

Lab 1a - Staging, Viewing, Interrogating MODIS Data and Inferring Cloud Properties

Table: MODIS Channel Number, Wavelength (μm), and Primary Application

Reflective Bands			Emissive Bands		
1,2	0.645, 0.865	land/cld boundaries	20-23	3.750(2), 3.959, 4.050	sfc/cld temp
3,4	0.470, 0.555	land/cld properties	24,25	4.465, 4.515	atm temperature
5-7	1.24, 1.64, 2.13	“	27,28	6.715, 7.325	water vapor
8-10	0.415, 0.443, 0.490	ocean color/chlorophyll	29	8.55	sfc/cld temp
11-13	0.531, 0.565, 0.653	“	30	9.73	ozone
14-16	0.681, 0.75, 0.865	“	31,32	11.03, 12.02	sfc/cld temp
17-19	0.905, 0.936, 0.940	atm water vapor	33-34	13.335, 13.635	cld top properties
26	1.375	cirrus clouds	35-36	13.935, 14.235	cld top properties

Table: Summary of Hydra Commands

Hydra menu

Displays world map with image control functions indicated on the bottom

Reset

Zoom in (left click plus drag)

Zoom out (left click plus drag)

Rubber band zoom (left click plus drag to create box for enlargement)

Translate (left click plus drag)

Pick image (left click plus drag displays location of the chosen pixel)

Subset image (left click plus drag to create subset of image; this is automatically transferred from Hydra into the Multichannel viewer when both are engaged)

Also shows menus for **Data**, **Settings**, and **Start** at top

Data menu:

Local allows you to scroll through local directories to find data

Remote allows you to find an AIRS granule from a remote server (a) MODIS Direct Broadcast or (b) Goddard DAAC

Exit

After a MODIS or AIRS granule is selected hydra displays the infrared window on a world map

Settings menu

Set color range (left click shows VisAD histogram – color range can be altered with a right click plus drag at either end of the color scale)

Set color scale gives choice of color, grey, or inverse grey (which produces white clouds)

Start opens **Multichannel Viewer**

wherein a spectra (wavenumber on x-axis and radiance on y-axis) is displayed along with a spectral band superimposed on a world map. Left click on pick image in bottom tool bar the allows you to see the pixel value for a given lat-lon (using left click and drag)

Tools menu

Linear Combinations opens channel combination tool display where you can specify linear combinations of spectral bands a,b,c and d

$(a \pm \times \div b) \pm \times \div (c \pm \times \div d)$

Compute creates an image of the selected linear combination (indicate at the bottom preference for this linear combination to be x- or y-axis in the scatter plot)

Scatter allows you to create a scatter plot of the chosen x- and y-axis linear combinations. Five color area boxes (or area curves) can be initiated at the bottom of the scatter plot; a left click drag in the scatter plot highlights the chosen points in the scatter plot and simultaneously in the x- and y-axis images. Conversely left click drag in the x- or y- axis images shows the locations of the chosen pixels in the scatter plot. Each color area box (or area curve) can be erased with a left click when the color box is engaged; after erasure another area box (or area curve) can be selected for this color.

Transect allows you to create a line on the image and see the temperatures or radiances of the transect. This is enabled with a left click drag.

Capture Display makes jpeg in location you specify

Statistics allows you to display min and max values and locations on image (toggle on or off)

Settings menu

Set color range opens VISAD histogram of brightness temperature (BT) values

Radiance – BT allows you to select radiance or brightness temperature in the display

Projection allows you to put the data in a given projection (mercator is the default)

Set Color Scale gives you the choice of color, grey, or inverted grey

Exercise 1

1. Analyze the cloud scene over Italy on 29 May 2001 detected by MODIS using the Hydra software. Click on the menu data and then click on local. Go into the Data directory and select the file MOD021KM.A2001149.1030.003.2001154234131.hdf, click on the open button. Click on the start menu and then click on the Multi-Channel Viewer. Using the Multi-Channel Viewer window get familiar with the menu band, and menu Set Color Range and radiance->BT under the Settings tool.

2. Browse through the scene in several different wavelengths in the Multi-Channel Viewer window. Look at the scene both in radiances and BT (use radiance->BT under the Settings tool):

(a) verify that for window channels the surface features are visible while for absorption channels they are not;

(b) At 11 μm the BT ranges between 220 K and 320K . Can you locate where the minimum and maximum of BT for band 31 (11 μm) occur?

(c) look at clouds, ocean, and vegetated surfaces in different reflective bands. For each type (by selecting a single Field Of View) describe the changes in reflectance for different channels (top panel of Multi-channel viewer window).

3. Load the high-resolution image. To load the high-resolution image highlight the Hydra window click on the seventh button from the left in the lower part of the window (*subset image*) and click and drag the right button of the mouse to select a small sub-region on the scene. The selected region, at 1 km resolution, will appear in the Multi-Channel Viewer window. Sub-select different regions (over clouds, desert and ocean). In the Multi-channel viewer window click on the button with the array (sixth button from the left: *pick image*) and click on any pixel of your

scene. The spectrum on the top panel of the Multi-Channel Viewer window will show the observed radiances for that channel:

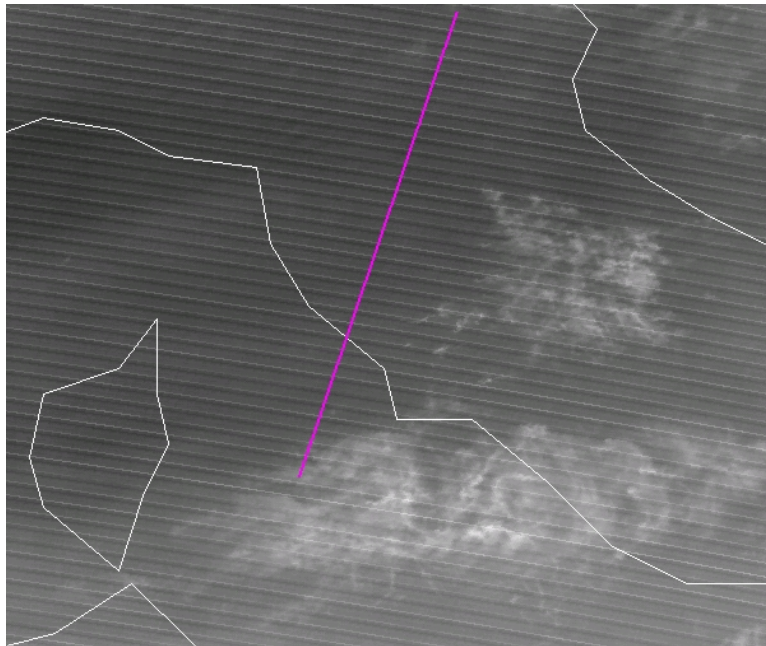
- (a) describe for each scene the relative changes for the emissive bands at 11 μm and at 12 μm ;
- (b) for each scene identify the most and the least reflective bands;
- (c) for each scene try to draw by hand a curve for the reflectance as function of the wavelength;

4. Now select a region over the ocean and select band number 27 (6.7 μm) and display the image in BT. This band is used in cloud detection but also to derive upper tropospheric humidity (UTH). Describe most evident characteristics in the image that are due to:

- (a) the atmosphere
- (b) artifacts

Click on the menu command Tools and use transect. Approximately draw a line (point to the start point, use SHIFT+Right-Click+-Drag to the end point). The plot in the transect window will show periodic peaks. What causes these? How would you correct this problem if

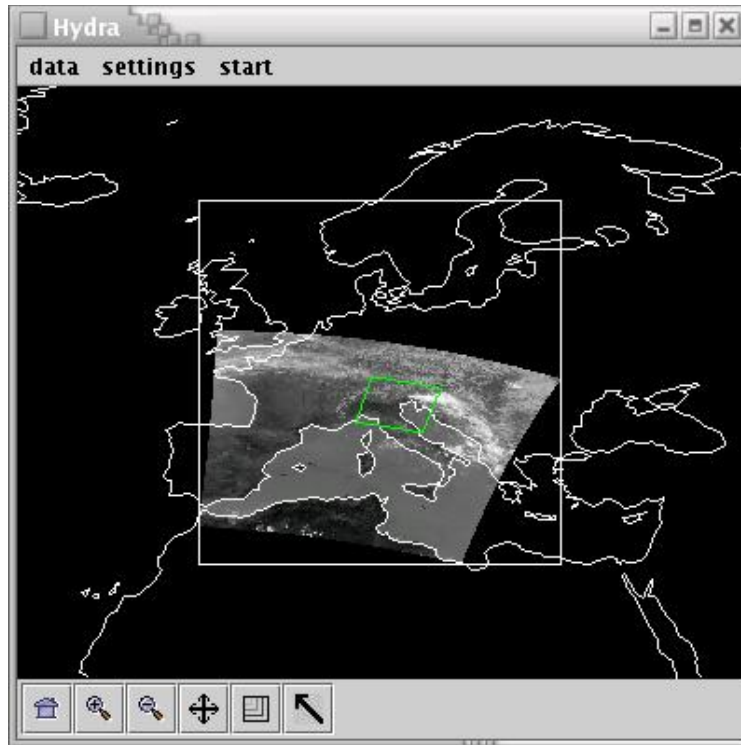
- (a) the detector is bad;
- (b) the detectors are biased.
- (d) Band 28 (7.3 μm) also shows this 'striping' (Select band 28 and repeat the procedure). Close this window when you are finished.



Band 27 Water vapor image

Exercise 2

Select the following region (outlined approximately by green box) from the Hydra window. Now select band 4 (0.55 μm) and display in reflectance using the Settings menu (BT->radiance) button.



Snow, Clouds, and Clear Sky

(a) Investigate the radiances emanating from the scene in different wavelengths; look at Bands 1 (0.65 μm), 2 (.86 μm), 6 (1.64 μm), 20 (3.7 μm), 31 (11 μm) and 35 (13.9 μm). Note how, in BT, clouds appear larger at 11 μm than at 3.7 μm (select those two bands and toggle back and forth between them). Can you explain why?

(b) Comment on the cloud and clear sky characteristics in each of these spectral bands. Which three bands would you choose to determine a cloud / no cloud "mask"; why? What radiative characteristics of the cloud, surface and atmosphere led you to select these spectral bands? What reflectance or brightness temperature thresholds would you use?

(c) Consider the Band 31 (11 μm) image. What is the range of brightness temperatures over the land surface? What are the brightness temperatures of the different cloud types in the scene? Could you assume something about cloud phase from the cloud brightness temperatures?

(d) Use the Tools/Linear Combination math tool to combine spectral bands that can be used to detect clouds and infer cloud properties (hit return after entering numbers in the box). Try the following band combinations (by entering the suggested wavelengths in the colored boxes), and for each combination click on the compute button.

i. Band 2 (0.86 μm) / Band 1 (0.65 μm)

ii. (Band 1 (0.65 μm) - Band 6 (1.6 μm)) / (Band 1 (0.65 μm) + Band 6 (1.6 μm))

iii. (Band 2 (0.86 μm) - Band 1 (0.65 μm)) / (Band 2 (0.86 μm) + Band 1 (0.65 μm))

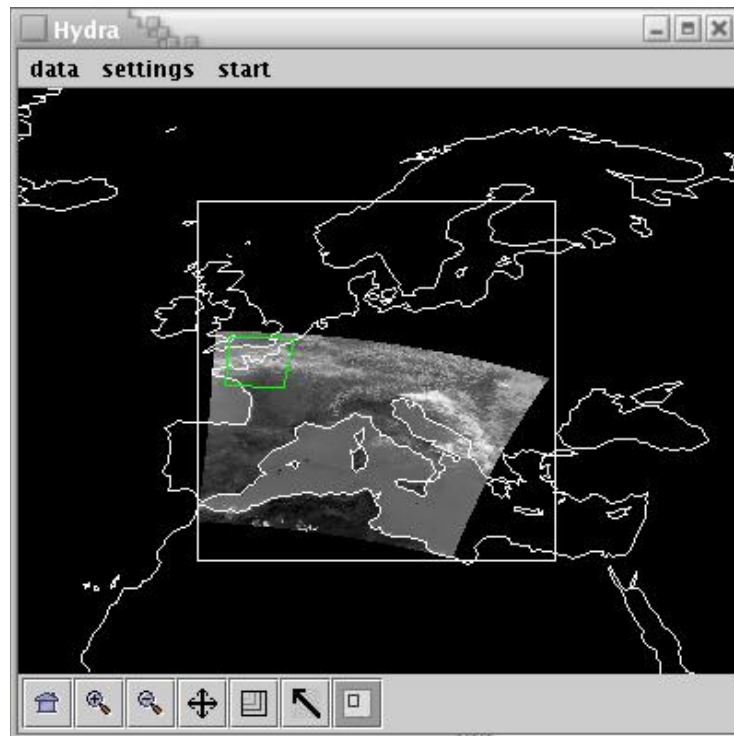
(e) Map one of the linear combinations to X axis (by clicking the X axis button) and another one to the Y axis (by clicking the Y axis button). Click on the scatter button to open a scatter plot window.

(f) Looking at the images of the linear combinations, estimate what threshold values you would use in each test to indicate the presence of clouds? Select different regions in the scatter plot window and look at the corresponding points in the linear combination window (use the CTRL key and the right mouse button to select a rectangle or use the SHIFT key and the right mouse button to select a region by hand)

(g) Using the plot/Scatter-Plot math tool plot Band 31 ($11\mu\text{m}$) versus [Band 29 ($8.6\mu\text{m}$) minus Band 31 ($11\mu\text{m}$)]. Look at the image of [Band 29 ($8.6\mu\text{m}$) minus Band 31 ($11\mu\text{m}$)]. In the same way construct an image of [Band 31 ($11\mu\text{m}$) minus Band 32 ($12\mu\text{m}$)]. Note where the largest differences occur in each image. Describe what you see. Are there clouds in these brightness temperature difference images that could not be seen in the visible images? Close all the Scatter Plot figures.

Exercise 3

Now, in Hydra subselect the region shown below (use the Select button, the last on the right, in the Hydra window). Once the selected area shows up in the MultiChannelViewer window, select BT, and use the Tools/LinearCombination function



Clouds and clear sky

(a) Make an image of Band 31. To do so de-select the minus sign between the red and green boxes on the Channel Combination Tool and then click the Compute button. Then make an image

of Band 31 - Band 32. Map Band 31 on the x-axis (click on the button X-Axis) and the difference between Band 31 and Band 32 on the y-axis (click on the button Y-Axis) and click the Scatter button.

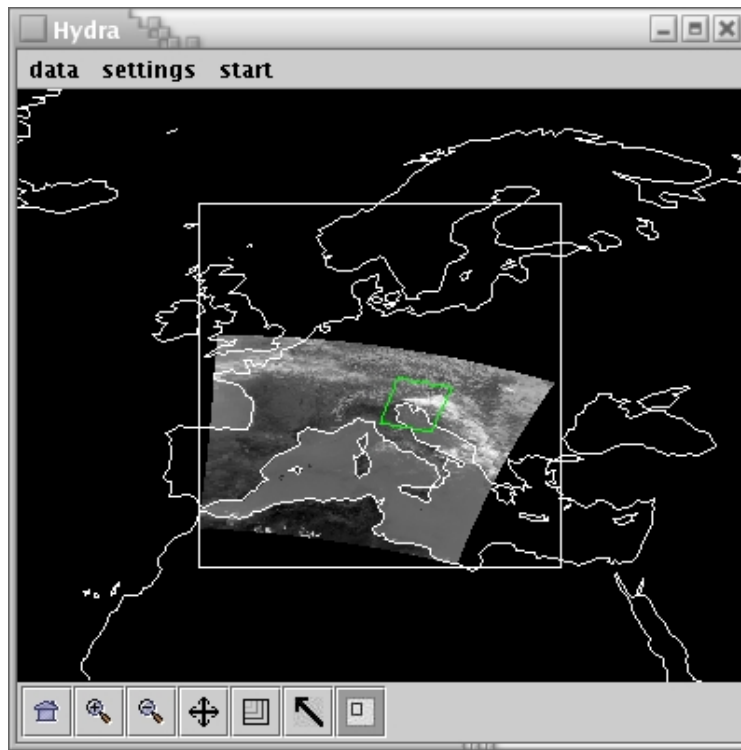
(b) Map Band 31 on the x-axis and Band 31 – Band 32 on the y-axis (by clicking on the circular buttons in the *pseudo-channel* windows) and click on the Scatter button. Now you can select a rectangular region on the scatter plot and look at the images to determine the location of the selected points in the pseudo-images. Alternatively use the system to select a rectangular region of one of the pseudo-images that display the linear combinations and look at the position of the selected pixels in the scatter plot. Try to determine the type of cloud viewed in this region. Did you notice these clouds in the band 4 image earlier in the lab? Does Band 26 (1.38 μm) support or contradict your cloud classification. If you were to design and automated algorithm to detect these cloud types, what would you include in your algorithm?

(c) Make a new linear combination Band 29 (8.6 μm) minus Band 31 (11 μm). Look at the range of point values that occur along each axis. Which difference is larger for this cloud, [Band 29 (8.6 μm) minus Band 31 (11 μm)] or [Band 31 (11 μm) minus band 32 (12 μm)]?

(d) In the Multi-Channel Viewer window select band number 31 (11 μm), temperatures and select the region shown below (Select function). Then use the Tools/CombineChannel functions again.

Exercise 4

Now, in Hydra subselect the region shown below (use the Select button, the last on the right, in the Hydra window). Once the selected area shows up in the MultiChannelViewer window, select BT, and use the Tools/LinearCombination function



Thermal emission of clouds.

(a) Make an image of Band 31 and map it onto the x-axis and [Band 31 - Band 32] onto the y-axis and click on the Scatter button. Select different subregions (you like to use free hand drawing instead of rectangular boxes) to determine the type of cloud viewed in this region. Examine these cold ice clouds. If you select a small region on our image that has clear sky and cloudy pixels, you should see a hook shape pattern in the scatter plot window. In this case, which brightness temperature difference signal is stronger (larger range of values). Plot the Band 31 (11 μm) on the x-axis and plot [Band 29 (8.6 μm) minus Band 31 (11 μm)] on the y-axis, and then plot Band 31 (11 μm) versus [Band 31 (11 μm) minus Band 32 (12 μm)] to bring out this signal.

(b) Selecting a region in the scatter plot try to identify the origin of the clear portion of the hook shape by looking at sub-regions of the box outline. Now identify the origin of the cloud portion.

(c) To determine what causes the hook shape, consider the following. Calculate the radiances at 8.6, 11, 12 μm for a scene of clear sky at 300 K and a cloud at 230 K with varying cloud amount. Let the cloud fraction vary from $N = 0.0, 0.2, 0.4, 0.6, 0.8,$ and 1.0 . Convert the radiances to brightness temperatures. Plot brightness temperature differences 8.6 - 11 versus 11 μm for the six different cloud fractions. What does this imply about the hook shape detected in the previous problem? What other factors might influence the shape of this 'hook'?