Detailed script – Circulation Features Module

Slide 1: Title

Slide 2: Learning Objectives

In this module we will focus on using imagery to identify and monitor basic circulation features, primarily using the 3 water vapor channels that will be on GOES-R since water vapor can be used as a passive tracer to follow motions in the atmosphere.

Slide 3: Upper level ridge – loop with some info

Our first focus will be on an upper level ridge using this short loop with an image every 10 min. Note that we have used the 4-panel format that is available on AWIPS-2. We are using imagery over the Pacific from the Himawari satellite as a proxy for GOES-R, with 3 similar water vapor bands and visible imagery.

In the next slides we will highlight some features that we can identify on the water vapor imagery. We will annotate on the loop since it is a short loop and the features identified do not change that much over the course of a few hours.

Slide 4: Loop with first set of annotations for features of the upper level ridge

First let's look at some details of the upper-level ridge. In each of the water vapor panels we have drawn a yellow line. This line marks the poleward extent of the ridge as seen in each water vapor channel. How did we determine where to draw each line? We know that flow goes around an upper level ridge in a clockwise or anticyclonic direction, while flow around a trough is counter-clockwise or cyclonic. The line marks the approximate location of the most poleward extent of the clockwise flow, and so the northern extent of the ridge.

If we look at the ridge extent in each image we can note a slight expansion of the ridge as we get lower into the atmosphere. The 3 channels of water vapor imagery allow us to get more of an idea of the 3 dimensionality of features, in this case a dome of warmer air that gets larger in area as we go lower in the atmosphere.

We can also use the flow following features of the water vapor imagery to determine where the center of the high or clockwise circulation is located. We don't show a high center in the low level loop because it is so dry that for this color table there is a broad area with one color, making it hard to track the flow. One might try different color tables to get the most out of the different channels of water vapor imagery.

The overall dry signal seen in the ridge is consistent with a broadly subsiding, warming and drying airmass. Monitoring the change and extent of this drying are useful for determining the strength of the upper level ridge; note here that even in this short loop we are seeing an increase in the warming brightness temperatures, drying and by inference subsidence in the mid level water vapor image. Even though the atmosphere is quite dry, we see from the visible imagery that the very low levels over the ocean are moist enough to sustain at least shallow convection. Although we would not expect this convection to develop much given the strong subsidence inversion associated with the ridge, the fact that we see it emphasizes the point that while GOES-R will have a new low-level water vapor band, seeing a very dry signal in this band does not necessarily mean the dry air extends all the way to the surface.

Slide 5: Same loop – jet features

Substantial upper-level flow often extends around the edge of an upper level ridge, as is the case here. How can we use the water vapor imagery to diagnose the jet stream? The zone of deformation at the northern edge of the ridge also generally marks the location of the core of the upper level Polar Jetstream, which we have marked by light green arrows in the mid and upper level water vapor images. In these channels we will typically see an elongated zone of warmer brightness temperatures corresponding to drier air on the cyclonically sheared side of the jet axis, in contrast to an increase in moisture or even a solid band of clouds if enough moisture is present on the anticylonically sheared side of the jet. We can think of why this is so by remembering that the Polar jet is associated with the thermal contrast or baroclinicity across a frontal zone, with warmer and more moist air to the south. In our case there are not many clouds and all we see is the elongated dry zone that helps us identify where the polar jet lies.

At the far western edge of the images there is also a subtropical jet, which is typically located relative to cloud and water vapor imagery in a similar way to the Polar jet. We have marked the subtropical jet by yellow arrows on the upper level water vapor image, where it is best seen. In this case we do not see much of a dry band signal, probably owing to a branch of the Polar jet lying so close by.

Slide 6: Same loop – embedded shortwaves

Now let's take a closer look at the jet stream zone around the periphery of the upper level ridge. In our case a broad upper level trough is found to the north across the North Pacific. Within the jet stream we find transient shorter wavelength troughs, known as shortwaves, and we have marked their position by white arrows at the beginning of the loop. We can think of each of these shortwaves as a smaller scale version of an overall trough with sinking air in the dry conveyor belt behind the axis of the shortwave and rising air in the warm conveyor belt ahead of it. Since the amount of moisture will vary we may not see much of a signal in visible or IR imagery, but shortwaves can be revealed more easily in water vapor imagery by a couplet of drier/warmer brightness temperatures in the sinking air behind the wave and an area of more moist air and colder brightness temperatures in the rising air ahead of the center of the shortwave.

Notice how the different shortwaves appear in the various water vapor bands, some more apparent at different levels of the atmosphere. The two most well developed waves at the eastern edge of the imagery are associated with a pair of cyclones seen in the visible imagery. We will discuss some of the structure seen with shortwaves in the various water vapor levels in more detail with the next case.

Slide 7: Upper level troughs

In our next case we look in more detail at upper-level troughs. The loop shown here covers a very active period with the jet stream farther south into the Pacific than we saw in the Ridge case. We have zoomed out a little, and again use a loop of Himawari imagery as a proxy for GOES-R and a 4-panel display that features the 3 water vapor channels that will be on GOES-R as well as an IR channel similar to what we now have on GOES. This loop extends over a longer period so we have chosen to look at imagery at hourly intervals. Next we will point out some of the features in this loop with one static image early on in the loop, at 12z on 1 May, then we will return to the loop so you can see how these features evolved.

Slide 8: Single time, 12z/1 May, with annotation of the upper level pattern

First, as we did before we show the approximate poleward extent of the upper level ridge by the yellow line, this time overlaid on the high level water vapor image. Since we often overlay different height analyses with satellite imagery, on the mid-level water vapor image we show the approximate location of the 570 dm height line from a 500 mb analysis. Across our domain we see two longwave troughs, one on the left side over Asia and the other in the central Pacific. The different shape to the two lines reminds us that water vapor imagery shows 3D flow through different levels of the atmosphere. Since the yellow line was drawn following the flow, we would not expect it to always resemble the white line that is taken from an analysis at a single level.

Also shown are the centers of two upper level lows and the upper level high, located by looping the water vapor imagery to find the circulation centers. There are two distinctly different upper level lows. The one in the far eastern edge of the domain is seen in all 3 water vapor images, but the main moisture signal is at the high level, and in the IR image there is little reflection of this feature in the cloud field. When we return to the loop you will notice that this system gradually weakens with time. Contrast this with the closed upper level low much farther north. We can tell that this is a mature and deep system by the rings of moisture wound around the center in the various water vapor channels. This upper low had a central height of 516 dm at this time, and was separated from the main flow. The low is gradually weakening over the time of the loop as will be seen in the water vapor imagery by the gradients gradually going away and the moisture being separated from the center of circulation. At the surface there is a similarly wound up looking cloud field in the IR image, a classic signature of an occluded storm.

Slide 9: Single time, 12z/1 May, add annotation of shortwaves

Now we look at a couple of the important shortwaves that are embedded within the two main troughs. In the western portion two shortwaves are noted by the thick white arrows. The southern wave is within the subtropical jet and is tilted out of the low level image. Although this is not a particularly strong wave we will see in the loop that it moves to the northeast and interacts with the stronger northern shortwave. The northern shortwave has a well defined signature of warmer brightness temperatures associated with sinking motion and drying in the dry conveyor belt on the west side of the shortwave. This signature is seen at all 3 water vapor levels and after this time strengthens, initially at higher levels and then quickly down through the lowest water vapor level, a signal of a deepening wave. Indeed, after this wave interacts with the southern wave a deep cyclone develops in northeastern Asia.

The second shortwave we have highlighted is marked by the thick yellow arrow in the Central Pacific, pointing to the area of warmest brightness temperature that marks the strongest localized subsidence within the fairly broad subsident region of the overall trough. This shortwave is approaching the stalled frontal zone noted earlier and evident in the IR imagery. However, as we will see next in the loop, the drying signal with this shortwave does not intensify over time and this wave continues to progress eastward without deepening. As a result we see only limited cyclogenesis along the frontal zone.

Slide 10: Full loop without annotation from 01z/1 May – 21z/2 May at hourly intervals

Here is the loop again with images at hourly intervals.
Recall the features we noted in the snapshot -

1) the progressive shortwave just noted and the lack of development
2) the gradual filling of the deep closed low at the northern edge of the domain in contrast to the weakening upper level low farther south
3) the strengthening shortwave over the western portion of the images and how it interacts with the wave in the subtropical jet leading to the development of a strong cyclone
4) Finally, notice the slowly westward-moving cloud clusters across the southern Pacific – these are easterly waves moving to the west beneath the upper level ridge.

Slide 11: RGB loop (26/10:28)

There are other tools that try to put together information from various bands into a single image. The RGB Airmass Product is an example of such a image, using the 3 water vapor bands along with two IR bands. The idea is to better depict the different airmasses. This loop focuses on the two interacting shortwaves that we saw in the last loop that led to the cyclone in eastern Asia. This imagery is discussed further in the Cyclogenesis module.

Slide 12: Summary (11/10:39)

In summary, the new water vapor channels on GOES-R, along with other products, will enable one to visualize more of the atmosphere and with greater spatial and temporal resolution than we have today.