Hampton University Direct Broadcast Polar Orbiter Workshop
7 June 2017   Lab 2 Part 1: Investigating MODIS and VIIRS SSTs
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Table 1: MODIS Band 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

Table 2: VIIRS Band Number, Wavelength (μm), and Primary Application

Reflective Bands			Emissive Bands		
M (780 m FOV)					
1,2	0.412, 0.445	ocean color/aerosols	12	3.74	sfc/cld temperature
3,4	0.488, 0.555	"	13	4.05	SST, fires
5-7	0.672, 0.746, 0.865	"	14	8.55	cloud properties
8	1.24	cloud particle size	15	10.8	SST, clouds
9	1.38	thin cirrus	16	12.0	SST, moisture
10	1.61	snow vs cloud			
11	2.25	cloud particle size			
I (390 m FOV)					
1	0.64	imagery	4	3.74	imagery clouds
2	0.86	NDVI	5	11.5	cloud imagery
3	1.61	snow map			

Table 3: Comparable VIIRS/MODIS Bands

MODIS		VIIRS-M	
8, 9	0.415, 0.443	1,2	ocean color
10, 12	0.490, 0.565	3,4	"
14-16	0.681, 0.75, 0.865	5-7	"
5**	1.24	8	cld particle size
26	1.38	9	thin cirrus
6**	1.61	10	snow
7**	2.13	11	cloud properties
20	3.75	12	sfc/cld temp
23	4.05	13	sfc temp
29	8.55	14	sfc/cld temp
31	11.0	15	sfc/cld temp
32	12.0	16	sfc/cld temp
		VIIRS-I	
1*	0.645	1	imagery
2*	0.865	2	"
6**	1.64	3	"
20	3.75	4	"
31	11.0	5	"

* available at 250 m, ** available at 500 m resolution
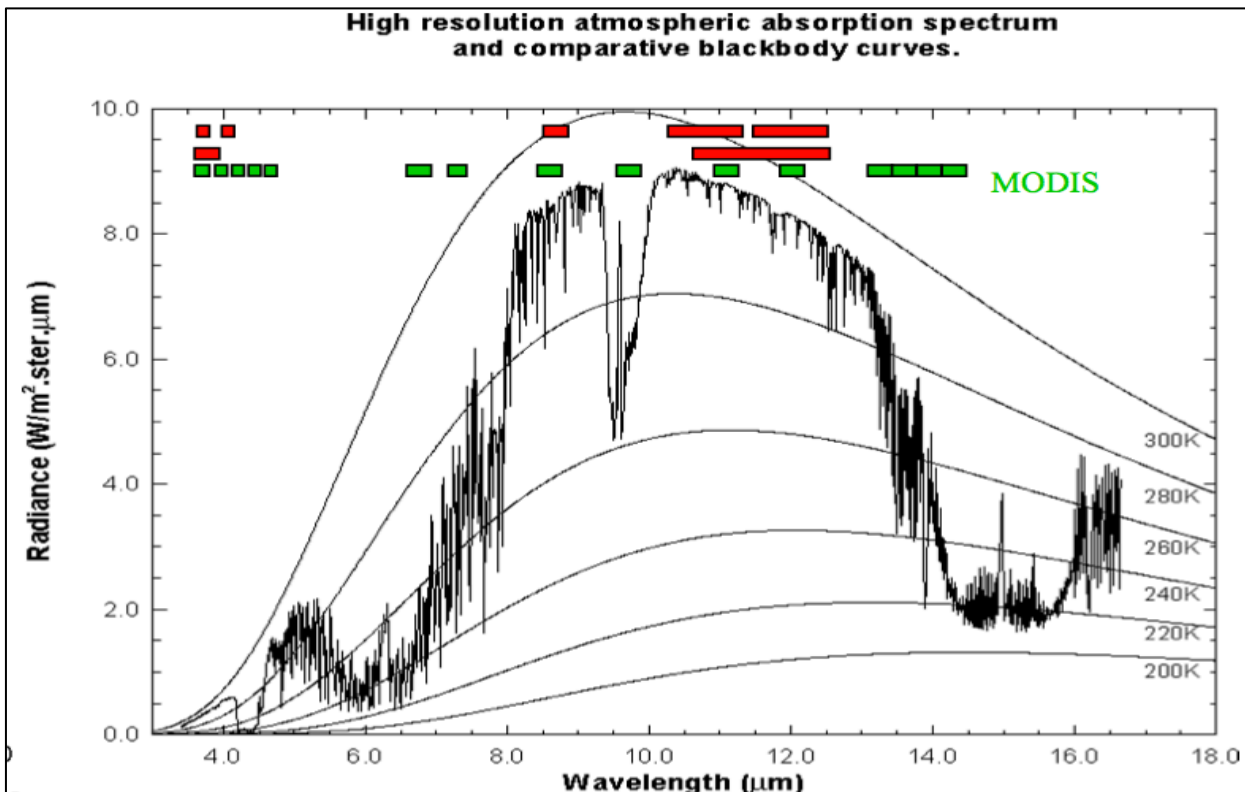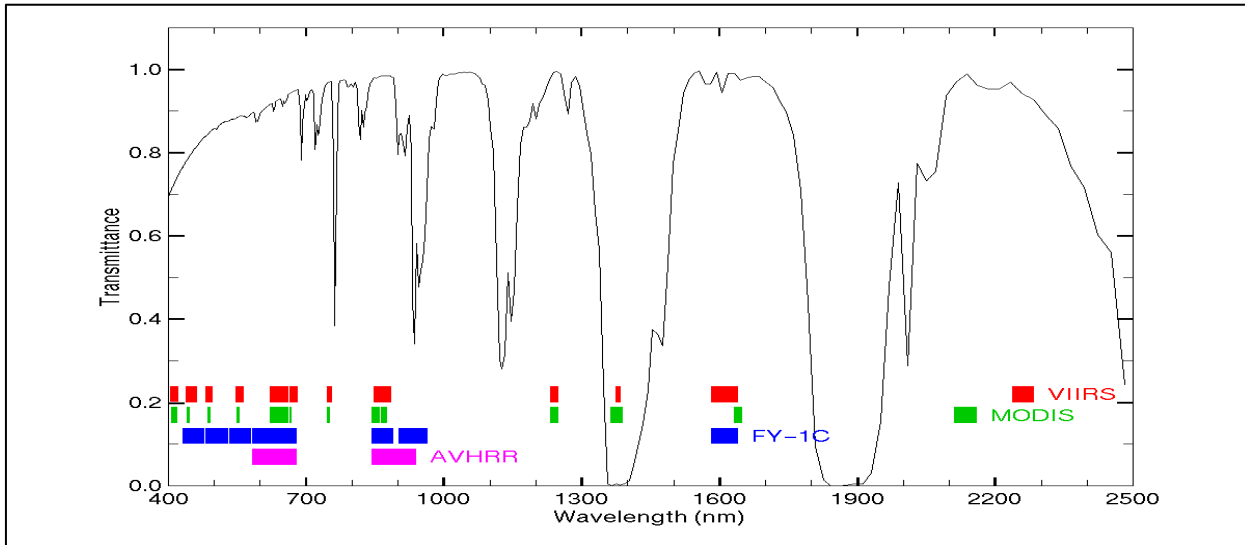
Figure 1: MODIS and VIIRS bandwidths plotted against standard atmosphere transmittance in the visible and near-infrared wavelengths (top) and black body radiance at terrestrial temperatures in infrared wavelengths (bottom).

1.1. Launch Hydra, choose **File** from the **Main HYDRA window**, click on **Directory->VIIRS** and guide HYDRA to the directory containing S-NPP VIIRS data from 19 June 2014. Select the directory and click on **Choose**. Select the region shown in Figure 2 by holding down the left mouse button as you outline the region with the mouse, and then select M-Band 5 (.67 μm), and click on **Display**.
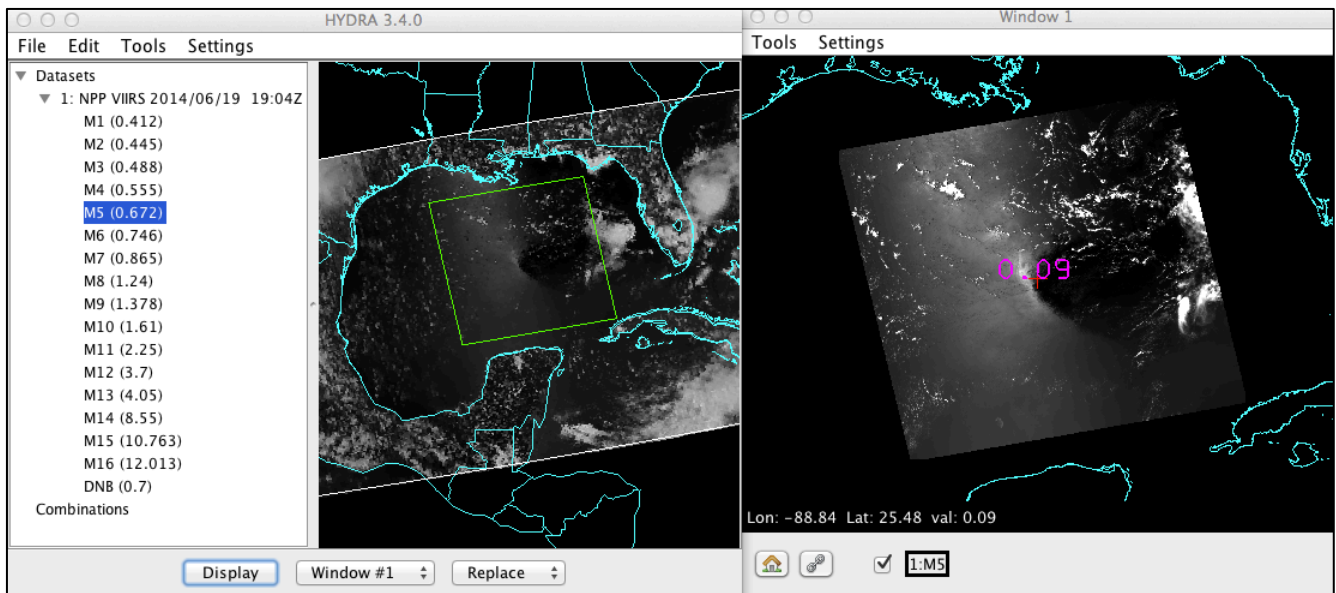
Figure 2: VIIRS data Hydra screen capture from 19 June 2014, 19:04 UTC with a full resolution display of M-Band 5 (.67 μm) in the right panel.

2. Make a natural color (true color) image of this region by choosing **Tools->RGB** Composite from the main HYDRA window. Highlight a color box from the **RGBComposite** window, and then choose a dataset band from the S-NPP VIIRS band list to insert. Choose **Red->M-Band 5 (.67 μm), Green->M-Band 4 (.55 μm) and Blue->M-Band 3 (.48 μm)**. Once the RGBComposite boxes are filled, select the **Create** button. Your RGBComposite bands will be added to the bottom of the dataset list, under the **Combinations** heading. Once it has been added, overlay the band combination image in Window 1. Enhance your RGB image by clicking on the **band combination box** in your image Window 1. A window will open allowing you to change the range of each band that went into the composite. Change the **Gamma** value in the bottom of the enhancement window to .3, and hit return. Describe the patterns observed in the water.

3. Now investigate the region by overlaying the reflectances in Band 10 (1.6 μm) and the brightness temperatures in Band 12 (3.7 μm) and Band 15 (10.7 μm). Enhance the images to bring out features in the water. Briefly describe the features and their characteristics. Where are the warmest and coldest temperatures over the water in Band 12 (3.7 μm) and Band 15 (10.7 μm)? Why would the temperatures be different for these two infrared window channels? How does the dark/bright region in the middle of the visible reflectance data match up with the temperatures in Band 12 (3.7 μm) data? How about the visible bright spot in the middle – is it a cold or warm region in the infrared (3.7 μm)? What is this dark/bright feature in the data?

4. Remove all of the overlays from your Window except for the true color and M-Band 5 image frames (Select the **red circle with a "-" in it** to delete a display). Now overlay the MODIS SST file from a similar Aqua overpass by clicking on **File**, click on **File(s)** and selecting **a1.14170.1915.mod28.hdf**. The MODIS SST is a 1km product file, with the temperatures displayed in Degrees C. It is not cloud cleared, so focus on the water by setting the enhancement boundaries. You can either **left click+drag** the green bars (grab the green boxes at the top) to change the lower or upper thresholds, or type them manually into the range boxes. Change the lower threshold to 20 C and the upper threshold to 35 (See Figure 3).
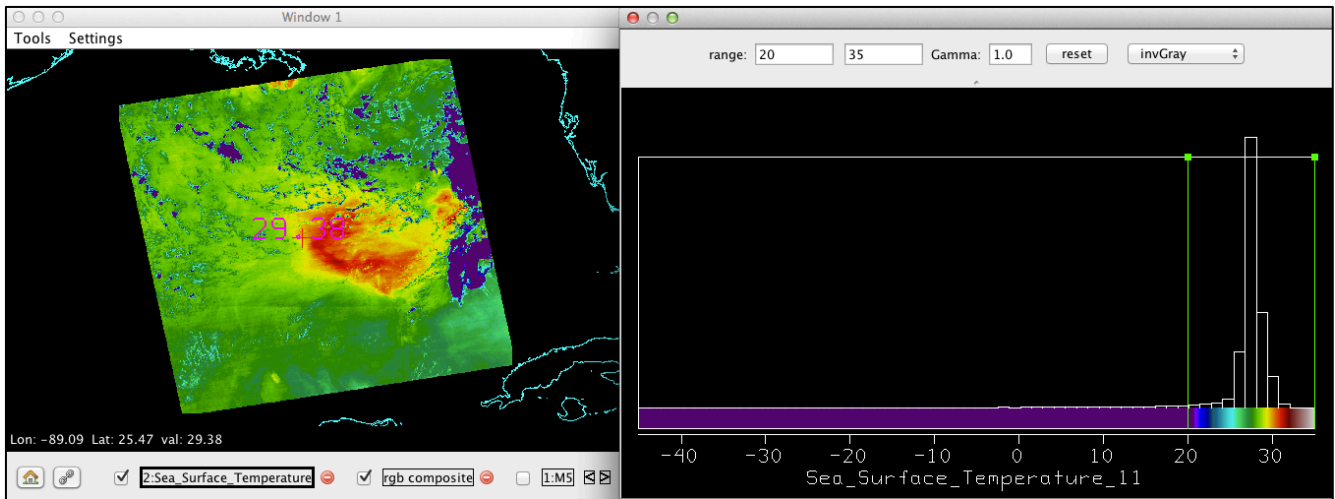
Figure 3: Aqua MODIS Sea Surface Temperature product image (left) and the data color scale and range for the Aqua pass from 19:15 UTC, 19 August 2014.

5. How does the warmest region in the SST image compare with the pattern you have identified in the VIIRS visible and infrared bands? What is causing this region of warm ocean surface temperatures? Hint: Figure 4 is a Surface Analysis from 18 UTC, 19 June 2014.
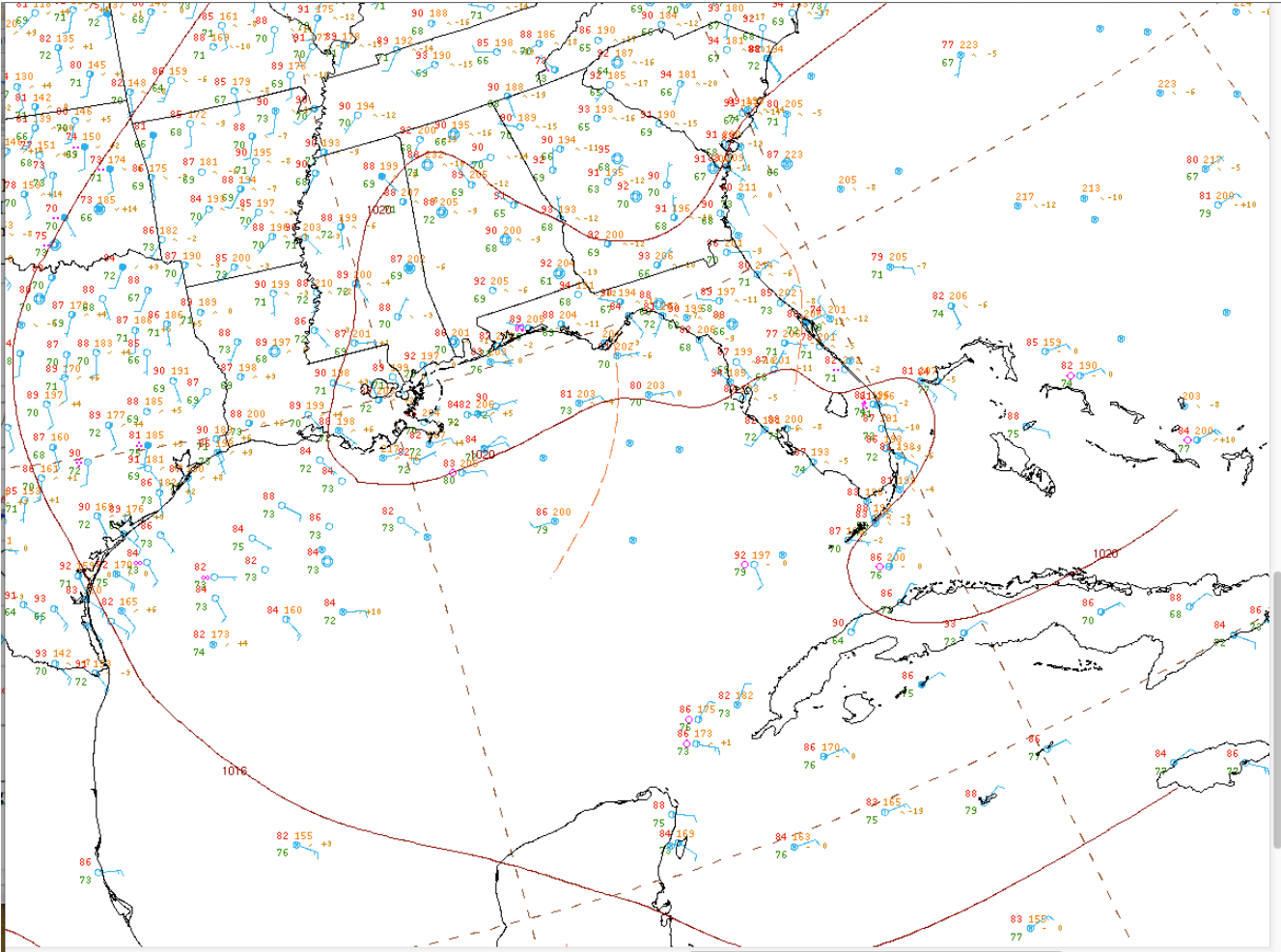

Figure 4: NOAA NWS North American surface analysis from 18 UTC, 19 June 2014.

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6. How might this help you in quickly identifying sea state?

7. Examine other regions using the MODIS SST from this day. Look at the high spatial resolution data around the Gulf coast states, around Cuba and the Yucatan Penisula. What are the advantages and disadvantages of this polar data set when compared with other SST information available over the Gulf of Mexico and Atlantic waters?   Close HYDRA when you are done.

Lab 2 Part 2: Investigating Clouds Using MODIS

2.1 Launch Hydra, click on **File**-> **File(s)**, and load the Terra MODIS Level 1B 1000m data from 19 May 2017 (Day 139), 15:49 UTC (**t1.17139.1549.1000m.hdf**). Select the sub-region shown in Figure 5, and display Band 31 (11.0 μm) brightness temperatures at full spatial resolution.   Change the image enhancement from **Inverse Gray** to **Inverse Rainbow** and note the range of temperatures across the scene.
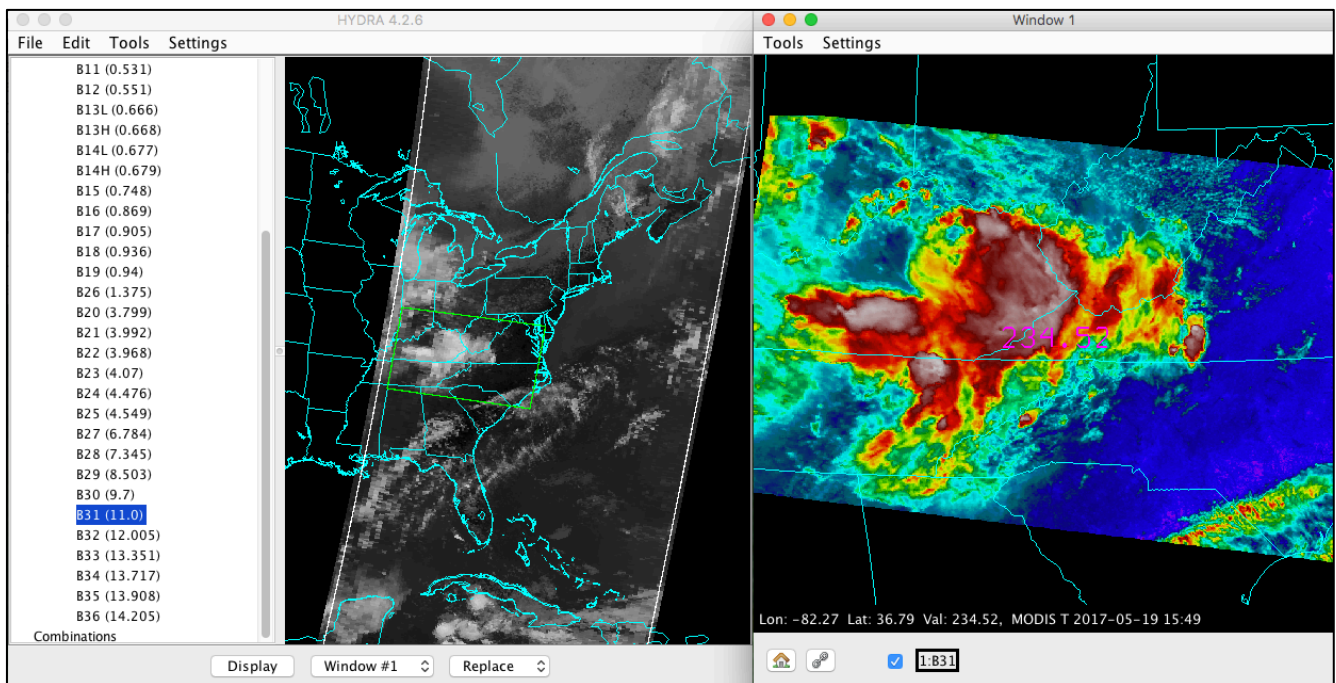
Figure 5: Terra MODIS observations from 19 May 2017, 15:49 UTC.

2. Now load Band 1 (.65 μm) and Band 6 (1.6 μm) into new individual windows. Make a quick scan by dragging the cursor and noting how and where the reflectances differ in these two bands. Where are the differences the greatest? Use the Band 31 (11.0 μm) brightness temperatures to help you guess at what might be the cause of the largest reflectance differences.

3. Create a scatter diagram between Band 1 (.65 μm) and Band 6 (1.6 μm) by selecting **Tools->Scatter** in the MODIS Band 1 image window and then **Tools->Scatter** in the Band 6 image window.   Click on the "**points**" **button** on the scatter diagram to switch to **"density"**, and draw a curve around the large protruding lobe of points, as shown in Figure 6. Where do these points lie in the image? Map other features in the scatter diagram to the corresponding image locations. What features have low reflectivities in both bands? High reflectivities? How could you use these two bands to tell you something about cloud phase? Why is that important?

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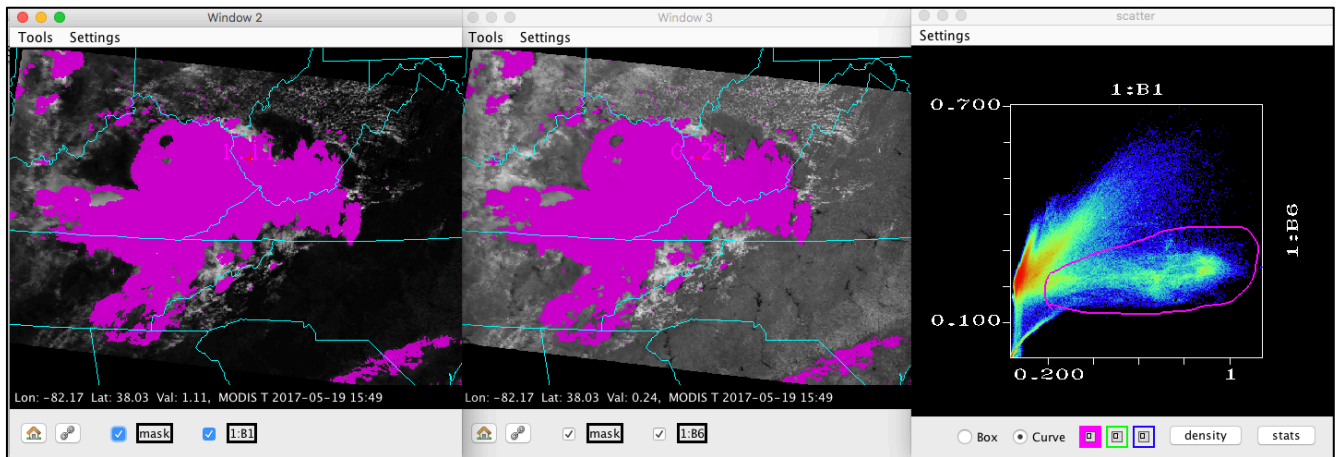
Figure 6: Band 1 (.65 μm) (left panel) and Band 6 (1.6 μm) (center panel) reflectance images along with the scatter diagram created by plotting Band 6 versus Band 1 (right panel).

4. Now close the scatter diagram window and open the MODIS cloud product file from the same date and time (**File-> File(s)-> t1.17139.1549.mod06.hdf**). Choose **Cloud_Phase_Infrared**, and **Overlay** this field onto the Band 6 (1.6 μm) image. The color coding for the Cloud Phase product is:

> **Pink** is Ice Cloud
> **Blue** is Water Cloud,
> **Yellow** is possible Mixed Phase Cloud and
> **Green** is Undetermined.

Toggle between the Cloud Phase and Band 6 (1.6 μm) image to see how the phase matches with the low and high reflectances in the clouds. How well does the Terra MODIS cloud phase (MOD06) product discriminate ice/water cloud in this scene? Do you think you could quickly determine cloud phase by looking solely at Band 6 (1.6 μm). What could this tell you about the maturity of a thunderstorm or complex of storms? What are the limitations of using only Band 6 reflectances to determine cloud phase?

5. Now go back to the Band 31 (11.0 μm) data. Display the Band 34 (13.7 μm) brightness temperatures into a new window. Draw a transect through the cold cloud deck in Band 31 (11.0 μm) as show in Figure 7 by selecting **Tools->Transect** and positioning the line by grabbing and moving the end points. Add the Band 34 (13.7 μm) brightness temperatures to the transect by selecting **Tools->Transect** in that image window. How do the brightness temperatures compare? Where are the temperatures similar and where are they different? What is causing the differences? Now display Band 35 (13.9 μm) and Band 36 (14.2 μm) in new windows, and add transects for both. What is causing the difference in the temperatures away from the cold clouds? How could these bands be used to differentiate different types of clouds? Close the transect window when you are finished.

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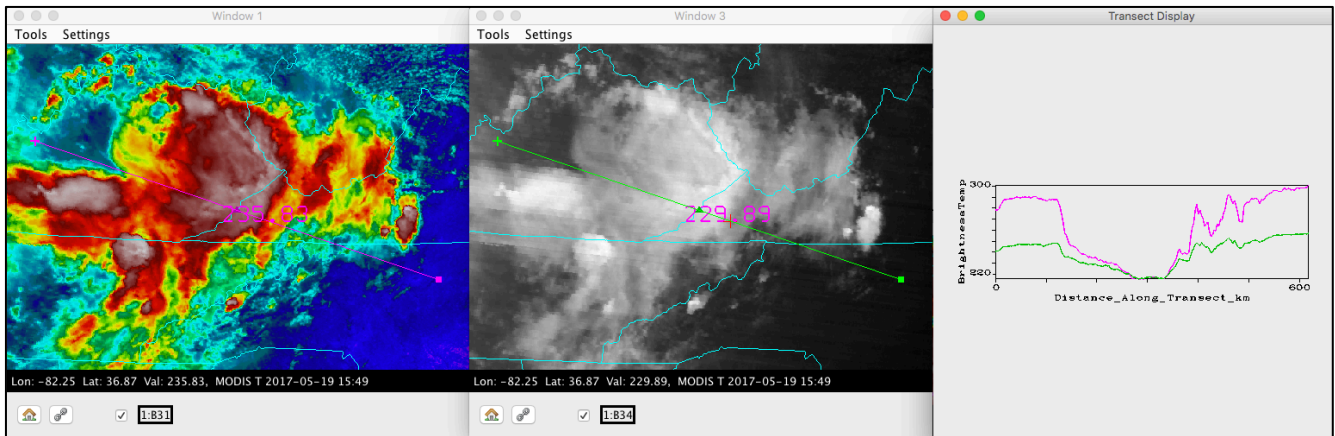
Figure 7: Terra MODIS Band 31 (11 micron) (left panel) and Band 34 (13.7 micron) (center panel) brightness temperature images and a transect of values through cold cloud and surrounding regions (right panel).

Extra Credit – Continuing Cloud Investigation

6. Display the Band 26 reflectances (1.37 μm) (located in the band list after band 19) in a new window. Create a scatter diagram of Band 31 (11.0 μm) brightness temperatures versus Band 26 (1.37 μm) reflectances (choose **Tools->Scatter** in both windows starting with Band 26). Create a second scatter diagram of Band 36 (14.2 μm) brightness temperatures versus Band 26 (1.37 μm) reflectances. Compare the two diagrams (see Figure 8). What is the major difference between the two? What do the slopes of the data points tell you about the relationship between these two bands? Compare the details in the clouds between the Band 26 (1.37 μm) and Band 36 (14.2 μm) image. Are the clouds that are observed similar? Which image is "crisper" (provides more detail, such as in the tops of the clouds)? What are the advantages and disadvantages of using these two spectral bands to look at high cloud.
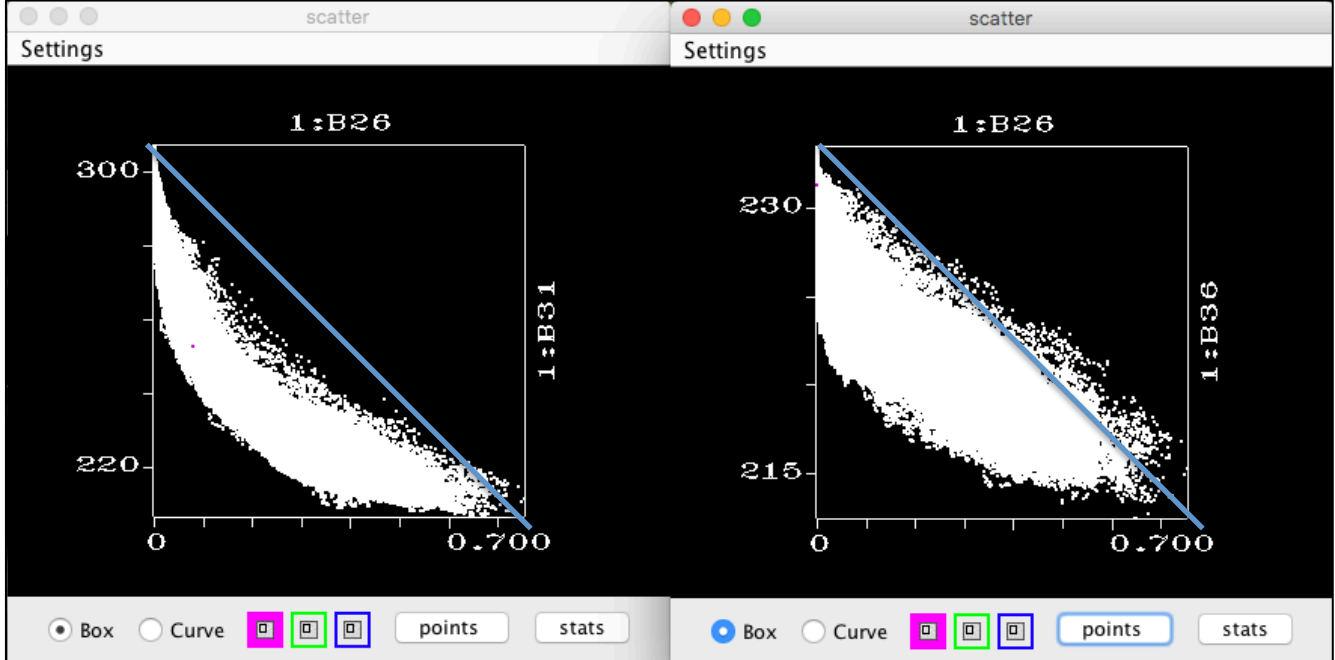
Figure 8: Scatter diagram of Band 31 (11.0 μm) brightness temperatures versus Band 26 (1.37 μm) reflectances (left panel) and Band 36 (14.2 μm) brightness temperatures versus Band 26 (1.37 μm) reflectances (right panel) from the 19 May 2017 Terra MODIS data set.

Lab 2 Part 3: Investigating the Potential for Severe Weather using MODIS

3.1 Overshooting cloud Tops (OTs) are convective cloud tops that have broken through into the lower stratosphere as a result of a strong updraft. Convective storms with OTs have the potential to produce severe weather at the ground (heavy rain, damaging winds, hail and tornadoes) as well as aviation hazards including lightning and turbulence. Can you identify any cold protruding tops in our Terra MODIS scene from 19 May 2017? Where are the coldest protrusions located?

2. Dr. Kris Bedka et al., published a paper outlining a technique to identify these OTs using 11 micron window channel brightness temperatures (MODIS Band 31). This technique is described in detail in:

K.M. Bedka, J.C. Brunner, R. Dworak, W.F. Feltz, J. Otkin, T. Greenwald, 2010: "Objective satellite-based overshooting top detection using infrared window channel brightness temperature gradient". J. Appl. Meteorol. Climatol., 49, pp. 181–202.

This algorithm has been adapted for MODIS data, and an OT product can be created as part of the IMAPP software product suite in near-real time. Open the MODIS OTs data file for the same date and time (**File->File(s)-> geocatL2_OT.Terra.2017139.155212.hdf** ->**Open**). Overlay the ot_overshooting_top_grid_magnitude [**OT_grid_mag**] field onto the Band 31 (11.0 μm) brightness temperatures (Window 1) (Note, the area within the green Main Hydra window box will look blank, but when you Display the data, it will be there). Change the Band 31 (11.0 μm) image enhancement to **Inverse Gray**, and change the enhancement of the overshooting top grid magnitude image to **Heat**. The technique attempts to distinguish the temperature of the OTs from the surrounding anvil (cirrus cloud shield). Are the locations of the OTs the same as the coldest tops in the scene? Do you think all overshooting tops have been identified? If not, can you think of reasons why?

3. According to the study by Bedka et al. 2010, with the presence of an overshooting top there is a 25% or greater chance of experiencing atmosphereic turbulence within 25 km of the overshooting top center. The OT software includes image generation that displays a red circle overlaid on a Band 31 (11.0 μm) brightness temperature image representing the area within a 25 km radius of the respective overshooting top center (Figure 9). Overlay the MODIS **Cloud_Top_Pressure** product (part of the MOD06 Cloud product) from this date and time onto the Band 31 image window. Use the Cloud Top Pressure along with the Skew-T diagram from a RAOB launched in Roanoke-Blacksburg, Virgina at 12 UTC, 19 May 2017 (Figure 10) to estimate the flight level where the greatest turbulence may occur around the overshooting top(s) (the Cloud Top Pressure product displays the tops in units of hPa).
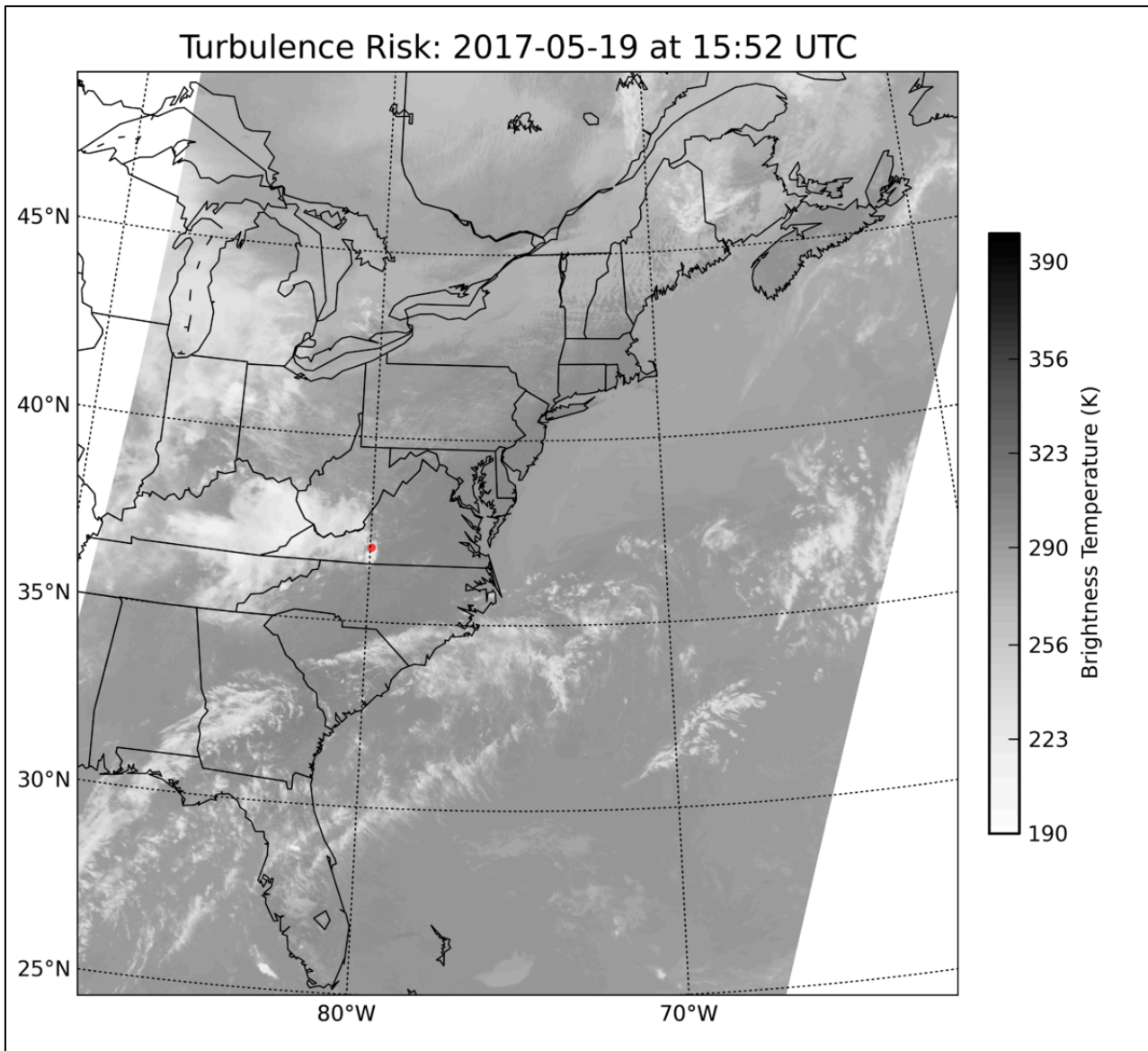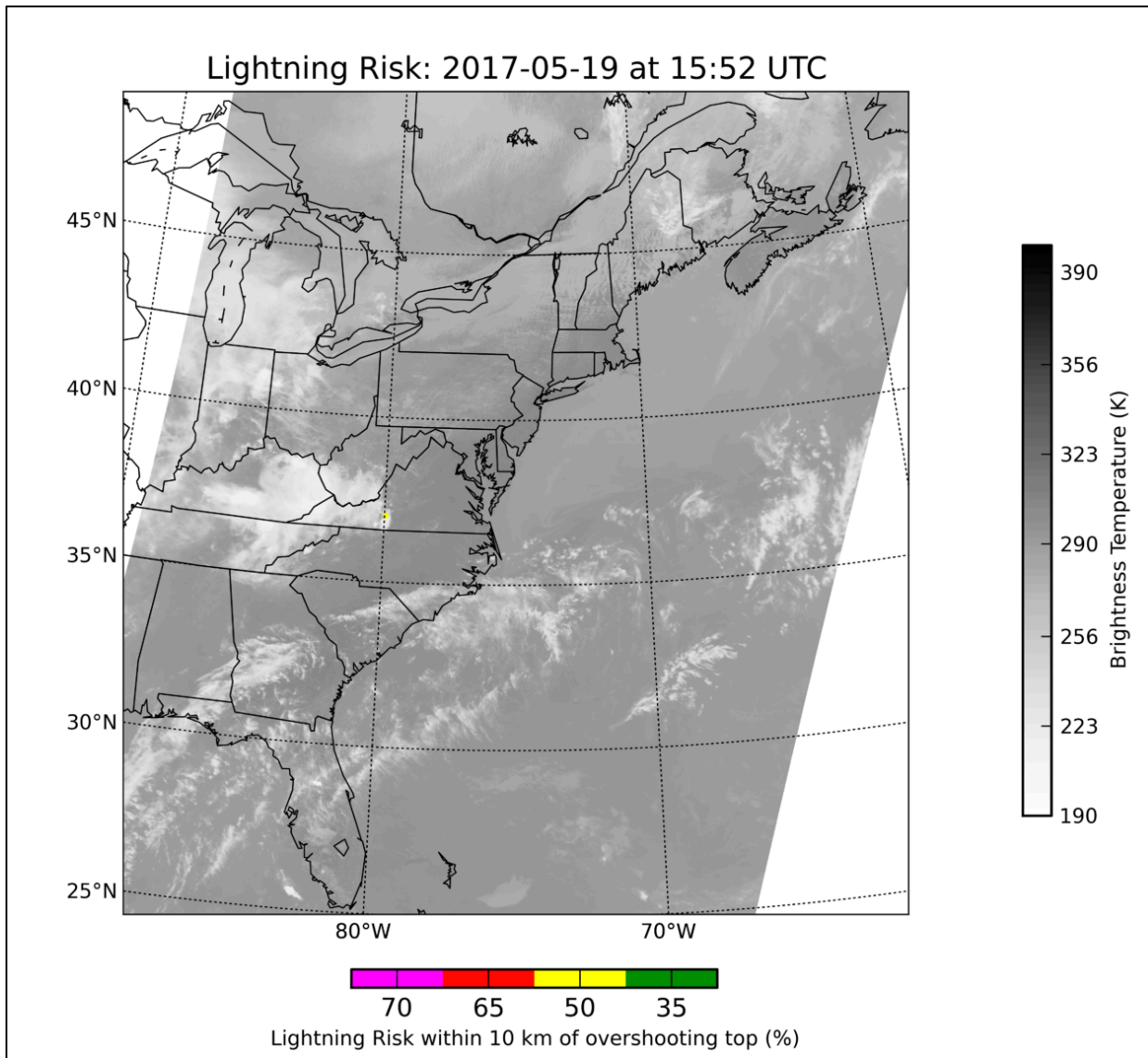
Figure 9: Areal coverage of the turbulence risk surrounding the Overshooting Top identified by the MODIS OT algorithm for the Terra 19 May 2017 data set.
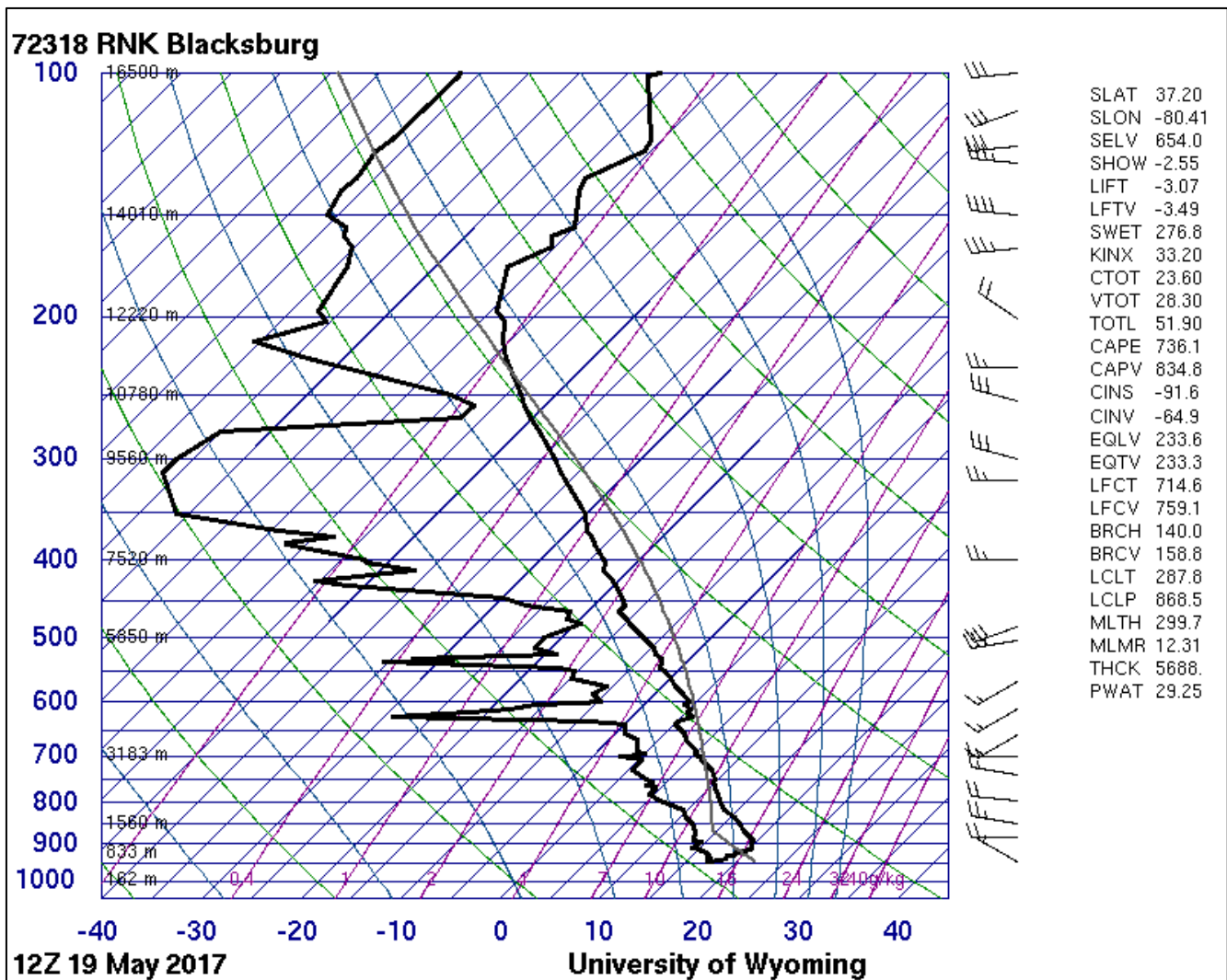
Figure 10: Skew-T thermodynamic diagram of a sounding launched from Roanoke-Blacksburg, Virgina, on 12 UTC, 19 May 2017.

This study also found that with the presence of an overshooting top, there is a 35% chance or greater, 50% chance or greater, 65% chance or greater, or 70% chance or greater of experiencing Cloud-to-Ground (CG) lightning within 10 km of the overshooting top center depending on the brightness temperature of the overshooting top, respectively. The colder the overshooting top brightness temperature is, the greater the chance of CG lightning. These relationships are shown for our 19 May 2017 MODIS scene in Figure 11, with each colored dot identifying the area within a 10 km radius of the overshooting top center. What is the potential risk for CG lightning for the OT(s) in our region?

4. Delete the Cloud Top Pressure image from your Hydra Window (select the ⊖ button beside it). You should have a Band 31 (11.0 µm) image and the overshooting tops displayed in your window. Now save the display as a KML (**Tools->Capture->KML**). Save the KML file, close the KML capture window, and open the file in **Google Earth Pro** (**File->Open**). The display should look similar to that shown in Figure 12.

Figure 11: Areal coverage of the risk of Cloud-to-Ground lightning surrounding the Overshooting Top(s) identified by the MODIS OT algorithm for the Terra 19 May 2017 data set.

5. The National Weather Service composites and archives US storm reports for each day. Below is a segment of the severe wind reports received on 19 May 2017. The times are in UTC. In Google Earth, overlay a location listed in the report that closely matches the time of the overpass in our area of interest in Virginia (type the city/state in the **Search** box). How well does the location match with the overshooting top(s)? Are they perfectly matched up? If not, can you think of reasons why?

6. Temporal resolution of observations is very, very important when looking at atmospheric convection (thunderstorms). How can the polar obiter data and products compliment the observations provided by the geostationary satellites. Where might the polar satellite observations and products be most helpful for identifying convection?

Time	Speed	Location	County	State	Lat	Lon	Comments
							(SJT)
1205	60	WOODSON	THROCKMORTON	TX	3301	9905	(SJT)
1220	UNK	IVAN	STEPHENS	TX	3287	9873	DOWNED UTILITY LINES | JUST SOUTH AND WEST OF IVAN. TIME ESTIMATED VIA RADAR. (FWD)
1255	UNK	1 SSW SCIENCE HILL	PULASKI	KY	3717	8464	TREES AND POWER LINES DOWN. (JKL)
1340	UNK	LONDON	LAUREL	KY	3713	8408	LARGE TREE LIMB DOWNED. ESTIMATED WIND GUST OF 40 MPH. (JKL)
1550	UNK	8 E ANTHONY	HARPER	KS	3715	9788	DELAYED REPORT. ROAD SIGN BLOWN DOWN. (ICT)
1559	UNK	2 E ROCKY MOUNT	FRANKLIN	VA	3701	7984	ONE TREE DOWN ALONG MUSE FIELD ROAD (RNK)
1603	UNK	3 E ROCKY MOUNT	FRANKLIN	VA	3701	7982	ONE TREE DOWN AT THE INTERSECTION OF CHESTNUT HILL ROAD AND WASHBOARD ROAD (RNK)
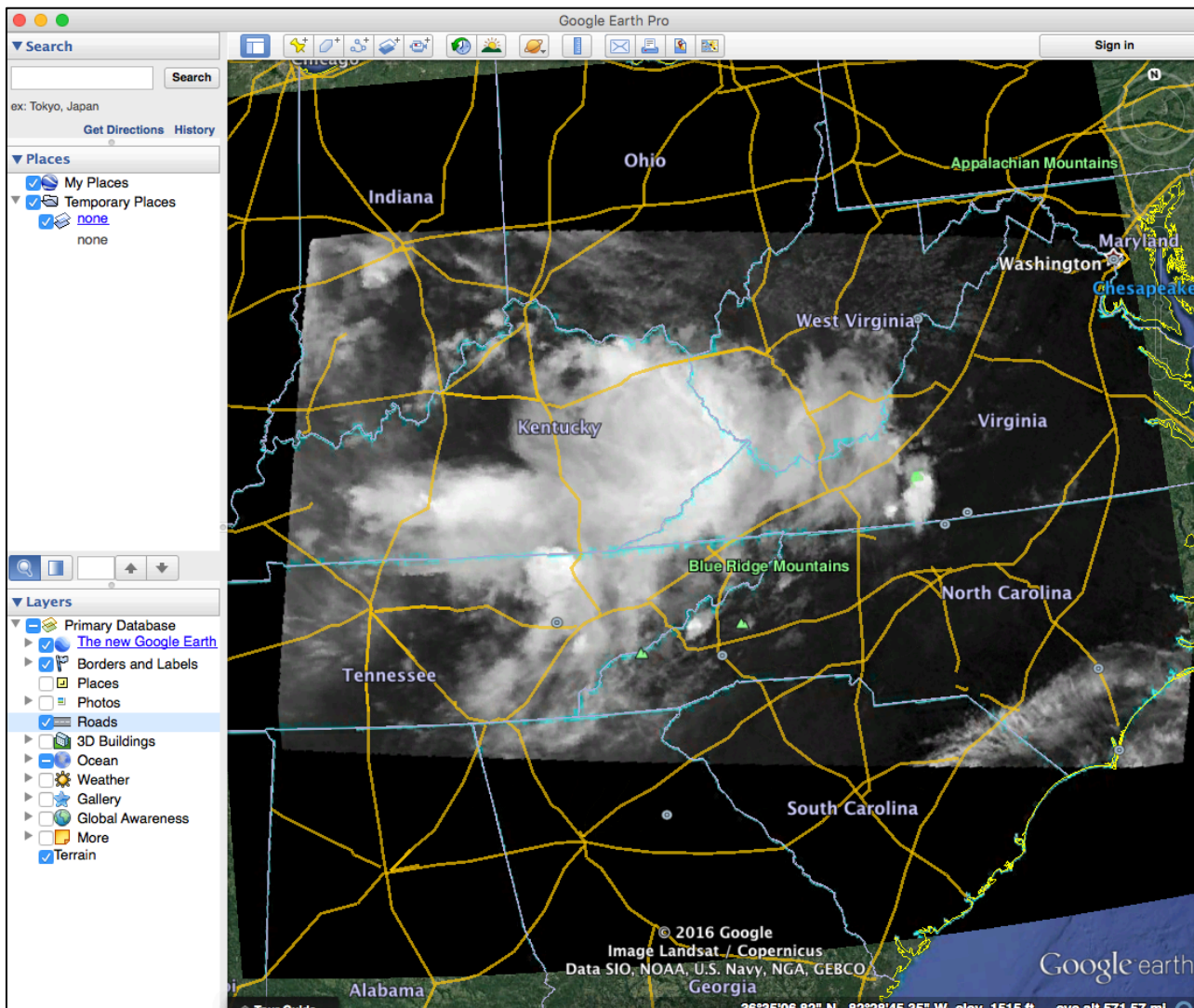
Figure 12. MODIS Band 31 Brightness temperatures overlaid by the MODIS Overshooting top magnitudes as shown in Google Earth from the Terra data set on 19 May 2017, 15:49 UTC.

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