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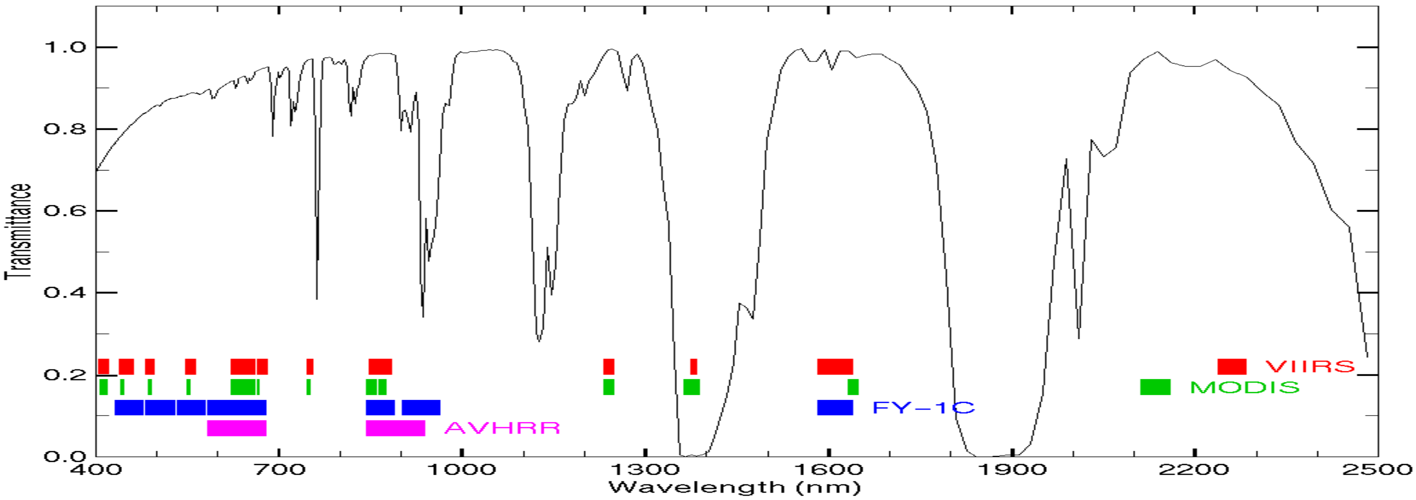
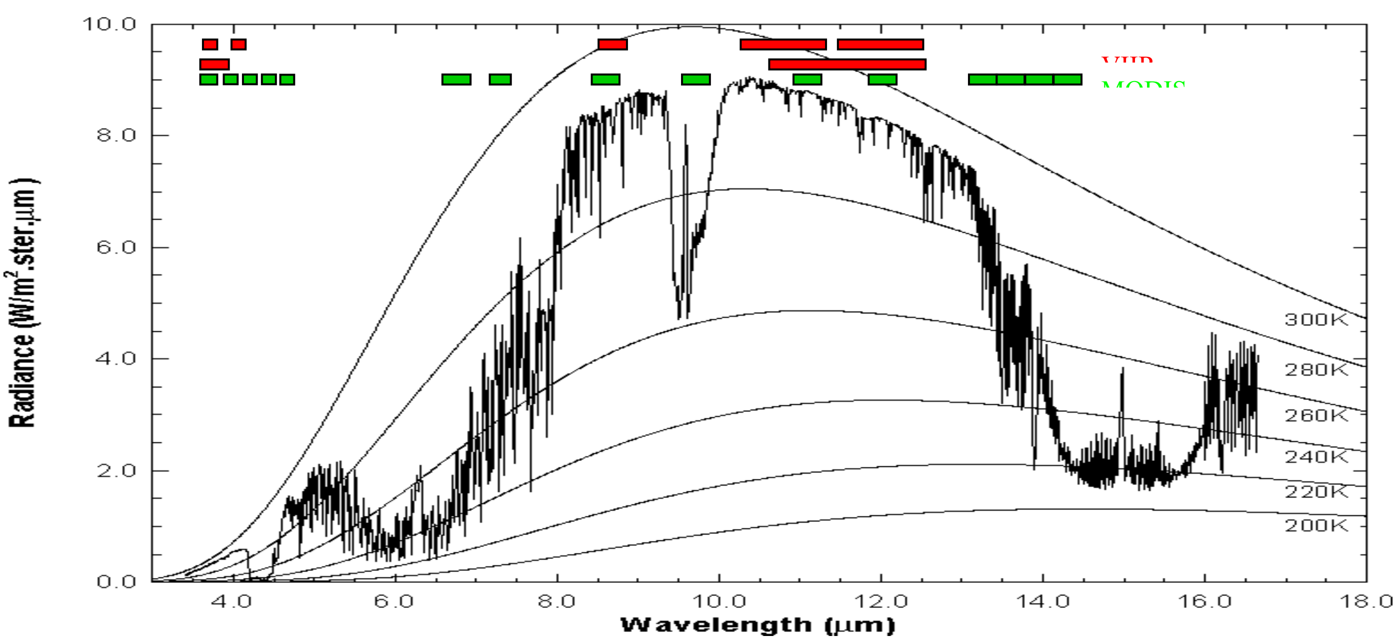
Lab Questions for Remote Sensing Seminar
Maratea, Italy
22 – 31 May 2003
Lab on Clouds

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



High resolution atmospheric absorption spectrum and comparative blackbody curves.



Exercise 1

1. Analyze the cloud scene over Italy on May 29, 2001 detected by MODIS using the UW MODIS Analysis Toolkit (see attached instruction sheet explaining how to run **manatee**). Proceed in the following steps. Start up MAT in matlab and load image file MOD021KM.A2001149.1030.003.2001154234131.hdf. Get familiar with the command menu ***band number***, and buttons ***radiance*** and ***projection*** under the ***variables*** tool. Browse through the scene in several different wavelengths. Note that for Band 31 (11 μm) the color bar (grayscale) on the left indicates that the maximum value of the brightness temperature is above 315 K; can you locate where this maximum occurs? Where is the minimum value of Band 31? Using the ***animate*** function (under the ***plot*** tool), note how the cloud, atmosphere, and surface features appear in each band.

2. Now select ***band number*** 27 (6.7 μm) and display the image using the ***temperature*** button. This band is used in cloud detection but also to derive upper tropospheric humidity (UTH). Describe features in the image that are

a) due to atmospheric circulations and
b) are artifacts of the image.

Click on the menu command ***select*** and use ***select line*** to approximately draw the following line (point to the start point, right click on the mouse, point to the end line, and right click with the mouse). In the Selected line and Cross-section Plot window (opened by the select line), select Band 27 (6.7 μm) and click the **Cross-section Plot** option. How would you correct this 'striping' if

a) the detector is bad, or
b) the detectors are biased.

Band 28 (7.3 μm) also shows this 'striping'. Close this window when you are finished.

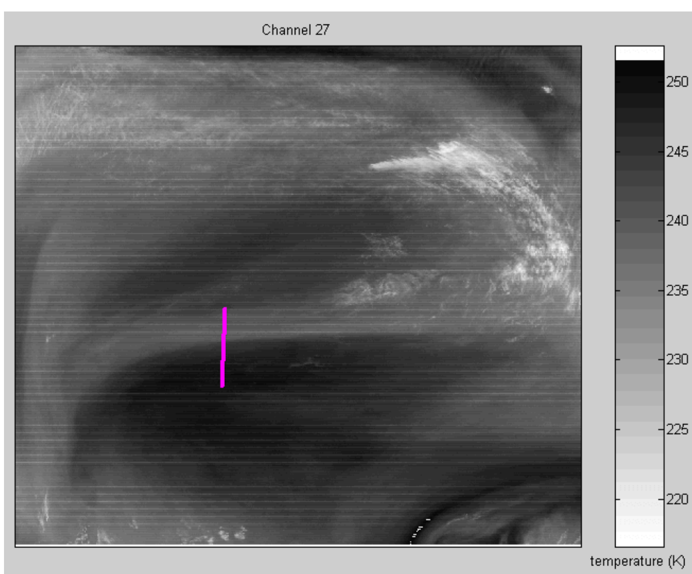


Figure 1: Band 27 Water vapor image.

Exercise 2

3. Now select ***band number*** 4 (0.55 μm) and display the image using the ***reflectance*** button. Click on the menu command ***select*** and select the following region (outlined approximately by magenta box):

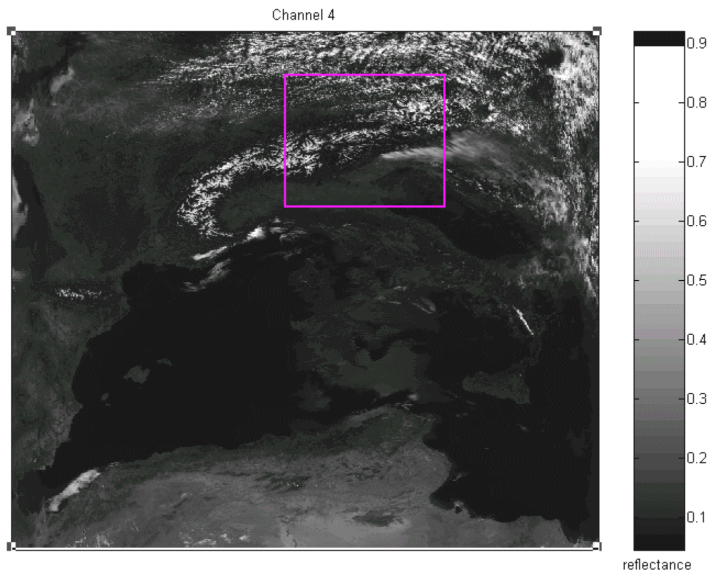


Figure 2: Snow, clouds, and clear sky.

a) Investigate the radiances emanating from the scene in different wavelengths; look at Bands 1 (0.65 μm), 2 (.86 μm), 6 (1.64 μm), 20 (3.7 μm), 31 (11 μm) and 35 (13.9 μm). Using the ***plot/animate*** command on the main menu note how clouds appear larger at 11 μm than at 3.7 μm (select those two bands and toggle back and forth between them).

b) Comment on the cloud and clear sky characteristics in each of these spectral bands. Which three bands would you choose to determine a cloud / no cloud "mask"; why? What radiative characteristics of the cloud, surface and atmosphere led you to select these spectral bands. What reflectance or brightness temperature thresholds would you use? (Use the ***plot/RGB*** command on the menu bar to verify your selection.)

c) Consider the Band 31 (11 μm) image. What is the range of brightness temperatures over the land surface? What are the brightness temperatures of the different cloud types in the scene? Could you assume something about cloud phase from the cloud brightness temperatures?

d) Use the ***plot/ScatterPlot*** math tool to combine spectral bands which can be used to detect clouds and infer cloud properties (hit return after entering numbers in the box). Try the following band combinations, and indicate the advantages and disadvantages of each combination for cloud detection.

Band 2 (0.86 μm) / Band 1 (0.65 μm)
Band 1 (0.65 μm) – Band 6 (1.6 μm) / Band 1 (0.65 μm) + Band 6 (1.6 μm)
Band 2 (0.86 μm) – Band 1 (0.65 μm) / Band 2 (0.86 μm) + Band 1 (0.65 μm)

e) Click on the ***ScatterPlot*** button and then, using ***pseudoChannel*** function, estimate what threshold values you would use in each test to indicate the presence of clouds? (Use the ***get points*** function to select points in the scatter plot and to map them on the MODIS scene.)

f) Using the ***plot/ScatterPlot*** math tool plot Band 31 (11 μm) versus [Band 29 (8.6 μm) minus Band 31 (11 μm)]. With the ***PseudoChannel*** tool, construct an image of [Band 29 (8.6 μm) minus Band 31 (11 μm)]. In the same way construct an image of [Band 31 (11 μm) minus Band 32 (12 μm)]. Note where the largest differences occur in each image. Describe what you see. Are there clouds in these brightness temperature difference images that could not be seen in the visible images? Close the ***Selected Region and Scatter Plot*** figure.

Exercise 3

4. Now, in the main figure, select ***band number*** 31 (11 μm), temperatures and select the region shown in Figure 3(***Select*** function). Then use the ***plot/ScatterPlot*** function.

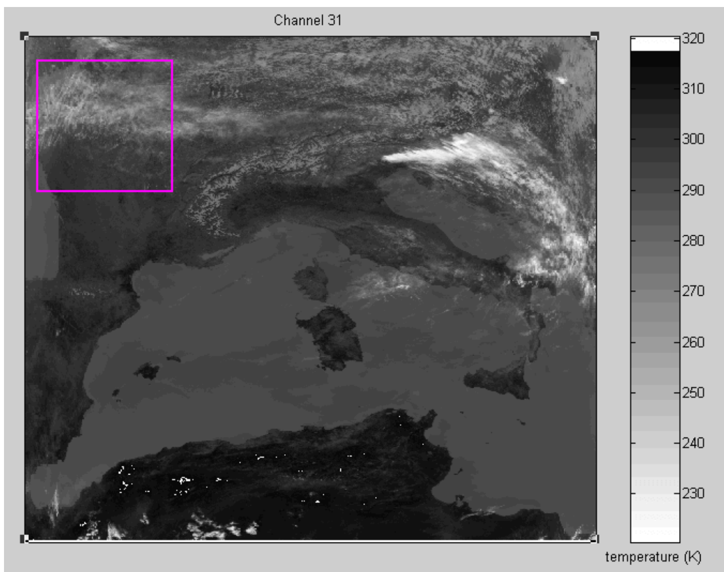


Figure 3: Clouds and clear sky

a) Plot Band 31 on the x-axis and Band 31 – Band 32 on the y-axis and click on the ***ScatterPlot*** button. Use the ***SubRegion*** , ***get points*** and ***PseudoChannel*** tools to determine the type of cloud viewed in this region. Did you notice these clouds in the band 4 image of question 3? (Use the ***refresh*** button to clear out the boxes). Does band 26 (1.38 μm) support or contradict your cloud classification. If you were to design and automated algorithm to detect these cloud types, what would you include in your algorithm?

b) Now clear out the boxes (use ***refresh***). Look at the range of point values that occur along each axis. Which difference is larger for this cloud: [Band 29 (8.6 μm) minus Band 31 (11 μm)] or [Band 31 (11 μm) minus band 32 (12 μm)]?

5. Now, in the main figure, select ***band number*** 31 (11 μm), temperatures and select the region shown in Figure 4 (***Select*** function). Then use the ***plot/ScatterPlot*** function.

a) Plot Band 31 on the x-axis and [Band 31 – Band 32] on the y-axis and click on the ***ScatterPlot*** button. Use the ***SubRegion*** , ***get points*** and ***PseudoChannel*** tools to determine the type of cloud viewed in this region. Examine these cold ice clouds. You should see a hook shape pattern in the plot window. In this case, which brightness temperature difference signal is stronger (larger range of values). Plot the Band 31 (11 μm) on the x-axis and plot [Band 29 (8.6 μm) minus Band 31 (11μm)] on the y-axis, and then plot Band 31 (11 μm) versus [Band 31 (11 μm) minus Band 32 (12 μm)] to bring out this signal.

b) Using the ***get points*** identify the origin of the clear portion of the hook shape by looking at sub-regions of the box outline. Now identify the origin of the cloud portion.

c) To determine what causes the hook shape, consider the following. Calculate the radiances at 8.6, 11, 12 μm for a scene of clear sky at 300 K and a cloud at 230 K with varying cloud amount. Let the cloud fraction vary from N = 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0. Convert the radiances to brightness temperatures. Plot brightness temperature differences 8.6 - 11 versus 11μm for the six different cloud fractions. What does this imply about the hook shape detected in the previous problem? What other factors might influence the shape of this 'hook'?

d) Now load the cloud mask image for this small region using the **Plot/.Level 2 Products/ Cloud Mask** tool in the main menu (select the file MOD35_L2.A2001149.1030.003.2001155022654.hdf). The cloud mask has 4 categories, *Confident Clear, Probably Clear, Uncertain, Cloudy*. How well do you think the cloud detection algorithm worked on this scene?

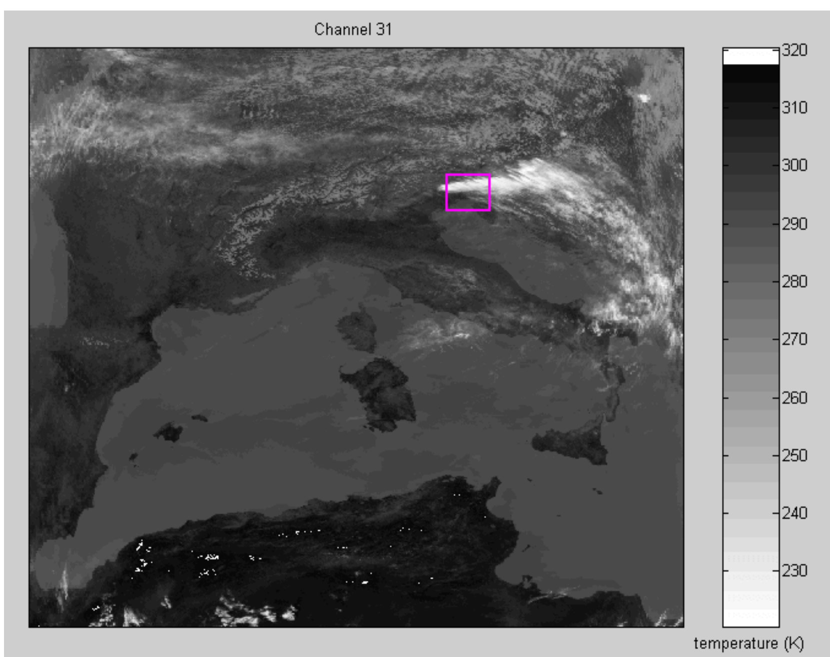


Figure 4. Thermal emission of clouds.

Exercise 4

6. Close the cloud mask window, but keep the brightness temperature figures of the cirrus open. Using ***Load Data*** in the main menu load MOD021KM.A2001162.0645.003.2001167183512.hdf. This shows a dust storm over Iran. Use ***Select*** to highlight the approximate region:

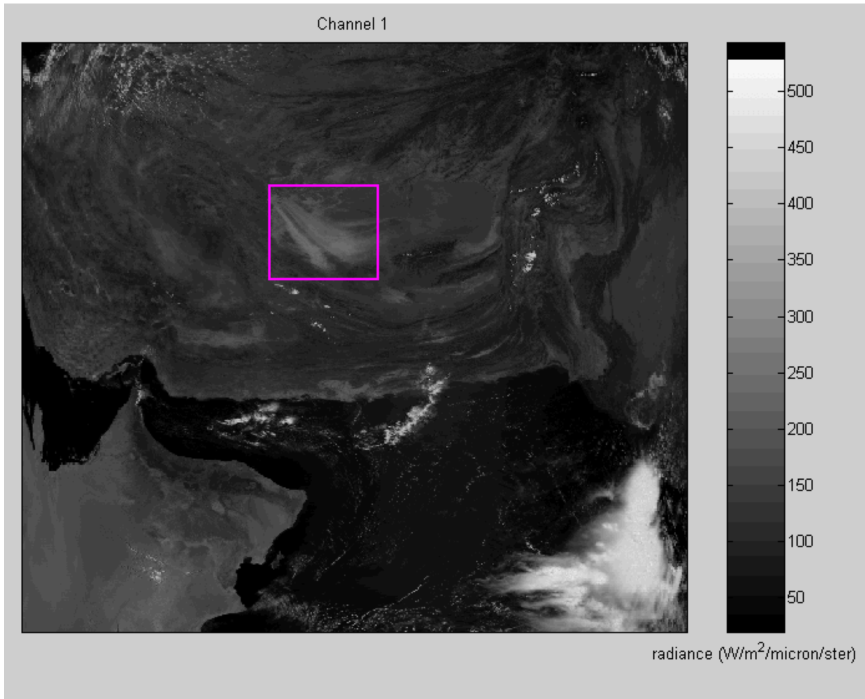


Figure 5. Dust scene over Iran.

a) Plot Band 31 on the x-axis and [Band 31 - Band 32] on the y-axis and click on the ***ScatterPlot*** button. 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. Repeat with Band 31 (11 µm) versus [Band 31 (11 µm) minus Band 32 (12 µm)]. Use the ***SubRegion*** , ***get points*** and ***PseudoChannel*** tools to determine the features of the dust storm. Which brightness temperature differences show a larger range of values. How does this compare to the cloud diagrams? Do you think you can distinguish dust storms from clouds using these channels.

7. With reference to one of the homework questions, consider the following application. An infrared radiometer with 4 spectral bands is viewing a clear field of view (fov). The following table presents wavelength and noise equivalent radiance. The surface temperature is 300 K. A little bit of high opaque cloud at 230 K moves in. How much cloud can be present in the fov (what percentage) and still not be detected (be within instrument noise) for each band? Use B proportional to T^X where $x=c_2*\nu/T$.

Band	Wavenumber (cm^{-1})	NEDR ($mW/m^2/ster/cm^{-1}$)
1	2500	0.004
2	1450	0.1
3	900	0.1
4	700	0.8