Slide 1: Title

Slide 2: Learning Objectives – In this module we will look at how to make optimal use of GOES-R series imagery and products to identify and monitor basic circulation features such as ridges, troughs and upper-level jets. In the short time we have we will concentrate on using the 3 water vapor channels that are now available since the imagery can be very useful in identifying these features.

Slide 3: Some background info

Water vapor imagery is very useful since it can give us a three dimensional look at the atmosphere, and now even moreso with three water vapor bands available. While water vapor imagery tells us a lot about the atmosphere, it can be tricky to interpret correctly, so we give a brief review here. Much more on water vapor imagery is discussed in the GOES-R "ABI Water Vapor Bands" module.

A water vapor band senses radiant energy emitted from water vapor through a layer of the atmosphere, with the different wavelengths of the bands allowing them to be sensitive to different layers. On previous GOES we had one water vapor band at 6.5 microns, which was considered to be a mid-level band with peak absorption in the 250 to 550 mb range. GOES-16 and 17 have a similar mid-level band but at 6.9 microns that peaks a little lower in the atmosphere, plus 2 new Water Vapor bands, listed here with their approximate range of greatest sensitivity. On AWIPS we see a brightness temperature displayed, which represents the net temperature of each layer. As explained in the Water Vapor Bands Module, the actual attenuation ranges or layers for each water vapor band will depend on the temperature and moisture structure in the atmosphere, with an additional dependence on the satellite viewing angle. These ranges can be calculated for a given location assuming clear sky conditions, and we will show a couple of examples shortly.

We can use the properties of how the water vapor bands work to infer synoptic and mesoscale vertical motions. Since these vertical motions are associated with features like troughs, ridges and jets, we can relate what we see in the water vapor imagery to properties of these features.

Slide 4: Short GOES-16 4-panel loop around 12z/8 Nov

Now let's apply the properties of the water vapor channels. Here is a short loop around 12 UTC on 8 November 2018 using a 4-panel display on AWIPS with the three water vapor channels from GOES-16 and in the lower right IR imagery overlaid with a 500 mb plot. The GFS analysis of 500 mb heights and winds on the mid level water vapor imagery shows us the main feature of a broad trough over the western half of the CONUS. Embedded within this trough are shorter wavelength features or shortwave troughs and we can use the water vapor channels to tell us more about these features. One area that stands out is the region of relatively warmer brightness temperatures in all 3 water vapor channels centered over central California. In this portion of the trough there is strong downward motion and this sinking air is drier, allowing each water vapor band to sense a layer lower in the atmosphere than surrounding areas, hence the warmer brightness temperatures. Strong winds and very dry conditions behind this feature set up conditions for high fire danger on this day, and in fact the very destructive Camp Fire in north-central California developed just a little after this time, around 1430z.

Meanwhile near and ahead of the main trough axis widespread cooler brightness temperatures are seen within a general region of rising motion. Areas of rising motion will often be associated with cooler brightness temperatures since more moisture will be present, shifting the absorption curves of the water vapor bands to higher levels of the atmosphere.

Slide 6: Static GOES-16 4-panel with more analyses at 12z/8 Nov

This is the same 4-panel but we've stopped the loop near 12 UTC and added a GFS analysis of 500 to 300 mb vorticity on top of the upper level water vapor image. If you look carefully you will notice this strong gradient of brightness temperatures tilts with height, and is farther south in the lower level water vapor image, characteristics of a strong progressive shortwave. You may have noticed a separate area of warmer brightness temperatures to the north of this feature in the earlier loop. This is another embedded shortwave and we can see that it also corresponds to a vorticity max in the analysis.

In the general area ahead of the trough axis we do not see features in the water vapor imagery as dramatic as the ones just noted. If you look closely you can notice a narrow area of warmer brightness temperatures in west-central Nebraska. The vorticity analysis shows another maxima corresponding to this more subtle shortwave. One reason why this feature does not stand out nearly as well as the features behind the trough is because of the widespread cloudiness within the general region of rising motion ahead of the trough. How does this cloudiness affect the water vapor imagery? To get a better idea of what the imagery is actually sensing ahead of the trough we will examine the water vapor weighting functions at Dodge City in southwest Kansas, and contrast this to the strong signal we saw behind the trough by looking at the same information for Oakland California in the next couple of slides.

Slide 7: OAK WV analysis

We'll start with Oakland, which at 12z on 8 November is in the middle of the strong signal of warmer brightness temperatures behind the shortwave trough. Shown is the 12z sounding and from this sounding the weighting functions for each water vapor band. Remember these are calculated from the sounding but assuming that there are no clouds, which for this case is a good assumption. The weighting functions are fairly simple in this area because the atmosphere is generally dry. The brightness temperature shown for each band are obtained from a read cursor output on AWIPS of the water vapor imagery at the Oakland point. Remember the temperatures from our AWIPS cursor readout represent the net temperature of the water vapor layer being sensed by each band and not a specific level of the atmosphere. The fact that they are quite different from each other indicates that we are sensing different layers of the atmosphere, with those layers shown by the weighting functions. This information supports our interpretation of this being an area of strong downward motion behind a potent shortwave trough.

Slide 8: DDC WV analysis

Here is the same information for Dodge City, in southwestern Kansas, located in the more moist environment ahead of the trough. We do see a sounding that is in fact quite moist for the most part from the surface to above 500 mb. The IR image shows lots of cloud cover near Dodge City. Since the weighting functions are calculated assuming clear sky conditions we cannot use them in our interpretation in the same way that we did for the area near Oakland. The radiant energy emitted by the cloud layer and subsequently detected by the sensors in the satellite changes the weighting functions considerably, in this case they would be shifted to higher levels. We get a sense of this shift by the much colder brightness temperatures for all three water vapor bands when we do a cursor readout at Dodge City. This means in this location we are really mainly looking at the upper levels of the atmosphere. In fact, had the clouds been thicker, like in other areas east of the trough, we would have only sensed the temperature near the top of the cloud layer. Widespread moisture ahead of a trough like this may not allow us to see some of the features we may normally be able to detect with the water vapor imagery.

Slide 9: Larger area GOES-16 loop

Now let's use these ideas as we look at this larger scene using GOES-16 imagery for this early October 2018 weather pattern. In the lower right panel is the Air Mass RGB, which can be useful for interpreting synoptic patterns. Remember at this larger scale on AWIPS both time and space resolution are reduced over their full resolution values, but with this larger domain we can look at features from the tropics to the northern mid-latitudes. In this loop we can see a number of distinct areas of warmer brightness temperatures in the 3 water vapor channels interspersed amongst the generally broader areas of cooler brightness temperatures. Next we will overlay some analyses to see how this imagery relates to the various weather features.

Slide 10: Same loop but with analyses from the GFS.

Now we've added various GFS analyses or at some times short term forecasts to the same loop. There is certainly a lot going on in this loop, but let's start with the broad upper level ridge in the middle of the domain. One would expect broad sinking motion within this ridge, and while we do find more areas of warmer brightness temperatures within the ridge, especially in the mid and lower level water vapor imagery, the water vapor imagery reveals a number of smaller scale features moving within this upper level circulation. We can see how water vapor imagery can be a nice tracer of motions within the atmosphere just by observing these features within the upper level ridge.

One of the warmest areas in all 3 WV channels is found to the WSW of the tropical system in the Atlantic, Hurricane Leslie, with likely storm induced sinking through a deep portion of the atmosphere showing up as a warm signal in all 3 WV channels. Another notable warm area is found south of the upper level low off the California coast, with the strongest implied sinking motion just to the south or on the anticyclonic side of the upper level jet.

Farther north we see a couple of distinct shortwave troughs moving across the northern CONUS in the faster flow to the north of the upper level ridge. We see a nice signal of sinking behind the 2 main shortwaves, as we noted with our earlier example, with warmer brightness temperatures over portions of the Northeast and western Montana in all three water vapor channels.

The Air Mass RGB uses the upper and lower level water vapor bands along with 2 other IR bands to help distinguish air masses and other features. A warmer airmass will appear green, seen within much of the upper level ridge, while colder airmasses are blue, for example as seen in the Pacific Northwest and off the West Coast behind the upper level trough. See the Quick Guide on this RGB for more information. Other RGBs may also prove useful, especially those that include water vapor channels.

Slide 11: Same loop but with analyses from the GFS.

We'll finish up with this dynamic loop of the same imagery but for a developing East Coast storm in March 2018. The jet and waves are stronger for this event; see if you can identify some of the features, then advance to the next slide for the answer.

Slide 12: Same loop but with analyses from the GFS.

Here is the same loop with analyses from the GFS added. You might want to let the loop run for awhile and see how some of the jet and vorticity features relate to the signals we see in the water vapor imagery.

Slide 13: Summary.

In summary, we showed ways in which the GOES-R series aids in the identification and monitoring of circulation features. Overlaying analyses and short-term forecasts on the imagery not only gives you a better idea of features and patterns but is also a good check on how well a short-term model is capturing a particular feature. Often satellite imagery will reveal subtle features that may be difficult to forecast.

We emphasized the three water vapor bands since water vapor imagery is so useful for tracking atmospheric motions as well as depicting areas of sinking and rising air associated with weather systems. But it is important to remember just what the imagery is sensing as we interpret the three water vapor bands. In our limited time we only examined the Air Mass RGB, but other RGBs and products will also be useful for monitoring atmospheric features.