Slide 1 – Title

Slide 2 – Learning Objectives – Here are the learning objectives. We'll be using the new imagery, RGBs and products from GOES-16 for an atmospheric river event that hit California in March 2018. It is important to note that because we need to look well off the West Coast with GOES-16 we will have to use full disk imagery, which has lower horizontal and temporal resolution than CONUS-scale imagery.

Slide 3 – AR definition

Slide 4 – Diagnosing an AR What's new in the GOES-R era to help us with Atmospheric Rivers? In terms of qualitative evaluation there are 3 water vapor channels versus just one previously, as well as new RGBs and data from the Global Lightning Mapper. For quantitatively evaluating an Atmospheric River we want to determine the amount of precipitable water or PW in the AR plume. Polar orbiters provide the operational blended total PW product, as well as a new Advected Layered PW product that we will look at. GOES-R also has a PW product, and we will demonstrate that product and how it differs from the Polar products in this module.

Slide 5 – 20-22 Mar AR overview

Slide 6 – (Overview continued.) This turned out to be a significant event as we can see from these weather story pages from some of the affected WFOs. Hit the pause button if you would like to look at these further.

Slide 7 – Here is a long 10.35 micron IR loop at hourly intervals so that we can show the entire event. The color table is IR_Color_Cloud_Winter. Because this is GOES-16 in the GOES-East position we see that image resolution goes down as we move westward into the. GOES-17 was not available for this March 2018 event but would be the satellite of choice for better resolution in its GOES-West position.

There are 2 main intrusions of moisture into California and the western US in this loop.

The first is at the beginning of the loop on the eastern side of the upper level low that is stalled well offshore.

After a slight break we see the second surge. There is a new tropical connection of moisture into this surge coming off the ITCZ in the SW corner of the imagery. This moisture combines with the main plume as it all moves onshore. The event starts to end as the overall trough pushes eastward.

In the next few slides we will be examining the first day and a half of this loop with various GOES-16 bands, RGBs and products, in particular focusing on this second surge of moisture.

Slide 8 – 4-panel of WV channels with Airmass RGB in the lower right, loop goes from 2100z/19 Mar to 1500z/21 Mar at 15 min intervals.

This loop uses a 4-panel AWIPS display to show the 3 water vapor channels that are available on GOES-16 & 17, compared to only one before GOES-R, as well as a new product called the Air Mass RGB. The default color table is used for the water vapor imagery, called RAMSDIS_WV_12bit. The lower level water vapor channel is in the upper left panel, the mid-level channel in the upper right, and the higher level water vapor band in the lower left.

Since clouds have sufficient moisture to quickly saturate the water vapor channels we generally see similar brightness temperatures with the clouds in the Atmospheric River plume in all 3 water vapor channels, except somewhat colder for the higher level water vapor channel. Of course because the cloudiness saturates all 3 water vapor channels, we cannot use water vapor imagery to determine much about the atmospheric river once it is filled with clouds, but we can still use the imagery to gain some information. For example, notice how the initial moisture surge into California at the beginning of the loop appears first in the higher level water vapor band, well before we see it in the lowest level 7.34 micron imagery. This tells us that the initial moisture coming onshore was at higher levels and not very thick, and indeed rain did not begin along the coast until 08z on 20 March.

Another area where the water vapor imagery is helpful for this event is in showing the surge of moisture moving northward from the ITCZ noted earlier, seen here in the lower left portion of each panel. This time the northern edge of moisture and cooler brightness temperatures is similar for all 3 water vapor channels, implying more than just higher level moisture at the leading edge of this surge. The reason we can see this surge so well is that the area has only partial cloudiness initially with more widespread cloud cover not coming until later.

The air mass imagery shown in the lower right panel uses some of the water vapor and IR channels to highlight different air masses and also cloud top heights in a single image. It can be useful to identify the different air masses present, and for our case also nicely shows the second northward moving moisture plume. You might also want to look at other RGBs that use water vapor channels, such as the Differential Water Vapor RGB and the Simple Water Vapor RGB.

Slide 9 – Here is the same 4-panel loop but with GFS analyses interspersed with 3-h forecasts overlaid on the lower 2 panels; 300 mb isotachs with the higher level water vapor imagery and 500 mb heights on the Air Mass imagery. With the 500 mb height overlay we can get a better idea how the different colors of the Air Mass imagery are related to the troughs and ridges. The core of the strong jet in the Pacific overlays nicely with the warmer brightness temperatures in the 6.19 micron water vapor imagery, with the Atmospheric River on the anticyclonic side of the jet.

Slide 10 – Here we have the same water vapor imagery in a 4-panel loop but now in the lower right panel we display a new GOES-R product: the GOES Total Precipitable Water product. GOES TPW is a Legacy Atmospheric Profile, or LAP Baseline Product, derived from the 3 water vapor channels on GOES-R, with a 10-km horizontal resolution. The GOES TPW product is available at 5-min intervals, although here we have 15-min intervals since we are on a larger scale. A limitation of this product is that TPW is derived only in clear or nearly clear sky conditions, as can be seen in this loop where the blank or black areas correspond to clouds in the water vapor imagery. However, note that unlike the water vapor imagery, we get a quantitative measure of the moisture present. The limitation with respect to clouds does not allow us to determine the PW within the AR plume, and in this loop we have focused on the northward surge of moisture. Specifically, note the northward push of the red and bluish colors in the far southwest portion of the image during the first part of the loop, showing the deepening moisture to levels at and above 2" of TPW moving northward, before cloudiness develops.

Slide 11 – In this 4-panel we have zoomed out, and now the same GOES TPW imagery is in the upper left with the IR 10.35 micron imagery below it. In the upper right is another GOES-R Baseline Product that would be of use for AR events, the GOES Rain Rate/QPE product, displayed as a rate in inches per hour. There are some known problems still being resolved with this product and it is expected to become more accurate, but one can see the potential value with rain rates shown well off the California coast beyond radar range and within the Atmospheric River plume. Another Baseline Product is shown below this in the lower right panel, the Cloud Top Height Product, which is most effectively used in concert with the IR imagery. Both these products are discussed further in separate modules. This loop is shorter than the previous loops, during the period when the AR plume had spread well inland. While we lose a lot of information in the GOES TPW product in the cloud-filled AR, note how you still can get glimpses of the TPW in fairly small areas where there is some temporary clearing.

Slide 12 – Since the GOES TPW product has no information in areas of cloudiness one could combine the product with cloud imagery, as seen here where band 2/0.64 micron visible imagery has been used for this shorter loop on 22 March.

Slide 13 – Instruments aboard some Polar orbiting satellites allow for TPW to be measured in both clear and cloudy conditions, with data dropout possible in areas of precipitation. Here we show the longer loop again with a 4-panel where the operational Blended TPW product is in the lower right panel with the GOES TPW in the lower left panel. The low and mid level GOES-16 water vapor imagery are shown in the top two panels. The TPW scales differ somewhat mainly for values below one inch. While the areal coverage is much better from the Blended TPW product the time resolution is worse, and the horizontal resolution is 16 km. But the obvious advantage of the Blended TPW is the ability to measure the PW within the cloudy areas, including the core of the Atmospheric River.

Slide 14 – A more recent TPW product derived from polar orbiting satellite data is the Layered Precipitable Water or LPW product, which separates the atmosphere into 4 layers from the surface through 300 mb. Shown in this loop is a newer version of the LPW product called the Advected LPW product. More information on these products is available in a Quick Guide found on the VISIT website, and the product is available experimentally to WFOs for display on

AWIPS2. Contact myself or Dan Bikos for how to get the imagery into AWIPS. There are occasional areas of no data when satellite coverage was incomplete. Otherwise the smaller areas of no data are regions of precipitation. This loop covers the entire event and we can see several of the features discussed earlier, as well of course the distribution of PW in the vertical within and near the AR plume.

Slide 15 – Data from the Global Lightning Mapper or GLM was not operationally available for this March case, but it would be useful for AR analysis in terms of identifying particularly active convection within the plume. Here is an example of the GLM Flash Extent Density product from GOES-16 on AWIPS for a modest Atmospheric River event into Central California and the West on 28 November 2018. The GLM shows some active convection in the cold frontal band to the north that was merging with the AR plume, overlaid on band 2 visible imagery from GOES-17, hence the higher resolution imagery off the west coast. GLM was not operational yet for this case, but will of course be better to use with the GOES-17 imagery.

Slide 16 – Summary