

MODIS and AIRS Workshop

6 April 2006 Pretoria, South Africa

LAB 3

Lab on MODIS Aerosols, Dust Detection, Cloud Phase, Sea Surface Temperature and Sediment Concentration

This Lab was prepared to provide practical insight into MODIS IMAPP level 2 product retrieval theory and techniques.

Exercise 1 Aerosol Detection

The goal of this exercise is to gain an understanding of aerosol radiative characteristics over the MODIS bands used in the aerosol retrieval algorithm. By the end of this exercise, the user should be able to identify which MODIS bands are used to detect aerosols and why they are used, and how to estimate an approximate aerosol optical thickness for band 3 ($0.47 \mu\text{m}$) and band 1 ($.68 \mu\text{m}$).

1. Load into hydra the local Aqua MODIS file from 20 August 2003 covering Southeastern Africa and Madagascar, MYD021KM.A2003232.1110.004.2004148203517.hdf. Start the Multi-Channel Viewer, and then select the small region displayed in Figure (1).

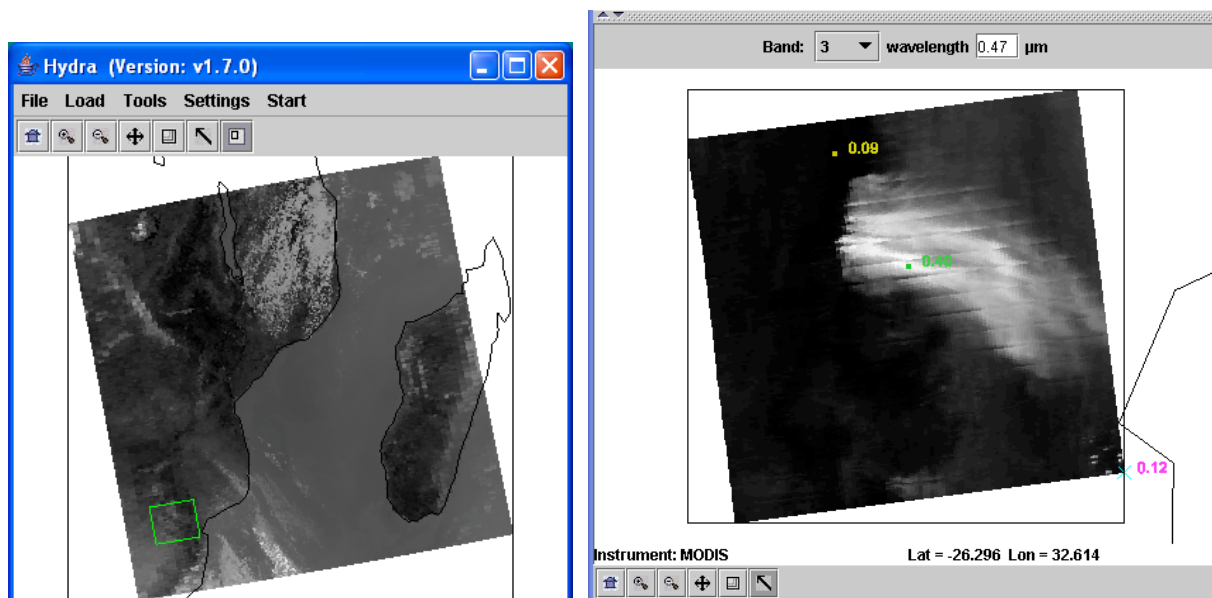


Figure 1. Main hydra window with a selection of the image from Aqua MODIS on 20 August 2003 at 11:10 UTC (left) and high resolution band 3 ($.45 \mu\text{m}$) reflectance image in the Multi-Channel Viewer (right).

Examine the scene in visible bands Band 1 (.68 μm), Band 3 (0.47 μm) and Band 7 (2.13 μm) and thermal bands Band 20 (3.80 μm), Band 21 (3.99 μm), and Band 31 (11 μm).

(a) Describe what you see. Are there differences in the max/min reflectances and brightness temperatures?

Bands 1 (0.65 μm)	Band 3 (0.47 μm)	Band 7 (2.1 μm)	Band 20 (3.8 μm)	Band 21 (3.99 μm)	Band 31 (11 μm)

(b) Can you think of some reasons for these differences?

2. Open the Linear Combinations Window and create single images of Band 1 (.68 μm), Band 3 (0.47 μm) and Band 7 (2.13 μm). Change the color scale to **gray** and enhance the images. Now create a scatter diagram of Band 3 (0.47 μm) on the X-axis and Band 7 (2.13 μm) on the Y-axis.

(a) Examine the smoke plume by selecting regions of the plume in the image to see where the points lie on the scatter diagram. In which band is the smoke signal stronger?

(b) Now do the same for Band 1 (.68 μm) and Band 7 (2.13 μm). How does this compare with the Band 3 (.47 μm) and Band 7 (2.13 μm) results?

(c) Can you determine a relationship between the reflectances of the surface background just using the scatter diagram (Hint: what is the slope of the background land pixels).

3. The MODIS aerosol algorithm utilizes a look up table to get an initial estimate of the aerosol optical thickness τ_λ over land, based upon the measured reflectances and the surface reflectance. This relationship can also be approximated by:

$$\tau_{.68} \sim (r_{.68} - .50*r_{2.1})$$

$$\tau_{.47} \sim (r_{.47} - .25*r_{2.1})$$

(a) Calculate $\tau_{.68}$ and $\tau_{.47}$ at 3 locations over the smoke plume. You can get the values of the same pixels for different channels selecting the *Arrow* button in the Multi-Channel Viewer as you change bands, and then either do your calculations by hand, or by using the calculator that may be available through the computer. What values did you get?

(b) What is the purpose of subtracting out the reflectances in Band 7 (2.13 μm)?

(c) How do the τ values change as the plume moves away from the source?

(d) Now use the Channel Combinations Tool to create approximate $\tau_{.68}$ and $\tau_{.47}$ images. Create an image of Band 1 (.68 μm) - .50 * Band 7 (2.13 μm). Use the White box in front of the Green band selector to type in the constant. Do the same for Band 3 (.47 μm) - .25 * Band 7 (2.13 μm).

(e) How do the $\tau_{.68}$ and $\tau_{.47}$ values compare? What are some causes for the differences? Once you are done, close the Linear Combinations Window.

4. Now load the cloud mask for our small section of data (file MYD35_L2.A2003232.1110.hdf). Overlay the *Unobstructed_FOV_Quality_Flag* onto the Band 1 (.68 μm).

(a) How do you think the mask performs over this region? When you are finished, close the Cloud Mask Window and the Multi Channel Viewer.

Exercise 2 Dust Storm

The goal of this exercise is to gain an understanding of the IR window channels responses in the presence of a dust storm.

1. Using **Load Data** in the main menu load MOD021KM.A2005006.0950.005.20050711171157.hdf. This shows a dust storm over North Africa. Sub-select the approximate region:

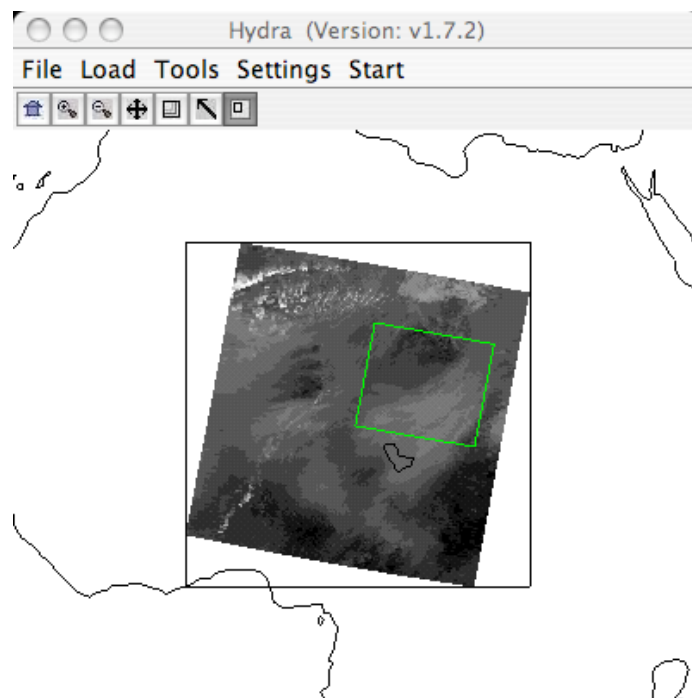


Figure 2. Dust scene over Central Africa.

1. For each of the following cases use the **scatter plot** tools to determine (and describe) the features of the dust storm:

(a) Plot Band 31 on the x-axis and [Band 31 - Band 32] on the y-axis and click on the **Scatter** button.

(b) Repeat with Band 31 (11 μm) on the x-axis and [Band 29 (8.6 μm) minus Band 31 (11 μm)] on the y-axis.

(c) Repeat with Band 31 (11 μm) versus [Band 31 (11 μm) minus Band 32 (12 μm)].

(d) Which brightness temperature differences show a larger range of values?

(e) How does this compare to the cloud diagrams?

(f) Do you think you can distinguish dust storms from clouds using these channels? Why?

Exercise 3 Cloud Phase

The goal of this exercise is to gain an understanding of the MODIS cloud phase algorithm strengths and weaknesses. By the end of this exercise, the user should be able to identify which MODIS bands are used to determine cloud phase and why they are used, and

implement the algorithm as it is done in operations.

1. Load the cloud scene over South Eastern Africa and the Mozambique Channel from 2 March 2003 (day 61), at 11:30 UTC detected by Aqua MODIS using the Hydra software (file MYD021KM.A2003061.1130.004.2004079065535.hdf). Open the Multi-Channel Viewer and select the small scene shown in Figure 3 in the main Hydra window.

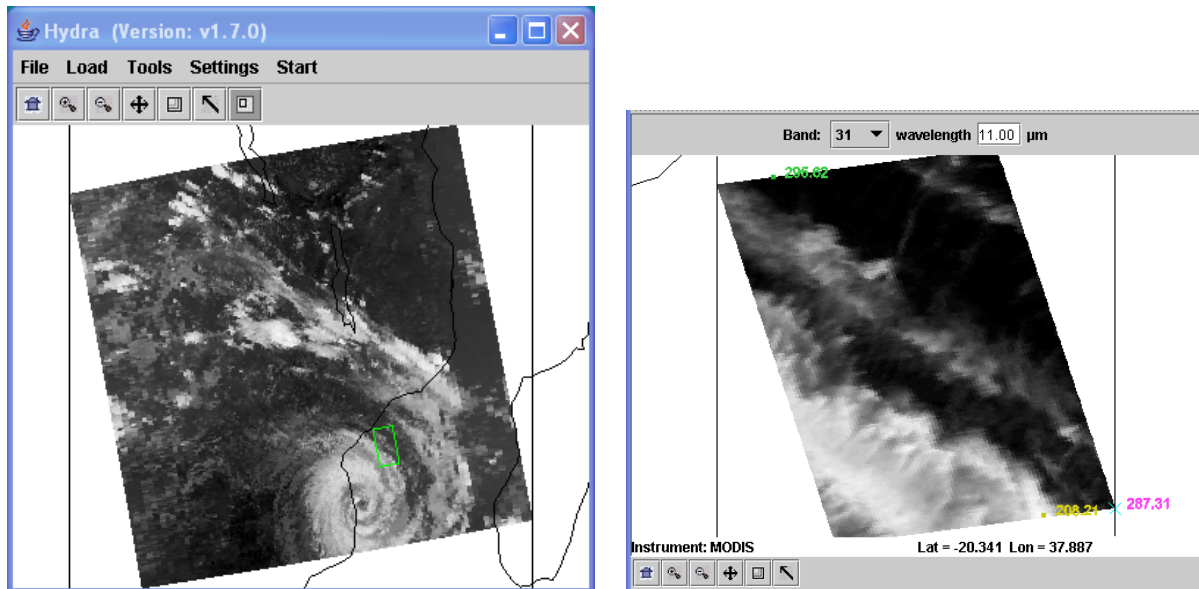


Figure 3. Cyclone cloud band section of image from Aqua MODIS on 3 March 2003 at 11:30 UTC.

(a) Examine the scene. What range of brightness temperatures do you see in Band 31 ($11\ \mu\text{m}$) over the clouds?

(b) Look at the scene in Band 35 ($13.9\ \mu\text{m}$) and Band 26 ($1.38\ \mu\text{m}$). Can you tell what kind of clouds these are?

2. The MODIS infrared phase detection algorithm is based upon the differential absorption of ice and water over the 8-12 micron window region. To examine the technique more closely, create a

scatter plot of Band 31 (11 μm) on the X-axis and [Band 29 (8.6 μm) - Band 31 (11 μm)] on the Y-axis. Make sure the *color scale* of the combined difference image is set to *gray*.

(a) Describe what you see. Where are biggest differences (where do they lie in the images)?

(b) What can you infer about cloud amount from the scatter diagram?

(c) What can you infer about ice cloud absorption between 8 and 11 microns?

3. The algorithm uses these thresholds to determine ice cloud:

Band 31 (11 μm) Brightness Temperature < 238 K or Band 29 – Band 31 difference > .5 K

(a) Using this criteria, how much of the scene will be identified as ice cloud?

4. The water cloud algorithm thresholds are:

Band 31 (11 μm) Brightness Temperature > 238 K and Band 29 – Band 31 difference < -1.0 K

Or

Band 31 (11 μm) Brightness Temperature > 285 K and Band 29 – Band 31 difference < -0.5 K

The remaining regions are labeled as uncertain.

(a) Map these thresholds onto the scatter diagram and describe how well the algorithm performs on the ice and/or water clouds. Remember, the clear scenes should not be counted. They will be excluded by the cloud mask.

(b) After this investigation, how would you describe the strengths and weaknesses of the algorithm?

5. Now create a scatter diagram of [Band 31 (11.0 μm) - Band 32 (12 μm)] on the X-axis and [Band 29 (8.6 μm) - Band 31 (11 μm)] on the Y-axis.

(a) What sort of pattern do you see? (You should see a hook shape). By selecting a region in the scatter plot, try to identify the origin of the clear portion of the hook shape. Now identify the origin of the cloud portion.

(b) To determine what causes the hook shape, consider the following:

Estimate the Planck radiance (using the table on the next page) at 8.6, 11, 12 μm for a scene containing clear sky at 300 K and a cloud at 230 K with varying cloud amount, where the cloud fraction varies from $N = 0.0, 0.2, 0.4, 0.6, 0.8,$ and 1.0 (0.0 is completely clear; 1.0 is completely cloudy). The total radiance $B_{\lambda,\text{obs}}$ emanating from a partially cloudy field of view (FOV) for a given wavelength is given by

$$B_{\lambda,\text{obs}} = (1-N)B_{\lambda,\text{clear}} + NB_{\lambda,\text{cloud}}$$

Where $B_{\lambda,\text{obs}}$ is the observed radiance,

N is the cloud fraction,

$B_{\lambda,\text{clear}}$ is the radiance from the clear part of the FOV,

$B_{\lambda,\text{cloud}}$ is the radiance emanating from the cloudy part of the FOV.

You can convert the Planck radiances to brightness temperatures using the table on the next page.

(c) Plot the brightness temperature difference [Band 29 (8.6 μm) - Band 31 (11 μm)] versus Band 31 (11 μm) for the six different cloud fractions. What does this imply about the hook shape detected in section 2(b)? What other factors might influence the shape of this 'hook'?

When you are finished, close all of the windows except for the main hydra window.

Planck Radiance (R) vs. Brightness Temperature (BT)
 for 8.6, 11.0, and 12.0 microns from 230 to 300 K
 (radiance units are Watts per sq. meter per steradian per micron)

BT	R 8.6	R 11.0	R 12.0	BT	R 8.6	R 11.0	R 12.0
230.00	1.76	2.52	2.62	250.00	3.15	3.97	3.99
230.50	1.78	2.55	2.65	250.50	3.19	4.01	4.03
231.00	1.81	2.58	2.68	251.00	3.23	4.06	4.07
231.50	1.84	2.61	2.71	251.50	3.27	4.10	4.11
232.00	1.87	2.64	2.74	252.00	3.32	4.14	4.14
232.50	1.90	2.68	2.77	252.50	3.36	4.19	4.18
233.00	1.93	2.71	2.80	253.00	3.41	4.23	4.22
233.50	1.96	2.74	2.84	253.50	3.45	4.27	4.26
234.00	1.99	2.77	2.87	254.00	3.50	4.32	4.30
234.50	2.02	2.81	2.90	254.50	3.54	4.36	4.34
235.00	2.05	2.84	2.93	255.00	3.59	4.40	4.39
235.50	2.08	2.87	2.96	255.50	3.63	4.45	4.43
236.00	2.11	2.91	2.99	256.00	3.68	4.49	4.47
236.50	2.15	2.94	3.03	256.50	3.73	4.54	4.51
237.00	2.18	2.98	3.06	257.00	3.78	4.59	4.55
237.50	2.21	3.01	3.09	257.50	3.82	4.63	4.59
238.00	2.24	3.05	3.13	258.00	3.87	4.68	4.63
238.50	2.28	3.08	3.16	258.50	3.92	4.72	4.68
239.00	2.31	3.12	3.19	259.00	3.97	4.77	4.72
239.50	2.35	3.16	3.23	259.50	4.02	4.82	4.76
240.00	2.38	3.19	3.26	260.00	4.07	4.86	4.80
240.50	2.41	3.23	3.30	260.50	4.12	4.91	4.85
241.00	2.45	3.26	3.33	261.00	4.17	4.96	4.89
241.50	2.48	3.30	3.36	261.50	4.22	5.01	4.93
242.00	2.52	3.34	3.40	262.00	4.28	5.06	4.98
242.50	2.56	3.38	3.43	262.50	4.33	5.10	5.02
243.00	2.59	3.41	3.47	263.00	4.38	5.15	5.07
243.50	2.63	3.45	3.51	263.50	4.43	5.20	5.11
244.00	2.67	3.49	3.54	264.00	4.49	5.25	5.16
244.50	2.71	3.53	3.58	264.50	4.54	5.30	5.20
245.00	2.74	3.57	3.61	265.00	4.60	5.35	5.25
245.50	2.78	3.61	3.65	265.50	4.65	5.40	5.29
246.00	2.82	3.65	3.69	266.00	4.71	5.45	5.34
246.50	2.86	3.69	3.72	266.50	4.76	5.50	5.38
247.00	2.90	3.73	3.76	267.00	4.82	5.56	5.43
247.50	2.94	3.77	3.80	267.50	4.88	5.61	5.48
248.00	2.98	3.81	3.84	268.00	4.93	5.66	5.52
248.50	3.02	3.85	3.87	268.50	4.99	5.71	5.57
249.00	3.06	3.89	3.91	269.00	5.05	5.76	5.62
249.50	3.10	3.93	3.95	269.50	5.11	5.82	5.66

BT	R 8.6	R 11.0	R 12.0	BT	R 8.6	R 11.0	R 12.0
270.00	5.17	5.87	5.71	290.00	7.93	8.22	7.79
270.50	5.23	5.92	5.76	290.50	8.01	8.29	7.85
271.00	5.29	5.98	5.81	291.00	8.09	8.35	7.90
271.50	5.35	6.03	5.85	291.50	8.17	8.42	7.96
272.00	5.41	6.08	5.90	292.00	8.25	8.48	8.02
272.50	5.47	6.14	5.95	292.50	8.33	8.55	8.07
273.00	5.53	6.19	6.00	293.00	8.42	8.62	8.13
273.50	5.60	6.25	6.05	293.50	8.50	8.68	8.19
274.00	5.66	6.30	6.10	294.00	8.58	8.75	8.25
274.50	5.72	6.36	6.15	294.50	8.67	8.82	8.31
275.00	5.79	6.41	6.20	295.00	8.75	8.88	8.36
275.50	5.85	6.47	6.25	295.50	8.83	8.95	8.42
276.00	5.91	6.53	6.30	296.00	8.92	9.02	8.48
276.50	5.98	6.58	6.35	296.50	9.01	9.09	8.54
277.00	6.05	6.64	6.40	297.00	9.09	9.16	8.60
277.50	6.11	6.70	6.45	297.50	9.18	9.22	8.66
278.00	6.18	6.75	6.50	298.00	9.27	9.29	8.72
278.50	6.25	6.81	6.55	298.50	9.35	9.36	8.78
279.00	6.31	6.87	6.60	299.00	9.44	9.43	8.84
279.50	6.38	6.93	6.65	299.50	9.53	9.50	8.90
280.00	6.45	6.99	6.70	300.00	9.62	9.57	8.96
280.50	6.52	7.05	6.76				
281.00	6.59	7.11	6.81				
281.50	6.66	7.17	6.86				
282.00	6.73	7.23	6.91				
282.50	6.80	7.29	6.97				
283.00	6.87	7.35	7.02				
283.50	6.95	7.41	7.07				
284.00	7.02	7.47	7.13				
284.50	7.09	7.53	7.18				
285.00	7.17	7.59	7.24				
285.50	7.24	7.65	7.29				
286.00	7.32	7.71	7.34				
286.50	7.39	7.78	7.40				
287.00	7.47	7.84	7.45				
287.50	7.54	7.90	7.51				
288.00	7.62	7.97	7.57				
288.50	7.70	8.03	7.62				
289.00	7.77	8.09	7.68				
289.50	7.85	8.16	7.73				

Exercise 4 Sea Surface Temperature and Sediment Concentration

Sea Surface Temperature and Sediment Concentration

In this exercise you will examine the appearance of the ocean surface; use thermal infrared bands to estimate sea surface temperature; and use visible/near-infrared bands to estimate chlorophyll and sediment concentration.

1. Sea Surface Temperature

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 4, and check for the presence of clouds in the subset region.

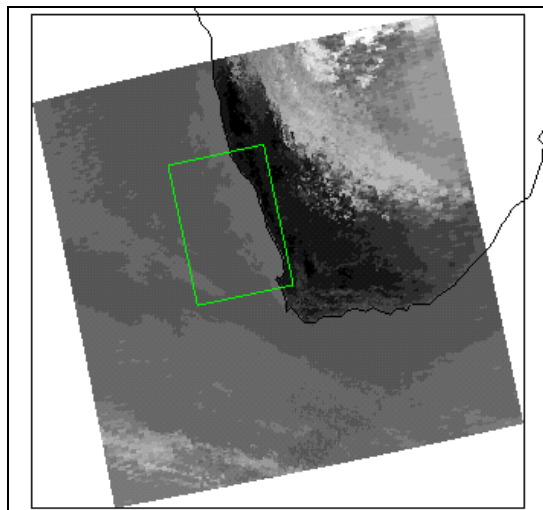


Figure 4: Ocean subset image

(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 (12 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:

$$\text{SST} \approx B31 + (B31 - B32)$$

Writing the equation in this form makes it clear that the $(B31 - B32)$ term is a correction factor which compensates for water vapor, i.e., the higher the amount of water vapor, the greater the correction to B31. Figure 5 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.

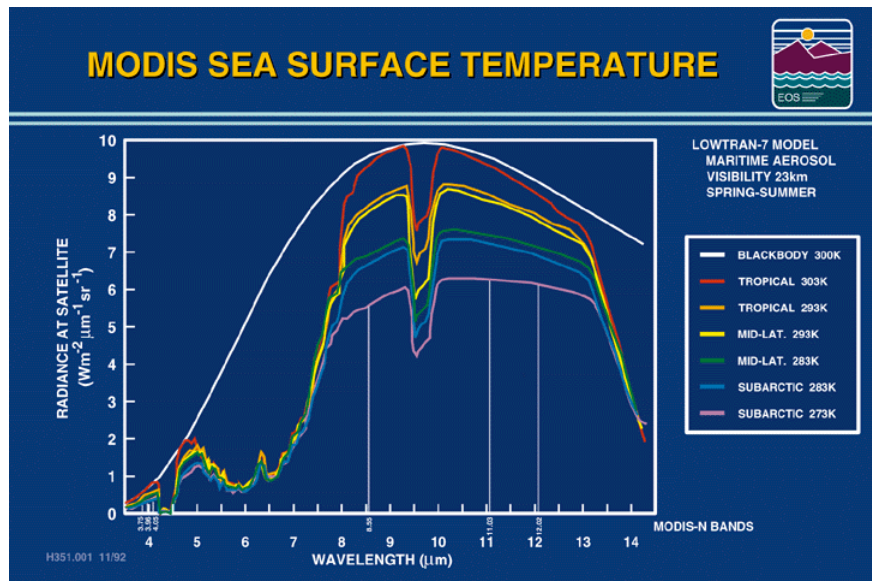


Figure 5: Ocean upwelling radiance for varying water vapor amounts

(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 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?

2. Sediment Concentration

MODIS bands 3 (0.45 μm), 1 (0.65 μm), and 2 (0.87 μm) microns 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 6, and describe the patterns of sediment seen in each band in the vicinity of the Orange River outflow.

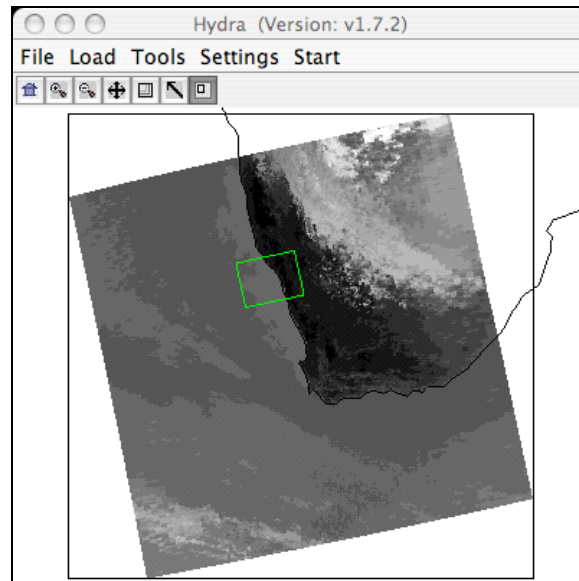


Figure 6: Region selection for Orange River outflow

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

(c) Try constructing an image of band 2 / band 1, 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?