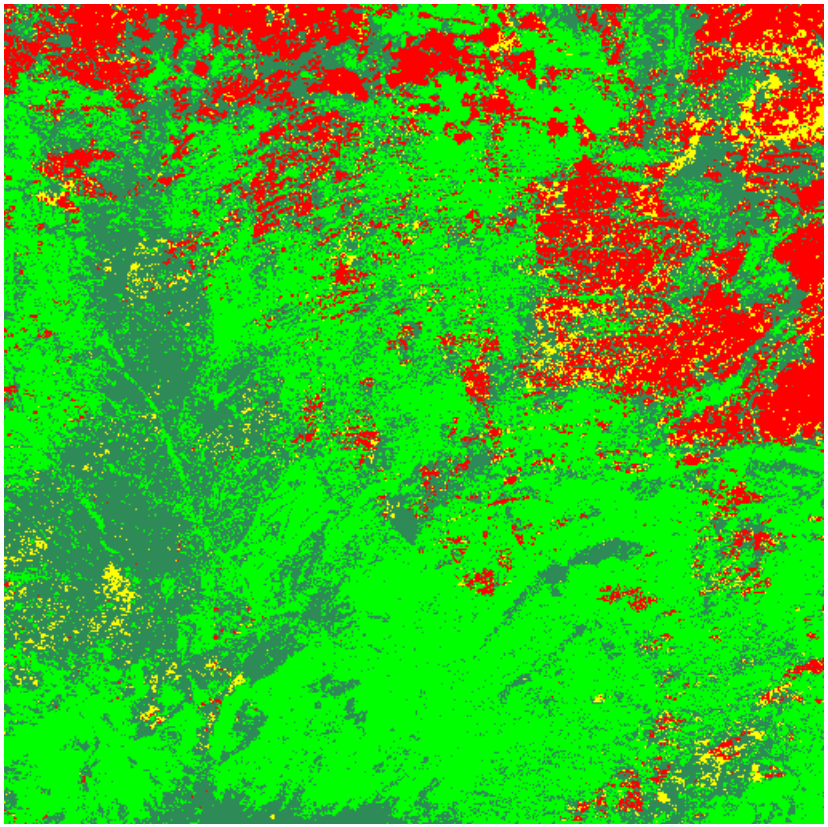
bit_10_sur_refl_state_500m

Example: Reading QA Information

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



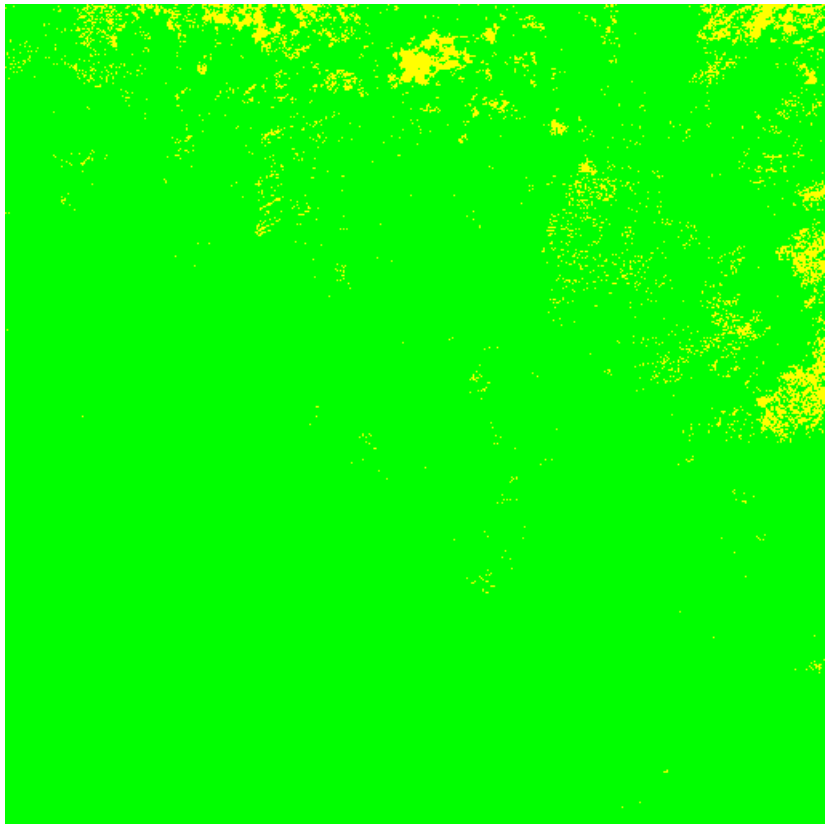
RGB Composite of surface reflectance from bands 1, 3 and 4



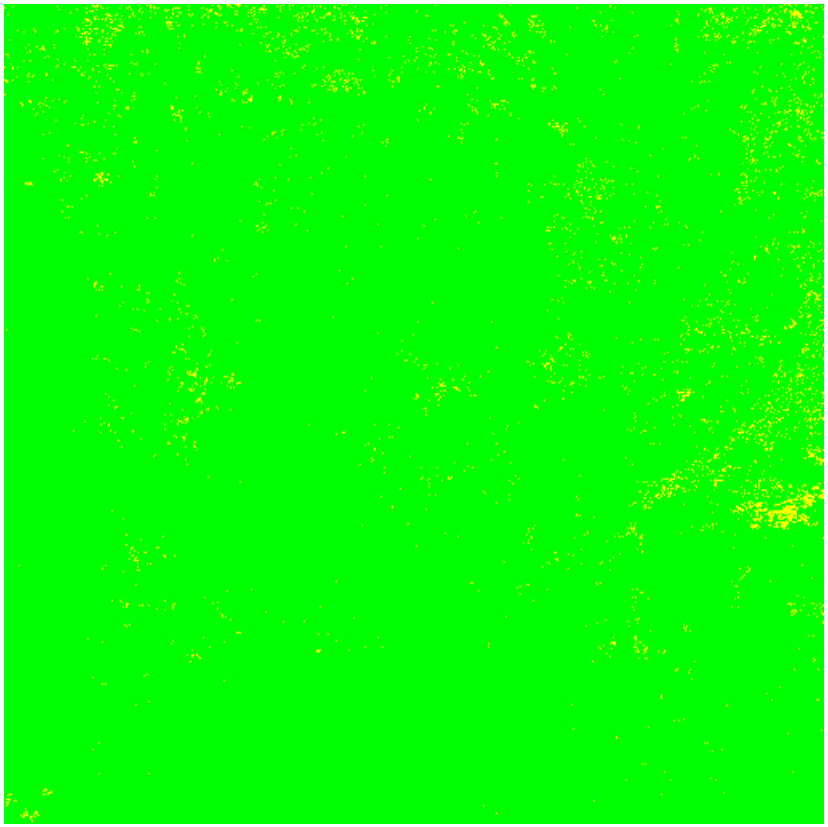
Aerosol flag: Red (0): Climatology, green (1): low, sea green (2): average, high (3): yellow

Example: Reading QA Information

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



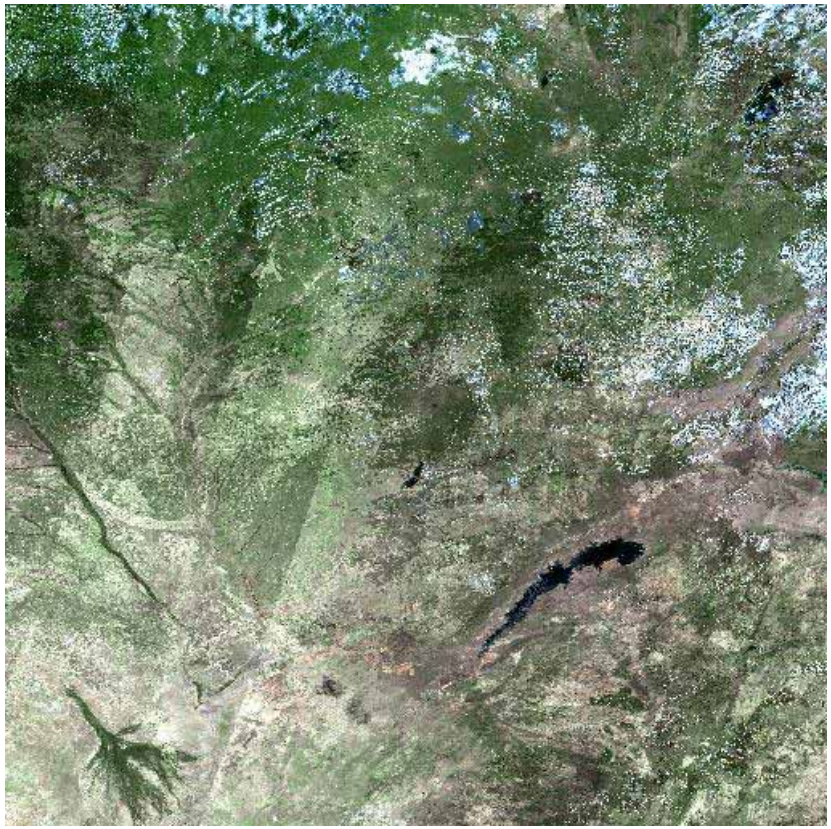
Internal Cloud Mask, green (0): clear, yellow (1): cloudy



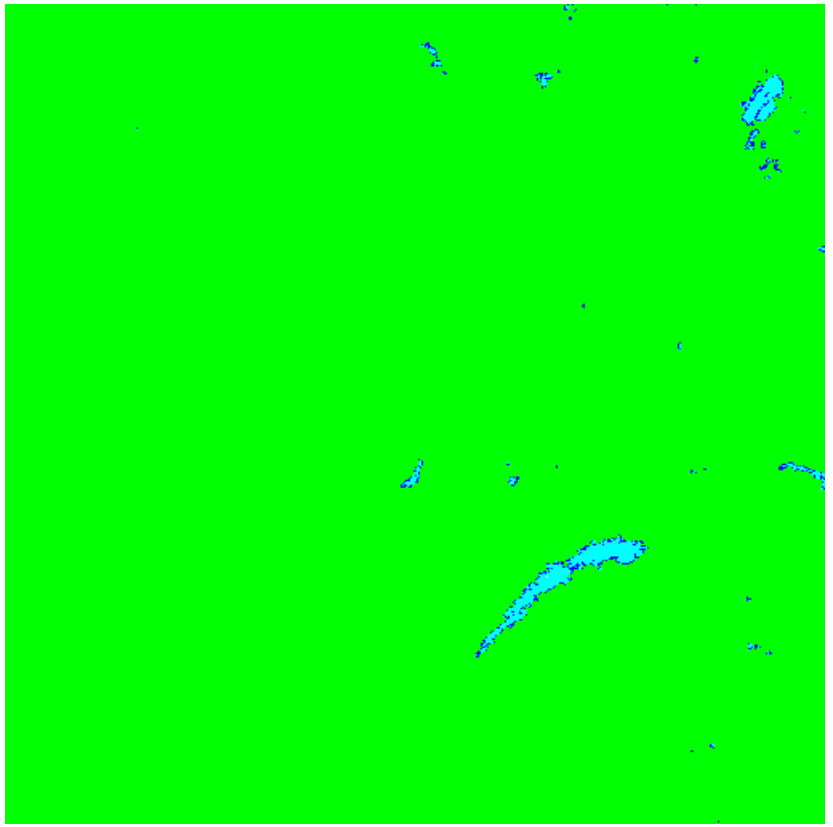
MOD35 Cloud Mask, green (0, 1): clear, yellow (2, 3): cloudy

Example: Reading QA Information

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



RGB Composite of surface reflectance from bands 1, 3 and 4



Land water mask: Green (1): land, blue (2): coastline and shoreline, cyan (3, 5): inland water

Example: Filtering Science Data Using pixel level QA

Task: Filter good quality surface reflectance from MOD09A1 over land where good quality is defined as observations flagged as "low to medium aerosol AND clear AND band quality is good"

Tool: mask_sds

Input: HDF file containing the SDS to be filtered and file containing QA SDS

Output: HDF file containing one or more SDS where observations are filtered by the user specified constraint.

Example: Mask or filter good quality observations from surface reflectance bands 1, 3, and 4 of MOD09A1.A2000305.h20v10.005.2006330041025.hdf

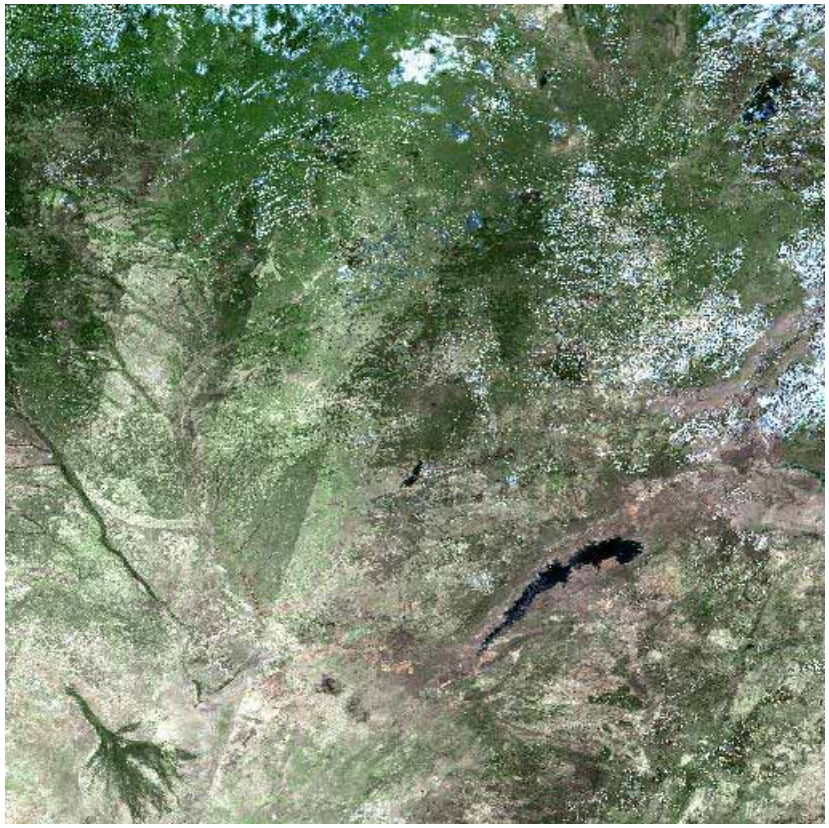
Command: mask_sds –sds=sur_refl_b01,sur_refl_b03,sur_refl_b04 –mask= "MOD09A1.A2000305.h20v10.005.2006330041025.hdf,sur_refl_state_500m,6-7>00,AND,*,*,6-7<11,AND,*,*,10==0,AND,*,*,3-5==001,AND,*,sur_refl_qc_500m,0-1==00" -of=Masked. MOD09A1.A2000305.h20v10.005.2006330041025.hdf MOD09A1.A2000305.h20v10.005.2006330041025.hdf

Result: Output HDF file will contain three SDS

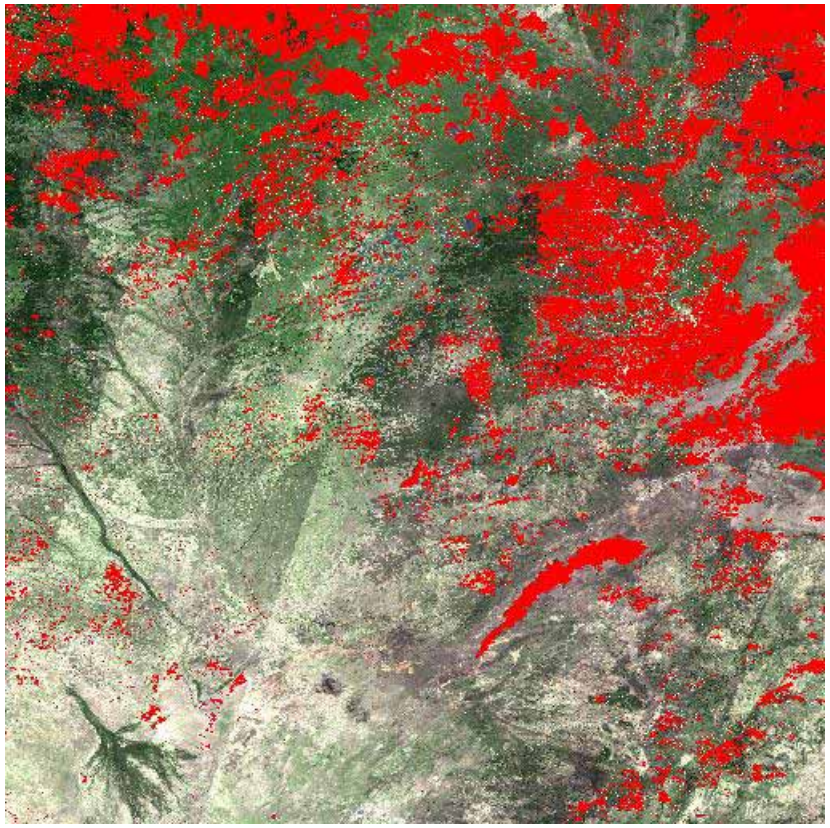
sur_refl_b01
sur_refl_b02
sur_refl_b03

Example: Filtering Science Data Using pixel level QA

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



RGB Composite of surface reflectance from bands 1, 3 and 4



RGB Composite of surface reflectance from bands 1, 3 and 4. Red: fill value forced by the constraint filtering

Example: Mosaic of Gridded Products

Task: Make a mosaic of two or more input gridded MODIS Land product

Tool: mosaic_sds

Input: HDF file

Output: HDF file containing the mosaic

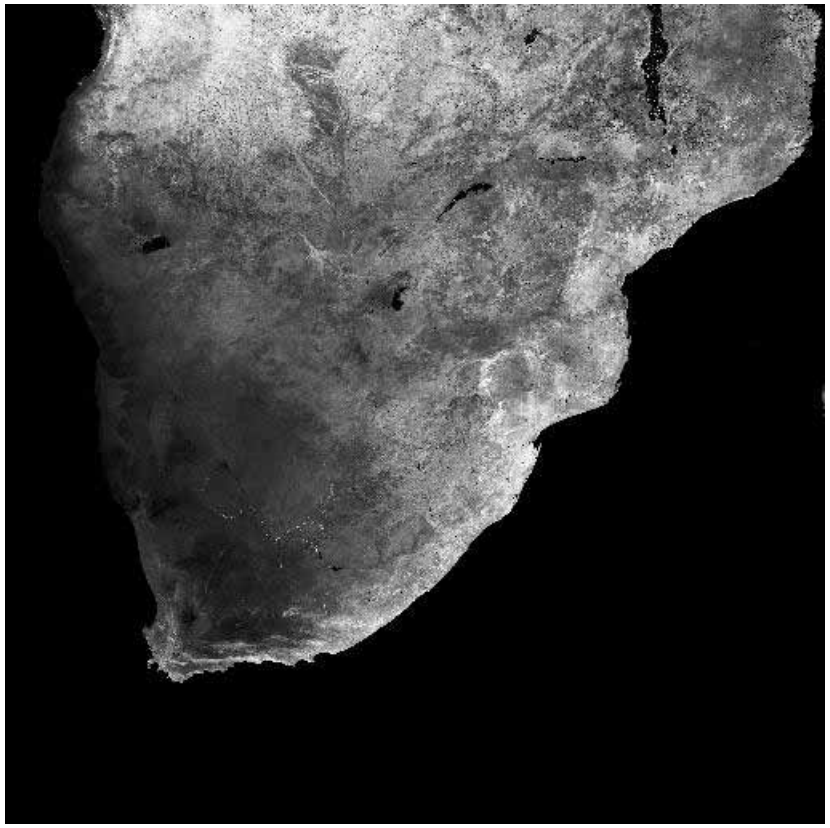
Example: Make mosaics of NDVI and EVI over South Africa (tiles horizontal 19 – 21 and vertical 10-12) for day 2000305

Command: mosaic_sds –sds="1 km 16 days NDVI,1 km 16 days EVI"
–of=Mosaic.MOD13A2.A2000305.SA.005.hdf
MOD13A2.A2000305.h19v10.005.2006330014908.hdf MOD13A2.A2000305.h19v11.005.2006330021418.hdf
MOD13A2.A2000305.h19v12.005.2006330070823.hdf MOD13A2.A2000305.h20v10.005.2006329010717.hdf
MOD13A2.A2000305.h20v11.005.2006329033507.hdf MOD13A2.A2000305.h20v12.005.2006330023220.hdf
MOD13A2.A2000305.h21v10.005.2006330015405.hdf MOD13A2.A2000305.h21v11.005.2006330021629.hdf

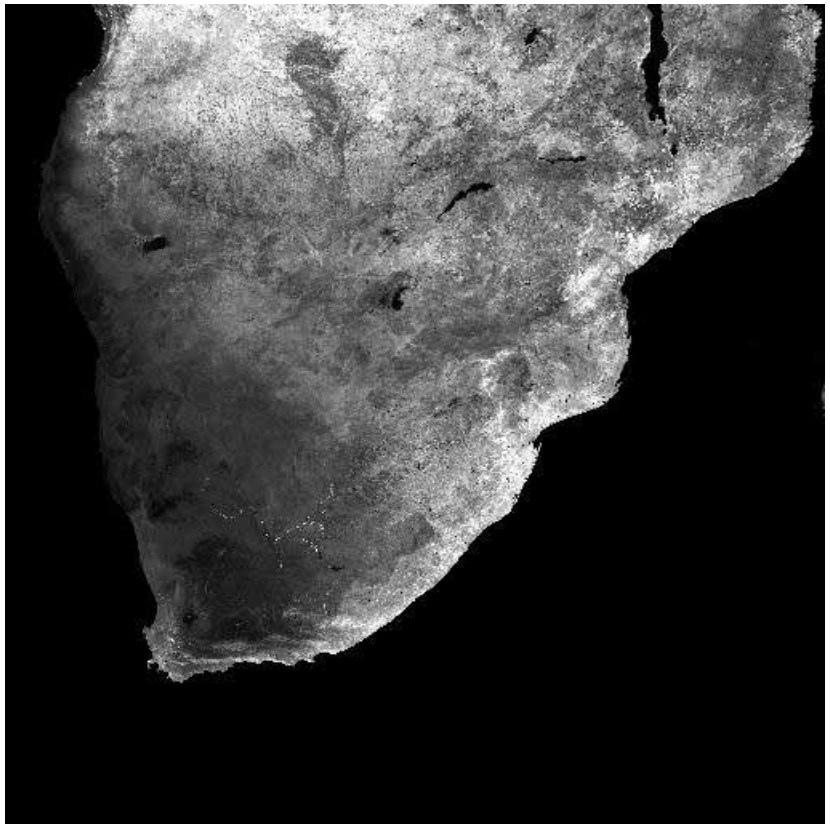
Result: Output HDF file will contain two SDS
1 km 16 days NDVI
1 km 16 days EVI

Example: Mosaic of Gridded Products

Mosaic.MOD13A2.A2000305.SA.005.hdf



1 km 16 days NDVI



1 km 16 days EVI

Example: Simple SDS Math

Task: Compute difference/sum/division of two SDSs

Tool: math_sds

Input: HDF file

Output: HDF file containing the sds math result

Example: Compute the difference between day and night LST in MOD11A2.A2001065.h20v10.005.2007002071908.hdf

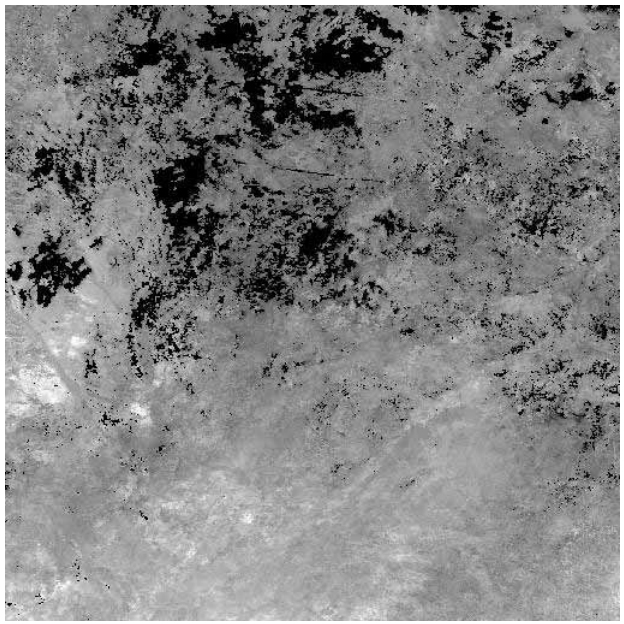
Command: math_sds –math="LST_Day_1km, MOD11A2.A2001065.h20v10.005.2007002071908.hdf - LST_Night_1km, MOD11A2.A2001065.h20v10.005.2007002071908.hdf,INT16,0,0,-1,-2" -of=LST_Diff. MOD11A2.A2001065.h20v10.005.2007002071908.hdf

Result: Output HDF file will contain 1 SDS

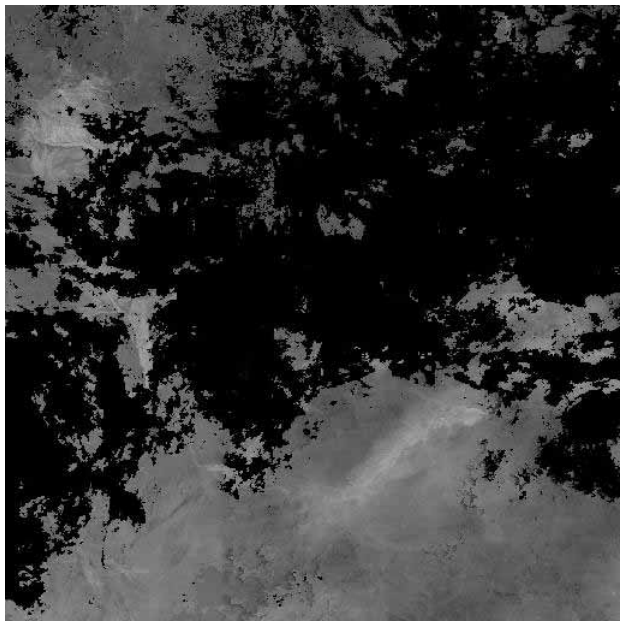
LST_Day_1km – LST_Night_1km

Example: Simple SDS Math

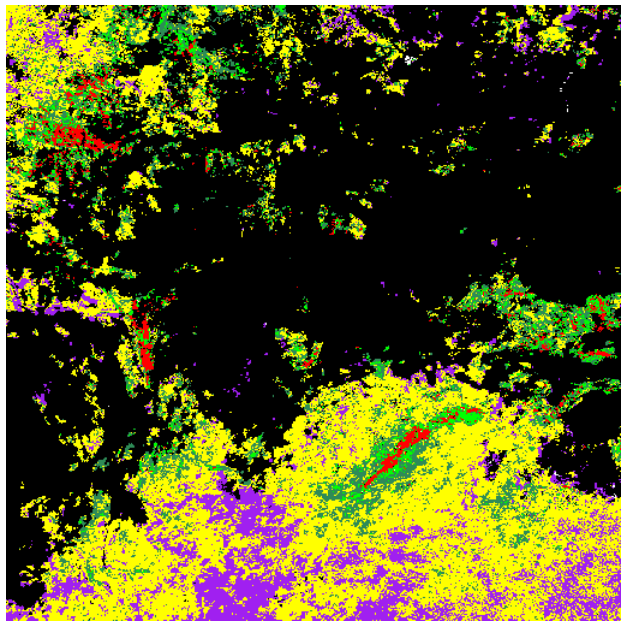
MOD11A2.A2001065.h20v10.005.2007002071908.hdf



LST_Day_1km



LST_Night_1km



LST_Day_1km – LST_Night_1km

Red: -ve, green 0 – 2K, yellow: 2 – 6K, purple > 6k

Example: Making Coarse Products

Task: Make coarse resolution SDS from the full resolution SDS by sub sampling

Tool: reduce_sds

Input: HDF file containing full resolution SDS

Output: HDF file containing the coarse resolution SDS

Example: Create coarse resolution 5 km data sets by sub sampling the full resolution surface reflectance bands 1, 3, and 4 in MOD09A1.A2000305.h20v10.005.2006330041025.hdf

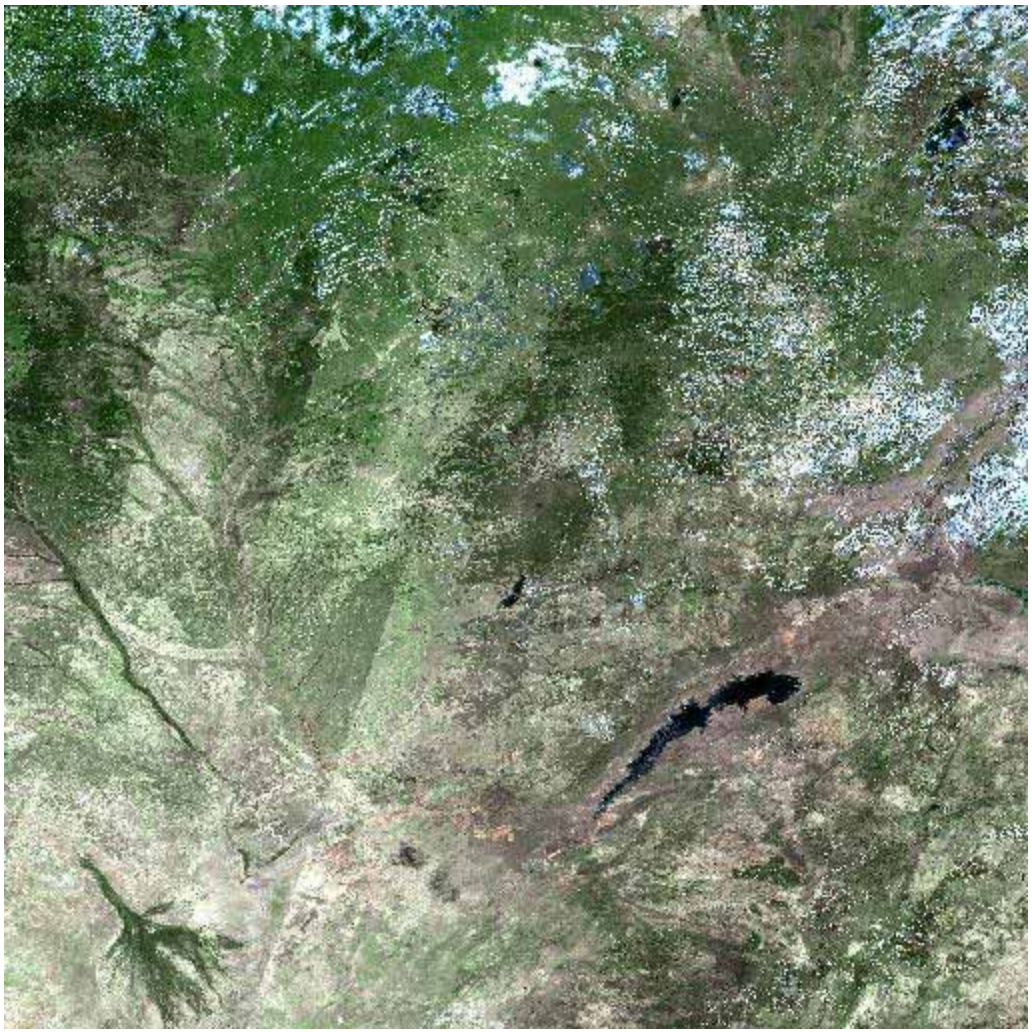
Command: reduce_sds –sub –rf=10 –sds=sur_refl_b01,sur_refl_b03,sur_refl_b04 –of=CRS_SS. MOD09A1.A2000305.h20v10.005.2006330041025.hdf MOD09A1.A2000305.h20v10.005.2006330041025.hdf

Result: Output HDF file will contain 3 SDS

sur_refl_b01
sur_refl_b03
sur_refl_b04

Example: Making Coarse Products

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



RGB Composite of surface reflectance from bands 1, 3 and 4

Example: Making Coarse Products

Task: Make coarse resolution SDS from the full resolution SDS by averaging

Tool: reduce_sds

Input: HDF file containing full resolution SDS

Output: HDF file containing the coarse resolution SDS

Example: Create coarse resolution 5 km data sets by averaging the full resolution surface reflectance bands 1, 3, and 4 in MOD09A1.A2000305.h20v10.005.2006330041025.hdf

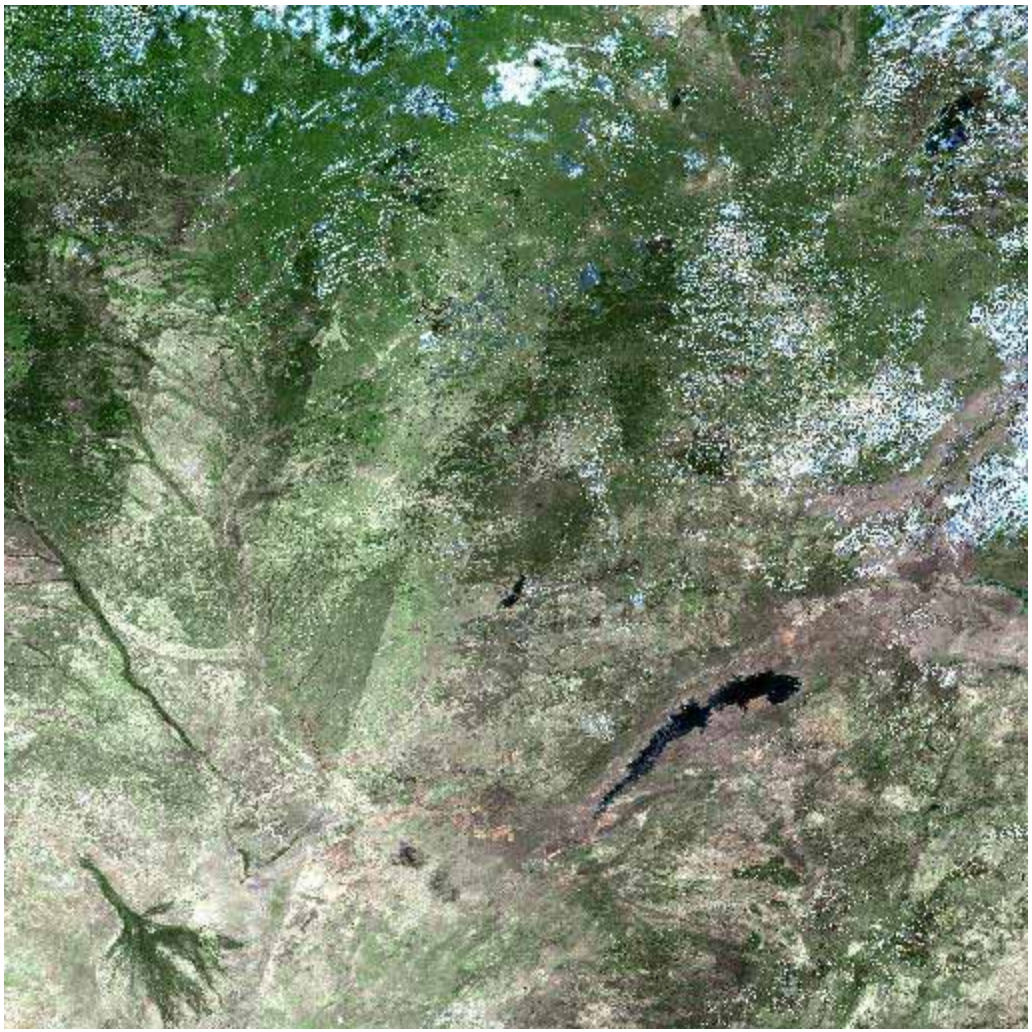
Command: reduce_sds –avg –rf=10 –sds=sur_refl_b01,sur_refl_b03,sur_refl_b04 –of=CRS_SS. MOD09A1.A2000305.h20v10.005.2006330041025.hdf MOD09A1.A2000305.h20v10.005.2006330041025.hdf

Result: Output HDF file will contain 3 SDS

sur_refl_b01
sur_refl_b03
sur_refl_b04

Example: Making Coarse Products

MOD09A1.A2000305.h20v10.005.2006330041025.hdf



RGB Composite of surface reflectance from bands 1, 3 and 4

Example: Making Coarse Products

Task: Make coarse resolution land cover product from the full resolution SDS by majority class

Tool: reduce_sds

Input: HDF file containing full resolution SDS

Output: HDF file containing the coarse resolution SDS

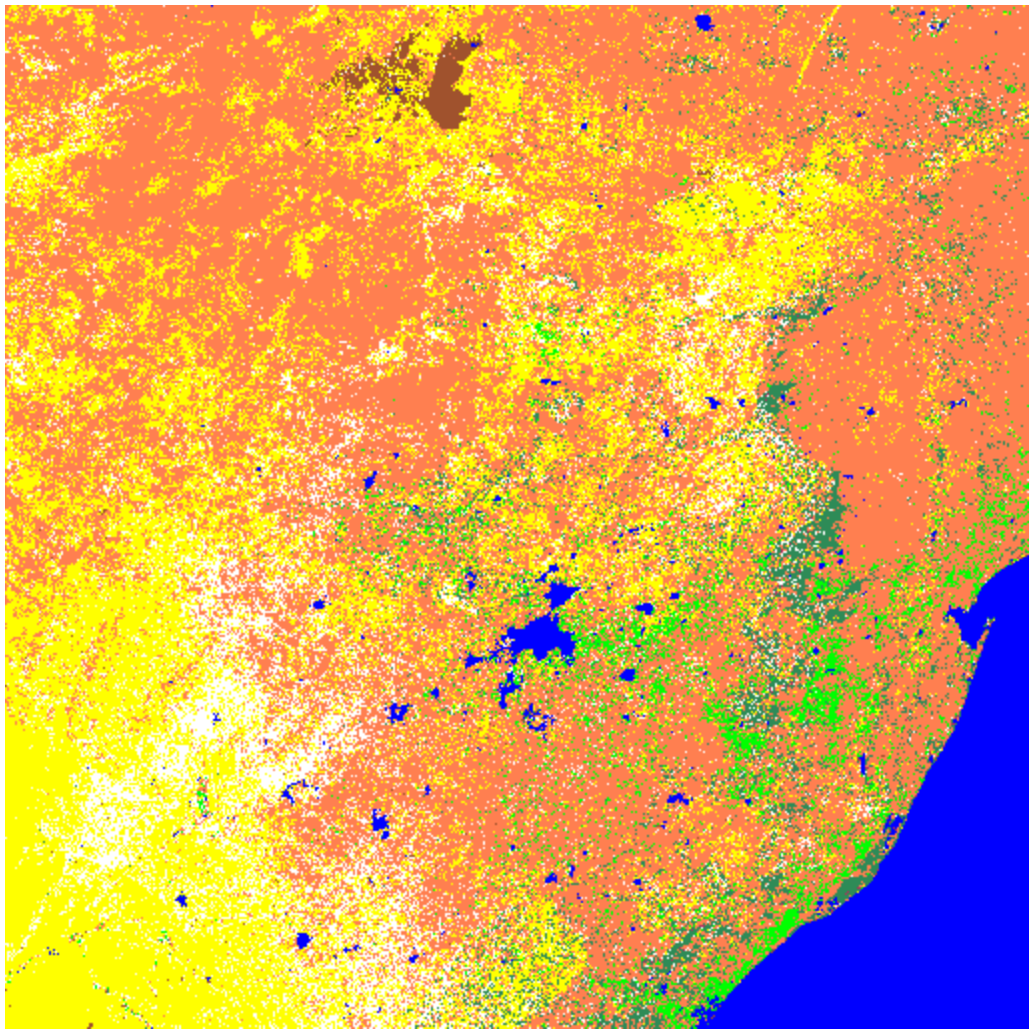
Example: Create coarse resolution 5 km land cover by majority voting from the full resolution land cover SDS in MOD12Q1.A2001001.h20v11.004.2004358134406.hdf

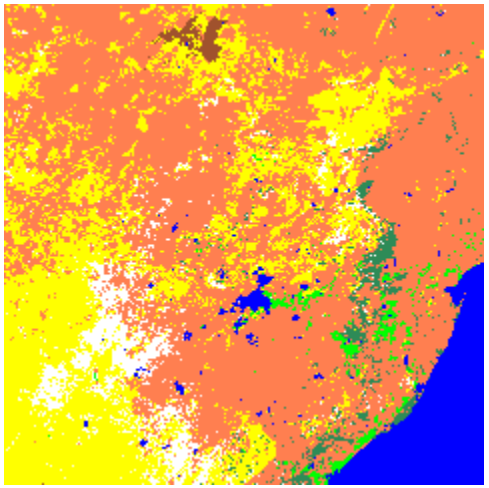
Command: reduce_sds –cl –rf=5 –sds=Land_Cover_Type1
–of=CRS.MOD12Q1.A2001001.h20v11.004.2004358134406.hdf
MOD12Q1.A2001001.h20v11.004.2004358134406.hdf

Result: Output HDF file will contain 3 SDS
Land_Cover_Type1

Example: Making Coarse Products

MOD12Q1.A2001001.h20v11.004.2004358134406.hdf





- Water
- Open shrub lands
- croplands
- Broadleaf forest, mixed forest, closed shrub lands
- Savanna
- Deciduous needle leaf forest
- grassland

Summary

- Fixing bugs
- New tools are under development – e.g. new l2g reader for C5
- User feedbacks/comments welcome