**Name:\_\_\_\_\_\_\_\_\_Key\_\_\_\_\_\_\_\_\_\_**

**MR3522 Lab 6: Multi-Instrument Analysis of Tropical Convection**

Purpose: Use infrared brightness temperatures from a geostationary satellite, microwave brightness temperatures from an SSMI/S satellite, and radar data to investigate a precipitating cloud population in the central equatorial Indian Ocean.

*Starting up*

1. In the file viewer of your JupyterLab, go to “MR3522/Lab6” and double click tropicalconvection.ipynb.
2. Show line numbers in each cell by clicking “View” -> “Show Line Numbers” in the menu bar.

*About the code* ***(Please read before running code)***

*readradar.py:* Reads radar data.

*readsat.py*: Reads geostationary and SSMI/S data.

*tropicalconvection.ipynb*: This is the driver code. It feeds variables to the other codes to aid in plotting. This is the one you will run.

The last three cells in the Jupyter notebook plot, respectively, METEOSAT data, SSMI data, and radar data. For the SSMI and radar data, you may scroll over with a mouse and get latitude, longitude, and the data value. For METEOSAT data, only the latitude and longitude are shown when scrolling over. The thick red line on the METEOSAT plots represents the 240 K contour. You can count the different shades of gray from that red line in increments of 5 K to determine the temperature at any location, and the color bar will help you determine which direction to count.

In the last cell, multiple options for plotting are available. In addition to the different variables, you may plot different sweeps based on the elevation angle of the antenna. Anything above sweep = 7 will throw an error. You may also turn on or off a filter to remove ground clutter. Whenever you change anything in this cell, please be patient as a few seconds may be required to load from the large dataset. Since we are using an external resource to run the lab, we have a limited amount of memory we can use to store data.

Finally, the code sometimes misbehaves for reasons I have not yet determined, so you may have to change the plotted variable in the drop-down menu for each cell when you first run the code in order to make the plots display correctly.

*About the data:*

The data captures a rain event in the vicinity of the S-PolKa (dual-frequency dual-polarization S- and Ka-band radar system) radar when it was situated in the central equatorial Indian Ocean in late 2011. The particular event for focus in this lab occurred around 1250 UTC 15 October 2011. Some showers occurred near the radar site, and a line of convection was present to the southeast of the radar. The data includes 1) dual-polarimetric radar variables from S-band, radar reflectivity factor (dB*Z*) from Ka-band, 7.3- and 11-micron brightness temperatures from Meteosat, and 19, 22, 37, and 92 GHz brightness temperatures from SSMI/S.

*Plotting:*

This is the approximate equation to convert range and elevation angle to height:

, *r’* = 4/3\*radius of Earth.

You can select the height as a variable from the drop-down menu of radar data.

The color bar attached to the plot will tell you the height, and the numbers beneath the plot will also provide you latitude/longitude coordinates. Note for reference the following conversion between sweep number and elevation angle.

|  |  |
| --- | --- |
| Sweep Number | Elevation angle (degrees) |
| 0 | 0.5 |
| 1 | 1.5 |
| 2 | 2.5 |
| 3 | 3.5 |
| 4 | 5 |
| 5 | 7 |
| 6 | 9 |
| 7 | 11 |

1. Run the entire code. Three plots should appear. (If any data do not appear, just toggle the drop-down menu back and forth once and it should work.)
   1. **What are the approximate coordinates (within 1/10 degree in latitude and longitude) of the most intense (highest reflectivity) convection within the radar domain (150 km range)?**

* 1. **Record the S-band reflectivity (a range 5–10 dB wide is OK) at that location for the lowest elevation angle in this echo. Also record the 92H brightness temperature, and 7.3- and 11-micron brightness temperatures at the same location.**

1. By default, you are looking at data from the 0.5° elevation angle. Changing sweep to 1 will cause the 1.5° elevation angle to plot. The key for which values of sweep correspond to which elevation angles is found in the table above.
   1. **What is the maximum height of 30 dBZ echo?**

**b. Can you see the top of all convection with this radar volume? How do you know?**

1. Click the button to turn on the clutter filter, which will replot the reflectivity. **What did the clutter filter remove?**
2. Next, plot the variable “vel”, which is the Doppler velocity.
3. Suppose ASCAT made a pass over the exact area at the exact same time. **What wind direction would it indicate within the radar domain?** There are not multiple answers to this question, but an approximate azimuthal direction is OK. 0, 90, 180, and 270 degrees are due north, east, south, and west, respectively. **Note**: A *northerly* wind, for example, is one that is *out of the north*, and has a compass direction of 0°.
4. **Above the freezing level located at 5 km, which direction were the winds?**
5. Next, we will look at the dual-polarimetric variables.
   1. **Are there any indications (large *Z*, *KDP*, *ZDR*, and low *ρHV*) of hail?**
   2. **Given the environmental regime (tropical ocean), why does this make sense?**
6. Plot the Ka-band reflectivity (varname = “dbzk”) at any elevation angle.
   1. **Is more or less convection seen? Why?**
   2. **Is there any convection seen by Ka-band (particularly at low elevation angles) that is not seen by S-band? If so, why?**
7. Plot the lowest sweep of S-band reflectivity (varname = “refl”) data again. Pick a point where reflectivity exceeds 40 dBZ. **Record in your lab write-up the latitude and longitude coordinates of that point, and record the reflectivity and differential reflectivity also. Don’t forget to convert from logarithmic to linear units for *Z* and *ZDR*.** Assume a Z-R relationship of Z = 127.5R1.47 and a Z-ZDR-R relationship of R = 0.0085\**Z*0.92\**DR*-5.24.
   1. **Calculate the estimated rain rate at this point using both relationships.**
   2. **Which is bigger and why might it be?**
8. **Based on infrared and microwave brightness temperatures, argue for or against the following statement: “The tropospheric moisture content where rain was not occurring was substantially (10mm or more) less than within 10 km of a raining area.”** You may want to adjust the contour interval when plotting microwave data, depending on the channel you plot. Note that the red contour in the plots of METEOSAT data represents the 240K contour.
9. **If a space-borne cloud radar flew from north to south (or south to north) along the 72°E longitude, what might it see that the ground-based S-band radar cannot?**
10. **For the same space-borne cloud radar, suppose it were viewing downward at 1.25°S, 73.6°E. Would the observed reflectivity be largest at the top or the bottom of the cloud. What about for a ground-based radar of the same wavelength/frequency?**
11. **Is the peak of the 6-micron weighting function higher in the atmosphere at 0.5°N, 73°E or 1.5°S 73°E?**
12. **Is the sea surface temperature in this location greater than or less than 290K? How do you know?**
13. **Why does no microwave channel detect the isolated convective elements in the northwestern portion of the ground-based radar domain?**
14. In the “Plotting function for METEOSAT data”, comment out lines 15, 16, 28, and 29 (i.e. put a # at the front of those lines). In the “Plotting function for SSMI data”, comment out Lines 21 and 22. Re-run these cells, then replot the IR, WV, and whatever microwave data at which you want to look. Note the new ranges of latitudes and longitudes plotted for the METEOSAT and SSMI data. You’ll see that the radar can’t see far enough to capture other interesting features. The radar was located to the northwest of a large mesoscale convective system.
15. Look at some cloud near 2°N, 74.6°E. Or some cloud near 5.6°S, 80.4°E. The 11-micron brightness temperatures are between 250 and 260K depending on exactly where you look. At 0.69°S, 73.15°E, KAZR observed similar cloud with tops near 12 km high. But the temperature at 12 km is much colder than 250–260K.However, the sounding from the same location indicated a temperature at 12 km of about 220K. **Explain why such a large (30–40K) difference exists between actual cloud top temperature and the brightness temperature observed at 11 microns.**
16. **At 70°E, approximate the northernmost and southernmost latitudes of the Intertropical Convergence Zone based on the total precipitable water apparent from the observations you have available.** (Tip: Use microwave data and/or change the -10 and 10 in Lines 2 and 5 of the “Read in METEOSAT data” cell to -20 and 20.)