

MODIS and SeaDAS Tutorial

MODIS Data Products Workshop
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This tutorial is designed to take you through a few basic procedures that are commonly used when working with MODIS Ocean data products. Many of you may already be familiar with SeaDAS, IDL, and Matlab. We will guide you through the steps involved in using these programs with MODIS Ocean data. There are several steps that are unique to MODIS Ocean data, and thus even the most experienced programmers will need to know about these procedures.

This handout contains the following sections which we will follow in the order listed here:

- I. MODIS Oceans HDF **file descriptions**
- II. Using **SeaDAS** and MODIS Oceans products
 - i. Load and display products.
 - ii. Load and display quality flags.
 - iii. Remapping.
 - iv. True Color generation.
 - v. Batch-mode processing
- III. Using **IDL** and MODIS Oceans products
 - i. Load HDF files.
 - ii. Product and Quality flag display.

Further information may be found at the following websites:

1. An Introduction to HDF:
<http://www.swa.com/meteorology/hdf/tutorial/Intro.htm>
2. An Introduction to HDF-EOS:
http://www.swa.com/meteorology/hdf/tutorial/Intro_EOS.htm
3. Visualizing and Working with MODIS Ocean Data:
<http://modis-ocean.gsfc.nasa.gov/tools.html>
4. Level 2 Quality-Level Flags:
<http://modis-ocean.gsfc.nasa.gov/qa/L2QLflags.V3.html>
5. MODIS Ocean Parameters:
<http://modis-ocean.gsfc.nasa.gov/parameters.html>
6. Reading an HDF-EOS Swath with the New MATLAB High-Level Interface:
<http://www.mathworks.com/support/author/ip/hdfeos/HDF-EOS-2000/swath.htm>
7. IDL example for Filtering Level 2 Data by Quality Level:
<http://modis-ocean.gsfc.nasa.gov/qualfilter/idllevel2.html>
8. SIMAP, a simple MODIS-Mapper:
<http://daac.gsfc.nasa.gov/MODIS/simap>

I. MODIS Data Products: File Descriptions

MODIS Level 2 data

MODIS level 2 granules are available by ordering from the Goddard DAAC (GDAAC) at <http://acdisx.gsfc.nasa.gov/data/dataset/MODIS/index.html>. These granules are at 1 km² resolution and each contains 5 minutes of collected data.

The MODIS Oceans level 2 products are grouped together into several HDF files. The GDAAC has recently implemented a capability to order individual products for a prescribed geographic area and time. However, here we describe the HDF files in which products are grouped. These are listed below. The list of products in each file are contained in *Appendix #1*, and also found at:

<http://modis-oceans.gsfc.nasa.gov/parameters.html> and
<http://picasso.oce.orst.edu/ORSOO/MODIS/code/Table11params.html>

The MODIS Oceans Level 2 products are contained within the following HDF files:

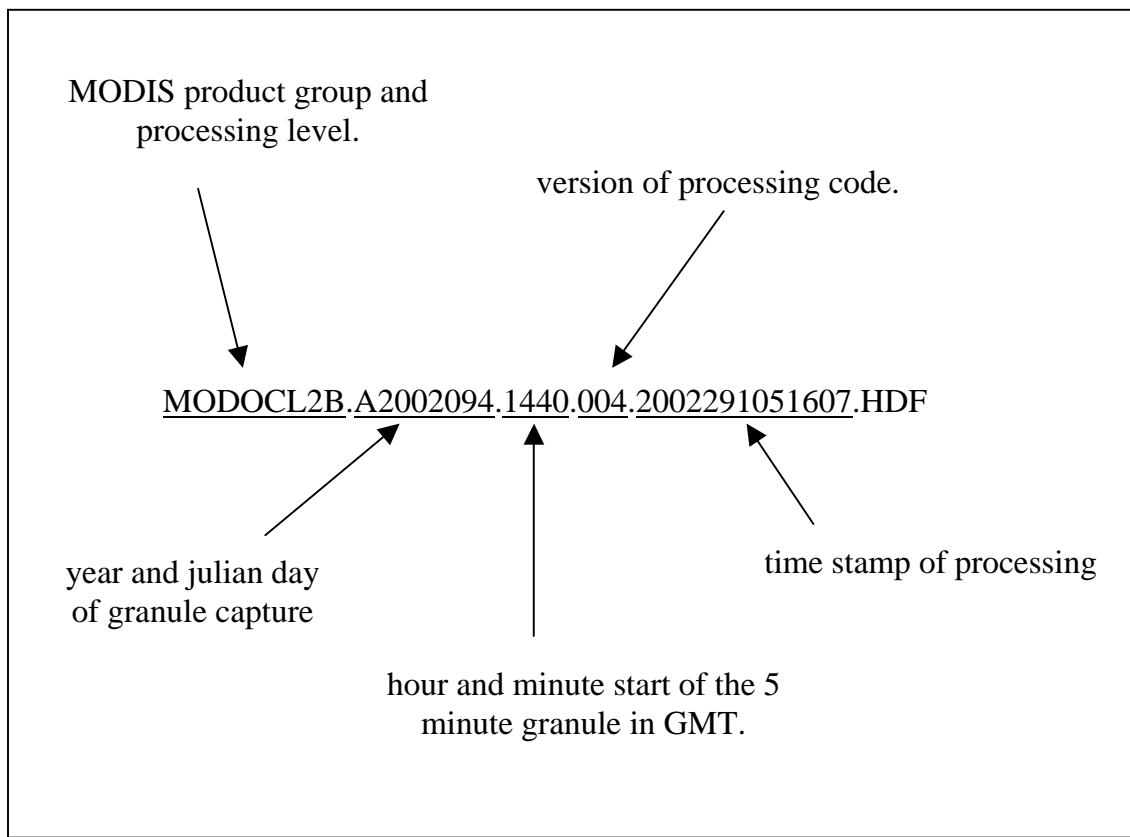
MODOCL2	→	Water-leaving radiances and related products
MODOCL2A	→	Ocean color group 1 products
MODOCL2B	→	Ocean color group 2 products
MOD28L2	→	Sea-surface temperatures and related products
MODOCQC	→	Ocean color QC products
MOD28QC	→	SST QC products
MOD03	→	Geolocation level 1a file (see *NOTE 1)
MOD09	→	MODIS land products (see **NOTE 2)

*NOTE 1: MODIS Oceans Level 2 files need corresponding ‘geolocation’ information (i.e., latitude and longitude) for any remapping. This information is contained in the MODIS Level 1A ‘MOD03’ product (MODOCQC, MOD28QC, and MOD09 also contain lat/lon products).

**NOTE 2: This file contains ‘atmospherically-corrected’ radiances for MODIS bands 1-7, generally used for land remote sensing. This file contains a number of high resolution bands (250m and 500m) which do contain ocean radiances for coastal zones. This file can also be used to generate ‘true-color’ composites. These files are NOT generally available from the GDAAC but can be included in a “push” order. They are very large – 600Mbytes per granule.

Filename convention

MODIS level 2 filenames all follow a similar convention. The breakdown is illustrated on the following figure.



MODIS Level 3 data

MODIS Level 3 data are available from the GDAAC (4km, 36km and 1 degree resolution) at <http://acdisx.gsfc.nasa.gov/data/dataset/MODIS/index.html> and at the MQABI site (at 36km, 1 degree res.) (<http://jeager.gsfc.nasa.gov/browsetool/>).

What is HDF?

HDF stands for Hierarchical Data Format. All MODIS level 2 and level 3 data are in this format. Actually, MODIS data are in HDF-EOS format, which is more of a specialized HDF format. This format adds new specialized data fields (Point, Swath and Grid) developed for Earth science data. This format can still be read using 'regular' HDF read commands as 'SDS' (Scientific Data Set) variables. Several of the websites listed above go into depth on HDF and HDF-EOS. HDF can be read very easily in SeaDAS, IDL and Matlab.

II. SeaDAS and MODIS

SeaDAS (SeaWiFS Data Analysis System) is a software package developed and supported by NASA that is intended to be used with ocean color satellite data. It is freely available at <http://seadas.gsfc.nasa.gov>. SeaDAS is built on IDL and runs with a licensed version of IDL. A version of SeaDAS is also available that used an imbedded IDL core and *does not require* an IDL license to run. Both versions can run in Interactive and Command-line modes, and batch mod processing. The examples that follow are prepared in Interactive mode.

Although it was originally used for SeaWiFS processing, recent upgrades have included the ability for SeaDAS to read in MODIS level 2 data, display MODIS flags, and remap level 2 granules. It is NOT able to process MODIS data from level 1 to level 2.

NOTES:

1. The MODIS level 2 granules that will be used are in the directory */home/jimi/scratch/workshop/images/l2*.
2. The MODIS level 3 files are in */home/jimi/scratch/workshop/images/l3*.

Start SeaDAS – At the command prompt, launch SeaDAS by entering ‘seadas’ <CR>.

Example of loading MODIS Level 3 Mapped products into SeaDAS

The files in the */home/jimi/scratch/images/l3* directory are global 4km monthly and 36km weekly images. The 4km images are very large.

1. From the *seadis* widget, select ‘Load→MODIS Oceans Data’.
2. At the ‘MODIS Filename’ prompt, select ‘MO04MM26.chlor_a_2.ADD2001121.004.2002211074834.hdf.’ No geofile is needed.
3. Set the Pixel Sample Rate and the Line Sample Rate to 4 – computer memory isn’t large enough for the full 4km resolution. Setting these to ‘1’ will load the entire 4km global image, but will cause these computers to grind to a halt.
4. Select the ‘chlor_a_2_mean’ product - the only one (see *NOTE 1), and load it in.

5. To load a color palette, hit the ‘*Functions*’ button on this window, and go down to the ‘Color LUT→Load Color’. A window appears with a variety of color palettes. I recommend either the ‘RAINBOW’ palette (13th in the list), or Miami’s palette ‘Rainbob’ which is second to last. Once you’ve highlighted a palette, you need to hit the ‘*apply*’ button for the palette to take effect in the image window.

6. The initial 'look' of the image will not be correct when you first display it. The data needs to be 'rescaled'. To do this, go to the *Setups* → *Rescale* option of the window with the level 3 image.
7. For *Scale Type*, select "Log". The Scale Min value of 0.01 is good, but the Max value can be adjusted. Try 65.0, and hit 'Redisplay'.
8. Repeat steps 2-4 to view other products. When two windows are open, they will be displayed with the same color palette. There's a way to display two separate color palettes but that is beyond the scope of this exercise.

*NOTE 1: MODIS Oceans Level 3 products are found in individual files. Thus, there is only one product per level 3 HDF file.

Example of loading MODIS Level 2 products in SeaDAS

All MODIS product groups can be read into SeaDAS. There are several ways to get them in. Since they are in HDF format, they can be read in as 'HDF' files. However, SeaDAS has a special option for reading in MODIS Ocean level 2 granules, which this example will demonstrate.

1. From the *SeaDAS Main Menu* widget, select '*Display*→*seadisp*'. The *seadisp* widget will appear.
2. From the *seadisp* widget, select '*Load*→*MODIS Oceans Data*'. Another widget appears.
3. For the 'MODIS Filename' prompt, select the file 'MODOCL2B.A2000294.1600.004.2002259014241.hdf'.
4. For the 'Geolocation Filename', select the file 'MOD03.A2000294.1600.004.2003035164647.hdf' (see *NOTE 1).
5. Set the Pixel Sample Rate and the Line Sample Rate to '1'.
6. Select the 'chlor_a_2', 'chlor_a_3', and 'quality' products and then hit the 'Load' button (see **NOTE 2).
7. A new window appears – this is the *Band List Selection* window which will list any products loaded into SeaDAS. To display the 'chlor_a_2' product, highlight it in the list and then hit the 'Display' button at the bottom of this widget.

8. A new window appears with the image in a gray scale. You may need to scroll around to find familiar features. To expand the window, drag the corner *very slowly!*
9. To load a color palette, hit the '*Functions*' button on this window, and go down to the 'Color LUT→Load Color'. A window appears with a variety of color palettes. I recommend the 'RAINBOW' palette (13th in the list). Once you've highlighted a palette, you need to hit the 'apply' button for the palette to take effect in the image window.
10. To load a coastline or land mask, go to the 'Setups' button at the top of the image window. Hit either the 'Coastline' or 'Land Mask' button. A new widget will appear with a few options. To generate a decent coastline or landmask, make sure the 'CIA DB Resolution' is set to 'High' (~1km). You can set the color, line thickness, and other parameters in this window to your choosing. Using the 'High' resolution database can take a few minutes for coastline or landmask generation, so proceed at your own risk.
11. The coastline and landmask are actually displayed in a separate 'plane' and are not part of the image. All graphics generated within SeaDAS are placed in this plane. To clear the coastline, landmask, or any other graphics, go to the 'Functions' button on the image window, and select 'Graphics Control → Erase All'. This will clear the entire graphics plane without affecting the image itself.

*NOTE 1: MODIS Oceans Level 2 files have geolocation information saved in a separate file – the MOD03 files. These need to be loaded as separate files in SeaDAS for anything to do with georeferencing (e.g., coastline placement or image re-mapping).

**NOTE 2: Many Widgets (or Windows) will remain open in SeaDAS after you have used them. You can 'Quit' any of these after use to reduce the clutter on the computer screen.

Quality flags

Quality flags can be displayed in SeaDAS. All MODIS Quality products have a value of 0, 1, 2 or 3. In general, the quality levels are described as follows:

- 0 – good
- 1 – questionable
- 2 – cloud
- 3 – bad

Example of Quality Flag display in SeaDAS

1. From the *seadisp* widget, select '*Load* → *MODIS Oceans Data*'.
2. Hit the first 'Select' button for the 'MODIS Filename', and select the granule 'MODOCL2B.A2000294.1600.004.2002259014241.hdf', and hit the 'Ok' button.
3. Hit the second 'Select' button for the 'Geolocation Filename', and select the granule 'MOD03. A2000294.1600.004.2003035164647.hdf', and hit the 'Ok' button.
4. Set the Pixel Sample Rate and the Line Sample Rate to '1'.
5. Select the 'chlor_a_3' and 'quality' products and then hit the '*Load*' button.
6. Display the 'chlor_a_3' product from the *Band List Selection* window.
7. From the *seadisp* widget, select '*Functions* → *MODIS Quality Flags Display*'. A new window appears.
8. You can select from here which quality flags to display in a window with an image. The data will be sent to the graphics plane. To show where 'Quality 1' pixels are located, slide the top bar to the band number of the quality flags found in the *Band List Selection* (i.e., it is the number to the left of the 'quality' product).
9. Slide the next bar to the window number containing the chlor_a_3 image, and '*Load*' the image.
10. To display other quality flags, select those from the list and hit '*Load*' (see *NOTE 1).

*NOTE 1: In order to load individual flags without displaying any previously loaded flag, flags must be cleared. This is done by selecting 'Flag Function Menu → Clear All Flags' from the *MODIS Quality Flags Display* window.

Remapping

The products of MODIS Oceans Level 2 granules can be remapped to a variety of projections using SeaDAS. Remapping transforms the original image from 'satellite' view to a standardized projection. This allows for images from different granules to be composited, or granules from different days to be put into the same projection. This example takes you through an 'interactive' session, but this type of activity is well suited for 'batch-mode' processing.

Example of Remapping MODIS images in SeaDAS

1. Load the 'chlor_a_2' product in as illustrated in the 'Loading in Products' example above (skip this if you've already loaded it into SeaDAS).
2. Load the 'sst' product from the MOD28L2 product group.
3. From *seadis* widget, select Functions → Projection. A new window appears.
4. From this window, highlight the 'chlor_a_2' and 'sst' products in the Selection list at the top (it will automatically be placed in the 'Selected for Projection' list).
5. Under 'Map Projection Inputs', set the following values:
 - a. Projection → Conic (Lambert's)
 - b. Center Lat → 40.0
 - c. Center Lon → -70.0
 - d. Rotation → 0.0
 - e. Standard Parallels → 36.1667, 43.833 (into separate fields)
6. Click the 'No' option for 'Automatically load defaults' line.
7. Select the 'Set Scale' option, and set the 'Scale' to 5.0028125e+06.
8. Set the output size to 1300 x 1300.
9. Hit the 'Go' button – this will take a few minutes.

10. A new image should eventually appear in the *Band List Selection* window.
11. Display it, and check it out.

True color generation

True color composite images can be generated by assigning radiance bands as Red, Green and Blue intensities. These can be assigned using level 1b or level 2 data. Here we will use the MOD09 file (a MODIS Land product) and the MODOCL2 file to generate true color composites. The advantage of using MOD09 is that you get clouds and land in the true color scene, whereas with MODOCL2 these are masked out in the level 2 processing and you are dealing only with radiances from the 'water' pixels. Also, atmospheric effects are removed using the MODOCL2 file, while some atmosphere is retained in the MOD09 file.

Example of True Color Generation from MOD09

1. Using *Seadis* → *Load* → *HDF*, open MOD09.A2000294.1600.003.2002197194557.hdf.
2. Select Band 1, 3, and 4 (1km or 500m), and hit 'load'.
3. Bring up the *Seadis* → *Load* → *True Color* widget.
4. Select the 'Band List' option at the top.
5. Enter the 'Band number' from the Band List Selection as follows:
 - R band = Reflectance Band 1
 - G band = Reflectance Band 4
 - B band = Reflectance Band 3
6. Enter the following numbers for the slope and intercept fields:

<u>Band</u>	<u>Slope</u>	<u>Intercept</u>
R	4	5
G	4	40
B	4	1
7. Hit 'Load'.
8. A new image will appear in the Band List Selection. Display the image.
9. These numbers may have to be adjusted to get what you think is a 'correct' looking RGB. Adjust the slope and intercept values, and hit the 'Go' button

to generate new RGB images. Let me know if come up with any ‘magic’ combination.

Example of True Color Generation from MODOCL2

Repeat steps, except load MODOCL2.A2000294.1600.004.2002259014240.hdf in step 1, and in step 4, designate nLw_665 (‘Red’), nLw_551 (‘Green’), and nLw_412 (‘Blue’). Start with values of 50 for the Slope and 10 for the Intercept, and experiment from there.

Batch processing in SeaDAS

Remapping MODIS images using SeaDAS can be done in batch-mode. Batch-mode processing requires a licensed installation of IDL. Batch-mode programs can be run from a shell command line, or as an automated cron job. The example that follows and the routines provided can be setup to run from either.

In this example, select MODIS Level 2 products (i.e., chlor_a2, OCL2B quality, and SST) to be remapped to a defined projection. The following files in the ‘batch’ directory used for the batch job are:

- *do_modis_remap1* - starts seadas in batch mode and executes *do_modis_remap2*
- *do_modis_remap2* - compiles and runs inside SeaDAS *do_modis_remap3*
- *do_modis_remap3* - executes the *l2_modis_remaps.pro* routine

- *l2_modis_remaps.pro* – the control program for remapping MODIS L2 granules. This routine calls *l2_remaps_modis_ocl2b.pro*, *l2_remaps_modis_sst.pro*, *l2_remaps_modis_qual_flags.pro*.

- *l2_remaps_modis_ocl2b.pro* – this routine remaps the ‘chlor_a2’ product from the MODOCL2B group to the specified projection. It will generate a composite remap from the given input files, and save this to a new hdf file. Other products from this group to be remapped can be added in this file.

- *l2_remaps_modis_sst.pro* – this routine remaps the ‘sst’ product from the MOD28L2 group to the specified projection. It will generate a composite remap following the same granules used in *l2_remaps_modis_ocl2b.pro*, which is appended to the same output hdf file. Other products from this group to be remapped can be added in this file.

- *l2_remaps_modis_qual_flags.pro* – this routine remaps the ‘quality’ flags from the MODOCL2B group to the specified projection. It will generate a composite remap from the given input files.
- *l2_remaps_modis_mod09.pro* – this routine remaps bands 1, 3, and 4 at 1km from the MOD09 group to the specified projection. It will generate a composite remap from the given input files. These bands can be used to generate true color images.

1. To run the batch job, at a command prompt type ‘*do_modis_remap1*’ from the batch directory.
2. You can run seadas to check out the output images by loading them in as ‘SeaDAS Mapped’ images using *Seadis* → *Load*.

III. Reading MODIS files in IDL

Reading MODIS Oceans products (Level 2 and Level 3) into IDL is relatively simple with the 2 IDL routines provided, which are found on the website ‘Visualizing and Working with MODIS Ocean Data.’ <http://modis-ocean.gsfc.nasa.gov/tools.html>. In the following example, you will be using these 2 routines to read in MODIS products, display the images, and use quality flags to extract and plot data. These routines can be used to read any of the MODIS products and any Level 2 quality flag. Check the web page for more in-depth information.

Start IDL - Launch IDL by typing *idlde* from a shell window (**NOTE:** SeaDAS must not be running for IDL to launch!).

Example of Reading in products with the *Get_SDS* function in IDL

1. Define the filename and input directory:

```
IDL> fname = 'MODOCL2B.A2000294.1600.004.2002259014241.hdf'  
IDL> l2dir = '/home/jimi/scratch/workshop/images/l2/'
```

2. Load the chlor_a2 data:

```
IDL> chlor_a2=Get_SDS(l2dir+fname,'chlor_a_2')
```

3. Load the ‘Rainbow’ color palette:

```
IDL> loadct, 13
```

4. Since products are stored as integers in the MODIS HDF files, they must be converted to floating point values using a translation stored as a ‘Slope’ and ‘Intercept’ value in the HDF file. These values are obtained as follows:

```
IDL> Get_HDFMeta,l2dir+ fname, 'chlor_a_2', units, slope, int, equation,  
date, proftime <CR>
```

5. Translate chlor_a2 integer array into floating point values and ‘reverse’ the image (see *NOTE 1).

```
IDL> chlor_a2 = float(reverse(chlor_a2,2))*slope + int
```

6. Display the image using the *scroll_window* routine (see **NOTE 2):

```
IDL> scroll_window, chl2gry(chlor_a2)
```

* NOTE 1: IDL reads in MODIS hdf images in reverse order.

** NOTE 2: Images can only be displayed as 'byte' arrays. The *chl2gry* function translates the image from floating point values to byte values (= 0-255).

Example of Reading in Quality flags using the *Bit* function in IDL

1. Load the quality byte for the Group 2 Level 2 product (see *NOTE 1):

```
IDL> quality_ocl2b = Get_SDS(l2dir+fname,'quality')
```

2. The quality flag bit 'pairs' are described on the website 'Level 2 Quality Flag Levels'. The chlor_a2 quality flags are stored in bits 7 and 8. To access these bits, use the *bit* function:

```
IDL> qual_chlor_a2 = bit(quality_ocl2b,7,2)
```

The '7' indicates the bit position, and the '2' indicates the number of bits to extract. This function returns a longword (4 bytes). However, the values returned are 0, 1, 2 and 3.

3. Reverse the qual_chlor_a2 image and transform it from a longword to a byte:

```
IDL> qual_chlor_a2 = byte(reverse(qual_chlor_a2,2))
```

4. Load 'quality' color palette:

```
IDL> loadct, 56
```

5. Use the *scroll_window* routine again to display the image:

```
IDL> scroll_window,qual_chlor_a2
```

Color code:

Quality 0: Green

Quality 1: Blue

Quality 2: Red

Quality 3: Black

*NOTE 1: The product groups MODOCL2, MODOCL2B, and MOD28L2 each have a 1-byte quality flag structure. The product group MODOCL2A has a 4-byte quality flag structure.

Example of mapping L2 image data

This example uses the *map_L2* routine from Miami (contained in *mocean_l2_map.pro*), and maps a level 2 granule product to a global map. It also displays data associated with a given quality level.

1. Create some shortcut string arrays for filenames:

```
IDL> focl2b = 'MODOCL2B.A2000294.1600.004.2002259014241.hdf'  
IDL> fgeo = 'MOD03.A2000294.1600.004.2003035164647.hdf'
```

2. Compile the IDL program file containing *map_L2*:

```
IDL> .run mocean_l2_map.pro
```

3. Call the *map_L2* routine to map the 'chlor_a2' product, with quality=0 data, within the range of 0 and 3:

```
IDL> map_L2, l2dir+focl2b, l2dir+fgeo, 'chlor_a_2', 1, 0.0, 3.0
```

Example of using Level 3 products with the *Get_SDS* and *Bit* functions in IDL

1. Define the filenames:

```
IDL> fname1 = 'MO04MM26.chlor_a_2.ADD2001121.004.2002211074022.hdf'  
IDL> fname2 = 'MO04QM26.chlor_a_2.ADD2001121.004.2002211074542.hdf'  
IDL> l3dir = '/home/jimi/scratch/workshop/images/l3/'
```

2. Load the chlor_a2 and quality flag products:

```
IDL> chlor_a2_l3 = Get_SDS(l3dir + fname1, 'chlor_a_2_mean')  
IDL> chlor_a2_qual_l3 = Get_SDS(l3dir + fname2, 'chlor_a_2_qual_b')
```

3. Get slope and intercept data, and transform the image

```
IDL> Get_HDFMeta, l3dir + fname1, 'chlor_a_2_mean', units, slope, int,  
equation
```

```
IDL> chlor_a2_l3=reverse(chlor_a2_l3*slope +int,2)  
IDL> chlor_a2_qual_l3=reverse(chlor_a2_qual_l3,2)
```

4. Display the chlor_a2 image using the *scroll_window* routine:

```
IDL> loadct, l3 ( 'Rainbow')  
IDL> scroll_window, chl2gry(chlor_a2_l3)
```

5. Display the chlor_a2 quality image using the *scroll_window* routine:

```
IDL> loadct, l3bin  
  
IDL> scroll_window, chlor_a2_qual_l3
```

Appendix A: MODIS Files and Product Groups

Product Group	Product Name
MODOCL2	'nLw_412' 'nLw_443' 'nLw_488' 'nLw_531' 'nLw_551' 'nLw_667' 'nLw_678' 'Tau_865' 'Eps_78' 'aer_model1' 'aer_model2' 'eps_clr_water' 'common_flags' 'L2_flags' 'quality'
MODOCL2A	'CZCS_pigment' 'chlor_MODIS' 'pigment_c1_total' 'chlor_fluor_ht' 'chlor_fluor_base' 'chlor_fluor_effic' 'susp_solids_conc' 'cocco_pigmnt_conc' 'cocco_conc_detach' 'calcite_conc' 'K_490' 'phycoeryth_conc' 'phycou_conc' 'common_flags' 'L2_flags' 'quality'
MODOCL2B	'chlor_a_2' 'chlor_a_3' 'ipar' 'Arp' 'absorp_coef_gelb' 'chlor_absorb' 'tot_absorb_412' 'tot_absorb_443' 'tot_absorb_488' 'tot_absorb_531'

Product Group

Product Name

MODOCL2B (cont)

'tot_absorb_551'
'common_flags'
'L2_flags'
'quality'

MOD28L2

'sst'
'sst4'
'common_flags'
'L2_flags'
'quality'

MODOCQC

'U_Wind'
'V_Wind'
'Pressure'
'Humidity'
'Ozone'
'Latitude'
'Longitude'
'SolarZenith'
'SolarAzimuth'
'SatelliteZenith'
'SatelliteAzimuth'
'nLw670'
'La765'
'Ray443'
'Lg865'
'Lf865'
'aer_model1'
'aer_model2'

MOD28QC

'bright20'
'bright22'
'bright23'
'bright31'
'bright32'
'raw20'
'raw22'
'raw23'
'raw31'
'raw32'
'cldmsk_flags'
'common_flags'

MOD03

'Latitude'

Product Group	Product Name
	<ul style="list-style-type: none"> 'Longitude' 'Height' 'SensorZenith' 'SensorAzimuth' 'Range' 'SolarZenith' 'SolarAzimuth' 'Land/SeaMask' 'gflags' 'Moon Vector' 'L1 scan quality' 'Geo scan quality' 'orb_pos' 'orb_vel'
MOD03 (cont)	<ul style="list-style-type: none"> 'attitude_angles' 'sun_ref' 'impulse_enc' 'impulse_time' 'Scan Type' 'detector_offsets'
MOD09	<ul style="list-style-type: none"> 'BAND20ALBEDO' 'BAND20' 'BAND31' 'BAND32' '1km Atmospheric Optical Depth Band 1' '1km Atmospheric Optical Depth Band 3' '1km Atmospheric Optical Depth Band 8' '1km Atmospheric Optical Depth Band QA' '1km Atmospheric Optical Depth Band CM' '1 km latitude' '1 km longitude' '250m Surface Reflectance Band 1' '250m Surface Reflectance Band 2' '500m Surface Reflectance Band 1' '500m Surface Reflectance Band 2' '500m Surface Reflectance Band 3' '500m Surface Reflectance Band 4' '500m Surface Reflectance Band 5' '500m Surface Reflectance Band 6' '500m Surface Reflectance Band 7' '1km Surface Reflectance Band 1' '1km Surface Reflectance Band 2' '1km Surface Reflectance Band 3' '1km Surface Reflectance Band 4' '1km Surface Reflectance Band 5'

'1km Surface Reflectance Band 6'
'1km Surface Reflectance Band 7'
'1km Surface Reflectance Band 26'
'500m Reflectance Band Quality'
'250m Reflectance Band Quality'
'1km Reflectance Band Quality'

Matlab and MODIS

Matlab is commercial software from The Mathworks: www.mathworks.com
A useful accessory for mapping data is the Mapping Toolbox (also from The Mathworks).

NOTE: Some of the routines used in this tutorial do not work in Matlab 5.3 R11. They do work in Matlab 6.5 R13.

Matlab has internal functions for reading HDF files. The programs presented in this tutorial were created using these internal functions, and have been designed specifically for loading MODIS oceans data. Should you wish to write your own programs, information on the internal HDF functions can be found by typing *help hdf* at the matlab prompt.

To **start matlab**, double-click on the matlab icon.

At the matlab prompt, cd to the directory containing the matlab routines:
cd c:\COAS\matlab

NOTE: These routines must be run in the order presented, without clearing any variables. Some of the examples use data from previous examples. This was done to save time in the tutorials.

Example 1: How to load and display MODIS level 2 data

```
% define the path and filename
mypath='c:\COAS\images\';
fname= 'MODOCL2B.A2001213.1525.004.2002197063442.hdf';

% load the chlor_a_2 data
chlor_a_2=hdfread([mypath fname],'chlor_a_2');

% get the scaling equation from the HDF file
% to convert the data from raw counts to appropriate units
[name, units, slope, int, eq]=get_hdfmeta([mypath fname],'chlor_a_2');

% convert the data from raw counts to appropriate units
% IMPORTANT NOTE!!!
% NOT ALL PARAMETERS HAVE LINEAR SCALING EQUATIONS
% - check the contents of the variable 'eq' before proceeding
chlor_a_2=double(chlor_a_2)*double(slope)+double(int);

% open a figure window
figure

% load the 'rainbob' color palette and set the colormap to it
load rainbob
colormap(rainbob)

% display the image with a colorbar
imagesc(chlor_a_2)
colorbar

% change the range of data plotted by the colormap and redraw the colorbar
imagesc(chlor_a_2,[0.001 5])
colorbar
```

Example 2: How to read in and display the quality flags

```
% load the quality bytes for the HDF file
% NOTE: MODOCL2, MODOCL2B and MOD28L2 each have a 1-byte
% quality flag structure. MODOCL2A has a 4-byte quality flag structure.
quality_bytes=hdfread([mypath fname], 'quality');

% pull out the bits that correspond to the quality flag of interest
% (see http://modis-ocean.gsfc.nasa.gov/qa/L2QLflags.V4.html)
% For chlor_a_2, the appropriate bits are 7 & 8.
quality_chlor_a_2=bit(quality_bytes,7,2);
% the above will extract 2 bits starting at bit 7, and will return
% an unsigned byte with values between 0 (good) and 3 (bad).

% open a new figure window
figure

% load the provided quality flag color palette and set the colormap
load quality_colormap
colormap(quality_colormap)

% display the image
image(quality_chlor_a_2)
```

0=green
1=blue
2=red
3=black

Example 3: How to apply the quality flags to the data

```
% find all the pixels with a quality of 2 or 3
myquals=find(quality_chlor_a_2 >= 2);

% copy the data to a new array (keep the original)
good_chlor_a_2=chlor_a_2;

% remove all the bad data from this new array
good_chlor_a_2(myquals)=NaN;

% open a figure window
figure

% set the colormap to rainbob
colormap(rainbob)

% display the good image with a colorbar
imagesc(good_chlor_a_2,[0.001 5])
colorbar
```

Example 4: How to map level 2 data (This example requires the Mapping Toolbox)

First, we will load the two parameters: 'Latitude' and 'Longitude' from the MODOCQC or MOD03 file by using `hdfread` twice. If using the MODOCQC file, the lat and lon data will need to be converted from raw counts to appropriate units, as in example 1. The code should look like:

```
fname='MOD03.A2001213.1525.003.2001321044045.hdf';  
  
% load the chlor_a_2 data  
lat=hdfread([mypath fname],'Latitude');  
lon=hdfread([mypath fname],'Longitude');  
  
% change the lat/lon data to double precision  
lat=double(lat);  
lon=double(lon);  
  
% open a new figure window  
figure  
  
% set the projection to equidistant cylindrical  
% (available projections can be seen by typing getm mapprojection)  
axesm eqdcylin  
  
% set the colormap  
colormap(rainbob)  
  
% set the map lat/lon limits  
setm(gca,'maplatlimit',[min(min(lat)) max(max(lat))]);  
setm(gca,'maplonlimit',[min(min(lon)) max(max(lon))]);  
  
% plot the data and add a colorbar  
surfm(lat,lon,chlor_a_2) % this takes a long time!  
set(gca,'CLim',[0.001 5])  
colorbar('horiz')  
  
% add coastline data to the figure  
hold on; % this allows you to plot more than one thing on the same figure  
plotm(coast,'Color','white','Clipping','on')
```

Example 5: How to load and display MODIS level 3 data and quality
(This is essentially the same procedure as used for level 2 data.)

```
% define the path and filenames (data and quality)
l3path='c:\COAS\images\';
fname= MO36MW26.chlor_a_2.ADD2001089.004.2002186192400.hdf;
qname= MO36QW26.chlor_a_2.ADD2001089.004.2002186192356.hdf;

% load the data
chlor_a_2_l3=hdfread([l3path fname],'chlor_a_2_mean');
qual_chlor_a_2_l3=hdfread([l3path qname],'chlor_a_2_qual_b');

% get the scaling equation from the HDF file
% to convert the data from raw counts to appropriate units
[name, units, slope, int, eq]=get_hdfmeta([l3path
fname],'chlor_a_2_mean');

% convert the data from raw counts to appropriate units
% IMPORTANT NOTE!!!
% NOT ALL PARAMETERS HAVE LINEAR SCALING EQUATIONS
% - check the contents of the variable 'eq' before proceeding
chlor_a_2_l3=double(chlor_a_2_l3)*double(slope)+double(int);

% plot the chlor_a_2 data
figure
load rainbob
colormap(rainbob)
imagesc(chlor_a_2_l3,[0.001 1])
colorbar
title(name)

% plot the quality data
figure
load quality_colormap
colormap(quality_colormap)
imagesc(qual_chlor_a_2_l3,[0 3])
title([name ': quality'])
```

TIPS FOR BEGINNERS

To **start matlab**, type *matlab* at the command prompt (NOTE: on our system, use *matlab6*).

For **help** on any commands, type *help command* (where *command* is the command name) at the matlab prompt.

If a **semicolon** (;) is placed after a command, the results will not be displayed. Removing the semicolon causes the results to be shown. For example:

```
a=4*6;
```

will create a variable *a*, with the value 24, but will not show that on the screen.

```
a=4*6
```

will create the same variable, and will print “24” to the screen.

To **change directory**, type *cd path* at the matlab prompt, where *path* is the path you wish to change to. You can also use **ls** and **dir**.

To see a list of all of your **current variables** and their dimensions, type *whos*.

Arrays are enclosed in square brackets. For example:

```
a=[1 5 2:9];
```

creates the array:

```
1 5 2 3 4 5 6 7 8 9
```

For a two-dimensional array, use a semicolon to indicate the next line:

```
a=[1 3 6; 7 9 9; 8 2 1];
```

Creates:

```
1 3 6
```

```
7 9 9
```

```
8 2 1
```

Arrays can be made in as many dimensions as you like.

To reference the contents of an array, use round brackets:

```
a(4)
```

is the fourth entry in array a (the first entry is a(1)). In the first array above, this would be 3. In the second array, this would be 7. In a two-dimensional array, the contents can also be referenced as:

```
a(2,1)
```

where the first number is the row and the second is the column (all are numbered starting from 1). This would also return 7 for the second array above. You can similarly reference a subset of the array:

```
a(1:2,2:3)
```

returns:

```
3 6
```

```
9 9
```

Strings can be created using single quotes:

```
a='this is a string';
```

This creates a character array. Substrings can then be referenced just like a normal array:

```
b=a(2:4) % this returns the character array: his
```

Strings can be concatenated by combining two character arrays into one character array:

```
c=[b b] % this returns the character array: hishis
```

Multiple strings can be put in different rows of a single array, but they must all be the same length. For strings of varying lengths, consider using a cell array.

The **cell array** lets you group matrices of different sizes and types together into a single cell array. Cell arrays are made and referenced using curly brackets:

```
c={a b};
```

creates a cell array containing the two arrays a and b.

```
c{1}
```

returns the first array in the cell array (a).

Cell arrays can be multidimensional.

Loops and conditions can be made using if, while, and for statements. For more information, see the matlab help.

Comments can be made using % , for example:

```
% this is a comment
a=b+c; % everything after the percent sign is a comment
```

A series of commands can be put together into a single **program**. This is just an ascii file, with the commands listed one after the other like they would appear after the matlab prompt. The program filename must have the extension “.m”. To run the program, simply type the program filename (without the .m extension) at the command prompt. For example:

```
% This is a sample program.

% Blank lines will be ignored.
a=3;
b=a-1;
c=b/4 % this will print the value of c
```

Save this file as sample.m. To run this file, you can either:

1 - cd to the directory where you saved the program (from within matlab), and type *sample*, or

2 – add the program path to the matlab path using File – **Set Path** ... (from the main matlab toolbar), and then type *sample* at the matlab prompt. This last option will be saved after you exit matlab, so you can always run programs in that folder from any directory.

The value 0.5 will print on the screen.

Functions are made similar to programs, but at the start of the program (after any comments you may wish to include) you type:

```
function [a,b,c]=myfunction(input1,input2);
```

where the outputs will be a, b, and c, and the required inputs are input1 and input2. You can have as many inputs and outputs as you like (including none). Save this function file as myfunction.m (or whatever your function is called). To invoke the function from another program or within matlab, use:

```
[out1, out2, out3]=myfunction(in1,in2);
```

Note that the variable names do not have to match, but the correct order and number of variables must be preserved.

To **run a matlab program from the UNIX command line**, type:

```
/path/matlab < /progrpath/myprogram.m >! /outpath/myoutput.log
```

where `path` is the path where matlab resides, `progpah` is the path where your program (`myprogram.m`) resides, and `outpath` is where you would like the output (the matlab screen) sent. This output file is useful for debugging.

To **stop a program** from running, type *control-c*.

To **quit Matlab**, type *exit*.

Some other **useful matlab commands** you may want to use:

figure (opens a figure window)

plot (for a 2-D plot)

image (for a 3-D surface plot)

set (to change figure and axis properties)

find (to find data within an array that matches your criterion)

save (to output data)

print (to output a figure as a jpeg/tiff/etc)

clear (to delete a parameter from the workspace)

close (to close figure windows)

MODIS GUI and MODIS

The MODIS GUI was designed to interactively load and display MODIS oceans data. Matlab and the Mapping Toolbox (both from The Mathworks: <http://www.mathworks.com/>) are required. The MODIS GUI is available, along with online help, from: <http://picasso.coas.oregonstate.edu/ORSOO/MODIS/GUIhelp/>.

The main features of the MODIS GUI include:

- import level 2 and 3 MODIS HDF files (data, flags, and quality)
- import subregions of MODIS data
- choose the range of values to be plotted
- map the data
- zoom in or out
- change figure colors/projections/labels
- mask data
- make histograms
- make 2D plots
- save data
- save figures

In addition, data may be edited in the workspace and loaded into the GUI for mapping. There is no batch processing capability at this time.

For the tutorial, the MODIS GUI code has been placed in the directory:
c:\COAS\modisgui

The MODIS data are in the directory:
c:\COAS\images

To launch the MODIS GUI, first start Matlab by double-clicking on the Matlab icon. Then start the MODIS GUI by typing:

```
>> cd c:\COAS\modisgui  
>> MODISGUI
```

Example 1: How to load and display MODIS oceans level 2 data.

1. In the upper section, “Load MODIS HDF file”, choose the level 2 file:
c:\COAS\images\
MODOCL2B.A2000294.1600.004.2002259014241.hdf
2. Leave the “file type” as “level 2”.
3. Leave the “step size” at 5. This will load every 5th pixel only. To load all pixels, set this number to 1 (much slower).
4. Hit the “GO” button.
5. A list of all available parameters in that level 2 file will appear in a separate window. Select “chlor_a_2” and hit “GO”.
6. The loaded data will appear in the list in the second section (“Select loaded data to plot”). The left box contains the filename and parameter name. The middle box contains the dimensions of the loaded data (rows x columns). The right box contains the name of the array in the Matlab workspace, if you want to manipulate the data.
7. Make sure the data you wish to display is highlighted in the list.
8. Set the min and max values to 0.001 and 1 respectively, then hit “GO”.
9. In the Make Map section, hit “GO”.

Example 2: How to map MODIS oceans level 2 data.

1. Follow steps 1-8 in example 1 to load the level 2 chlor_a_2 data.
2. We will now load the corresponding latitude and longitude data. In the “Load MODIS HDF file” section, select the corresponding level 2 MODOCQC file:
c:\COAS\images\
MODOCQC.A2000294.1600.004.2002259014241.hdf
(You can also use the level 1b MOD03 file – load it as a level 2 file.)
3. Use the *same step size* as before, and hit “GO”.
4. Select the two parameters “latitude” and “longitude”, and hit “GO”.
5. Two new datasets will appear in the “Select loaded data to plot” section (latitude and longitude). They should have the same dimensions as your chlor_a_2 data.
6. Make sure the chlor_a_2 dataset is highlighted in the “Select loaded data to plot” list.
7. In the “Make map” section, hit “select lat/lon”.
8. In the drop-down lists, select the appropriate longitude and latitude datasets to use, then hit “GO”.
9. The range of lat/lon values will appear in the Make map section.
10. In the Make map section, hit “GO”.

Example 3: How to load and display MODIS oceans level 3 data.

1. In the section, “Load MODIS HDF file”, choose the level 3 file:
c:\COAS\images\
MO04MM26.chlor_a_2.ADD2001121.004.2002211074834.hdf
2. Leave the “file type” as “data (M,N,S)” and change the “step size” to 1.
3. Select the region 30 to 50 °N, -150 to -110 °E.
4. Hit the “GO” button.
5. The loaded data will appear in the list in the “Select loaded data to plot” section.
6. Make sure the data you wish to display is highlighted in the list.
7. Set the min and max values to 0.001 and 1 respectively, then hit “GO”.
8. In the Make Map section, hit “GO”.

Example 4: How to mask MODIS oceans level 3 data.

1. In the section, “Load MODIS HDF file”, load the level 3 file:
c:\COAS\images\
MO36MW26.chlor_a_2.ADD2001089.004.2002186192400.hdf
2. Leave the “file type” as “data (M,N,S)”, the “step size” at 5, the region as global, and hit “GO”.
3. Now load the corresponding level 3 file with the data you wish to use as a mask (F,1,2, or 3 file), such as:
c:\COAS\images\
MO36FW26.chlor_a_2.ADD2001089.004.2002186192400.hdf
This time, the “file type” should be “flag (F,1,2,3), and a step size of 5. Hit “GO”.
4. Eight new datasets will appear in the list in the “Select loaded data to plot” section, one for each flag in the file.
5. Make sure the data you wish to mask (the level 3 chlor_a_2 data) is highlighted in the list.
6. Hit the “apply mask” button.
7. Select one or two masks to apply from the 8 flags you loaded. The first mask is called the land mask, but it can be anything. Hit “GO”.
8. A new masked dataset will appear in the list. Make sure it is highlighted.
9. In the Make Map section, hit “GO”.