Talking points for SatFC-J Module: Influence of Clouds and Precipitation

Slide 1: Course Title

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

Slide 2: Module Title

- And will focus on the influence of clouds and precipitation in microwave remote sensing

Slide 3: Learning Objectives

- The learning objectives are 1) To pull together how absorption regions and emissivity characteristics, described in previous modules, are used to understand how microwave sensors provide moisture, cloud properties, and precipitation information against different surface backgrounds.
- 2) To interpret precipitable water, cloud liquid water, rain rate and liquid equivalent snowfall rate products from example imagery.
- And 3) To describe how blended microwave and infrared precipitation products are used to improve coverage of significant precipitation events.

Slide 4: Advantage of Microwave Remote Sensing

- The major advantage of using microwave remote sensing is that non-precipitating clouds are transparent. This means that microwave remote sensing can detect moisture at all levels of the atmosphere. Infrared can also detect moisture at different levels, but only in cloud-free regions.
- For the products shown in the next slides, it is necessary to observe the moisture throughout the atmospheric column down to the surface.

Slide 5: Total Precipitable Water (TPW)

- Total Precipitable Water or TPW is one way to measure atmospheric moisture, and uses the strong water vapor absorption near 22 GHz in the microwave. It represents the depth of water that would be accumulated if all the water vapor in a column of the atmosphere were condensed into liquid form. The product is valid everywhere over the oceans excluding areas of precipitation, and is expressed in units of millimeters.
- The blended TPW product is able to provide almost full global coverage by incorporating microwave data from polar-orbiting satellites, data from geostationary satellites, and GPS data over land.
- Total Precipitable Water generally has large values near the equator, where the ocean is warm and has high evaporation rates, and lower values near the poles. Knowing the location of the greatest tropospheric humidity is useful in forecasting the potential for heavy precipitation. Gradients in TPW can indicate the position of fronts and atmospheric rivers.

Slide 6: Advected Layered Precipitable Water (ALPW)

- The Advected Layered Precipitable Water product, or ALPW, provides further insight on the distribution of atmospheric water vapor across four vertical layers: surface-850 mb, 850-700 mb, 700-500 mb and 500-300 mb. The product is useful for monitoring water vapor transport.

Slide 7: Cloud Liquid Water (CLW)

- Cloud Liquid Water is another way to measure atmospheric moisture, and is retrieved using passive microwave frequencies where clouds are semi-transparent. It represents the depth of water that would be accumulated if all the cloud liquid water drops in a column of the atmosphere were compressed.
- Cloud Liquid Water depends on the type of clouds present and their density. Variable cloud cover means that many regions have a value of zero. In comparison to TPW in the previous slide, you can see that Total Precipitable Water values are about 100 times greater than Cloud Liquid Water. This means

that an atmospheric column with clouds present contains roughly 100 times more water in vapor form than in liquid form.

- The Cloud Liquid Water product can be used in aviation forecasts of aircraft icing.

Slide 8: Rain Rate (RR)

- Rain rate is another product that relies on passive microwave measurements. It represents the depth of hourly rainfall accumulated at the ground surface, and can be calculated for tropical to mid-latitude regions.
- Rain rate estimates depend on distinguishing between the background surface radiation and radiation from rain. The ocean surface is strongly polarized in the microwave and emission from rain is not, so vertical and horizontal polarization can be used to our advantage. Accuracy is better over the ocean since land emissivity is high and variable, which makes it difficult to interpret rainfall signals.

Slide 9: Snowfall Rate (SFR)

- The Snowfall Rate product, or SFR, is the instantaneous liquid equivalent snowfall rate in units of in/hr or mm/hr. It can be used to determine the extent of a snowstorm and pinpoint the heaviest snowfall.
- The merged Snowfall Rate product combines the SFR with instantaneous radar snowfall rate estimates from the Mutli-Radar/Multi-Sensor System (MRMS). It benefits from the broad spatial coverage of satellites and the more frequent observations from radar, and is available over CONUS.

Slide 10: Rain Rate from Infrared

- We look to remote sensing for precipitation measurements because adequate surface-based radar and gauge measurements are often unavailable in remote regions. In the Satellite Foundational Course for GOES-R a Rainfall Rate product was highlighted. The basic assumptions when using infrared are that: cloud-top temperature is related to cloud-top height, and cloud-top height is related to the strength of the updraft and rain rate. Additional channels on GOES-R Series Advanced Baseline Imager help improve the algorithm by teasing out information on cloud particle phase.
- Traditional infrared water vapor imagery detects water vapor mainly at middle and high levels of the troposphere. When clouds are present, infrared sensors observe only the temperature of the cloud top. Warmer cloud tops indicate lighter or no rain, while colder cloud tops indicate heavier rain. The cloud-top brightness temperatures shown in this graphic are for a continental mid-latitude air mass.

Slide 11: Microwave Interaction with Rain Cloud

- To see how microwave satellite observations can be used to quantify precipitation, let's take a look at the structure of a convective rain cloud. Above the freezing level, the cloud contains ice particles of various sizes. Below freezing level, we see liquid raindrops. These ice particles and raindrops interact strongly with microwave wavelengths, and rainfall estimates are based on the absorption and scattering. In the first module we touched on these points: ice essentially does not absorb microwave radiation; it only scatters. Liquid raindrops scatter and absorb, with absorption dominating.
- Different parts of the cloud are observed at different microwave wavelengths or frequencies. Higher frequency microwave channels primarily detect the scattering by ice particles. Lower frequency microwave channels are most effective in observing the liquid raindrops. Any ice is nearly transparent at these frequencies, and the energy emitted by liquid raindrops below is measured. Lower and higher frequency microwave channels are compared to determine precipitation type and amount.
- In single channel imagery, you'll notice a parallax error as illustrated here – there is a greater displacement for ice particles than for the lower-level raindrops. This can be very important, for instance, in the center fixing of tropical cyclones.
- Microwave precipitation rates are more accurate than infrared because they are based on direct observations of emissions from precipitation. While GOES provides greater spatial and temporal resolution, microwave measurements provide more detail on precipitation type and amount. Blended

precipitation products that combine microwave and infrared information can improve coverage of significant precipitation events. As always, becoming familiar with the strengths and limitations of a product will help with optimal utilization and continued improvement.

Slide 12: Tropical Cyclone Analysis

- In this example and the one on the next slide, infrared imagery is compared with the 36 and 89 GHz channels. These are heritage microwave channels on polar-orbiting satellites used for precipitation monitoring and other applications, particularly in the tropics. Now, more channels are available and used to derive products.
- Tropical Storm Maria was categorized as a hurricane at 18 UTC on September 17. By 12 UTC on September 18, it was classified as a major hurricane with winds in excess of 100 kts. This slide shows the hurricane at 05 UTC while it was undergoing rapid intensification. The images from left to right show the GOES-13 infrared, AMSR-2 36 GHz, and AMSR-2 89 GHz channels.
- The organization of the low-level center and convective rain bands directly relate to tropical cyclone intensity early in storm development. But these are often obscured by high clouds in the visible, infrared, and water vapor imagery. This central dense overcast scene type can be seen in the infrared image. In the 36 GHz microwave imagery, the location of the eye is more obvious, as well as the relatively warm rain bands. It is able to sense clouds and moisture close to the surface, and we predominantly see the absorption effects of liquid raindrops. In the 89 GHz imagery, we see the cold ice scattering signal in regions of deep convection as well as warmer regions associated with high rain rate.
- To recap from previous modules: both 36 and 89 GHz are window channels, with 36 GHz being the "cleaner" of the two. Here we see a brightness temperature less than 190K over the ocean, which is much colder than the ocean's physical temperature due to low microwave emissivity. The same region in the 89 GHz image shows a warmer brightness temperature, indicating absorption by water vapor. As you can see, interpretation can get complicated. The expert researcher programs all these features into an algorithm to obtain a coherent picture of precipitation type and rate.

Slide 13: Thunderstorms

- Let's now take a look at an example of thunderstorms over land. At the top, we have a GOES-16 infrared image. Below we have AMSR-2 imagery with two swaths at 36 and 89 GHz for comparison. Focusing on the AMSR-2 imagery, the higher emissivity of land results in warmer brightness temperatures around 300K, whereas the ocean appears a much colder 150 to 250 K. This makes it more difficult to discern atmospheric water vapor over land in these window channels because there is not as much contrast. Precipitating clouds are not transparent, particularly for the regions associated with deep convective clouds seen in the infrared. The 36 GHz predominantly shows the cool rain signature and the 89 GHz shows the cold ice signature as well as the cool higher rain rate signature. In other regions, for example Eastern Nebraska, it is hard to discern from these images alone if the cooler brightness temperature is associated with wet ground. Because there are complicating factors in terms of interpretation, the derived microwave products are easier to use over land than single channel imagery.

Slide 14: Summary

- In this module, we briefly introduced microwave products related to atmospheric moisture, and how emission and scattering properties help tease out that information. These products are Precipitable Water, Cloud Liquid Water, Rain Rate, and Liquid Equivalent Snowfall Rate. The greatest use of these products are in areas that don't have surface-based measurements and radar coverage.
- The best precipitation estimation algorithms use a combination of both infrared data from geostationary satellites (which have a higher refresh rate) and microwave data from polar-orbiting satellites (which are more accurate due to the transparency to clouds).
- Precipitation estimation is more reliable over the ocean, which provides a cold contrasting background.

Slide 15: Resources

- For more information, please visit the following resources.