Talking Points on SatFC-J Module: Microwave Surface Emissivity

Slide 1: Course Title

- This module is part of the Satellite Foundational Course for JPSS

Slide 2: Module Title

- If we had all the observations we needed from surface stations, radar, upper-air soundings and satellite-based visible and infrared measurements, then microwave remote sensing wouldn't be necessary. However, microwave does offer advantages over other measurements and how that information is gathered can get fairly complicated. In this module, we will explore microwave surface emissivity and how it influences interpretation.

Slide 3: Learning Objectives

- The learning objectives are: 1) to describe differences in microwave surface emissivity that aid in the characterization of land surfaces, snow and ice cover, and ocean and water surfaces.
- 2) to identify key parameters that affect emissivity.
- And 3) to provide single channel imagery and product examples for comparison and to demonstrate strengths and limitations.

Slide 4: Advantage of Microwave Remote Sensing

- Recall that a major advantage of microwave remote sensing is that non-precipitating clouds are transparent. The longer wavelengths can penetrate through cloud cover, except during heavy precipitation. This allows sensing of the surface in almost all weather conditions.

Slide 5: Land Products for Input to Models

- Microwave remote sensing makes unique products possible. On the left is a Land Cover product, and on the right is Soil Moisture for the same time. The land products shown here are derived from microwave imagery and are beneficial for large scale analysis and through incorporation into numerical models. How much microwave data makes it into the model depends on the latency of the product.

Slide 6: Sea Surface Products

- Variability in ocean emissivity allows for the derivation of Sea Surface Temperature shown on the left, and Sea Surface Wind Speed on the right. Both of these sea surface products can be used directly in operations.

Slide 7: Why Is Learning About Emissivity Important?

- Emissivity characteristics strongly affect the interpretation of microwave imagery, which is how we are able to derive the land and sea surface products shown. As always, there are strengths and limitations. Researchers don't necessarily capture all the instances when a derived product is exceptional or poor. Understanding the components that go into a product and providing feedback enhances the science behind a quality product. If something doesn't look right, ask questions and compare it with other observations. If a discrepancy happens often, consider relaying that information back to the researcher.

Slide 8: Summer vs. Winter

- Let’s take a look at another example. Here we have two images using the 10 GHz channel, one during winter and one during summer. Can you tell which is which?
- From a quick glance without even looking at temperature values, you may correctly guess that the one on the left is from winter and the one on the right is from summer. With this color table, reds correspond to warmer temperatures which we see throughout the U.S. and Canada in the image on the right, while the colder greens and yellows are more pronounced on the left. But take a closer look at the temperature range shown. The ocean appears extremely cold and is saturated in this color table. For reference, with an ocean temperature of 290 Kelvin (17 degrees Celsius), the observed brightness temperature at 10 GHz is closer to 90 Kelvin (-183 degrees Celsius). If we do the rough math using temperatures in Kelvin, 90 is roughly one third of 290. It is the emissivity factor at microwave frequencies that makes surfaces appear colder than their physical temperatures. As we will see in a following graph, water at 10 GHz has an emissivity around 0.3. How might that compare to dry land, or snow and ice?
- Another thing you may have noticed is the lack of clouds in the images. We’re looking at 10 GHz imagery - a frequency that falls directly within a window region.

Slide 9: Window Viewing Regions

- As we saw in the previous module, within the frequency range from 1 to 100 GHz, there is an oxygen absorption region centered at 60 GHz and a water vapor absorption region centered at 22 GHz. For the best view of surface features, we want to avoid these.
- The cleanest window regions are found with frequencies below 50 GHz, and a dirtier window region is above 65 GHz. As this graph shows, the amount of moisture in the atmospheric column will affect the transmittance of the surface-based passive microwave signal that the satellite detects.

Slide 10: Emissivity

- Satellite-observed brightness temperature is related to the physical temperature of a surface feature by its ability to emit radiation at that frequency. This is called emission efficiency, or emissivity, and is a value between zero and one. Microwave surface emissivities are often much less than one so that what is observed as the window channel brightness temperature may be substantially less than the physical temperature. We saw this for ourselves when looking at the ocean temperature earlier.
- Emissivity depends on a number of parameters such as wavelength or frequency, and the emitting material characteristics. This includes characteristics like conductivity, water content, and salinity and are collectively referred to as dielectric properties. Polarization, surface roughness, and viewing angle also have an effect. More information can be found in the COMET resources at the end of the module.
- The surface emissivity spectra show that bare soil and vegetation, such as short grass, are the strongest emitters of microwave energy and will appear closest to their physical temperatures. Water surfaces are the weakest emitters with emissivity values less than 0.5, and will appear much cooler than their physical temperatures. This is in contrast to the infrared where water has an emissivity near one.

- Snow emissivity in the microwave is variable and depends on the depth, temperature, wet-dry state, and water equivalent of the snowpack. Ice has a different structure than liquid water, so emissivity changes significantly with the transformation of snowpack over time. Wet melting snow has a larger emissivity than dry snow.
- The 37 GHz channel is often used to distinguish bare ground from snow, and compared to the 19 GHz channel for snowpack characteristics.
- Did you notice that the emissivity curve for wet snow is similar to bare soil? This presents a challenge. Wet snow interpreted as bare soil can cause an underestimation of snow depth if precedent information is not taken into account.

Slide 11: Land Surfaces

- Emissivity is generally high for most land surfaces but depends on soil type, the type and amount of vegetation, and moisture content. A very dry soil will appear with relatively warmer brightness temperatures, while saturated soil will appear relatively colder.
- The emissivity of vegetation, including grasslands and forests, is higher than that over bare soil. Vegetation emits its own microwave radiation and increases the emissivity for an otherwise wet surface below. By comparing several frequencies and both vertical and horizontal polarizations, the effects of vegetation can be distinguished from the effects of surface wetness.

Slide 12: Horizontal vs. Vertical Polarization

- Microwave surface emissivity and the resulting measured brightness temperature is strongly dependent on polarization, and is another important aspect to consider when teasing out surface feature information to use in products. These images are from the Advanced Microwave Scanning Radiometer for the 6.9 GHz channel with horizontal polarization on the left and vertical polarization on the right.
- When comparing the two images, a smaller temperature difference is observed over land where the blue diamonds show a 20-degree difference, than over water where the yellow plus signs show an 86-degree difference. This indicates generally weak polarization of land, and strong polarization of water. With a bit of background knowledge, the differences between horizontal and vertical polarization measurements can be used to help determine if snow or vegetation is present, among other surface characteristics.

Slide 13: Animation of AMSR-2 H-pol and V-pol Brightness Temperature – 11 Feb 2018

- This is an animation of AMSR-2 imagery comparing horizontal and vertical polarization. We can see how the clean window channel at 6 GHz moves towards a dirtier window at 89 GHz. The color table gradually changes, with the horizontal-polarization cold end showing a larger change than vertical polarization. Over the southern U.S. we see consistently warm brightness temperatures, while the northern U.S. and Canada show a progression to colder temperatures with higher frequency. These changes help tease out information on snow depth and snow water equivalence.
- Without radar and other surface-based measurements over the ocean, the 36 and 89 GHz channels are extensively used for tropical cyclone center location and to monitor development. Historically, horizontal polarization has been used more than vertical simply because that’s what was available.

Slide 14: Animation of AMSR-2 Snow and Ice Products – 11 Feb 2018

- AMSR-2 snow and ice products are shown for the Northern Hemisphere. The images are for one time but products may take into account prior snowpack and surface information. The first shown is snow cover. This is an important delineation for other product algorithms. If snow is present a relatively warm brightness temperature indicates wet snow with high water equivalent. If snow is not present, it indicates dry land. Algorithms must take into account the microwave frequencies and polarizations to determine whether bare ground, snow, or ice is present. And if snow or ice, then further determine snowpack characteristics. The snow depth and snow water equivalent products are used for hydrology and modeling applications. The sea ice product is expected to become available in AWIPS.

Slide 15: Ocean & Water Surfaces

- Ocean and water surfaces typically have low microwave emissivities in the 0.25-0.5 range.
- As wind roughens the ocean surface, the emissivity and therefore the brightness temperature increases, even though the ocean's physical temperature does not change. If foam forms this further increases emissivity. Differences in microwave ocean surface emissivity make it possible to estimate ocean surface wind speed.
- This AMSR-2 10 GHz example shows how wind-roughening increases microwave brightness temperatures. The circled area has warmer brightness temperatures, due mostly to winds along the California coast. In the surrounding ocean, slightly cooler brightness temperatures are associated with calmer winds and a smoother ocean surface.
- Low frequency channels from 6-10 GHz are used for their sensitivity to sea surface temperature. Sea surface temperature is accurate to a few tenths of a degree and near-surface wind speed is accurate to within 2 m/s.

Slide 16: Summary

- To summarize, microwave emissivity varies considerably by surface type and accounts for the large differences in observed brightness temperature imagery. In general, we see that dry land surfaces and vegetation are the strongest emitters of microwave energy resulting in the observed brightness temperatures closer to their physical temperature; while ocean and water surfaces are the weakest emitters resulting in very cold temperatures compared to their physical temperature. Snow- and ice-covered surfaces are moderate emitters and fall in between.
- Polarization is an important property of microwave radiation that varies with surface type. Observations at multiple frequencies and polarizations helps in the characterization of the various surface properties listed here, used in both operations and as input to models. The AMSR-2 sea surface temperature and near-surface ocean wind speed products, as well as the 36 and 89 GHz channels, for both vertical and horizontal polarizations, will be available in AWIPS.

Slide 17: Resources

- For more information, please visit the following resources.