

## GUAM DB 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 MODIS and VIIRS data over the western Pacific using the HYDRA software developed at CIMSS/ SSEC/UW-Madison. Your instructor will tell you where to find the data needed for this laboratory exercise on your workstation.

### 1.1 Examining MODIS Data

Now you will load the Terra MODIS L1B 1KM data over the western Pacific from 2018-03-26 at 01:15 UTC using HYDRA. Start HYDRA by following the directions given by the instructor. After starting HYDRA, the Data Window will appear (Figure 1).

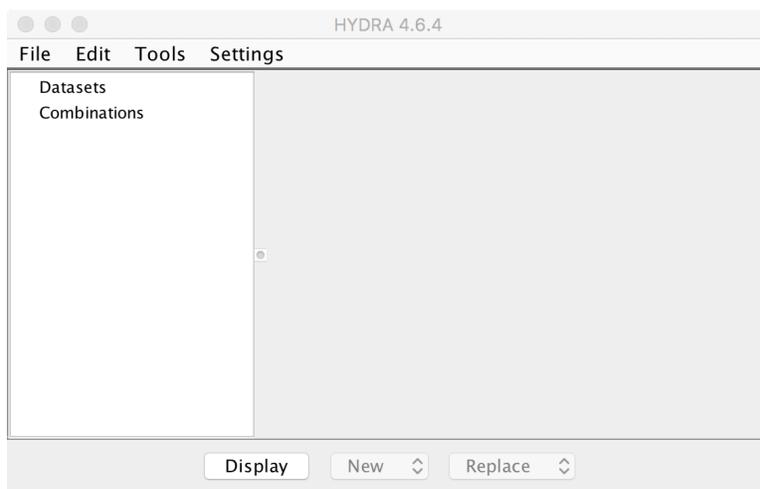


Figure 1: HYDRA Data Window at startup.

To load the MODIS Level-1B 1KM file, select **File / File(s)** and find the file to be loaded (t1.18085.0115.1000m.hdf). When the file is loaded, an image of MODIS Band 1 (0.66 micron) reflectance appears on the right hand side of the Data Window (Figure 2).

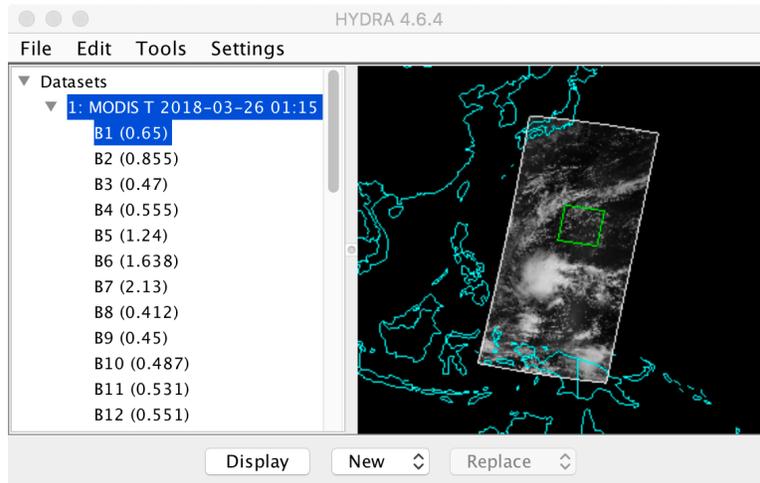


Figure 2: HYDRA Data Window showing Terra MODIS Level-1B 1KM data from 2018/03/26 at 01:15 UTC.

The HYDRA Data Window is the place where available datasets are shown, next to a reduced-resolution image where you can select a region to be displayed at full resolution. If you click on another band name in the left column, such as **B31 (11.0)**, then the reduced-resolution image data for that band will be displayed. The band name is displayed first (e.g., **B31**), followed by the central wavelength of the band in microns (e.g., **11.0**).

- Bands with central wavelengths less than 2.5 microns are known as Reflected Solar Bands. These bands are displayed as reflectances that typically range from 0.0 to about 1.5 (no units).
- Bands with central wavelengths greater than 3.7 microns are known as Thermal Emissive Bands. These bands are displayed as brightness temperatures that typically range from 180 Kelvin to about 350 Kelvin.

To display the MODIS data at full resolution (every line and pixel), select a region of the satellite image by left-click and dragging the cursor, and then click the **Display** button. The selected region (enclosed in the green box) will be displayed in a new Display Window. Now choose MODIS Band 31 in the band list, and select the central part of the MODIS scene as shown in Figure 3.

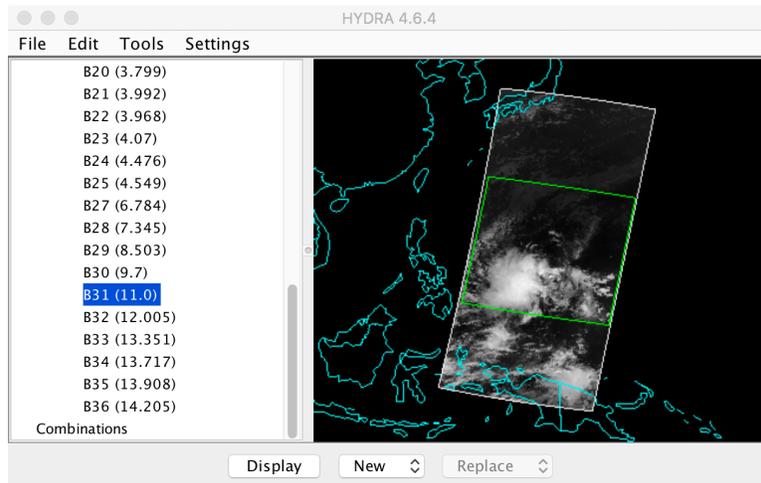


Figure 3. HYDRA Data Window showing MODIS Band 31 region to be selected

Load the full-resolution MODIS Band 31 data by clicking the **Display** button. The selected region will be displayed as shown in Figure 4.

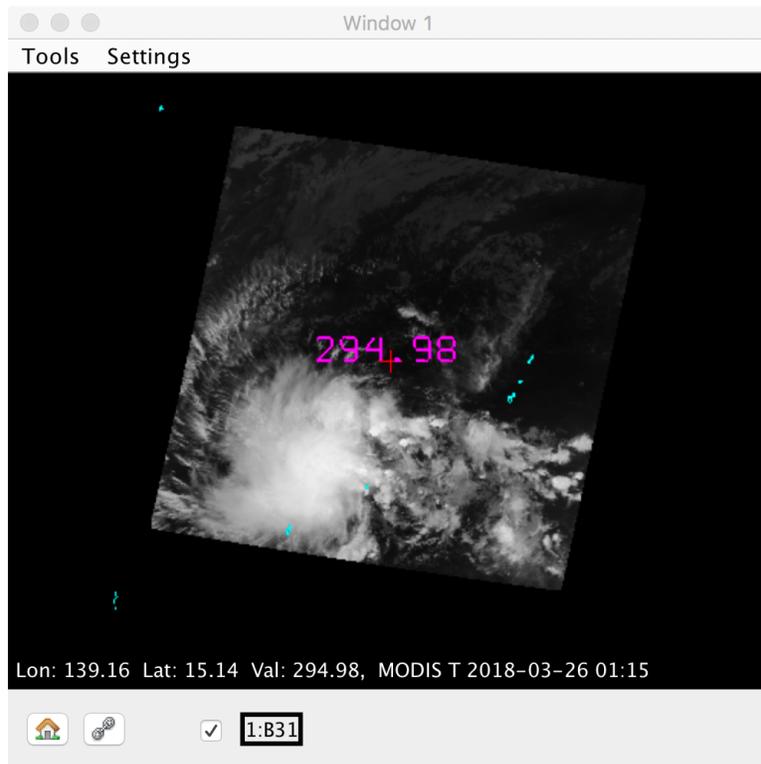


Figure 4: HYDRA Display Window showing MODIS Band 31 at full resolution

Now you can try different color table enhancements by left-clicking on the band number **B31** in the Display Window to display the Image Enhancement Tool. Adjust the min/max on the histogram by right-clicking on a green box and dragging. Type a data value in the range or gamma boxes and then hit Enter to apply it. Switch from invGray to Rainbow, and back again. Zoom the image using shift/left-click/drag or via the scroll wheel, and translate the image by using control/right-click/drag. Display the data value under the cursor (the red cross) by clicking on the cursor and then using left-click/drag. For MODIS thermal emissive bands (B20-B25, B27-B31), the data values are Brightness Temperature (Kelvin). For MODIS reflected solar bands (B01-B19, B26), the data values are Reflectance (no units).

Now investigate the selected scene in MODIS Band 31 (11  $\mu\text{m}$  thermal emissive). In the Display Window, select **Settings / min/max** to turn on display of the minimum and maximum values in the scene. Record the approximate minimum and maximum values of brightness temperature (Kelvin) over Land, Water, and Cloud, and describe the region where it occurs (e.g., “over tropical storm cloud top”). Note that you will need to exercise your judgement in determining which parts of the scene are land, water, or cloud. You may need to enhance the image to determine the scene type.

Land: Min \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Land: Max \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Water: Min \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Water: Max \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Cloud: Min \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Cloud: Max \_\_\_\_\_ K (describe the region): \_\_\_\_\_

Now load Band 2 (0.86  $\mu\text{m}$  reflected solar) data for the same region. Record the approximate minimum and maximum values of reflectance over land, water, and cloud, and describe the region where it occurs:

Land: Min \_\_\_\_\_ (describe the region): \_\_\_\_\_

Land: Max \_\_\_\_\_ (describe the region): \_\_\_\_\_

Water: Min \_\_\_\_\_ (describe the region): \_\_\_\_\_

Water: Max \_\_\_\_\_ (describe the region): \_\_\_\_\_

Cloud: Min \_\_\_\_\_ (describe the region): \_\_\_\_\_

Cloud: Max \_\_\_\_\_ (describe the region): \_\_\_\_\_

This exercise should have given you a good sense of the range of brightness temperatures and reflectances to be expected in MODIS image data.

## 1.2 MODIS Atmosphere and Cloud Characteristics

For cloud detection, Bands 1, 26, and 31 are often used.

- Band 1 (center wavelength 0.65 microns) is a reflected solar band in a region of the spectrum where the atmosphere is transparent if clouds are not present.
- Band 26 (center wavelength 1.38 microns) is a reflected solar band in a region of the spectrum where the atmosphere is opaque due to water vapor absorption.
- Band 31 (center wavelength 11.0 microns) is a thermal emissive band in a region of the spectrum where the atmosphere is transparent if clouds are not present.

Select the central part of the Terra MODIS scene from 2018-03-26, and briefly describe the appearance of different types of clouds in each of these bands, particularly in comparison to regions that appear cloud-free. You may find it helpful to display all 3 bands at the same time.

Low-altitude clouds

Band 1: \_\_\_\_\_

Band 26: \_\_\_\_\_

Band 31: \_\_\_\_\_

High-altitude opaque clouds

Band 1: \_\_\_\_\_

Band 26: \_\_\_\_\_

Band 31: \_\_\_\_\_

High-altitude thin clouds

Band 1: \_\_\_\_\_

Band 26: \_\_\_\_\_

Band 31: \_\_\_\_\_

Which of these bands are most useful for detecting clouds during the day? Why?

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Which of these bands are most useful for detecting clouds during the night? Why?

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Does Band 26 show as many clouds as Band 1? Why?

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Describe a case where Band 26 detects a cloud that is not obvious in Band 1.

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### 1.4 Examining VIIRS Data

Now you will examine the Suomi NPP VIIRS data from the same day (2018-03-26) at 03:35 UTC. First, display the Terra MODIS Band 31 data over the tropical storm as shown in Figure 5.

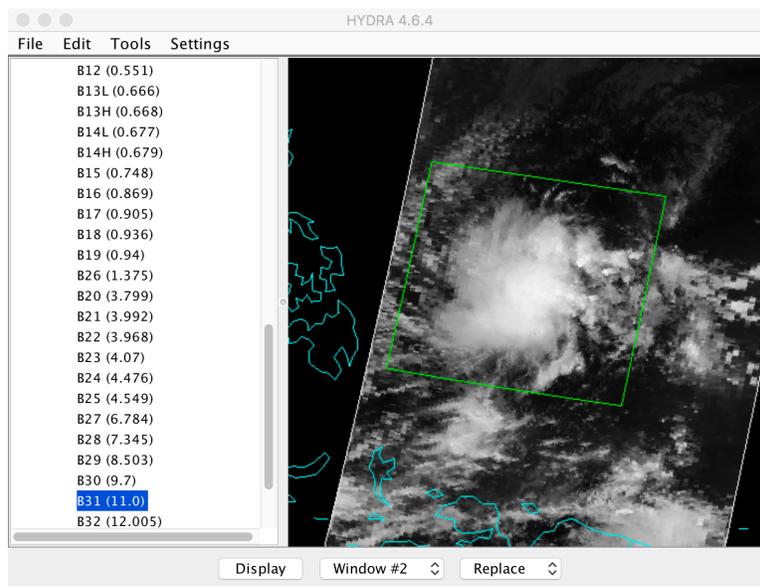


Figure 5: MODIS Band 31 brightness temperatures over the western Pacific on 2018-03-26 at 01:15 UTC.

To load the VIIRS data select **File / Directory / VIIRS** in the HYDRA Data Window 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 micron) brightness temperatures in the Data Window as shown in Figure 6.

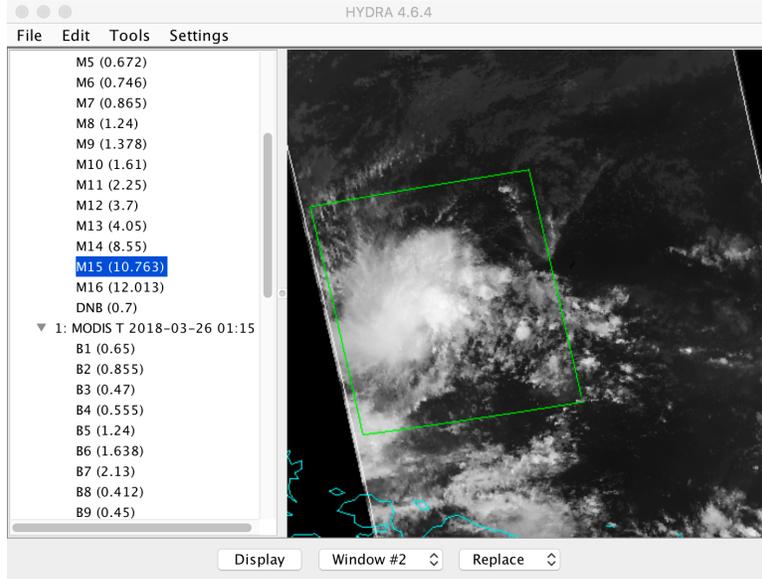


Figure 6: VIIRS M15 brightness temperatures over the western Pacific on 2018-03-26 at 03:35 UTC.

Display this region at full resolution in a new Display Window as shown in Figure 7.

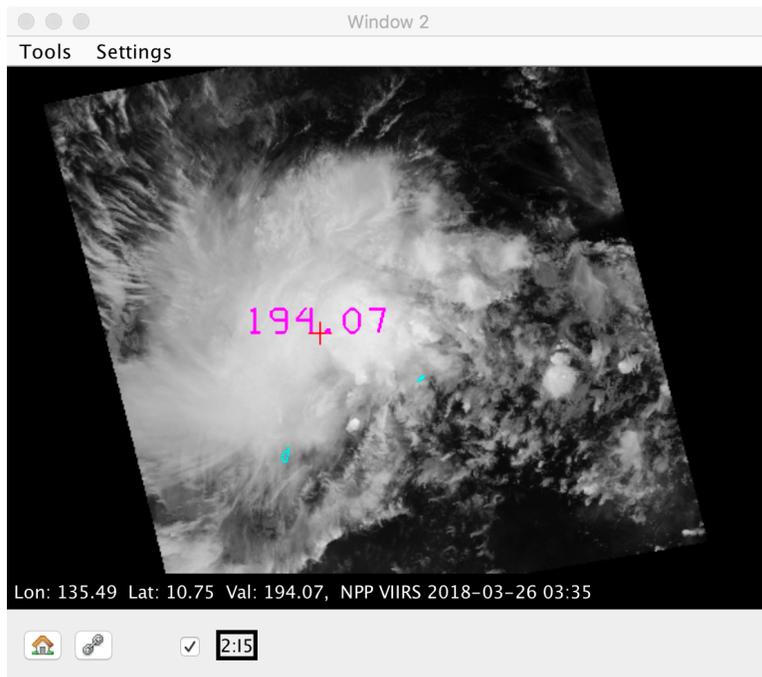


Figure 7: VIIRS M15 brightness temperatures over western Pacific on 2018-03-26 at 03:35 UTC.

Note that to compare the two images effectively, you may wish to enhance them to the same data range and gamma values. Now zoom in on the high cloud features. 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? If so, which one is better? Keep in mind that the images were obtained at different times so cloud features will have changed.

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Now load VIIRS band I5 in the same window where you previously displayed VIIRS M15. Enhance this image to look the same as the MODIS image. Do you notice an improvement in the resolution of the VIIRS data? If so, why is it better?

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Now load the same scene for MODIS band 1 (0.65  $\mu\text{m}$  visible) in Display Window 1 and VIIRS band M5 (0.67  $\mu\text{m}$  visible) in Display Window 2. What are the highest reflectances you can find in (a) VIIRS, and (b) MODIS?

VIIRS Reflectance \_\_\_\_\_ MODIS Reflectance \_\_\_\_\_

How would you explain a reflectance greater than 1.0?

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### **1.5 Examining Land and Water Features in VIIRS Data**

Now you will examine some features of land and water surfaces using VIIRS data. In the HYDRA Data Window, select a region including the Marianas Islands and display VIIRS band I2 in a new Display Window. Zoom in on Guam, as shown in Figure 8.

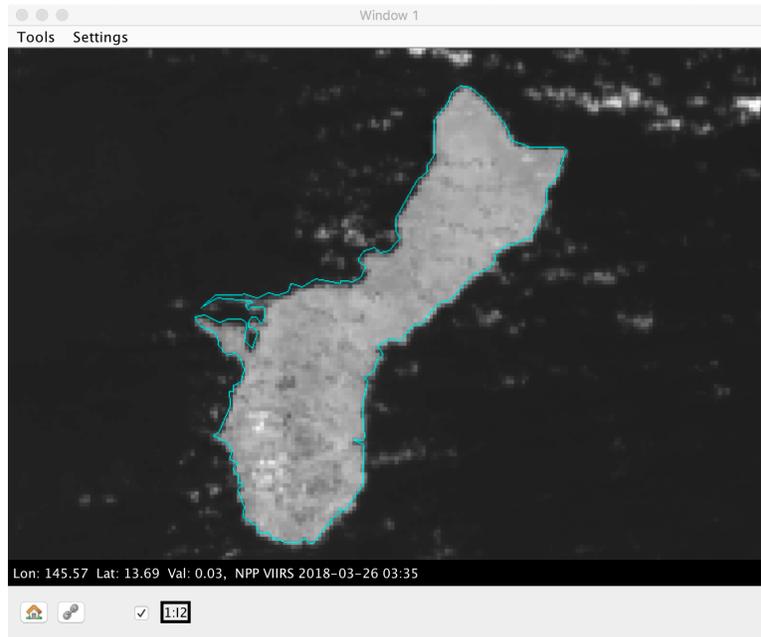


Figure 8: VIIRS I2 image of Guam on 2018-03-26 at 03:35 UTC.

Enhance the VIIRS I2 image to show the land and ocean features. Note the appearance of the water surface and the land surface. Identify land regions that are bright or dark:

Region where land is bright \_\_\_\_\_ Reflectance value \_\_\_\_\_

Region where land is dark \_\_\_\_\_ Reflectance value \_\_\_\_\_

Now display VIIRS band I1 (0.64  $\mu\text{m}$  visible) and examine the water regions that are free of clouds. Identify water regions that are bright or dark:

Region where water is bright \_\_\_\_\_ Reflectance value \_\_\_\_\_

Region where water is dark \_\_\_\_\_ Reflectance value \_\_\_\_\_

Close your existing Display Windows and load VIIRS band I2 (0.87 micron, 375 meter) for the same region in a new Display Window and zoom in to show Guam. Then load VIIRS band I1 (0.67 microns, 375 meter) 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. 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. Enhance both images to bring out land features.

Switch between VIIRS Band I1 and I2 in the Display Window, and notice where the 0.67 micron reflectance is different than the 0.87 micron reflectance. It should tell you something about the vegetation cover on the surface. Figure 9 shows the visible reflectance of several land surface types (soil, grass, snow) as a function of wavelength in the visible spectrum.

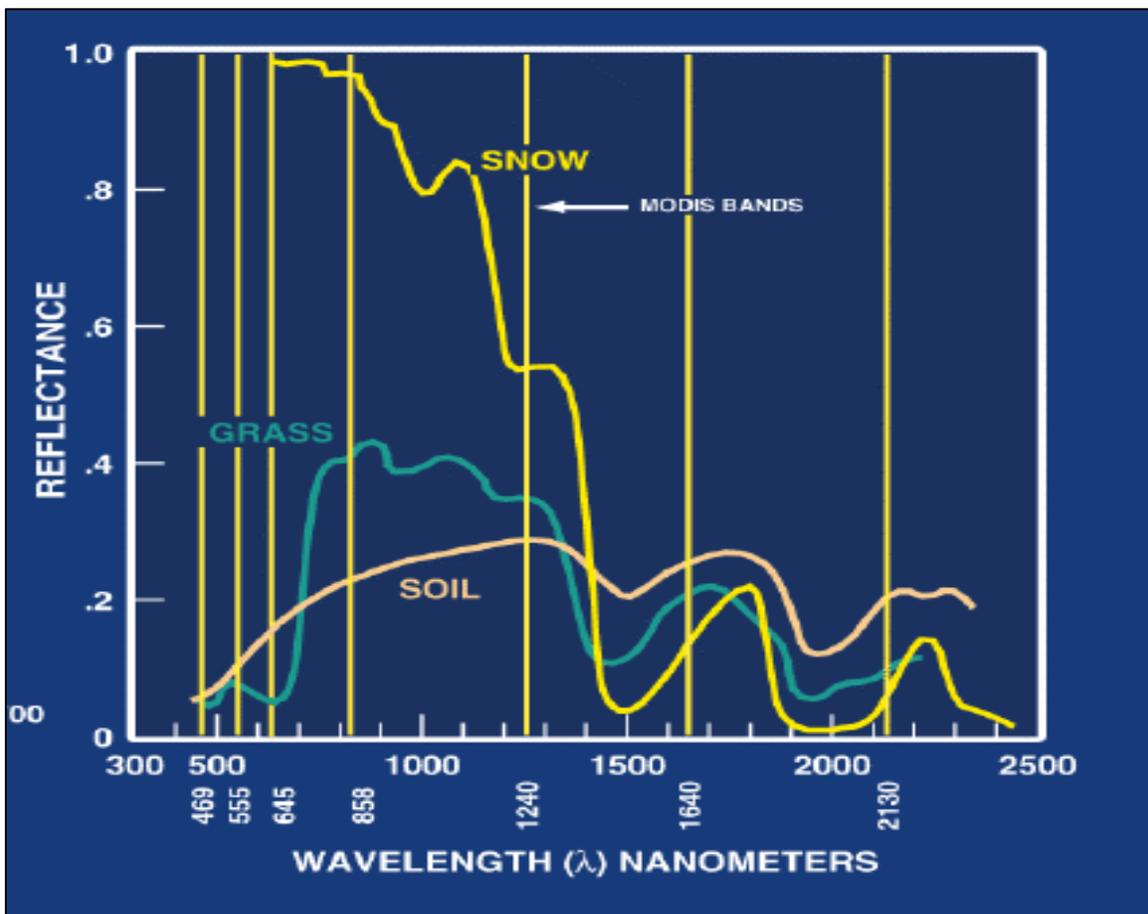


Figure 9: Land Surface Reflectance at Visible Wavelengths

The normalized vegetation difference index (NDVI) uses a weighted difference of the reflectance at 0.87 and 0.67 microns to estimate the density of vegetation. The formula for NDVI is

$$[R(0.87) - R(0.67)] / [R(0.87) + R(0.67)]$$

By referring to Figure 9, estimate the approximate value of NDVI for grass and soil, and record your estimates below:

Grass 0.67 micron reflectance\_\_\_\_ 0.87 micron reflectance \_\_\_\_ NDVI \_\_\_\_\_

Soil 0.67 micron reflectance\_\_\_\_ 0.87 micron reflectance \_\_\_\_ NDVI \_\_\_\_\_

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

$$\text{NDVI} = [\text{Band I2 (0.87 } \mu\text{m)} - \text{Band I1 (0.67 } \mu\text{m)}] / [\text{Band I2 (0.87 } \mu\text{m)} + \text{Band I1 (0.67 } \mu\text{m)}].$$

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

Does the NDVI image allow you to discriminate regions with dense vegetation to those with little vegetation? Describe an area where the NDVI image shows dense vegetation

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What are the NDVI values in regions with significant vegetation; what are they in non-vegetated regions?

NDVI for dense vegetation:\_\_\_\_\_ NDVI for sparse vegetation:\_\_\_\_\_

Now load VIIRS Band I5 (11.5  $\mu\text{m}$ ) in a new Display Window. Adjust the color scale to highlight the land surface features. What is the effect of vegetation on surface temperature?

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By how much does the surface temperature change over the areas of dense vegetation, compared to the rest of the region? \_\_\_\_\_

Now create a VIIRS True Color image of Guam by selecting **Tools / RGB Composite** in the Data Window. This image is a close representation of what would be seen with the human eye when looking down from orbit. Click on the band numbers in the Data Window in the order you want them to be displayed as red/green/blue (to create a VIIRS true color image, select bands M5, M4, M3). When the correct band numbers are displayed in the **RGBComposite** dialog, click the **Create** button. A new dataset will appear in the Data Window at the bottom of the list under **Combinations**. Enhance the image by opening the Enhancement tool and setting the overall gamma value to 0.5.

Does the True Color image support your conclusions about the presence or absence of vegetation as seen in the NDVI image? If so, describe the correspondence between the True Color image and the NDVI image.

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### **1.6 Examining the VIIRS Day/Night Band**

The VIIRS Day/Night Band is able to sense reflected and emitted radiation over a broad bandpass centered at 0.7 microns in both day and night conditions. During the day, illumination is provided by the sun. During the night, illumination is provided by the moon or stars. Light emissions from natural sources (e.g., wildfires, lightning, aurora) as well as anthropogenic sources (city lights, ships, gas flares) can also be observed. The VIIRS Day/Night Band can sense incoming radiance over seven orders of magnitude, so even in new moon conditions, or at overpass times when the moon is not in sky, useful imagery can be obtained.

Load the VIIRS DNB data from 2018-03-29 at 16:54 UTC over the western Pacific. Examine different regions of the DNB image to identify natural and anthropogenic light sources and phenomena, and briefly locate and describe them below.

Location of region	Description of feature


What can you say about the lunar phase on 2018-03-29?

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**END OF LABORATORY EXERCISE**