**MR3522 Lab 1: Interpreting Geostationary Satellite Data**

Purpose: Learn to open, manipulate, and interpret an example of real GOES-16 data from various bands. In this case, we will examine observations around a tropical cyclone.

**For your lab assignment, answer any questions that are bolded and in red below. You only need to include figures if the text in red asks for them.**

*Starting up*

1. Once in your JupyterLab, follow the MR3522 folder to the Lab1 folder, then double click “GOES.ipynb” in the file viewer. A Jupyter notebook should open.
2. Click “View” and from the dropdown menu that appears, select “Show Line Numbers”. Line numbers should appear in each cell.

*Python code*

You are free to modify the code as you wish; however, making a backup version before doing so is recommended. Line numbers in this lab refer to the original code provided.

*Making some plots*

1. To run the code, click the “Run” button (which looks like a “Play” button as each cell is highlighted to run the code cell by cell.
2. After you run all the code, a figure will appear alongside a dropdown menu. The menu contains four variables that you can plot: Radiance, reflectance, brightness value, and brightness temperature. A slider also appears with the figure. You can use it to change the band plotted. Variables will fail to plot if you try to plot something that doesn’t exist; for example, brightness temperature for Channel 2 will not plot because brightness temperature does not apply to shortwave radiation. You can hit the save button at the bottom of the panel to the left of each figure to save a figure. If you ever want to crank up the spatial resolution of the data and make it look sharper, change the value of “step” at Line 18 of the cell labeled “Function for plotting data” to an integer 1 or greater. The figures will load more slowly if you decrease this number.

The following questions pertain to Channels 1–3.

* 1. **What wavelengths are represented by Channels 1–3? At which wavelength among these is the radiance highest? Why is radiance highest at this wavelength?**

**Band 1: 450–490 (470) nm, Band 2: 590–690 (640) nm, Band 3: 846–885 (865) nm. Radiance highest at Band 1 because 470 nm is closest to peak emission by sun.**

* 1. **Assuming that the tropical cyclone is moving northward around 10 kts, do you expect it to weaken or strengthen? How can you tell based on just this data alone?** If you can’t see the answer yet, the next plots will make it obvious.

**It will weaken because it is moving over land, which we can tell because of the enhanced reflectance/radiance in the “veggie” band (Channel 3).**

1. Now let’s plot reflectance for the same 3 channels. You can do this by clicking the dropdown menu for “varname” and selecting “Reflectance”.
   1. **Which band is most reflective over land? What causes this reflection?**
   2. **Which band is most reflective over water in clear sky regions? What causes the reflection observed in this band in clear sky areas?**
2. **Band 3 is most reflective over land because vegetation scatters more efficiently at this wavelength than at Bands 1 or 2.**
3. **Band 1 is most reflective over water in clear-sky regions. This happens because blue light is more efficiently by air molecules than red light or near-IR radiation.**
4. Click the checkbox above the figure to toggle on the coastline.
   1. **Provide an approximate range of reflectances observed in Channels 1 and 2 at the very bottom of the figure off the coast of Alabama (in the area of 26°N, 86°W). The ranges should be close, but one channel should appear slightly more reflective. If you have trouble telling the difference, try reducing the value for vmax in Line 57 of “Function for plotting data” to a value of around 0.25.**

**Channel 1: 0.1–0.2, roughly; Channel 2: 0.05–0.1, roughly**

1. The brightness value is a qualitative value used to help visualize weakly reflective features. Generally, brightness value (BV) is given by

in which gamma is generally about 2.2 for real-time visualization purposes. If gamma were 2 exactly, this would be called a “square-root stretch”. The brightness values compress the upper end of the reflectance values and stretch out the lower end. Next, plot the brightness values for Channels 1–3 by choosing that option in the varname dropdown menu. Now, it is obvious which band is most reflective.

* 1. **The weakly reflective area south of Alabama near the bottom of the image looks like it may be some high cirrus cloud. This is especially visible in Channels 2 and 3. Confirm this using a different channel than the ones we have looked at so far, and include the plot of brightness value or brightness temperature. Which channel did you use?**

**Use Channel 4. It is a narrow band that is absorbed efficiently by water vapor; therefore, the reflected radiation visible in space will be only that reflected off of objects high in the atmosphere (i.e. cirrus clouds).**

1. Spectral radiances for the solar bands were given in units per *wavelength*; however, spectral radiances for IR bands are often given in units per *wavenumber*. Plot the radiances for Channels 8–10.
   1. **Which of the three channels observes the largest radiance, and why?**

**Channel 10 observes the largest radiance. The same body, given a temperature of 200–300K, a typical temperature of clouds, will emit more radiation at 7.34 microns (Ch. 10) than at 6.19 microns (Ch. 8). The peak emission of Earth occurs at around 10 microns. Additionally, water vapor more efficiently absorbs water vapor at 6.19 microns than 7.34 microns.**

1. Now plot the brightness temperatures for the same three channels.
   1. **What is the purpose of these three channels, and why are the channels located at their respective wavelengths?**
   2. **Why is the brightness temperature of the central dense overcast approximately the same in each channel?**
   3. **Is the air drier inside the eye or to the west of the tropical cyclone?**
   4. **On the same plot, draw a hypothetical weighting function for Channel 10 over the open ocean and another over the central dense overcast. Numbers are not needed; instead, we want to correctly represent the relative locations of the peaks.**
2. **The channels are positioned so that they are absorbed by water vapor differently. Channel 8 is centered in the middle of a water vapor absorption band, while Channel 10 is located on the edge of an absorption band. Therefore, radiation at the longer 7.34 micron wavelength (Ch. 10) can be observed in space from lower in the troposphere. Shorter wavelength radiation (like 6.19 microns at Ch. 8), after being emitted from the surface has a greater chance of being absorbed and re-emitted along its path length to space.**
3. **Little water vapor is present above the top of the clouds. Second, the air is nearly saturated beneath cloud top; therefore, upwelling radiation at all bands is mostly absorbed and re-emitted within the cloud before escaping cloud top.**
4. **Drier outside of the tropical cyclone. The Channel 10 radiance is higher outside the tropical cyclone over open ocean (in clear skies), meaning that the emitted surface radiation observed there less absorbed by water vapor along the path length to space.**
5. **Weighting function for the CDO has peak in upper-troposphere. Weighting function over open ocean probably has peak in lower to middle troposphere.**
6. **Use a channel in an atmospheric window to estimate the cloud-top temperature in the central dense overcast of the cyclone. Which channel did you use? In this channel, what is the brightness temperature of the ocean surface? Why might this not be the actual temperature of the ocean?**

**It’s best to use a channel in the IR atmospheric window. Channel 13, centered near 10.3 microns, is a good choice; although, others are acceptable. Brightness temperature is something low. This is not the actual temperature of the ocean because some small amount of the radiation emitted by the surface is absorbed as it propagates toward space. Additionally, the ocean may not be a perfect blackbody that emits at the Planck radiance.**

1. **Generally, for a single wavelength, what is the relationship between brightness temperature and radiance?**

**As radiance increases, brightness temperature increases.**

1. **Sketch two Planck functions: One representing blackbody emission at the top of the central dense overcast, and another denoting blackbody emission by the ocean beneath clear skies. Draw them on the same plot. They need not be quantitatively exact. Ensure that the magnitudes of the functions and the wavelengths of their peaks relative to each other are correct. Consider that for a blackbody with temperature 300K (a reasonable estimate of ocean surface temperature in this location), the wavelength of maximum emission is around 9.65 microns.**

**The cooler body should have a Planck function that is smaller in magnitude and with a peak at higher wavelengths (lower frequencies) than the warmer body.**