

Hampton University VIIRS/MODIS Workshop: Laboratory One

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The goal of this laboratory session is to become familiar with the properties of the reflected solar and thermal emissive bands of the MODIS and VIIRS sensors. You will explore the properties of daytime VIIRS and MODIS data over the southeastern United States and surrounding ocean and clouds using the HYDRA v4.4.0 software developed at UW/SSEC. Your instructor will tell you where to find the data needed for this exercise on your workstation.

1.1 Examining MODIS Data

Load the Aqua MODIS data over the southeastern US from 06 June 2016 at 18:25 UTC using HYDRA 4.4.0 (see the instruction information starting on page 15 of this document explaining how to run HYDRA). After starting HYDRA, the Data Window will appear (Figure 1).

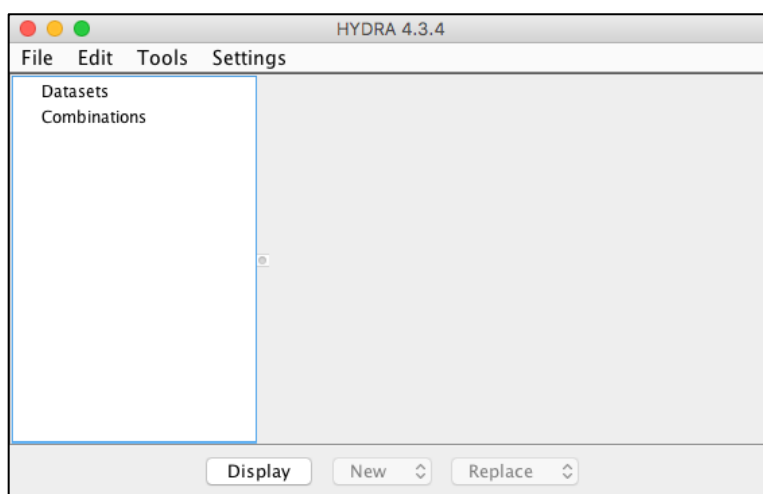


Figure 1: HYDRA Data Window at startup.

To load a MODIS Level-1B 1KM file from disk, select **File / Files** and find the file to be loaded (a1.16161.1825.1000m.hdf). When the file is loaded, an image of sub-sampled MODIS Band 1 (0.65 μm) reflectance appears on the right hand side of the Data Window (Figure 2).

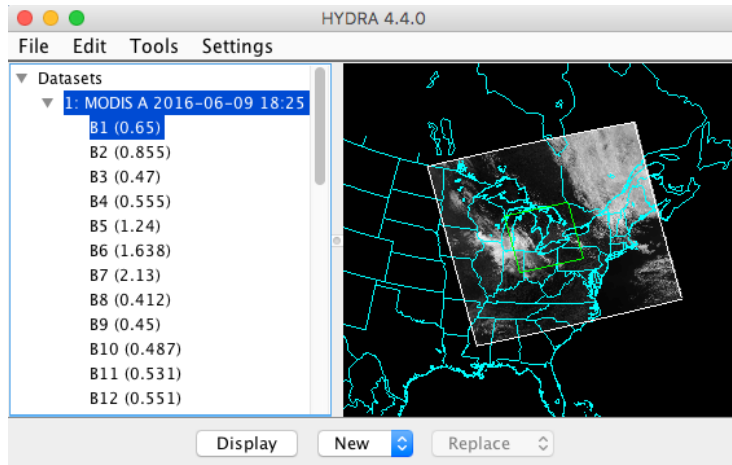


Figure 2: HYDRA Data Window showing MODIS Level-1B 1KM data from 2016/06/09 at 18:25 UTC.

To display the MODIS data at full resolution (every line and pixel), click the **Display** button, and the region enclosed in the green box will be displayed in a new Display Window (Figure 3).

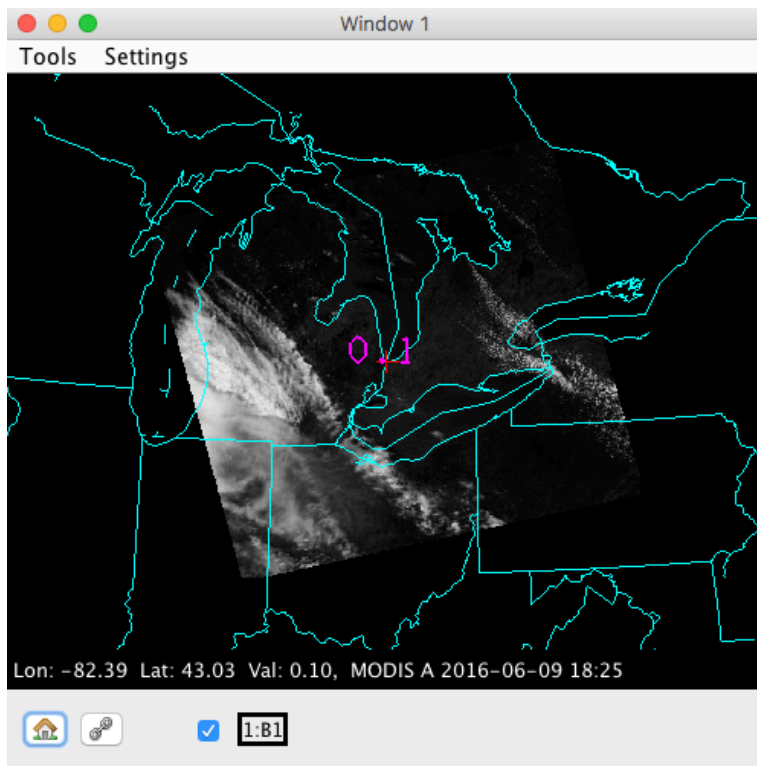


Figure 3. HYDRA Display Window showing MODIS Band 1 Reflectance at full resolution

To display a different region, go back to the Data Window and shift/left-click/drag on the image, then click **Display**. Switch to Band 31 (11 μm). Select the region shown in Figure 4 and display it.

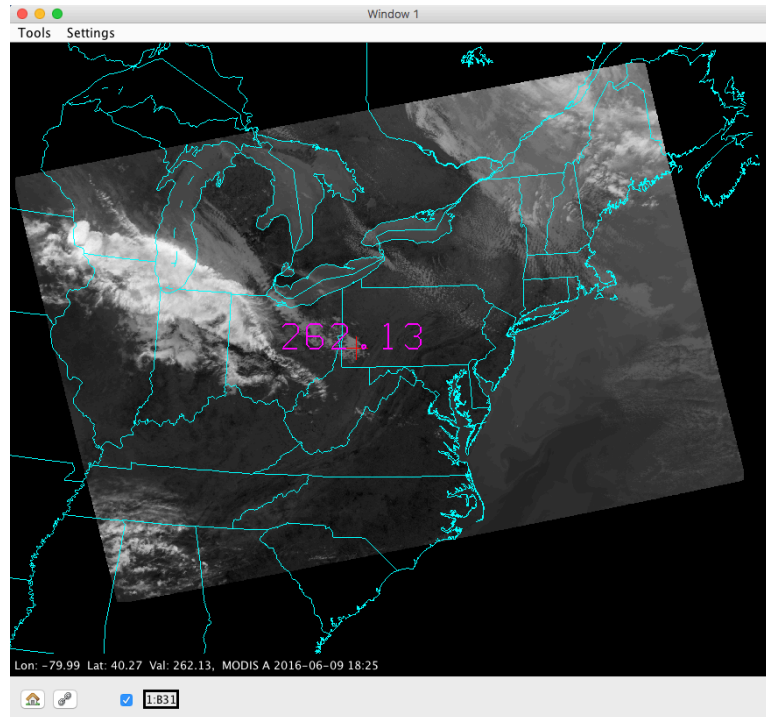


Figure 4: Ocean, Land, and Clouds data from MODIS Band 31

Now try different color table enhancements by left-clicking on the band number **B31** in the Display Window to bring up the image enhancement tool. Adjust the min/max on the histogram by right-clicking on a green box and dragging. You can also type a value in the range or gamma boxes and then hit Enter to apply it. Switch from invGray to Rainbow. Try different color enhancements, then close the Image Enhancement Tool. You can zoom the image using shift/left-click/drag or via the scroll wheel, and you can pan the image by using control/right-click/drag. You can display the data value under the cursor (the red cross) by using left-click/drag. For infrared bands, the data value is Brightness Temperature in Kelvin. For visible bands, the data value is Reflectance (no units).

Now investigate the selected scene in Band 31 (11 μm thermal). In the Display Window, select **Settings / min/max** to turn on display of the minimum and maximum values in the scene. Note

the minimum and maximum values of brightness temperature (Kelvin and Celsius) over Land, Ocean, and Clouds, and describe the region where it occurs (e.g., “just east of Richmond”):

Land: Min _____ K _____ C (describe the region):

Land: Max _____ K _____ C (describe the region):

Ocean: Min _____ K _____ C (describe the region):

Ocean: Max _____ K _____ C (describe the region):

Cloud: Min _____ K _____ C (describe the region):

Cloud: Max _____ K _____ C (describe the region):

Now load Band 2 (0.86 μm visible) data for the same region. Find the approximate minimum and maximum values of reflectance over Land, Ocean, and Clouds, and describe the region where it occurs:

Land: Min _____ (describe the region):

Land: Max _____ (describe the region):

Ocean: Min _____ (describe the region):

Ocean: Max _____ (describe the region):

Cloud: Min _____ (describe the region):

Cloud: Max _____ (describe the region):

In areas where Band 2 reflectance is unavailable, report the maximum Band 1 reflectance below:

Cloud: Max _____ (describe the region):

1.2 MODIS True Color and RGB Composite Images

Create a true color image of the same region you examined in section 1.1 by selecting **Tools / RGB Composite** in the Data Window. Click on the band numbers in the **Datasets** section of the Data Window in the order you want them to be displayed as red/green/blue (to create a MODIS true color image, select bands 1, 4, 3). When the correct band numbers are displayed in the **RGB Composite** dialog, click the **Create** button. A new dataset will appear at the bottom of the list under **Combinations** in the Data Window. Click **Display** in the Data Window to display the channel composite image. The true color image shows the scene as it would appear to the human

eye (approximately). Another useful RGB combination is bands 7, 2, 1 (2.1, 0.86, 0.66 μm). With both (1, 4, 3) and (7, 2, 1) RGB images on screen, comment on the appearance (e.g, color, brightness) of the following regions in each image (you may want to adjust the gamma for both images first).

Vegetation	(1, 4, 3)_____	(7, 2, 1)_____
Soil	(1, 4, 3)_____	(7, 2, 1)_____
Water	(1, 4, 3)_____	(7, 2, 1)_____
Clouds	(1, 4, 3)_____	(7, 2, 1)_____

1.3 MODIS Atmosphere and Cloud Characteristics

The following MODIS bands are useful for examining the properties of the atmosphere and clouds: 1-7, 26 (cloud detection and phase); 24, 25, 27, 28 (atmospheric temperature and moisture); 30 (ozone); 29, 31, 32 (cloud top temperature); 33-36 (cloud height). Note atmospheric features you can see in the selected region MODIS bands 1 and 31. In particular, note what kind of clouds appear in the region (e.g., stratus, cumulus, cirrus).

Band 1: _____

Band 31: _____

For cloud detection, Bands 1, 2, 26, 27, and 31 are often used. Briefly describe the appearance and type of cloud features in each of these bands, particularly in comparison to regions that appear cloud-free. You may find it helpful to several bands displayed at the same time.

Band 1: _____

Band 2: _____

Band 26: _____

Band 27: _____

Band 31: _____

Which of these bands would be most useful in the daytime? Why?

Which of these bands would be most useful at nighttime? Why?

Does Band 26 show as many clouds as Band 1? Describe a region where Band 26 detects a cloud that is not obvious in Band 1.

1.4 Examining VIIRS Data

Now load the Suomi NPP VIIRS data from the same date (2016/06/09) at 18:40 UTC. In the HYDRA Data Window, select **File / Directory/ VIIRS**, and navigate to the name of the directory containing the VIIRS data (don't go into the directory). Click once on the name of the VIIRS data directory, then click Choose. This will scan all the VIIRS SDR files found in the directory and display the M15 (11 μm) brightness temperatures in the Data Window (Figure 6). By default, the green data selection will encompass the same region you selected previously for MODIS. Display this region at full resolution in the existing Display Window (Figure 7).

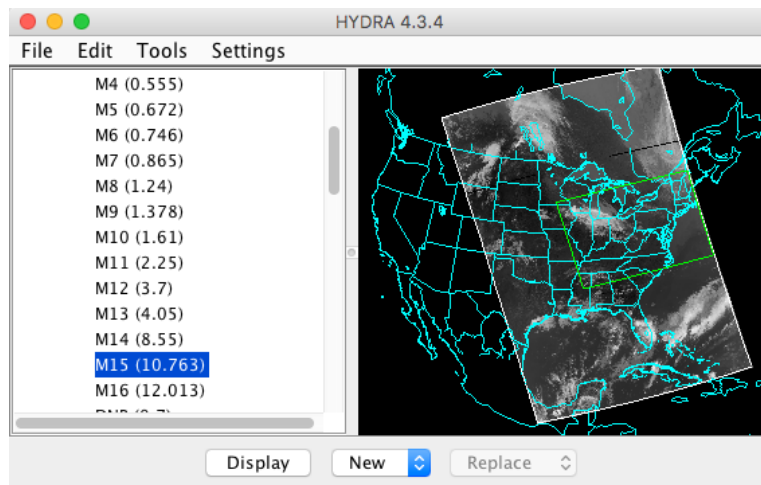


Figure 6: VIIRS M15 data from 2016/06/09 18:40 UTC

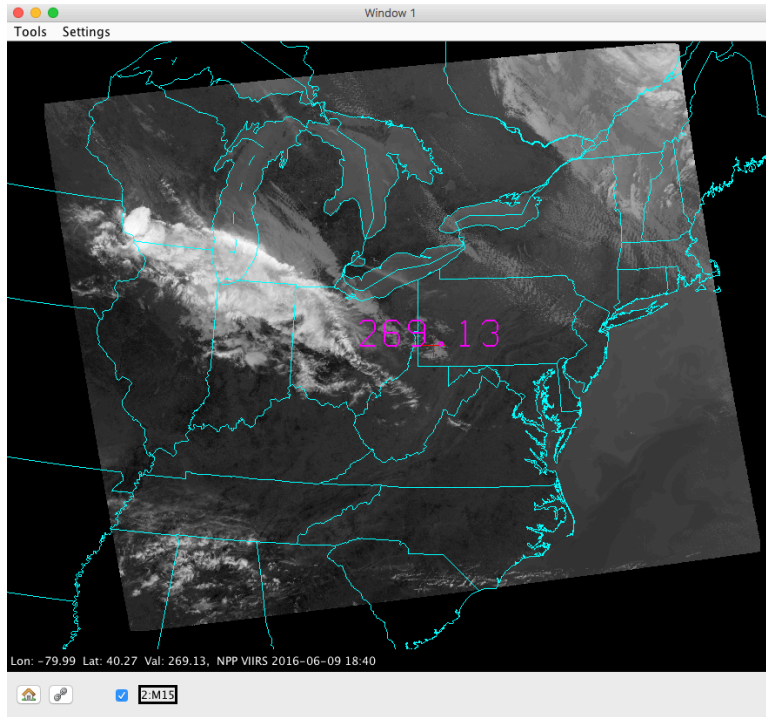


Figure 7: VIIRS M15 full resolution data from 2016/06/09 at 18:40 UTC

The MODIS data for this date should still be available in the HYDRA Data Window. Click on Band 31 of MODIS (11 μ m), and then examine the same region (Figure 8).

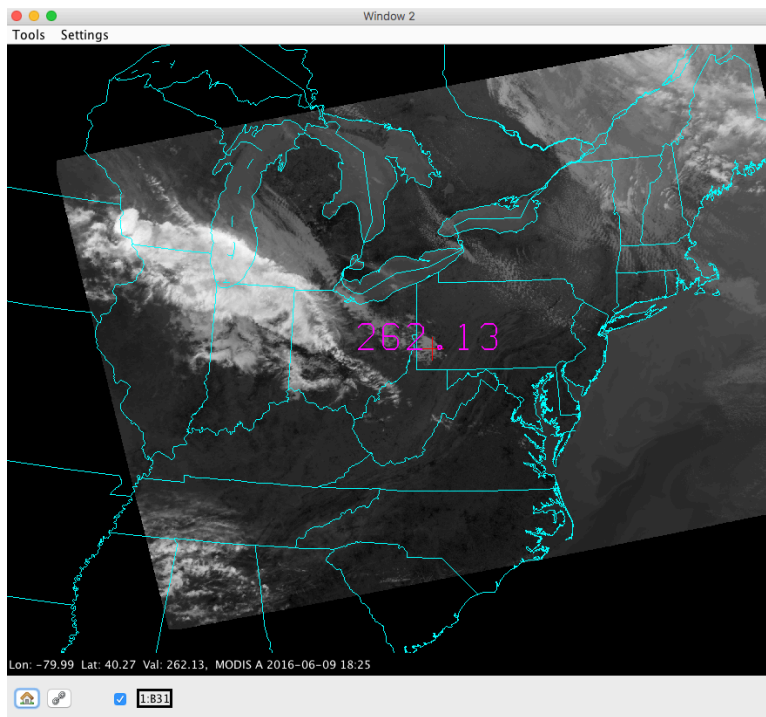


Figure 8: MODIS Band 31 full resolution data

Note that to compare the two images effectively, you may wish to enhance them to the same color range and gamma values. Now zoom in on the cloud features at the upper left of the image. What are the approximate coldest cloud top temperatures you can find in (a) VIIRS, and (b) MODIS? Changing to a different color scale may help you find the coldest regions.

VIIRS BT (K) _____ MODIS BT (K) _____

Does one sensor seem to be better at showing structure over the cold cloud tops? Keep in mind that the images were obtained at different times so features may have changed slightly.

Now load the same scene for VIIRS band M5 (0.67 μm visible) in Display Window 1 and MODIS band 1 (0.65 μm visible) in Display Window 2. Zoom in on the cloud features at the bottom left of the image. What are the highest reflectances you can find in (a) VIIRS, and (b) MODIS?

VIIRS Reflectance _____ MODIS Reflectance _____

Does one sensor seem to be better at showing structure over the bright cloud tops? Look at some of the smaller scale cloud features on the northeast edge of the region. Can you see any differences between the VIIRS M-band 750-meter pixels and the MODIS 1000-meter pixels?

1.5 Examining Land and Ocean Features in VIIRS and MODIS Data

Close all of your display windows. Select a new smaller region centered over the Washington D.C. and Hampton Roads region (see Figure 9). Display VIIRS band M7 and MODIS band 2 in two separate Display Windows. Enhance both images to show the land and ocean features (use the same enhancement for both). Note the appearance of the water surface and the land surface. At this wavelength bare soil will be dark and vegetation will be bright. At this wavelength the ocean should look dark unless there is sun glint.

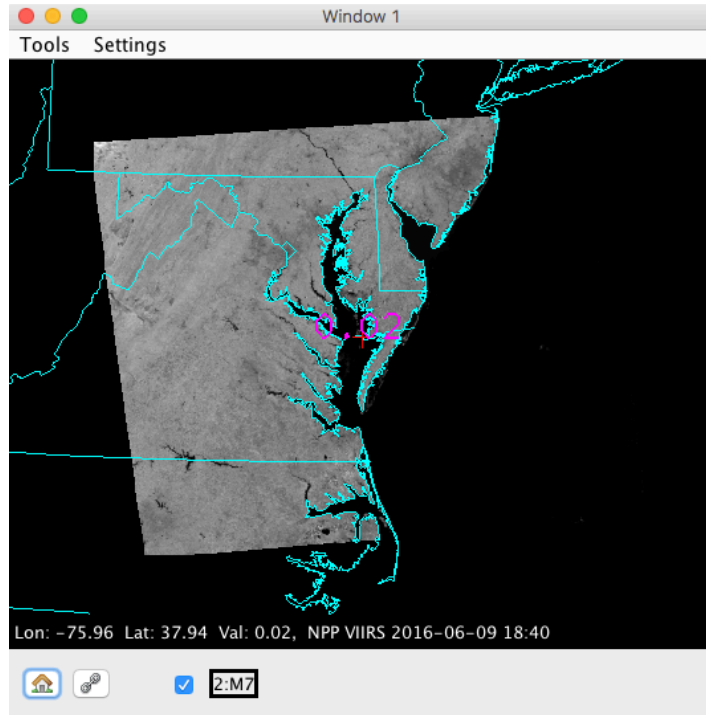


Figure 9: VIIRS M7 (0.865 μm) at full resolution

Comment on where land regions look bright and dark:

Land is bright in this region _____ Reflectance value _____

Land is dark in this region _____ Reflectance value _____

Now load VIIRS band I2 (375 meter) and MODIS QKM band 2 (250 meter) (Load new MODIS file->a1.16161.1825.250m.hdf) in new Display Windows. Center and zoom into the Hampton Roads region. Note the difference in image resolution compared to the VIIRS band M7 and MODIS 1KM band 2 images. Close the VIIRS M7 and MODIS 1KM band 2 images.

In the VIIRS band I2 Display Window, select **Tools / Transect** to activate the Transect tool. This will display a new window showing a transect plot along the magenta line shown in the VIIRS Display Window. You can move the endpoints or center of the transect by clicking on either end or the center and dragging. Use the Transect tool to create an east/west transect plot for VIIRS I2 from Parsons, WV to Columbia, MD (see Figure 10). On the transect plot, note where the highest and lowest values of 0.86 micron reflectance occur. Now load VIIRS band I1 (0.66 μm visible) in the same VIIRS Display Window as an overlay by changing **Replace** to

Overlay in the Data Window and clicking **Display**. When an overlay image is present in a Display Window, multiple band names will be listed at the bottom of the Display Window (Figure 10). When you click the arrows to the right of the Band numbers at the bottom of the Display Window, it will cycle through the overlay bands.

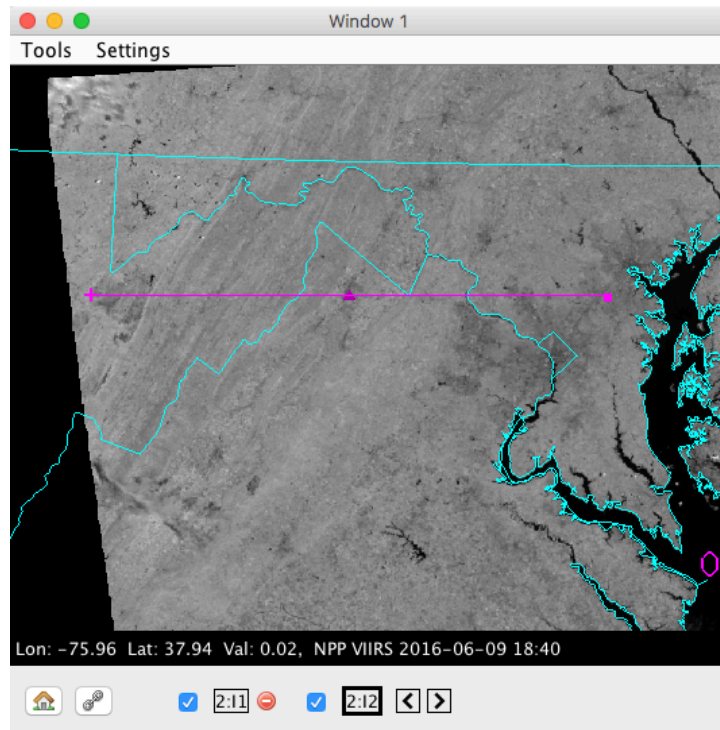


Figure 10: VIIRS Bands I1 and I2 in a Display Window with Transect.

Flip between VIIRS Band I1 and I2 in the Display Window, and notice where the $0.66 \mu\text{m}$ reflectance is different than the $0.86 \mu\text{m}$ reflectance. It should tell you something about the vegetation cover in Virginia. Figure 11 shows the visible reflectance of several land surface types (soil, grass, snow) as a function of visible wavelength.

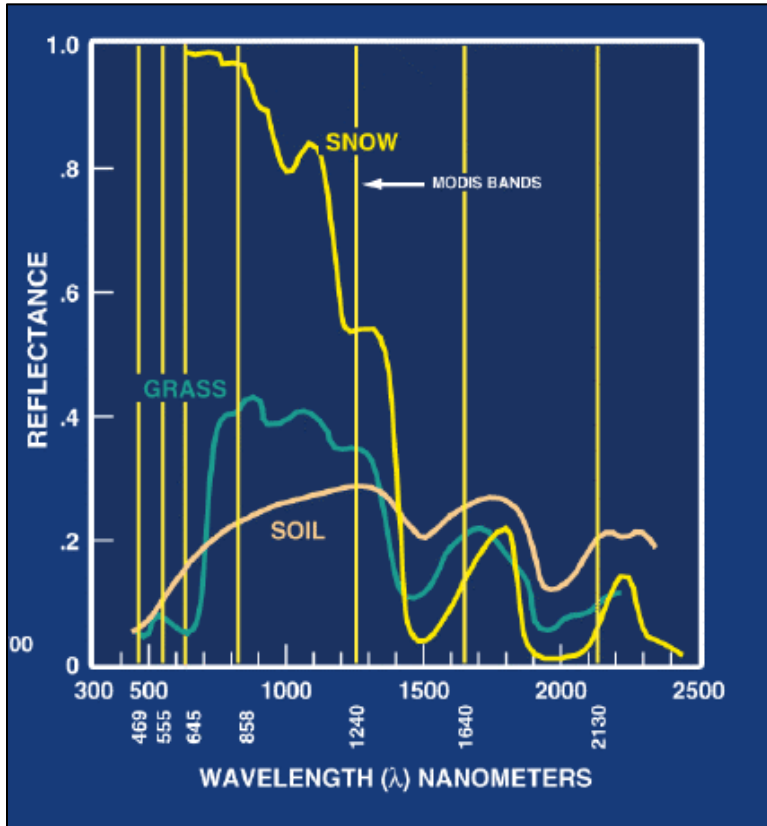


Figure 11: Land Surface Reflectance at Visible Wavelengths

From Figure 11, note the relative reflectance of soil vs. grass at 0.64 microns and 0.86 microns. Does the VIIRS imagery follow the same trend?

In the HYDRA Data Window, select **Tools / Band Math** to construct an image of normalized difference vegetation index (NDVI) according to the following equation:

$$\text{NDVI} = [\text{Band I2} (0.86\mu\text{m}) - \text{Band I1} (0.65\mu\text{m})] / [\text{Band I2} (0.86\mu\text{m}) + \text{Band I1} (0.65\mu\text{m})].$$

When the dataset has been created, display it in a new Display Window.

Can you discriminate regions with some vegetation from those with little? What are the NDVI values in regions with significant vegetation; what are they in non-vegetated regions?

NDVI for vegetation: _____ NDVI for soil: _____

Now load VIIRS Band I5 (11.5 μm) in a new Display Window. Adjust the color scale to highlight the land surface features over Virginia. Use the Transect Tool to create east/west

transect plots for the VIIRS NDVI Display Window and the Band I5 Display Window. What is the effect of vegetation on surface temperature?

Finally, create a true color image of Virginia using Tools / RGBComposite in the HYDRA Data Window from VIIRS Bands M5, M4, M3 and adjust the image enhancement so that the colors look natural (change the gamma value). Does the true color image confirm your discrimination of the areas of covered by vegetation vs. no vegetation?

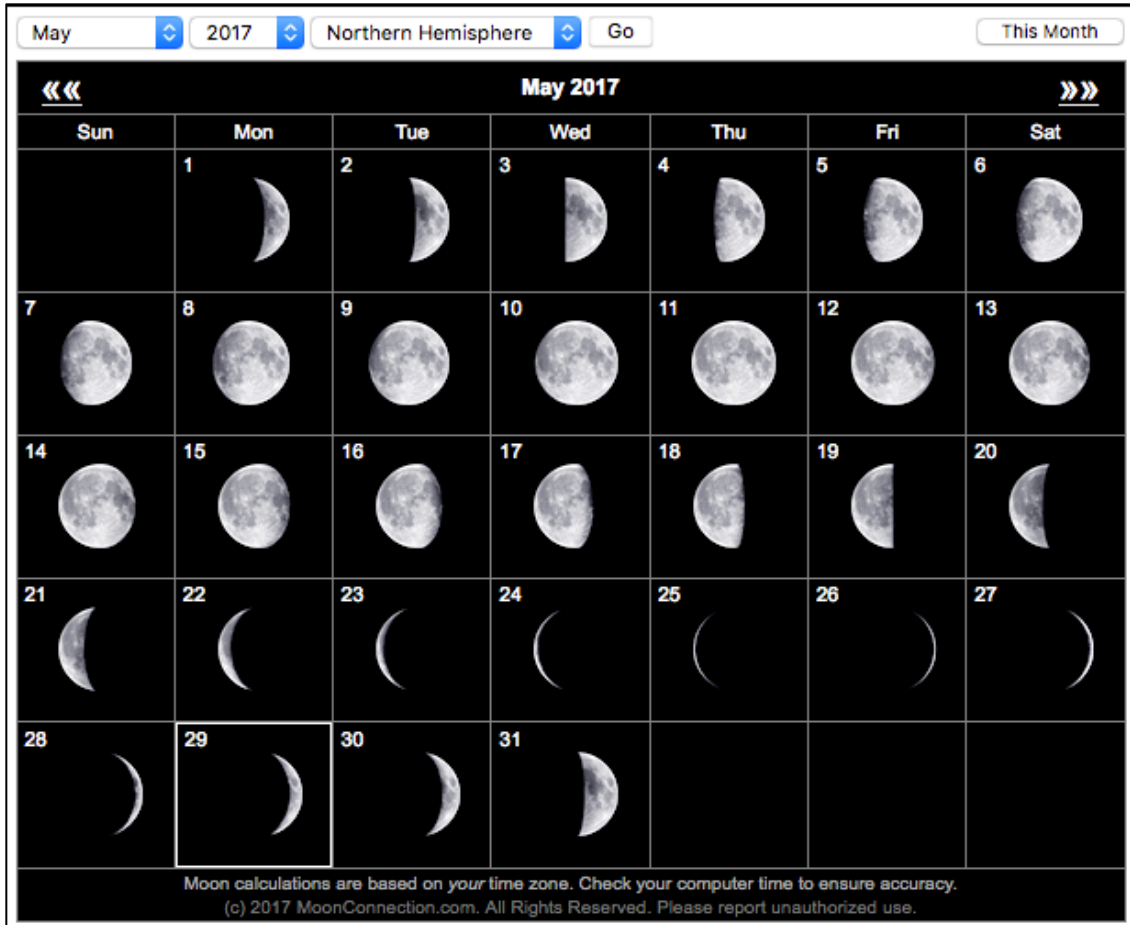
1.6 Investigating the VIIRS Day/Night Band Under Different Lunar Illuminations.

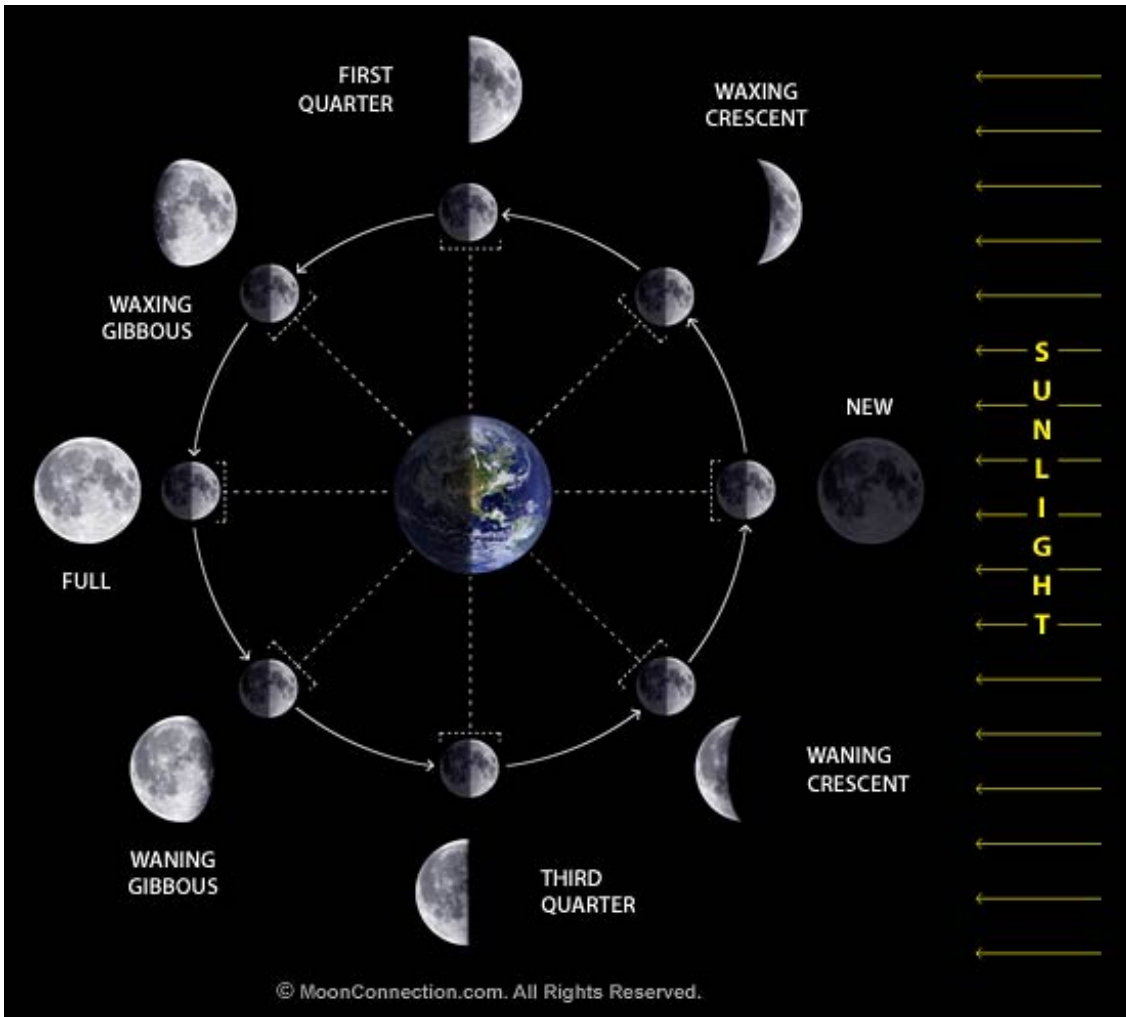
The VIIRS Day/Night Band is sensitive to a huge range of radiances (seven orders of magnitude) and can observe nighttime lunar reflection and nighttime visible light emissions. However, because the instrument is not lunar synchronous, the ability of the band to detect atmospheric features like clouds is highly dependent on the amount of lunar illumination during the overpass times.

Investigate two different VIIRS Day/Night Band data sets representing different lunar illumination regimes over the Central Atlantic US and surrounding regions. As you investigate the data sets, note:

- a) The phase of the moon,
- b) The range of radiance values in each scene and where the maxima appear.
- c) The ability to detect clouds and thunderstorms.
- d) The ability to observe city lights. How easily can you see them in each data set?
- e) What advantages and disadvantages does this band have over standard infrared bands?

You may use the following charts to help you.





Summary of HYDRA 4.4.0 Commands

In all displays

Shift-right click-drag to zoom in image within display

Right click-drag to move image or roam within display

In HYDRA window

Under File, select the Directory (for VIIRS, ABI or AHI folder,) or File(s) (MO(Y)D02 or a1(t1) for MODIS, AIRS for AIRS, SCRIS for CrIS, SATMS for ATMS) to be displayed.

(1) For VIIRS and MODIS, file selection will result in a listing of spectral bands available, an image of the IR window with coastlines, and a default subset of the granule that will be displayed in a new window upon clicking on display. The subset of the image can be adjusted with a right click and drag. The spectral band can be changed with a left click on another choice.

(2) For CrIS, AIRS, and ATMS, a new window opens showing the spectral band brightness temperatures and a spectral window image showing the data coverage. Left click a drag on the green line in the top display to change the spectral band displayed below.

Left click on spectral band desired (default is IR window)

Shift-left click-drag to highlight subset of image for display

Left click on display at bottom to create Spectral Display. Left click on arrow at right to have option for New Window or Replace/Overlay. First time will default to New Window. Thereafter New will open another Spectral Display Window while Overlay will overlay additional spectral band on original display.

Edit/Remove Dataset will remove any loaded dataset in the HYDRA dataset list

Edit/Remove Combination will remove any dataset created using the Tools/RGB Composite or Tools/Band Math utilities

Tools/RGB Composite will open new display where you have to select the R, G, and B spectral bands desired by left clicking on the color and then on the spectral band. When all three have been selected, left click on Create to add to Dataset tree under Combinations. Left click on Display to see the RGB image.

Tools/Band Math will open new display where you can select bands and operations to be performed on the bands. Select bands desired by left clicking on a box and then on the spectral band. Choose operators by left clicking on the arrows. When you have the equation you want, left click on Create to add to Dataset tree under Combinations. Left click on Display to see the image.

In Spectral and Band Math Displays

Left click-drag to move cursor within display

Left click on bottom left icon (house) to restore original display

When two displays are open, toggle on link button in lower left to link zoom and roam in two displays

Left click on bottom right box (band number) to open range, gamma, reset, and B&W vs color options

Range can manually set BTmin (rmin) and BTmax (rmax). Range entries can be typed in to enhance low or high reflances or BTs.

Gamma can be adjusted to stretch the dynamic range. It is a non-linear mapping from color to value. For infrared $\text{color_value} = \text{BT}^{\text{gamma}}$. For visible when $\text{gamma} = 0.5$, this is the square root enhancement popular with VIS.

Reset restores the dynamic range to the min and max values in the display.

Color options include gray (BTmax is black, BTmin is white), inverse gray, rainbow (BTmax is red, BTmin is blue), and inverse rainbow

Tools/Transect left click-drag to change end point of transect. Transect can be opened in several separate displays simultaneously.

Tools/Scatter left click in first image for x-axis then left click in second image for y-axis of scatter plot

Tools/Capture to do a screen capture of the current image in the display window. Choices are JPEG or KML formats.

Settings/coastlines toggles the map off and on

Settings/min/max toggles scene minimum and maximum value location and value off and on

Settings/probe readout toggles the probe off and on

Settings/color bar turns the scene color bar, embedded in the image, off and on

In Scatter Display

Selecting purple, green, and blue points (with box or curve) in ScatterPlot will show the associated pixels in the Spectral or BandMath displays; conversely selecting pixels in Spectral or BandMath displays will show the associated points in the ScatterPlot.

Left click on points to create density scatter plot; toggle back and forth between points and density

Left click on stats to see stats for purple, green, and blue selections.

In AIRS, CrIS, or ATMS SDR (Sensor Data Record) Display

Select the file(s) to be displayed (AIRS for AIRS, SCRIS for CrIS, SATMS for ATMS).

Move the green line in the spectrum (left click drag) to change the spectral band displayed below.

When viewing the AIRS/CrIS/ATMS spectrum, zoom using shift- left click–drag. Restore to full spectrum using control-left click.

When viewing AIRS/CrIS/ATMS spectral band image left click drag to move cursor within image (note if VIIRS data over same area is open then cursor will move in both VIIRS and CrIS/ATMS images; same for AIRS and MODIS)

Click on Tools to have the option for Transect, Scatter, and FourChannelCombine. In FourChannelCombine the colored lines have to be moved (left click drag) to the desired wavenumber (GHz). Expanding beyond two spectral bands is initiated by completing the mathematical operator desired in the FourChannelCombine equation.

When viewing AIRS or CrIS profile retrievals (temperature, water vapor, and ozone can be found under the parameter), transect and scatter (under Tools) can be used in the same way as before.

In the AIRS or CrIS Retrvl Display left click and drag on the green line in the vertical profile to change the altitude of the parameter being displayed.

The red cursor in the CrIS Retrvl Display will move in synch with the red cursor in CrIS or VIIRS or ATMS spectral band displays; the blue cursor moves independent of any cursor in the other images.

Viewing Level 2 Products

Under File, select the CLAVRx file or files (clavrx*.hdf) for VIIRS cloud products, ACSPO SST (*STAR-L2P_GHRSST-SST*) Sea Surface Temperatures or AHI Level 2 cloud products (geocatL2) to be displayed

Left click on product parameter desired. Options are:

CLAVRx Cloud Products

Cloud_Type –	Cloud Type (10 categories)
Cloud_Phase --	Cloud Phase (5 categories)

Cloud_Mask -- Cloud Mask (4 categories)
Cld_Top_Press -- Cloud Top Pressure in hPa
Cld_Top_Temp -- Cloud Top Temperature in Degrees Kelvin
Cld_Top_Hght -- Cloud Top Height in meters

ACSPO SST

SST -- Sea Surface Temperature in Degrees Kelvin

GEOCAT Level 2 Cloud Products for AHI

Cld_Top_Hght -- Cloud Top Height in meters
Cld_Top_Press -- Cloud Top Pressure in hPa
Cld_Top_Temp -- Cloud Top Temperature in Degrees Kelvin
Cloud_Mask -- Cloud Mask (4 categories)
Cloud_Phase -- Cloud Phase (5 categories)
Cloud_Type -- Cloud Type (10 categories)

MODIS Level 2 Cloud Products (MO(Y)D06*.h5 or a1(t1).yyddd.hhmm.mod06.hdf

Cloud_Optical_Thickness -- Cloud Optical Thickness (daytime datasets only)
Cloud_Effective_Radius -- Size in microns
Cloud_Top_Pressure -- Cloud Top Pressure in hPa
Cloud_Top_Temperature -- Cloud Top Temperature in Degrees Kelvin
Cloud_Fraction -- Cloud fraction in 5x5 pixel region (0-100)
Cloud_Phase_Infrared -- Cloud Phase (4 categories)