Lab 2   Investigating Cloud Phase, NDVI, Ocean Color and Sea Surface Temperatures

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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 temperature
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
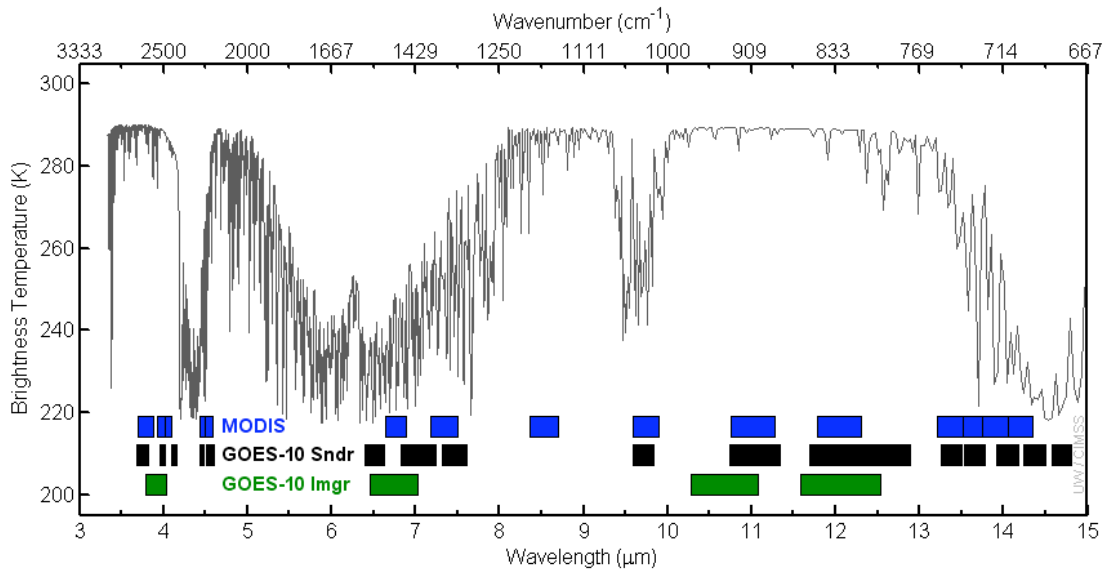
Figure 1: Infrared brightness temperatures for a standard atmosphere over the infrared window along with MODIS, GOES-10 Sounder and GOES-10 Imager bandwidths.

1. Load the MODIS 1KM image of the tropical cyclone again (MYD021KM.A2004087.1630.005.2007252102626.hdf) using Hydra.

2. Start the *Multi-Channel Viewer* and select a section of data going through the center of the cyclone as show in Figure 2.
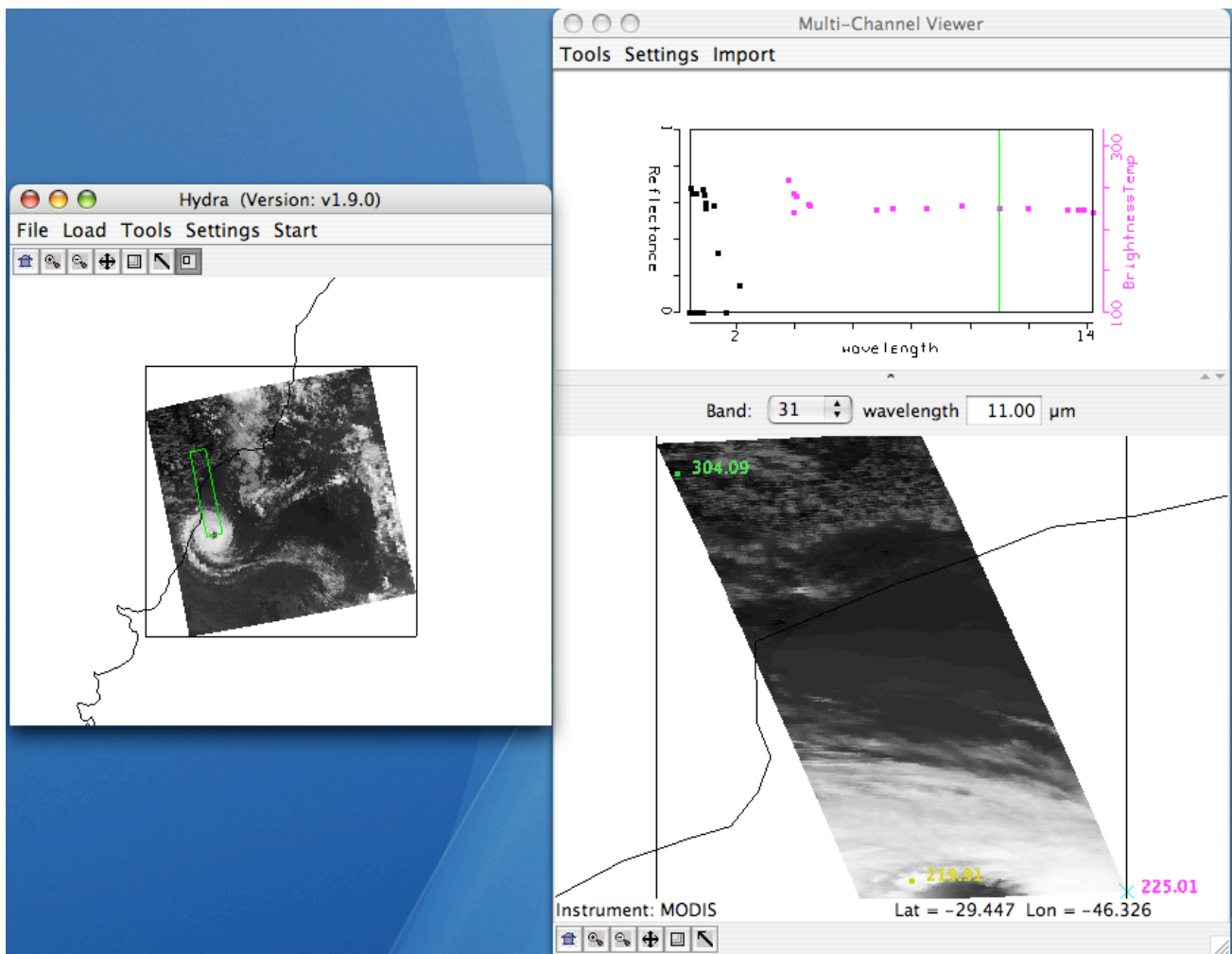
Figure 2: Subsection of data from 27 March 2004 MODIS 1km data set.

3. Now select Band number 20 (3.8 μm) and display the image. Note how much warmer the 3.8 μm brightness temperatures are than those for 11 μm. What can be responsible for this? Create an image of 3.8 μm brightness temperatures allowing the range of values to span 270 to 310 K (using *Set Color Range* under *Settings*). Do the same for 11 μm (Band 31). Create a power point slide with the two images side by side. Note how the clouds are much larger in the 11 μm image. Can you explain why?

(a) As you look at the images side by side, what do you notice about the clouds over the land. Can you explain the differences in brightness temperatures between the two?

(b) Look at the clouds over the water and the clouds over the land. Describe how they compare in bands 1 (0.65 μm), 26 (1.38 μm), 7 (2.1), 20 (3.8 μm), 27 (6.5 μm), 31 (11 μm) and 35 (13.9 μm). From what you have learned about the absorption characteristics of these bands, can you identify the type of clouds? The relative height of the clouds? Give reasons for your answers.

4. Now create combination images of these bands using the *Linear Combinations Tool*.

- Band 29 (8.6 µm) - Band 31 (11 µm) (Brightness Temperature)
- Band 31 (11 µm) - Band 32 (12 µm) (Brightness Temperature)

Note where the largest brightness temperature differences occur in the image.

5. Compute a single band image of Band 31 (11 µm) and use this as the X-axis. Create two scatter diagrams using the Band 29 (8.6 µm) - Band 31 (11 µm) brightness temperatures and the Band 31 (11 µm) - Band 32 (12 µm) brightness temperatures on the Y-axis as shown in Figure 3. Select regions in the scatter diagram to determine where the points are located in the images. Is there a pattern in the scatter diagram? Which band combination shows the largest range of values?
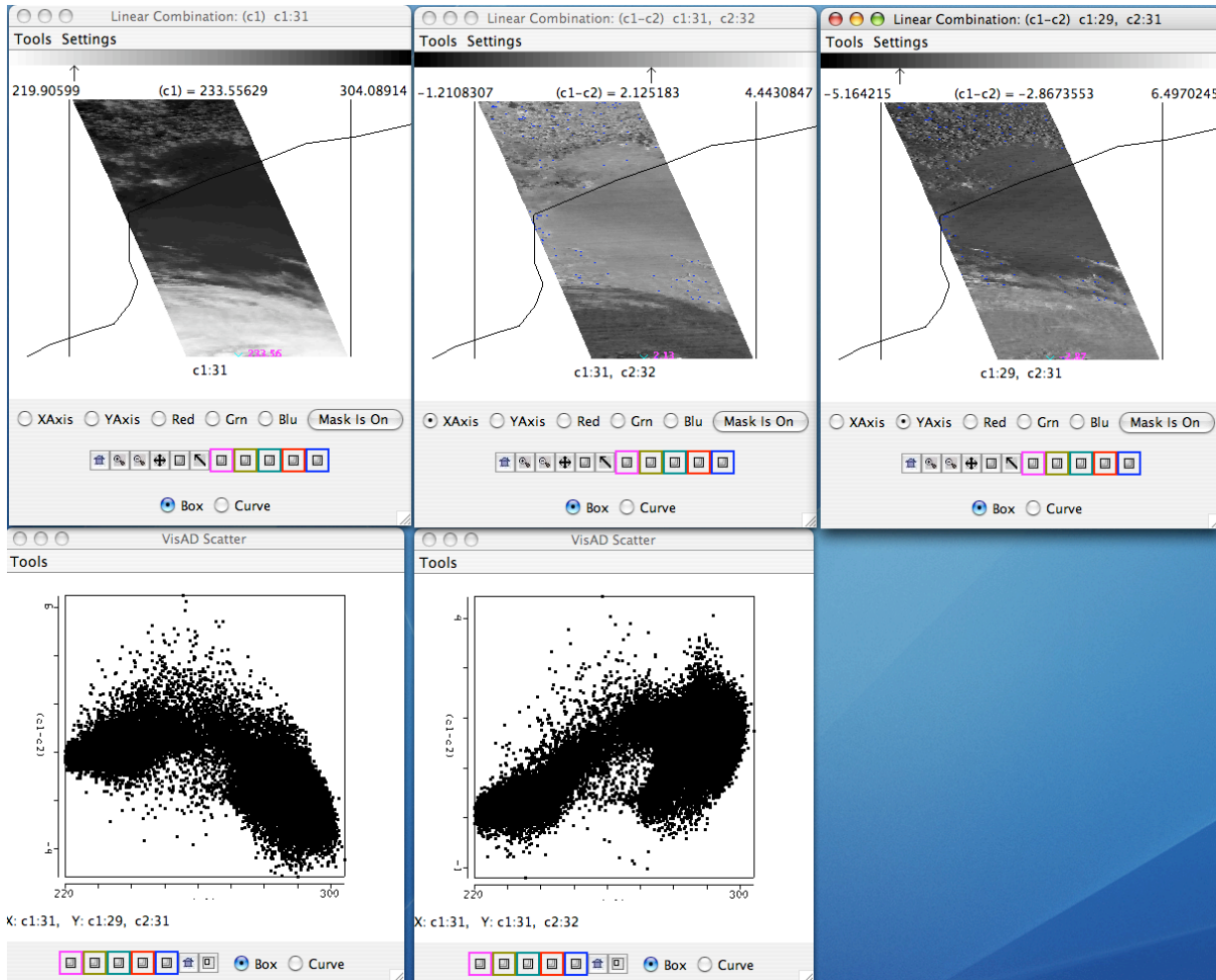

Figure 3: Images created using the Hydra Linear Combinations tool on the top panels and the scatter diagrams of Bands 29-31 versus Band 31 and Bands 31-32 versus Band 31 brightness temperatures on on the bottom panels.

6. Now create a scatter plot of Band 29 (8.6 µm) - Band 31 (11 µm) brightness temperatures differences on the X-axis and the Band 31 (11 µm) - Band 32 (12 µm) brightness temperatures differences on the Y-axis. Select a region of one of the brightness temperature difference images and look at the position of the selected pixels in the scatter plot, as shown in Figure 4. What type of cloud is this? Why? Can you describe the reason for this classic "hook" shape?
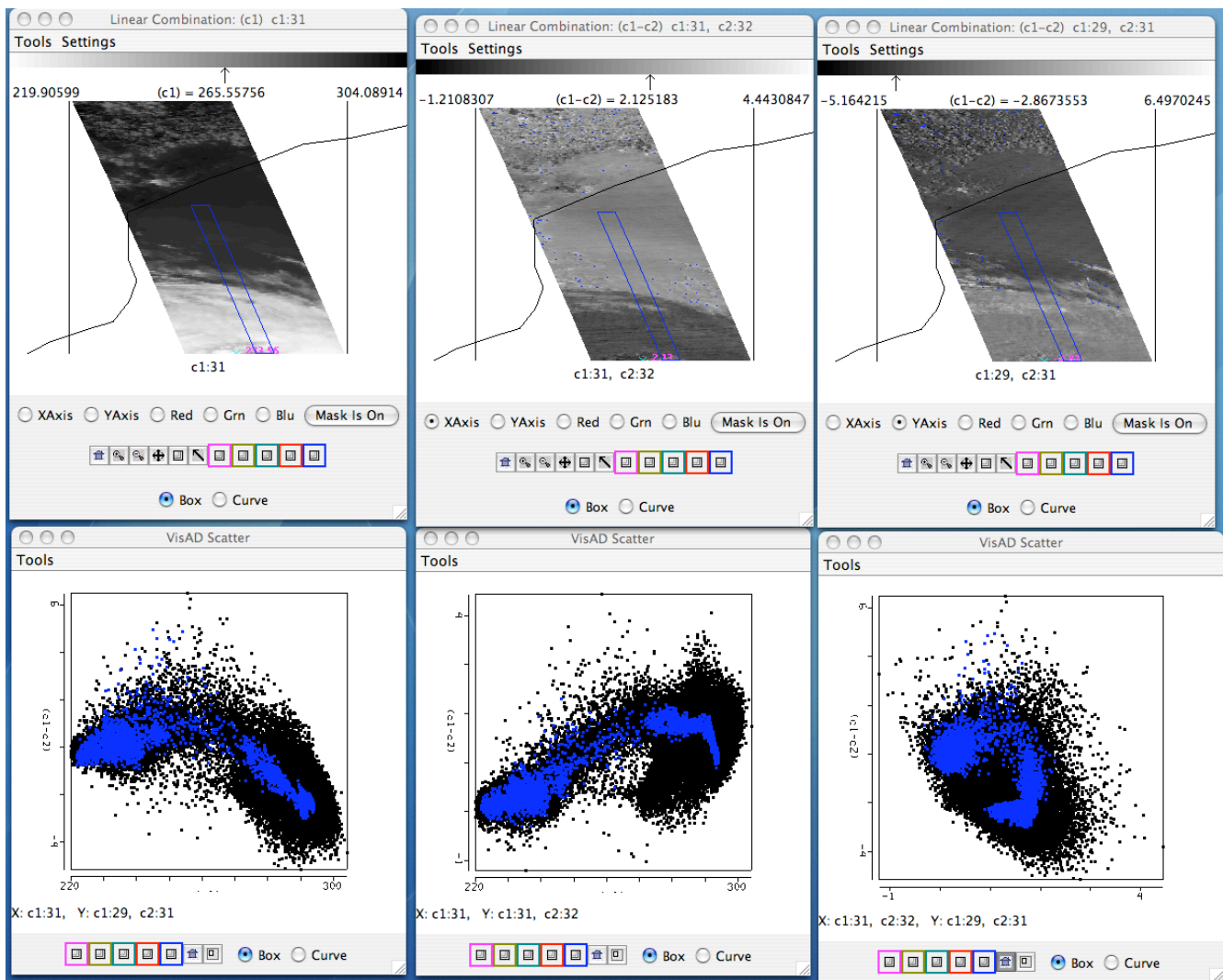
Figure 4: Images created using the Hydra Linear Combinations tool on the top panels and the scatter diagrams of Bands 29-31 versus Band 31 and Bands 31-32 versus Band 31 and Bands 29-31 versus Bands 31-32 brightness temperatures in the bottom panels.

7. Close the Linear Combinations Tool window and load in the MODIS Cloud Product file from this date and time (MYD06_L2.A2004087.1630.005.2006178160109.hdf). The MODIS cloud phase product will be overlaid on the Multi-Channel Viewer window. A new window will also appear which will display the 6 category cloud phase product and allow you to toggle the phase off and on over the image. Comment on how you believe the cloud phase algorithm performs. In regions where you think the algorithm does not perform well, why might it be failing? Why is this knowledge important?

8. Now close the Multi-Channel Viewer and load a new granule into Hydra located over South America from 1345 UTC, 26 July 2004 (MOD021KM.A2004208.1345.005.2007274200458.hdf) as displayed in Figure 5. Open a new Multi-Channel Viewer and quickly inspect the scene. Note the location and type of clouds in the scene.
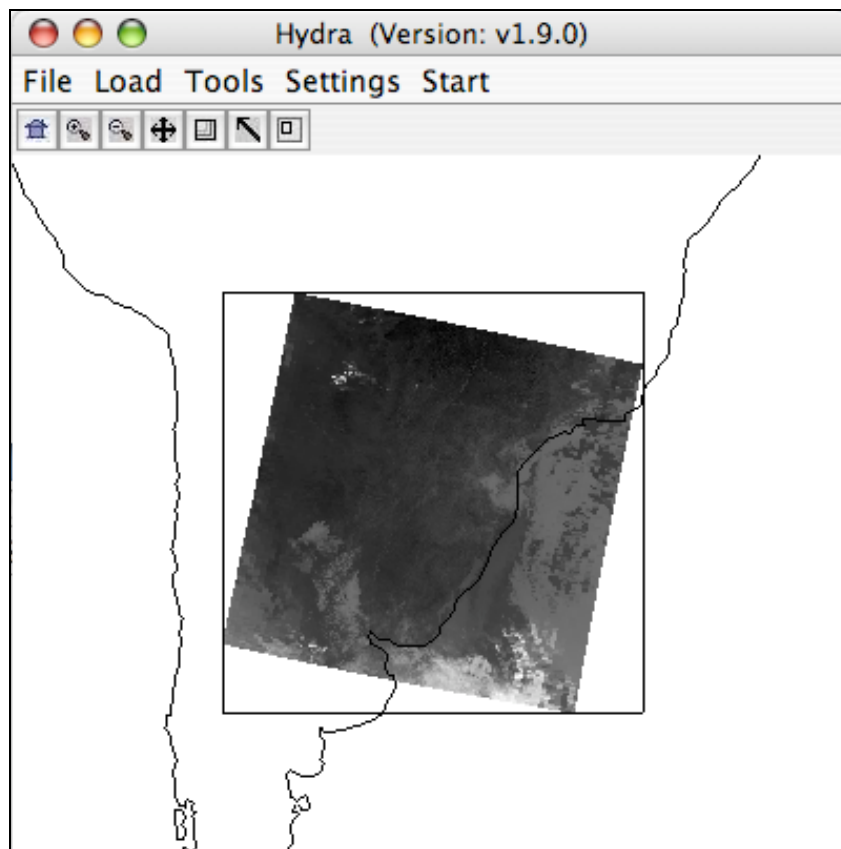
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Figure 5: MODIS Band 31 (11 µm) image as display in Hydra from 26 July 2004 at 1345 UTC.

9. Quickly compare the reflectances in Bands 1 (.65 µm) and Band 2 (.86 µm). How do they compare over land? How do they compare over water? Now display a *Transect* (under *Tools*) of the Band 2 reflectances as in Figure 6. Open the Transect window and hold down the ***Shift Key and Right Mouse Button*** while dragging the mouse over the image. This will display the reflectances along the chosen line of the image in the transect window. What are the minimum and maximum reflectances encountered? Now open a new Multi-Channel Viewer and display Band 1. Choose ***Tools->Transect*** from this new Multi-Channel Viewer. A transect will appear in blue in the band 1 image and the reflectances that lie along the transect should now appear along with band 2 in the transect window. Look closely at the patterns of values along the transect for both bands. Is there a relationship between the two (you can zoom in on a small section of values if you need to)?
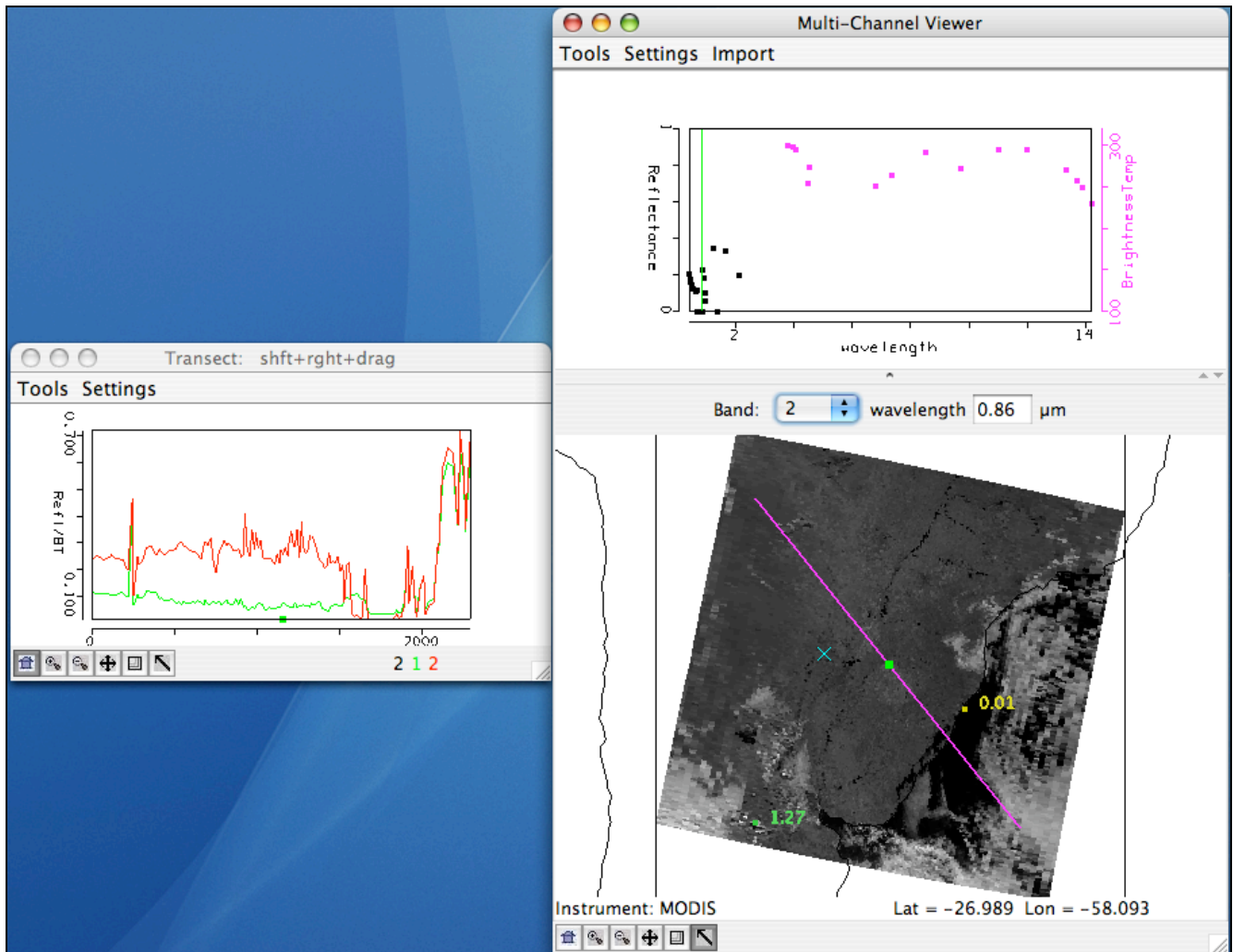
Figure 6: Transect of Band 2 (.86 μm) and Band 1 (.65 μm) over South America.

10. Select the small region shown in Figure 7. Create a Red, Green and Blue composite image of this small scene using the Hydra *Tools->rgb* option in the Multi-Channel Viewer. The default combination is Band 1 (.65 μm) for red, Band 4 (.55 μm) for green and Band 3 (.45 μm) for blue. Use these defaults to create the image by selecting the *Compute* button. Note the features in the image. Leave this rgb window open for the next exercise.
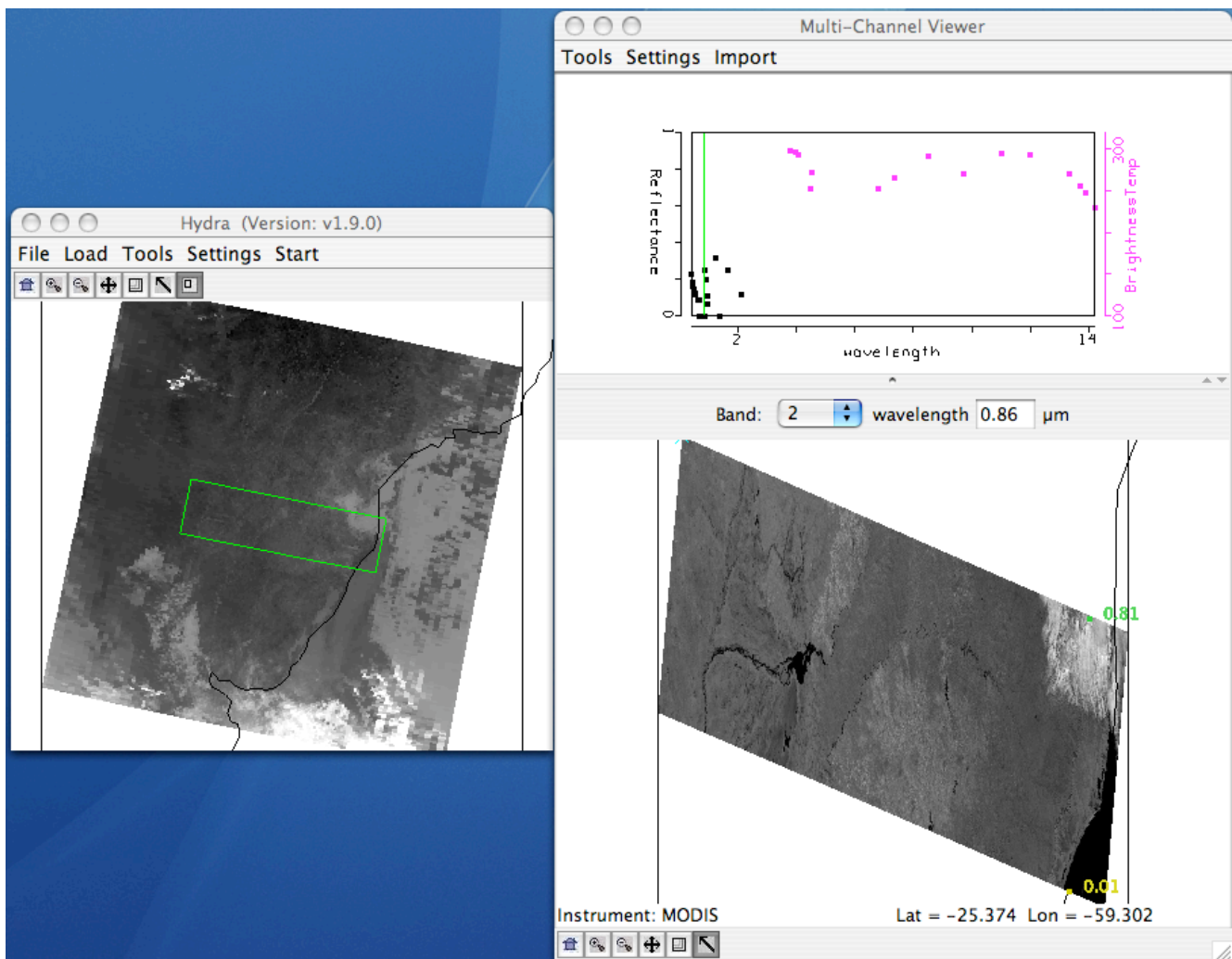
Figure 7: Hydra image a subset from the MODIS 26 July 2004 13:45 UTC granule.

11. Use the linear combinations tool to create a color image of Normalize Difference Vegetation Index (NDVI) where, NDVI = [Band 2 (0.86μm) – Band 1 (0.65μm)] / [Band 2 (0.86μm) + Band 1 (0.65μm)]. Can you discriminate regions with some vegetation from those with little? What are the NDVI values in regions without significant vegetation; what are they in vegetated regions?

12. Create an image of Band 31 (11.0 μm) using *Compute*. Map the NDVI that you created in exercise 11 on the Y-axis against Band 31 (11.0 μm) on the X-axis by creating a scatter diagram. Select different regions in the scatter plot window (see Figure 8) and look at the corresponding points in the linear combination windows. Is there a relationship between NDVI and window channel brightness temperatures? Use the rgb image that you created to help you identify different regions.
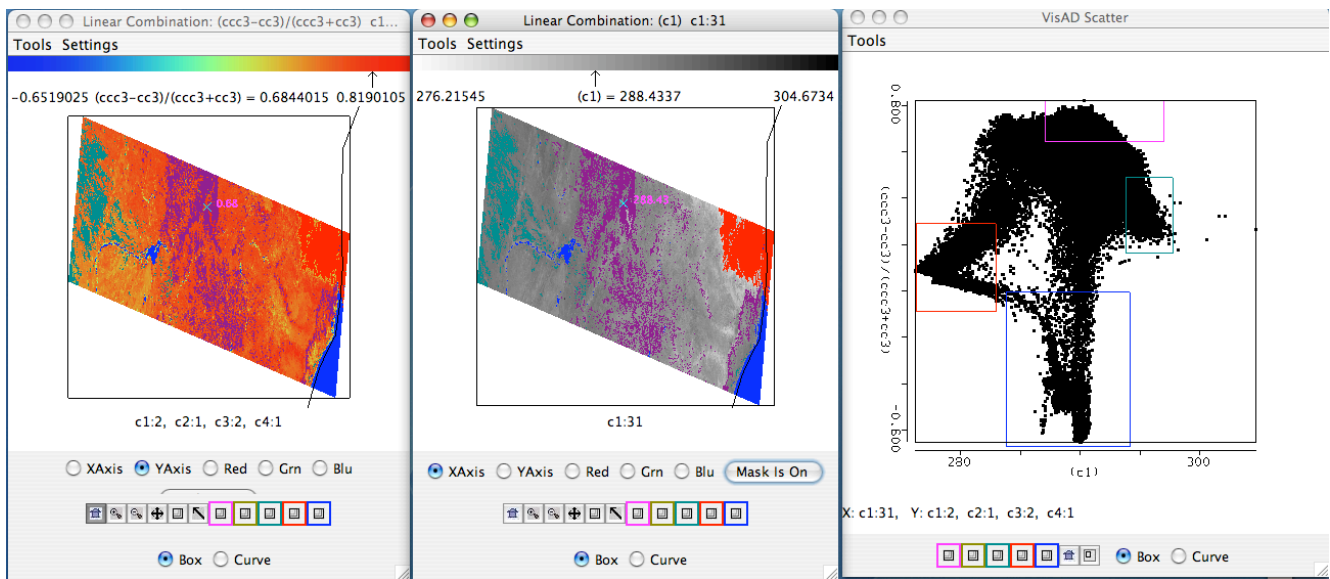
Figure 8: Pseudo NDVI image (left), single band 31 (11 µm) image (center) and the scatter diagram of NDVI versus band 31 (right) over the region outlined in Figure 7.

13. What atmospheric, surface or instrument properties might cause our NDVI values to be unrealistic?

14. Now load the MODIS 1km file from 15 February 2006 1340 UTC (MOD021KM.A2006046.1340.005.2007311104240.hdf). Start the Multi-Channel Viewer and select a region off of the coast of Argentina as displayed in Figure 9.
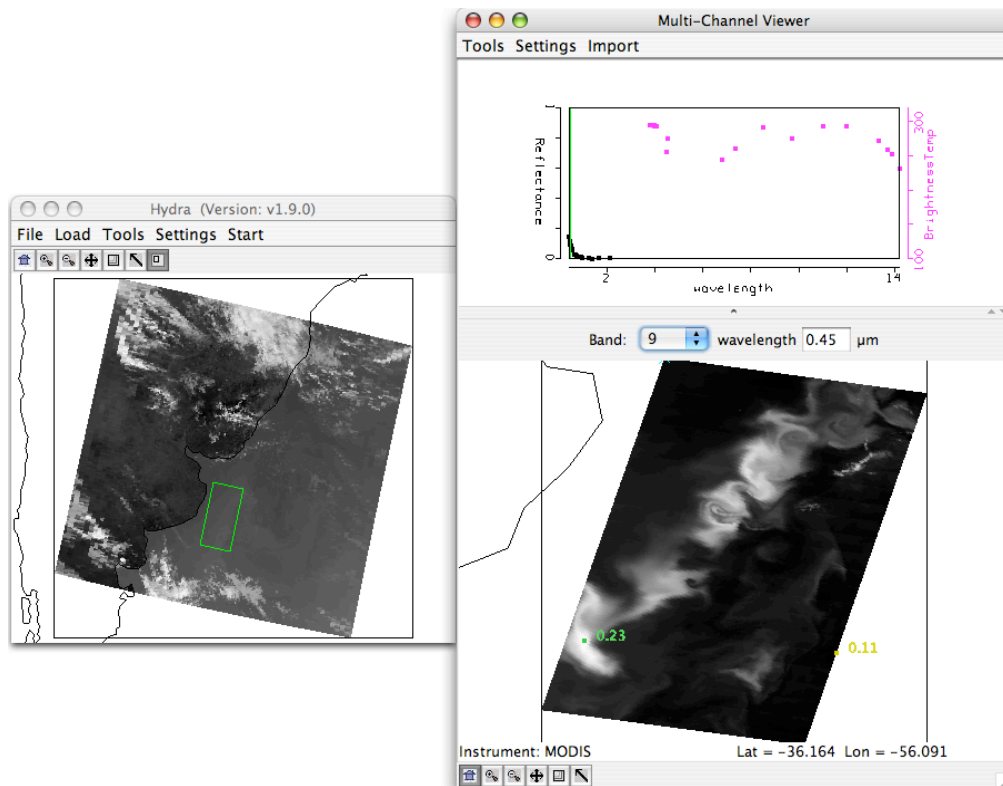

Figure 9: MODIS Band 31 (11 µm) image over Argentina and coastal waters from 15 February 2006 at 1340 UTC.

15. Examine the image in several bands including bands 1 (.65µm), 9 (.45 µm), 12 (.55 µm), and 31 (11 µm) and note the maxima and minima in each.

16. Create an rgb of this section of data using the default bands. What features do you see? Construct an image of [Band 12 (0.55µm) / Band 9 (0.45µm)]. Using Figure 10, explain why higher values of this ratio should indicate water regions with more phytoplankton from those with little?
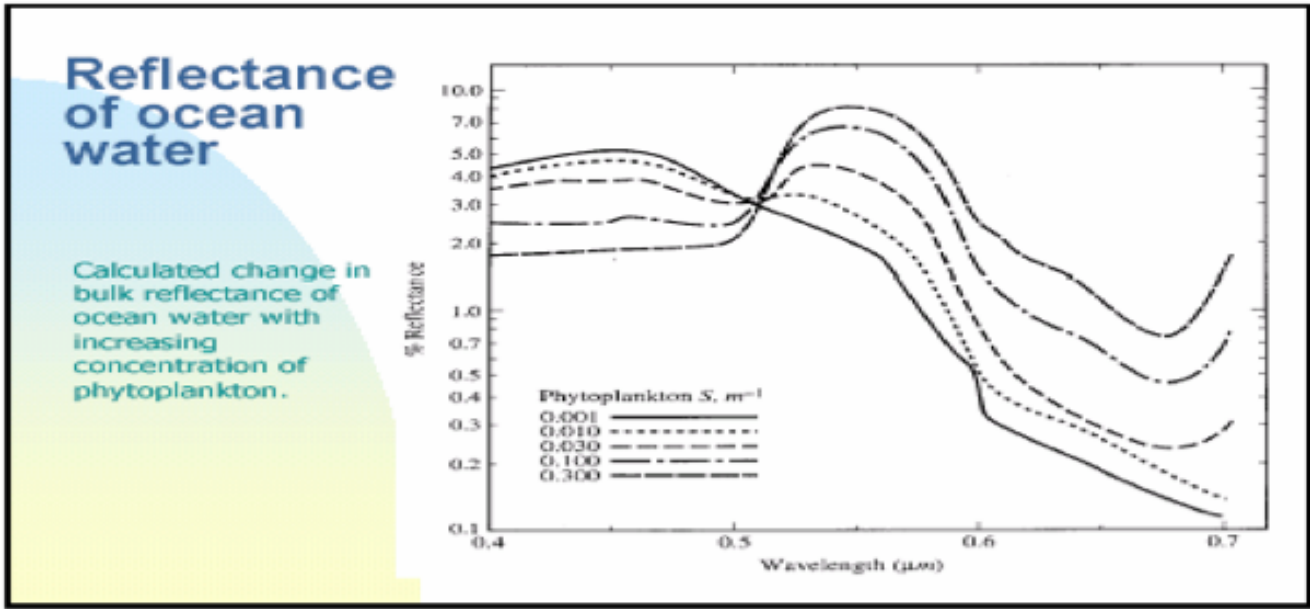

Figure 10: Reflectance of ocean water with increasing phytoplankton.

17. Now create a Sea Surface Temperature (SST) image of [2*Band 31 (11.0 µm) – Band 32 (12.0 µm)] . What is the range of SST values in this region of the ocean?

18. Map the phytoplankton values from exercise 16 on the Y-axis (by clicking the Y-axis button) against the SST from exercise 17 on the X-axis (by clicking the X-axis button). Click on the **Scatter** button to open a scatter plot window. Select different regions in the scatter plot window and look at the corresponding points in the linear combination windows. Is there a preferred water temperature in our scene where phytoplankton occurs?