**MR3522 Lab 4: An Introduction to Microwave Data from SSMIS**

Purpose: Plot and interpret microwave imagery at 19, 22, 37, and 92 GHz from the SSMI/S instrument aboard the DMSP F18 platform.

*Starting up*

1. In the file viewer, go to “MR3522/Lab4” and double click SSMI.ipynb.
2. Show line numbers in each cell by clicking “View” -> “Show Line Numbers” in the menu bar.

*About the code*

The code only has two functions: It reads the single SSMI/S data file in the “data” subdirectory located in the “Lab4” shared folder on your machine, and then it plots brightness temperature at 19, 22, 37, and 92 GHz frequencies. The 19, 37, and 92GHz channels include horizontally and vertically polarized brightness temperatures. The data is from around 0900 UTC over the Western Pacific, and in this lab, we will focus on microwave brightness temperatures detected over and near Typhoon Jebi on 1 September 2018. Operationally, microwave data is widely used in the assessment of tropical cyclone structure and intensity.

The fifth cell (“Select the specific area we want”) is the only one you will change. After the first part of the lab, you’ll comment out the first line (add a # to the start of it) and uncomment out the second line (remove the # from the start of it). The figure that plots at the end contains a drop-down menu from which you can select brightness temperatures from various frequencies and horizontal (H) or vertical (V) polarization. For example, choosing V37 from the menu will display brightness temperatures from the vertically polarized 37 GHz band. This code does not automatically save figures, but you may find saving them manually as you go useful for the later questions.

1. Run the code. A plot should appear. It contains two consecutive sweeps of the sensor. Unlike for IR sensors, which just pointed downward and obtained radiation from a wide field of view, the microwave radiometer scans back and forth, constantly detecting radiation within a small footprint. You may look at the different channels by choosing an option from the drop-down menu if you like, but there’s not much to see yet. **Based on the plot you made, is the scan strategy a cross-track scan or a push-broom scan?**

**Cross-track**

1. **What is the approximate central wavelength for each frequency, using 19, 22, 37, and 92 GHz as the central frequency? (Central meaning the center of the band)**

**Divide the frequency into the speed of light.**

**19 GHz => 0.016 m or 1.6 cm**

**22 GHz => 0.014 m or 1.4 cm**

**37 GHz => 0.0081 m or 8.1 mm**

**92 GHz => 0.0032m or 3.2 mm**

1. Next, uncomment Line 2 and comment out Line 1 in the fifth cell. Run just this cell and the last cell again, which should only take a second or two. You should see a plot of brightness temperature at 19 GHz for horizontally polarized radiation. By selecting a band and polarization from the drop-down menu, you can make plots of brightness temperature for H and V polarized radiation in several bands. There is no H polarization observed for the 22 GHz band because water vapor re-emits in all polarizations randomly, and so V brightness temperature would be indistinguishable from H brightness temperature. The plot shows several different sweeps of data along a swath.
2. **Fill out the following table indicating the approximate largest and smallest values you observed for each channel within 5 degrees of latitude or longitude from the center of the tropical cyclone. Use the mouse to scroll around the images and read off the value of Tb listed at the bottom of the figure, which represents the brightness temperature. In a domain-mean sense, was more horizontally or vertically polarized radiation emitted?**

**More vertically polarized radiation was emitted by the surface, which is why the brightness temperatures are generally higher for vertically polarized emissions.**

|  |  |  |
| --- | --- | --- |
| Channel | Lowest Brightness Temperature | Highest Brightness Temperature |
| 19H | **~160-165K** | **271K** |
| 19V | **~215-220K** | **275K** |
| 22V | **~250K** | **275K** |
| 37H | **~170-180K** | **274K** |
| 37V | **~230K** | **277K** |
| 92H | **~165K** | **289K** |
| 92V | **165-170K** | **285K** |

1. **Provide approximate latitude/longitude coordinates for where the highest and lowest brightness temperature was located in each channel (again only within 5 degrees latitude or longitude from the typhoon center). One or two approximate set of coordinates is acceptable to describe this point for all channels.**

**The warmest brightness temperatures are generally over the core of the tropical cyclone. The lowest brightness temperatures at 19–37 GHz within 5 degrees of the cyclone are in the drier area to its west (about 21°N, 133°E, although lower are seen NW of the TC at greater distances than asked by the question), and the lowest 92 GHz brightness temperatures are in the eyewall (around 20°N, 137.6°E). At 92GHz, the warmest brightness temperatures can be located with more precision at the eye near 20.8°N, 137.7°E.**

1. **At the point(s) you selected, what do the similarities and/or differences in brightness temperatures at each channel tell you about water vapor and liquid water concentration? How does spatial resolution of the different channels impact your interpretation of the moisture field in this location?**

**For 19—37 GHz, the higher brightness temperatures over the core of the cyclone indicate high values of liquid water and column water vapor because fewer emissions from the ocean surface reach the top of the atmosphere. Instead the brightness temperature is more representative of the temperature of atmosphere constituents (in this case liquid and vapor water). The lower brightness temperatures to the northwest of the TC indicate drier air and more emissions detected from the ocean, which is not an efficient emitter of microwaves.**

**Higher frequency means that more radiation is emitted from the surface; therefore, the footprint of the instrument can be smaller, and spatial resolution is higher. Thus, at 92 GHz, we are able to separately identify the relatively dry eye and the much wetter eyewalls to its west.**

The following questions will require comparisons of some of the plots you have made.

1. **Which band has the highest spatial resolution? Why is this the case?**

**92 GHz. 1) This is a shorter wavelength which is slightly closer to the peak of a Planck curve for a body with Earth’s temperature. Since more energy is emitted at 92 GHz than at 19 GHz, for example, the aperture can be smaller at 92 GHz to detect the same radiance. 2) The ocean is more emissive at 92 GHz.**

1. There is a ribbon of relatively low brightness temperature apparent to the northwest of the typhoon, for example around 28°N, 132°E.
   1. **What does it most likely represent? Based on our discussions in class, how do you know?** Consider looking back to see which channel gives you the smallest difference between the highest and lowest brightness temperature observed south of 30°N.

**Drier air than in the core of the tropical cyclone.**

* 1. **Where would the peak of the GOES-16 7-micron weighting function be located over the “ribbon” of low brightness temperature compared to over the cloudy part of the typhoon?**

**The peak of the weighting function for a GOES-16 water vapor channel would be lower in a drier environment.**

* 1. **Would the GOES-16 11-micron brightness temperature be larger over this “ribbon” or over the central dense overcast of the typhoon?**

**The brightness temperature would be higher over the dry air region. The ocean is nearly a blackbody in IR, but has an emissivity coefficient of only 0.4 to 0.6 at microwave frequencies.**

1. **Which SSMI/S channel would you use to detect formation of a secondary eyewall?**

**92 GHz. The others have insufficient horizontal spatial resolution.**

1. The brightness temperature over the secondary eyewall was roughly the same at low frequencies (≤37 GHz). **How does the eyewall brightness temperature compare at 92 GHz?**

**The brightness temperature in the eyewall at 92 GHz is much lower than at other frequencies. This occurs because absorption and scattering by vapor and liquid water is so prevalent at 92GHz that we only see emissions from near cloud top in the TC.**

1. Based on our discussion in class, we know that at 37 GHz (for example), higher sea surface temperature will yield a lower brightness temperature in the absence of clouds. Higher water vapor concentrations through the atmosphere will yield a higher brightness temperature.
   1. **Which factor had a bigger impact on brightness temperature over water in this scene?**

**Water vapor concentration. The minimum TPW in this scene was around 45 mm, and the maximum was over 60 mm. The differences in water vapor had a much larger impact on brightness temperatures than any differences in sea surface temperature that may have been present.**

* 1. **Why is SSMI/S not well suited for estimating salinity?**

**Its lowest frequency is 19 GHz. Changes in brightness temperature as a function of salinity only occur at frequencies less than about 8GHz.**

1. **You can see a primary rainband at all channels except 22 GHz. Why can you not see it at 22 GHz?**

**The 22 GHz channel is in a water vapor absorption band and so it is very sensitive to total precipitable water. Microwaves at 22 GHz are more sensitive to absorption by water vapor than extinction by liquid water. This channel cannot usually detect non-precipitating areas from precipitating areas in a generally moist environment because absorption and re-emission by water vapor dominates everywhere, regardless of the liquid water concentration.**