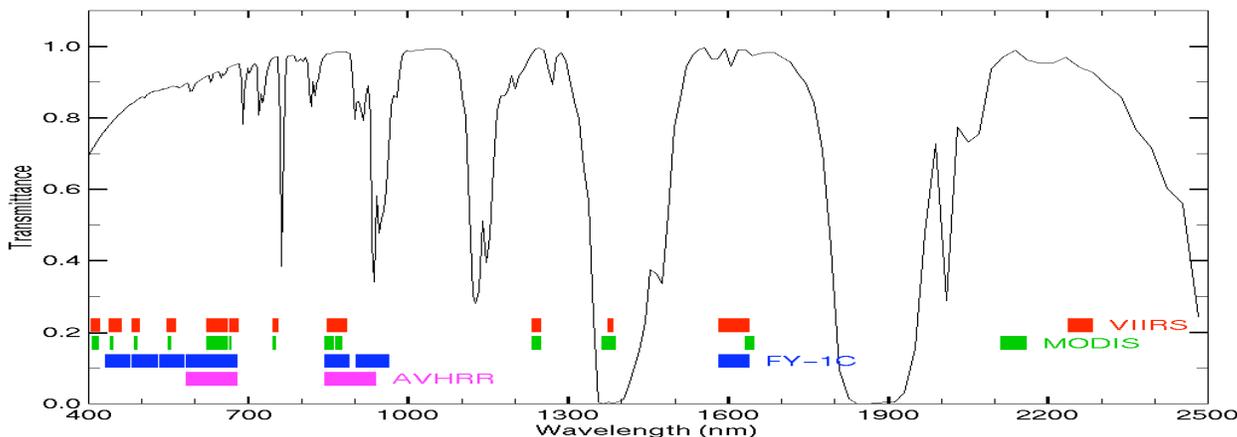


Table: MODIS Channel Number, Wavelength (μm), and Primary Application

Reflective Bands			Emissive Bands		
1,2	0.645, 0.865	land/cld boundaries	20-23	3.750(2), 3.959, 4.050	sfc/cld T
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 temperature
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 temperature
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



1. Sea Surface Temperature

This exercise aims to make you calculate the Sea Surface Temperature (SST) in daytime condition using a simplify algorithm that takes into account the water vapor correction. The exercise also describes a few ways to identify qualitatively the sediment in the Ocean.

Using Hydra load the Aqua MODIS Level 1B scene over the southwest coast of Africa named

MYD021KM.A2006073.1240.005.2006075012425.hdf

Start the Multi-Channel Viewer, and examine the entire scene in band 31 (11 μm). At this wavelength, recall that the atmosphere is almost transparent (i.e., band 31 is a window band), so the majority of the photons reaching the sensor are from the surface, with a small amount of absorption occurring in the atmosphere due to water vapor.

- (a) What are the minimum and maximum brightness temperatures you observe in band 31 over the ocean?

- (b) Check for evidence of clouds over the ocean as you learned in the cloud masking exercise. You may need to use other MODIS bands to screen out clouds. What are the minimum and maximum brightness temperatures in band 31 over the ocean in cloud free regions?

Now load the full resolution subset region shown in Figure 1, and check for the presence of clouds in the subset region.

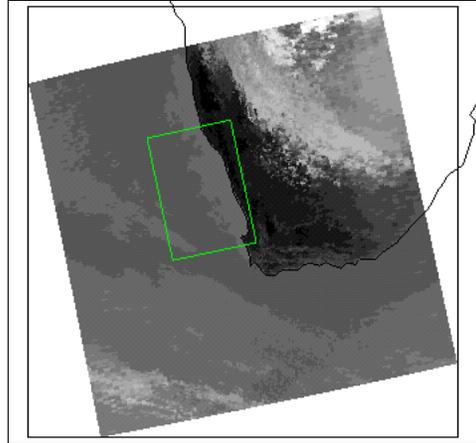


Figure 1: Ocean subset image

(c) Are there clouds present in this region? If so, which bands identify them best? Is there any evidence of cirrus clouds? How can you tell?

(d) What is the brightness temperature range over clear ocean in band 31 within this region?

Bands 31 (11 μm) and 32 (12 μm) of MODIS are sensitive to changes in sea surface temperature, because the atmosphere is almost (but not completely) transparent at these wavelengths. An estimate of the sea surface temperature (SST) can be made from band 31, with a water vapor correction derived from the difference between the band 31 and band 32 brightness temperatures:

$$\text{SST} \approx B_{31} + (B_{31} - B_{32})$$

Writing the equation in this form makes it clear that the $(B_{31}-B_{32})$ term is a correction factor which compensates for water vapor, i.e., the higher the amount of water vapor, the greater the correction to B_{31} . Figure 2 shows the radiance arising from the ocean surface as a function of water vapor in the atmosphere. You can see that as the water vapor amount increases, the difference between the radiance (and hence the brightness temperature) between band 31 and band 32 increases. Thus the difference between bands 31 and 32 is used as a way to correct for the influence of water vapor on band 31. Note that this is a very simplified version of the equations used to derive SST from MODIS.

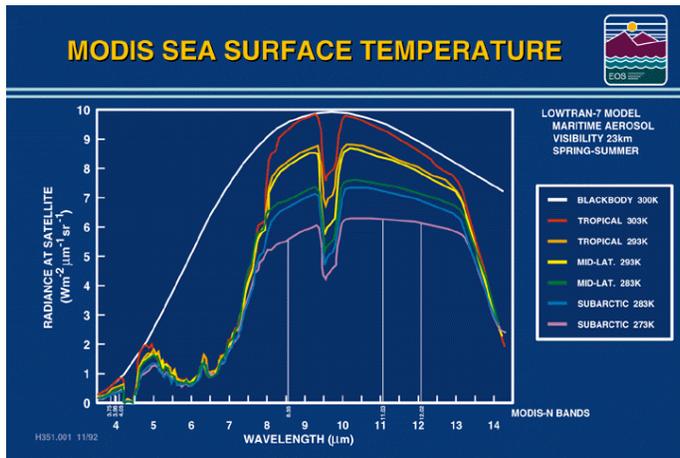


Figure 2: Ocean upwelling radiance for varying water vapor amounts

(e) Construct an image of SST for the subset region using the Linear Combinations tool. Compare the SST derived image to the original band 31 image. Do they look significantly different? Estimate the magnitude of the water vapor correction (B31 – B32) in degrees Kelvin.

(f) What range of SST values do you find along the coast, compared to the deep offshore waters? Can you explain why the SST is different near the coast, compared to the deeper waters?

(g) Draw a transect from shallow to deep water to demonstrate the SST change

2. Sediment Concentration

MODIS bands 3 (0.45 μm), 1 (0.65 μm), and 2 (0.87 μm) are sensitive to the reflectance of the ocean surface. Clear ocean waters are most reflective at shorter wavelengths, and become darker at longer wavelengths. Sediment laden waters are however more reflective at longer wavelengths, which gives them a brownish to reddish color.

(a) Construct images of bands 3, 2, and 1 over the region shown in Figure 3, and describe the patterns of sediment seen in each band in the vicinity of the Orange River outflow.

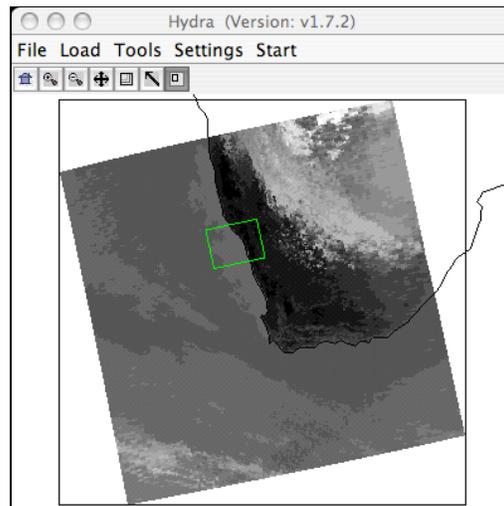


Figure 3: Region selection for Orange River outflow

(b) Which band is most sensitive to low amounts of sediment? Which band is most sensitive to high amounts of sediment?

(c) Try using combinations of visible bands to identify the sediment, and compare it to an image of SST as described previously. Do you see any correlation between sediment and SST? What might cause the sediment and SST values to be related?

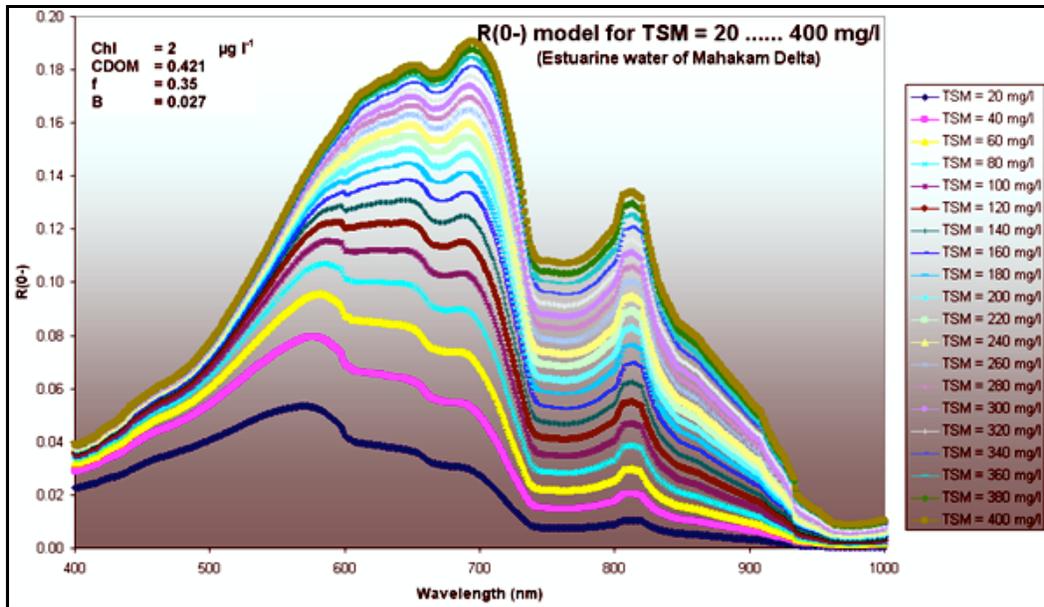


Figure 4: Spectral Reflectance for different concentration of Total Suspended Matter

Atmospheric Correction

This exercise aims to introduce you to the concept of atmospheric correction. Most of the radiance in the visible bands (especially in the blue band) is due to atmospheric scattering. In order to properly derive ocean properties in class II waters, the scattered component of the solar radiation has to be removed. To do so, in this exercise you will be using the “6s” software as follows.

Make sure that you are on the local network (follow the instructions at the end of this document). Open a browser and go to <http://192.168.0.1/>

- click on the first link *Geometrical Conditions* select the *User's* option and click on the *Submit Query*
- enter the date for the studied granule (14 Feb. 2006) and then enter 33 for the *Solar Zenithal angle* and -47 for *Solar Azimuthal angle*, 11 for the *Sensor Zenithal Angle*, and 80 for the *Sensor Azimuthal Angle*. Click on the *Submit Query* button.
- Click on the *Atmospherical Model* link. Enter the *Tropical Atmospheric Profile*. Enter the *Maritime Model* for the *Aerosol Model*. Click on the *Submit Query* button.
- Enter 0.1 for the *Optical Depth at 550 nm (AOT or Visibility)*. Click on the *Submit Query* button.
- Click on the *Target Sensor Altitude*. Select *Sea Level* for the target altitude. And *Satellite Level* for the sensor altitude. Click on the *Submit Query* button.
- Click on the *Spectral Condition* link. Select *Choose Band* for the *Spectral Conditions*. Select *MODIS band 1* for the *Select Band* field. Click on the *Submit Query* button.
- Click on the *Ground Reflectance* link. Select *Homogeneous surface* for the *Ground Reflectance Type*. Select *No Directional Effect* for the *Directional Effect* field. Click on the *Submit Query* button.
- Select *Mean Spectral Value of Clear Water*. Click on the *Submit Query* button.
- Click on the *Submit Query* button.

- j) Click on the *Signal* link.
- k) Select *Atmospheric Correction with Lambertian Absorption assumption* in the Atmospheric Correction mode field. Using Hydra find a value of the reflectance in band 1 that is representative for the area of interest. Click on the *Submit Query* button.
- l) Click on the *Results* link and wait a few seconds.
- m) Click on the *Output File* link and look for the *Atmospheric Correction Result* section at the end of the page. The corrected reflectance is indicated by the *Lambertian case*.

Once you found a correction factor for band 1 repeat the exercise for band 2.

a) How does the correction vary for all the ocean bands from 8 to 16? Can you explain this variation? Try to draw a plot of the atmospheric correction as function of the wavelength.

b) Derive the atmospheric correction for the same bands but for different optical depths [0.05, 0.15, 0.2, 0.25], for band 3 only try to draw a plot of the atmospheric correction as function of the optical depth.

Product Generation

The goal of this exercise is to obtain the same products derived in the previous exercises but more rigorously. Atmospheric Correction, SST and Sediment will be calculated using SeaDAS. visualization and processing software.

From prompt type “seadas –em”, a “SeaDAS MainMenu” window will open. Click on *Process->MODIS->msl12,4* a new window “SeaDAS MODISL2 File Generating Program” window will open. Select File L1 MYD021KM.A2003057.1210.004.2004077041121.hdf and click on the OK button. Select the GEO (geolocation) File MYD03.A2003057.1210.003.2003058193602.hdf and click on the OK button. The output filename is automatically selected but you have to choose the output parameters: click on the *Select L2 Product*. A “MSL12 Output File1 L2 Products Selection Widget” window will open. Now go through the following steps:

1. click on the *Select Defaults* button
2. in addition select manually
 - a. chl_oc2
 - b. chl_gsm01
 - c. water_vapor
 - d. tsm_clarck
3. in the lower part of the window also select:
 - a. the first 6 bands of Rrs (Remote Sensing Reflectance) up to 667 nm included;
 - b. the first 6 bands of Lw (Water Leaving Radiance) up to 667 nm included;
 - c. the first 6 bands of taua (Aerosols Optical Depths) up to 667 nm included;

Click on the *Okay* button.

In the “SeaDAS MODISL2 File Generating Program” window select the *Subset/Subsample* tab and enter the coordinates for the selected region: South-West Corner [Lat=39 Lon=15] and North-East Corner [Lat=43 Lon=20]. Click on the *Run* button.....wait.....wait some more...after a *Processing Completed* message appears in the shell window, go to the “SeaDAS MainMenu” window and click on the *Display* button to visualize the output products.

A new widget will prompt you for the product file (the one you just created, it is a .L2_LAC extension namefile), selected it from the directory where it was saved and click on the OK button. After the file has been selected a new window “Product Selection For MODIS File” will popup. First select the *l2_flags* and click on the *Load* button and the “Band List Selection” window will popup. Go back to the “Product Selection For MODIS File” window, click on the *Select All* button and then on the *Load* button.

Product Display

In the “Band List Selection” window select *chlora* and click on the *Display* button. To change the color-map in the new window “1)chlora:” click on the *Functions* button and select the *Color LUT->Load LUT* and in the “Load Color” window select the color table that you prefer. To add the colorbar click on the *Functions* button and select the *Color Bar->On*. In the same way from the “Band List Selection” window display the *chl_gsm01*.

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(a) Where do the algorithms differ the most?

(b) Can you guess why they differ?

In the “Band List Selection” window select *sst* and click on the *Display* button. Change the color-map in the new window “1)sst:” and add the colorbar in the same way you did in the previous point.

(c) The SST in gulf of Manfredonia looks colder than everywhere else. Can you guess why?
(make sure that you check the data quality)

Scatter Plot

From the “SeaDAS Main Menu’ click on the *Utilities* button and select *Data Visualization->L2 Flags Display*. A new widget will show you the a list of flags to be used to interpret the displayed image. Set the slider *Display window for Flag to be applied* to 2. Apply different flags to better understand why the two algorithms differ. Close the *L2 Flags Display* window and the two chlorophyll images.

From the “SeaDAS Main Menu’ click on the *Utilities* button and select *Data Visualization->Scatter Plot* to open the “Scatter Plot Main Widget”. Select *tsm_clarck* (sediment) and map it to the X-axis and select *sst* as Y-axis. Make sure that allowed range of values for these variables are realistic. Click on the *Go* button at the bottom of the window.

(a) Comment on the scatter plot.

(b) Close the scatter plot window and try to make different scatter plots you think might be interesting.

From the “SeaDAS Main Menu’ click on the *Utilities* button and select *Data Visualization->Scatter Plot* to open the “Scatter Plot Main Widget”. Select *chlor_a* (chlorophyll) and map it to the X-axis and select *sst* as Y-axis. Make sure that allowed range of values for these variables are realistic. Click on the *Go* button at the bottom of the window.

(c) Comment on the scatter plot.