

IMAPP Remote Sensing Workshop

1 Mar. 2006

Andenes, Norway

LAB 2

Lab on MODIS Cloud and Aerosol Detection

This Lab was prepared to provide practical insight into MODIS IMAPP level 2 product retrieval theory and technique. It aims to provide the user with a basic understanding of the Cloud Radiative Properties (Ex. 1), of the strength and weaknesses of the MODIS Cloud Mask (Ex. 2 and 3), of the MODIS aerosol optical depth product (Ex. 4) and the MODIS infrared phase product (Ex. 5). It is our recommendation that you keep a log of the Lab in electronic form with your results (images and comments related to the exercises). You can either edit the doc form of this lab, or make your own log document. At the end of the Lab session we will ask you to submit a copy of your log file to the instructors. This will allow us to verify how well/poorly the information was conveyed to you. You are welcome, but not requested, to include your names in the document.

Exercise 1: Exploring clouds in the MODIS scene

1. Analyze the cloud scene over Europe and the North Atlantic on 18 April 2003 (day 108) detected by MODIS using the Hydra software. Proceed in the following steps. Start up Hydra and load local image file MYD021KM.A2003108.1245.004.2004089182113.hdf.

(a) Look at clouds in different thermal emissive bands. For each type (by selecting a single Field Of View) describe the changes in radiance or BT detected in different channels (top panel of Multi-channel viewer window).

(b) Select the following region (outlined approximately by green box) from the Hydra window.

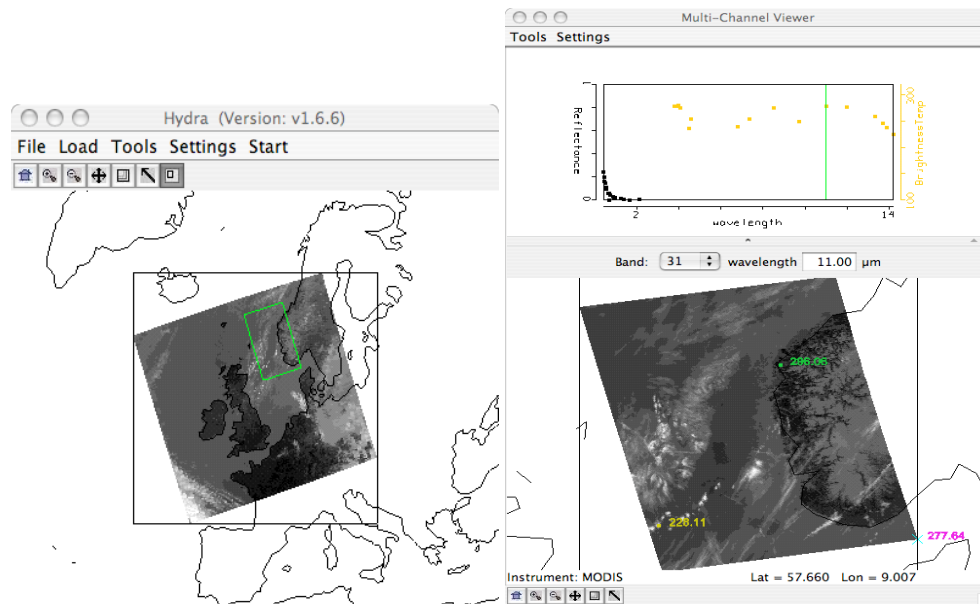


Figure 1: Subset selected for full resolution analysis of snow, clouds, and clear sky. Full resolution visible image of subset selected (right).

(c) Investigate the radiances emanating from the cloud within the scene in different wavelengths; look at the following bands

- Band 1 (0.65 μm) – clouds and snow reflecting
- Band 2 (0.86 μm) – contrast between vegetation and clouds diminished
- Band 26 (1.38 μm) – only high clouds and moisture detected
- Band 6 (1.64 μm) – water clouds reflecting, snow and ice clouds not reflecting
- Band 20 (3.7 μm) – thermal emission plus solar reflection
- Band 31 (11 μm) – clouds and snow colder than rest of scene
- Band 35 (13.9 μm) – only upper atmospheric thermal emission detected.

Once done close the Multi-Channel Viewer window.

Exercise 2: Exploring the MODIS Cloud Mask Algorithm

1. From the Hydra window reload the same MODIS data over Europe and the North Atlantic on 18 April 2003 (day 108), and start the Multi-Channel viewer with the lower resolution data. Proceed in the following steps.

(a) What are some reasons why the cloud Brightness Temperatures (BT) are different in different infrared bands and reflectances (also indicated with r) different in different visible channels?

(b) Now overlay the cloud mask product over the image displayed in the Multi-Channel Viewer by loading local image file MYD35_L2.A2003108.1245.hdf. The 4 category cloud mask will be displayed over the image and a new cloud mask window will be displayed. Please note that the highest confident clear category (green) is not displayed, you will see the underlying image for this category. Select ***Cloud Mask Window***, ***Cloud Mask Parameters***, ***Unobstructed_FOV_Quality_Flag***. The Cloud Window will reformat with a button appearing at the bottom that will allow you to toggle the mask off and on. Comment on the performance of the mask at this reduced resolution.

(c) Are there regions where it appears to do better/worse?

(d) From your examination of the data, can you explain why the cloud mask might have failed in some regions?

(e) Go back and look at the data again in different bands if you need to. When you have finished, make sure the cloud mask is toggled off and close the Cloud Mask Window.

2. Go to the main Hydra window, click on the bottom menu toolbar ***subset image*** icon (last one on the right) and select the following region by holding down the right mouse button and dragging it over the region of interest (outlined approximately by green box in Figure 2):

(c) Which three bands would you choose to determine a cloud / no cloud “mask”; why?

(d) What reflectance or brightness temperature thresholds would you use? (Use the pick image button (*Arrow*) from the bottom toolbar, and then hold down the right mouse button as you roam around the image to get the pixel values, or the *Select Color Range* option from the *Settings* drop down menu). Save your thresholds.

3. Now select *Linear Combinations* from the *Tools* menu at the top of the Multi-Channel Viewer window. A new window (*Channel Combinations Tool*) will open. You can create combined channel images and scatter plots which can be used to investigate the scene and infer atmospheric and surface properties by selecting the channels and mathematical operations located at the bottom of the window. To select a channel, you can either type the wavelength into the equation boxes at the bottom or move the colored bars to the desired wavelength using the *Grab* tool (*Arrow*) on the main toolbar and holding down the right mouse button while located on the color bar. Try the following band combinations to create combined images (once the channels and operations are correctly selected, click on the *compute* button), and indicate the advantages and disadvantages of each combination for cloud detection. It may help to set the color scale to grey (the default is inverse grey). Try to think globally.

- Band 20 (3.80 μm) – Band 11 (11 μm) (BT)
- Band 2 (0.855 μm) / Band 1 (0.650 μm) (r)
- Band 31 (11 μm) – Band 32 (12 μm) (BT)

(a) Using both the select image tool (*Arrow*) along the bottom combined image window and the *Select Color Range* option from the *Settings* drop down menu to enhance different regions, estimate what threshold values you would use in each test to indicate the presence of clouds?

Band	Threshold values
Band 20 (3.80 μm) – Band 11 (11 μm) (BT)	
Band 2 (0.855 μm) / Band 1 (0.650 μm) (r)	
Band 31 (11 μm) – Band 32 (12 μm) (BT)	

(b) Values under the cursor can be obtained by selecting the *select image* tool (*Arrow*) from the bottom toolbar and roaming around the image while holding down the right mouse button. When you choose *Select Color Range*, you

can move the limits of the enhancement around (or type the values in) and see how your thresholds work at detecting clouds. It may help to create a scatter diagram of the images. By displaying the band you wish to have on the x and y axes as an individual combined image (**deselect the mathematical operator**) you can then select the **axis button** at the bottom of the combined image window and then click on the **Scatter** button in the Channel Combination window. A separate window containing the scatter diagram will appear. You can then map the scatter points onto the axes image windows by selecting a region of points using the **select buttons** on the bottom and the **right mouse button**, or you can draw a region by hand by selecting the **Curve** button and moving the mouse while holding down the right mouse button.

f) The cloud mask threshold tables consist of 4 values, here are the thresholds files for daytime ocean:

Test bands (Name)	0 percent chance Clear Threshold	50 percent Clear Threshold change	100 percent Clear Threshold chance	Power (Linear Slope between 0% and 100% clear conf.)
Band 31 –Band 20 11-4 μm BT (do11_4lo)	-10.0	-8.0	-6.0	1.0
Band 31 11 μm BT (dobt11)	267.0	270.0	273.0	1.0
Band 35 13.9 μm BT (doco2)	222.0	224.0	226.0	1.0
Band 27 6.5 μm BT (doh20)	215.0	220.0	225.0	1.0
Band 2 .86 μm r (doref2)	0.065	0.045	0.030	1.0
Band 26 1.38 μm r (doref3)	0.04	0.035	0.03	1.0
Band 2/Band1 .86 μm r/ .65 μm r (dovrathi)	0.95	1.10	1.15	1.0
Band 2/Band1 .86 μm r/ .65 μm r	0.95	0.90	0.85	1.0

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(g) How do the thresholds that you set compare with these?

(h) Can you think of reasons why they might be different?

(i) Which thresholds would you change for this scene, and how would you implement these changes?

When you have finished, close the Linear Combinations window.

Exercise 3 MODIS Cloud Detection and Cloud Mask Algorithm

1. Using the same granule of MODIS data used in exercise 1: select the small section of data shown in Figure 3 in the main Hydra window to be examined at high resolution.

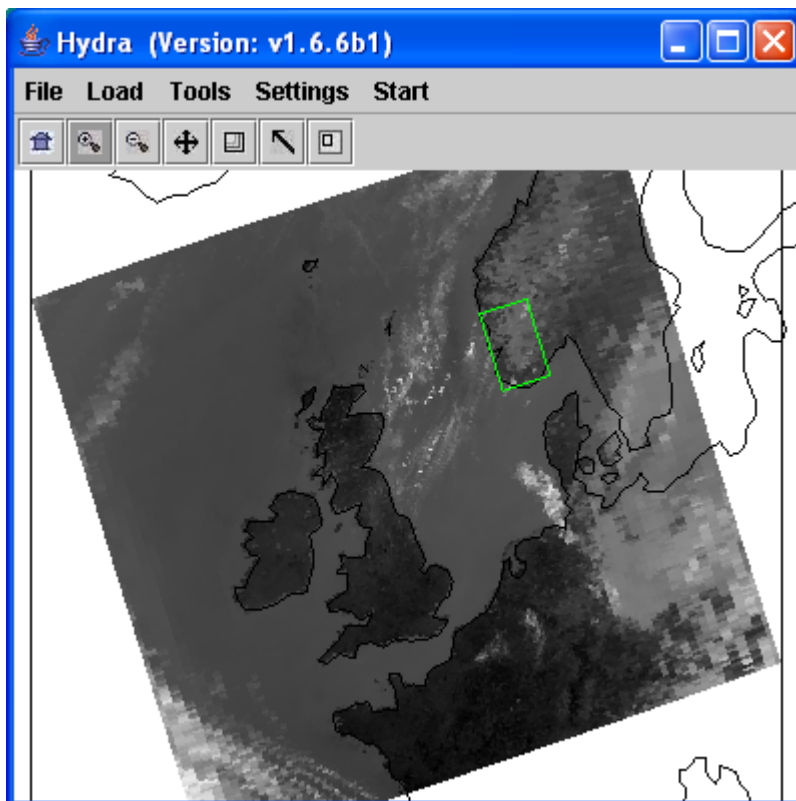


Figure 3. Snow covered section of image from Aqua MODIS on 18 April 2003 at 12:45 UTC.

Overlay the MODIS cloud mask *Unobstructed_FOV_Quality_Flag* from file MYD35_L2.A2003108.1245.hdf on top of the image in the Multi-Channel Viewer window. Load the band 1 (.68 μm) reflectances in the Multi-Channel Viewer. Toggle the cloud mask off and on.

(a) From your experience in Exercise 2, does the mask do a good job around the snow edges? Look at other bands if you need to.

2. The cloud mask algorithm looks for snow in daytime scenes. If snow is found, then the cloud mask will set the final confidence of clear to be high. Open the Linear Combinations window, and create an image of the Normalized Difference Snow Index (NDSI):

Band 4 (0.55 μm) - Band 7 (2.1 μm) / Band 4 (0.55 μm) + Band 7 (2.10 μm) (Reflectances)

(a) Describe the results.

(b) What threshold would you use to identify snow? Using the *Set Color Scale->Color* is effective at highlighting the snow regions very well.

3. Now load just the Band 1 image (0.68 μm) into the Linear Combinations window.

(a) What threshold would you use to separate the snow covered are from the rest of the land background?

(b) Using the thresholds that you just set, are there any regions that you can see are snow in the Band 1 image and are not flagged as snow by the NDSI?

(c) The actual cloud mask snow NDSI threshold is $>.75$. If the cloud mask does not think there is snow on the ground after applying this test, the regular cloud mask tests will be implemented. The Band 1 (0.68 μm) reflectance cloud test threshold over land is $>.22$. Are there values $>.22$ in the Band 1 (0.68 μm) image that are not flagged as snow by the NDSI?

(d) How do these regions correspond to the final cloud mask product?

(e) Is there way that you can think of to improve this result? When you have finished, close the Linear Combinations window.

Exercise 4 Aerosol Detection

1. Select the small section of data shown in Figure 4 in the main Hydra window to be examined at high resolution.

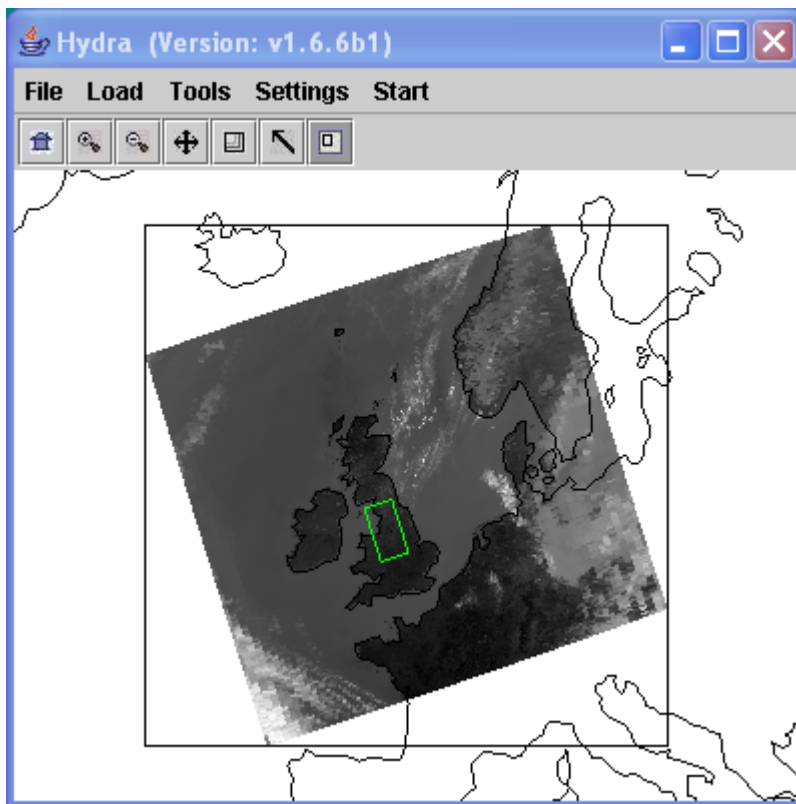


Figure 4. Smoke covered section of image from Aqua MODIS on 18 April 2003 at 12:45 UTC.

Examine the scene in several different bands including Band 1 (.68 μm), Band 3 (0.47 μm), 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	Band 3	Band 7	Band 20	Band 21	Band 31
	(0.65 μm)	(0.47 μm)	(2.1 μm)	(3.8 μm)	(3.99 μm)	(11 μm)

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(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. Look at the smoke over land and water separately. 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 do these compare?

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 a few locations over the land.

(b) What values did you get?

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

(d) Are the τ values that you get consistent as the plume moves out over water? Once you are done, close the Linear Combinations Window.

4. Now load the cloud mask for our small section of data (file MYD35_L2.A2003108.1245). 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 5 Cloud Phase

1. Load in the MODIS scene over Europe and the North Atlantic from 27 June 2003 (day 178) MYD021KM.A2003178.1210.004.2004116185031.hdf into the Hydra main window. Open the Multi-Channel Viewer and select the small scene shown in Figure 5 in the main Hydra window.

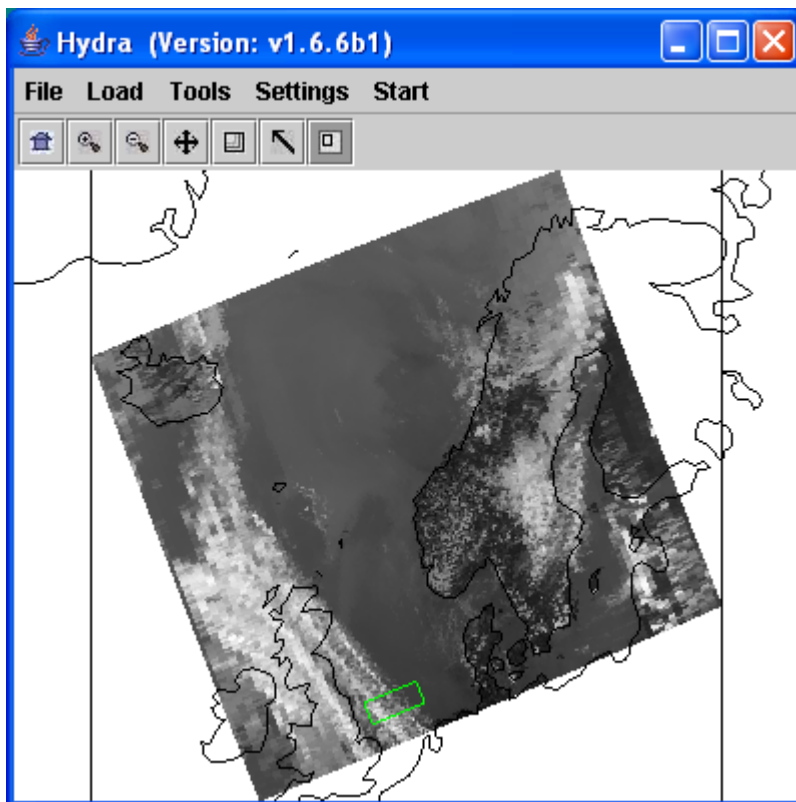


Figure 5. Ice cloud section of image from Aqua MODIS on 17 June 2003 at 12:10 UTC.

(a) Examine the scene. What range of brightness temperatures do you see in Band 31 (11 μm)?

(b) Can you tell what kind of clouds these are?

(c) Look at the scene in Band 1 (.68 μm), Band 20 (3.8 μm), Band 35 (13.9 μm), and Band 26 (1.38 μm). Which band helps you determine the height and or the phase of the cloud?

Bands 1 (0.65 μm)	Band 26 (1.38 μm)	Band 20 (3.8 μm)	Band 35 (13.9 μm)

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 image is set to *gray*.

(a) Describe what you see. Where are biggest differences?

(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?

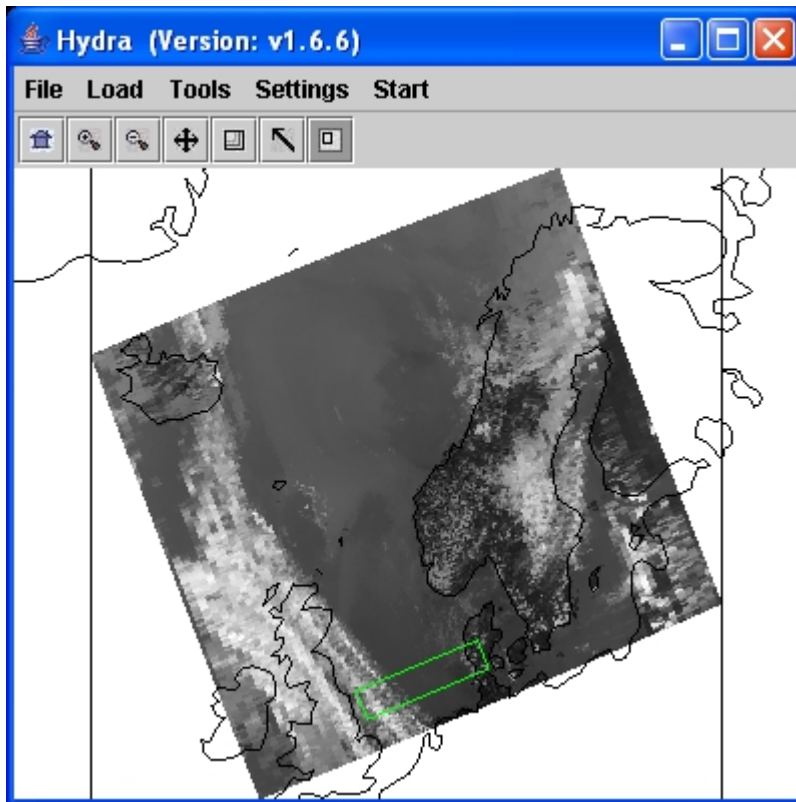


Figure 6.

4. Close the Linear Combinations Window and re-draw the small region you selected before, but extend it eastward to capture the small clouds in Denmark, as shown in figure 6. Examine this scene as you did in section 1(a):

(a) What type of cloud do you think we added and why?

(b) Now repeat the steps in section 2(a). What has changed?

(c) Use one of the Mapping Boxes within the *Band 31 Linear Combination* window to select a region that is similar to the original small full resolution area shown in Figure 5. Does the shape look familiar?

5. Now map a different color box in the *Band 31 Linear Combination* window that outlines a region over some of the small clouds in and around Denmark. Describe the results.

(a) Where do these points lie in the *Scatter Diagram*? Are they grouped together?

(b) What brightness temperature difference range [BT8-BT11] do you find?

(c) How much overlap occurs in the *Scatter Diagram* with the Ice Cloud?

6. 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 water clouds.

(b) After this investigation, how would you describe the strengths and weaknesses of the algorithm? Close all the used windows except the Hydra one.

Exercise 5 Extras

1. From the Hydra window re-load the same granule used in Ex. 1,2,3. Sub-select a region with clouds and clear sky and load the full resolution image at 4 and 11 microns.

(a) Do you notice any change in the cloud spatial dimensions? If yes, in which band does the cloud appear bigger?

(b) Can you guess why?