Talking points for Mountain waves and orographic enhancement

1. Title
2. Our learning objective is to how make optimal use of capabilities of the GOES-R series in identification of mountain wave clouds, which are may also be referred to as orographic cirrus or lee wave clouds. We'll address the benefits of greater spatial resolution and discuss the appropriate bands and products for identification.
3. The mountain wave clouds or orographic cirrus that we'll be discussing are stationary cirrus that develop to the lee of a mountain range. Under the condition that a stable layer exists from the mountain ridge to the upper part of the troposphere and wind direction is nearly constant, a wave is produced by the mountain ridge and is transmitted to upper levels. If sufficient moisture exists at upper levels, these orographic cirrus or mountain wave clouds will develop. These are important to account for in your forecast because they tend to be relatively thick cirrus which are efficient at preventing insolation, thus playing a significant role in the temperature forecast.
4. GOES-16 imagery from the 10.3 micron band for 22 November 2017 shows multiple regions of cold cloud tops, however, for mountain wave cloud identification we're interested in the clouds that develop along ridge tops and exists only in the downwind direction, in other words these type of clouds are quasi-stationary as they are tied to terrain features while other clouds advect along with the mean flow. During the loop, we notice the expansion of very cold cloud tops in western Montana extending southward to Wyoming, implying that the mountain wave clouds are becoming thicker. The 10.3 micron band should be the primary band for analyzing mountain wave clouds since it highlights the typically very cold cloud tops that are locked in to terrain features. Later, we'll discuss other bands and products that can be useful as well.
5. Is there any other useful information from the various bands available on the GOES-R series? Well, the water vapor bands do provide value as well. In this 4 panel we have the 10.3 micron band, along with the GOES-16 3 water vapor channels. One of the signatures you may observe in the water vapor channels is a region of warmer brightness temperatures associated with subsidence on the upstream side of where mountain wave clouds develop. At times, these may be a pre-cursor to mountain wave cloud development. Of the 3 water vapor channels, which channel depicts the upstream subsidence signature the best and why? ***pause***
6. The upstream subsidence signature shows up well in the lower water vapor band at 7.3 microns, the signature is much more subtle with the mid water vapor band at 6.9 microns and the signature is virtually absent in the upper water vapor band at 6.2 microns in this case. The physical reasoning is due to the weighting function profile as discusses in the Water Vapor Bands SatFC-G module. The 7.3 micron band weighting function profile sees the lowest altitude layer of the 3 WV bands. Typically the strongest subsidence is associated with the stable layer that develops just above ridge top level, therefore the 7.3 micron band is best suited to see that layer relative to the other 2 water vapor bands. However, for some events you may see a subsidence signal in all 3 bands, but the 7.3 micron band will likely still show the strongest signal. As you develop experience in looking at mountain wave clouds in your CWA, you may notice trends in the subsidence signature with the 3 water vapor bands that could prove useful

in forecasting mountain wave clouds. Finally, note the region of clouds and moisture approaching from the west and advecting over the mountain wave clouds, the wave clouds grow rapidly soon after the arrival of this feature.

7. There are other bands and products that can provide additional information on mountain wave clouds. During the nighttime hours, the 10.3 and 3.9 micron bands have similar brightness temperatures. During the daytime hours (shortly after 1400 UTC), note the brightness temperatures at 3.9 microns become considerably warmer, due to the introduction of the reflected solar component at 3.9 microns. This is particularly true over the mountain wave clouds where brightness temperatures warmed from about -70 C to slightly above freezing. The other higher clouds advecting along warmed only to about -20 C. Research has shown that smaller ice particle sizes reflect more solar energy than larger ice particle sizes. Thus, the existence of relatively small ice particles in the mountain wave clouds can explain the warmer brightness temperatures at 3.9 microns compared to all the other ice clouds. Finally, note the nighttime microphysics RGB imagery at the bottom, which can also tell you something about cloud particle size. However, for this case, during the nighttime hours we see green speckling over the mountain wave clouds in Montana which implies supercooled liquid water. But we know from the 10.3 micron imagery, cloud top temperatures are around -70, well below the homogeneous freezing temperature. Why do we see this false signature? There are 2 possible explanations for this "false signal". First, temperatures at 3.9 microns are cold enough to allow noise to appear in the imagery and the 3.9 micron band is contained in the green component of the nighttime microphysics RGB. Secondly, the existence of relatively small ice particles. When very cold clouds exist at night, use 10.3 microns rather than 3.9 micron imagery (or a product that uses the 3.9 micron band) due to significant noise in the 3.9 micron band.
8. We move on to a different case, this is in April of 2018 and we're focused over Colorado. Arguably the best way to look for mountain wave clouds is a 4 panel display, with highest priority on the IR band at 10.3 microns. The development of mountain wave clouds shows up best in the 10.3 micron band since it shows very cold cloud tops that are quasi-stationary since they are locked in to the terrain and advect downstream. Note that there is considerable high cloud cover advecting through the region of interest, mixing in with the mountain wave clouds which can make it difficult to identify the mountain wave clouds.
9. Next we look at various channel difference and baseline products to help discern mountain wave clouds from the high level clouds that are moving through. In the upper left we have the cloud particle size distribution baseline product. Recall that mountain wave clouds are characterized by relatively smaller ice particles. This product isolates the smaller ice particles, which are color enhanced as the purple shades that originate along the Front Range and appear locked in to the terrain. Similarly, the Day Fog channel difference product which is 3.9 minus 10.3 microns can be useful during the day. This difference product subtracts out the emitted component so that we are left with the solar reflected component. The large positive values over the mountain wave clouds (indicated in yellows and reds with this color table) indicate relatively small ice particles. Remember to use these channel difference and baseline products in conjunction with the 10.3 micron product to note where the colder cloud tops exist

10. Summary – last bullet: Finally, water vapor bands are useful in that you may see an upstream subsidence signature, particularly in the lower or mid water vapor channels with weighting function profiles that are not above where the subsidence exists.