Talking points for "**Utilizing Synthetic Imagery from the NSSL 4-km WRF-ARW model in forecasting Orographic Cirrus**".

1. This training session is part of a series that focuses on applications of synthetic imagery from the NSSL 4-km WRF-ARW model. Forecasting orographic cirrus is important because of their influence on temperature forecasts. Utilizing synthetic imagery generated from a model is a useful way to anticipate orographic cirrus. Orographic cirrus can be more easily visualized on synthetic imagery compared to model output fields such as relative humidity over some layer.
2. In this training session, we'll focus on orographic cirrus which develops in a stable atmosphere where a wave is produced by the mountain range and is transmitted to upper levels. If sufficient moisture is present, orographic cirrus develops. Orographic cirrus has the appearance of developing along a mountain range and advecting only in the downwind direction of the mountain range. Since the source of the cloud cover is stationary, this makes it appear readily in satellite imagery and thus in synthetic imagery as well.
3. Synthetic imagery is model output that is displayed as though it is satellite imagery. Analyzing synthetic imagery has an advantage over model output fields (such as relative humidity) in that the feature of interest appears similar to the way it would appear in satellite imagery. There are multiple sources of synthetic imagery available on the web, for example the CRAS model at the university of Wisconsin has been available in AWIPS via the LDM for some time. The primary focus of this training session is synthetic imagery generated from the NSSL 4-km WRF-ARW model. The model is run once a day (at 0000 UTC), certain model fields are distributed to CIRA and CIMSS. These model fields are used as inputs into a model that generates the synthetic imagery. Gaseous absorption is calculated for cloud-free points, and Modified Diffraction Theory is used to obtain scattering and absorption by the cloud particles. The model outputs brightness temperatures for a number of satellite bands. For more information on the details of synthetic imagery generation, refer to the references on the student guide webpage.
4. Hourly output is generated for the 12 to 36 hour forecast, valid 12Z of Day 1 to 12Z of Day 2. The bands are those that will appear on GOES-R since the project is based on demonstrating products that will be available on the GOES-R satellite, scheduled for launch around 2015. The bands are very close to those found on the current GOES satellites, so that the principles discussed in this training session readily apply to operational GOES satellites of the present.
5. On the left panel is the synthetic imagery for the IR band from the WRF-ARW model for December 3, 2010. The times are 00-06 UTC December 3, which means this is from the 0000 UTC 2 December run. On the right panel is the time matched GOES IR imagery with times given. Remember in GOES satellite imagery, orographic cirrus appears as cold brightness temperatures that originate over mountain ranges and advect only in the downwind direction,with the source region of the clouds being stationary as its tied to the mountain range. In this example, the model has what appears to be orographic cirrus downwind of the Sierra Nevada range in California, advecting into Nevada, downwind of the Silver City range in southwest Idaho, downwind of the Absaroka and Big Horn ranges in Wyoming and downwind of the Front and Sangre de Cristo ranges of Colorado and New Mexico later in the loop.

The model appears to do a good job with developing orographic cirrus downwind of the Sangre de Cristo and Front ranges. The other regions had orographic cirrus present in the model during this period, which is shown across Nevada but not as much downwind of the Absaroka and Big Horn ranges in Wyoming. In Idaho, there is high level cirrus advecting across the region making it more difficult to assess how much of this was orographic cirrus. Just like looking at any other model output, there will be times it performs well, and other times not so well. Poor initialization, lack of resolution and other familiar sources of model error will show up in the synthetic imagery.

6. Let’s compare the 6 hour NAM temperature forecast with the observed values from the RTMA at 0600 UTC (the end of the loop in the synthetic imagery we analyzed earlier). The major feature by 0600 UTC was the development of orographic cirrus downwind of the Front and Sangre de Cristo ranges in Colorado and New Mexico. The RTMA has warmer temperatures than forecast, likely due to some combination of the orographic cirrus keeping it warmer at night and downslope winds.

7. Now we switch to a different case, this is for January 5-6, 2011 in a situation with a tricky low temperature forecast. The synthetic IR imagery shows orographic cirrus developing developing in the evening hours and persisting overnight downwind of the Lewis range in Montana. The timing of this would keep the temperatures warmer than expected and result in a warmer minimum temperature forecast.

8. Looking at the verifying GOES IR imagery, we see that orographic cirrus does develop downwind of the Lewis range about the same time as predicted by the WRF-ARW model. The cloud cover also persists overnight as was forecast.

9. Here are is the NAM temperature 6 hour temperature forecast valid at 0600 UTC, from the 0000 UTC run. The NAM shows values in the upper 20’s to low 30s downwind of the Lewis range in Montana. Toggle to the next frame to show the RTMA temperatures at 0600 UTC. The observed temperatures are 5-10 degrees warmer than forecast downwind of the Lewis range in Montana and extending northward into Canada.

10. Here are is the NAM temperature 12 hour temperature forecast valid at 1200 UTC, still from the 0000 UTC run. Toggle to the next frame which shows the RTMA temperatures at 1200 UTC. The observed temperatures are considerably warmer under the region of orographic cirrus downwind of the Lewis range and extending into Canada. It appears that the orographic cirrus played a significant role in keeping the temperatures warmer overnight and into the next morning, making for warmer minimum temperatures than forecast by the model. Keep in mind that downslope winds may have contributed as well, in the next case we’ll consider multiple factors in addition to orographic cirrus that can play a role in the temperature forecast.

11. Now we switch to a different case, this is for November 18, 2010. We’ll start with a traditional approach of analyzing model output for orographic cirrus potential, by looking at the GFS 300-500 mb layer relative humidity. The general trend of increasing relative humidity in this layer stretches from northern California to Wyoming. There is a trend of increasing relative humidity downwind of the Front Range of Colorado.

12. Now let’s analyze orographic cirrus potential over the same time period. Some of the differences you should notice are that you’re now looking for what appear to be orographic cirrus, the way you’re used to diagnosing them in satellite imagery. It’s much easier to focus in on regions where clouds originate from a mountain range, as opposed to looking at trends in RH. The temporal resolution is another advantage, offering hourly images as opposed to the model output times at 3 or, with the GFS, 6 hour intervals. The imagery shows what appear to be orographic cirrus either present or developing in western Nevada, southwest Idaho, northern Wyoming and central Colorado, downwind of many of the mountain ranges we discussed earlier.

13. Here is the CRAS synthetic IR imagery for the same forecast period. The resolution is more coarse than the WRF-ARW, however it is good practice to look at other models the same way you look at the operational models and ensembles to gain confidence in your forecast. In this example, it appears that there is generally an agreement on where orographic cirrus will develop between the CRAS and WRF-ARW models.

14. Synthetic water vapor imagery is also available from the WRF-ARW model. This can be useful in looking at the general flow pattern and in the case of orographic cirrus, you will often times find regions of subsidence over the mountain region of interest with orographic cirrus advecting in the downwind direction. This can be another signature to look for to help you readily identify orographic cirrus.

15. Here is a cross section of the GFS relative humidity field over the Front Range of Colorado. It's important to note that we're not suggesting synthetic imagery replace analysis of model output fields, rather, to complement one another so that you may assess confidence in a forecast of orographic cirrus. For example, we earlier identified the potential for orographic cirrus in the WRF-ARW and CRAS synthetic imagery over the Front Range of Colorado. Now, we look at the GFS relative humidity in a cross section across the region of interest. Using this method allows you to check various models and allows one to assess confidence in the location and timing of orographic cirrus development.

16. Here is the GOES IR imagery during the period of interest. Note that synthetic imagery did a pretty good job in identifying where and when orographic cirrus would develop. The timing of the development of orographic cirrus can be crucial the temperature forecast. For example, notice the developing orographic cirrus across the Front range of Colorado during the late morning hours which would significantly reduce insolation during a key time of the day.

17. Here is the GOES water vapor imagery during the period of interest. Note the region over the mountain range where orographic cirrus develops is usually darker (i.e, warmer) than the region around it due to subsidence, although the signature is not as pronounced as in the WRF-ARW synthetic imagery.

18. Visible imagery zoomed in over Colorado. A combination of the lack of downslope winds and insolation due to developing orographic cirrus resulted in a colder region in north central Colorado along and just east of the Front Range. The morning inversion held on in regions where the winds were calm and insolation was significantly reduced, the result was temperatures well below MOS forecast high temperatures. Temperatures warmed up where insolation occurred or there was sufficient downslope flow to erode the morning inversion. Usually the temperature forecast comes down to a combination of factors like we see in this example.

19. Here is a picture of the orographic cirrus over Fort Collins at 2000 UTC November 18.

20. RTMA temperatures and winds along with METARs during the same period as the visible loop. Note the pocket of colder temperatures under the region where orographic cirrus developed. After sunset, the area under the cirrus would cool down more slowly compared to clear sky conditions.

21. At times, the synthetic imagery may look unusual. For example, here is the WRF-ARW synthetic imagery for December 7 and 8, 2010. This is 2 days worth of imagery with a gap between 06 and 12 UTC. The unusual aspect of this case are the long lines of cloud streaks that don't appear natural. The long streaks correspond to thin cirrus that are optically thicker in the model than observed. You will have to mentally block out the long streaks of clouds when you come across this type of situation. One way to more easily pick out the orographic cirrus is to

turn up the loop speed and rock it back and forth. Doing this, you can readily identify orographic cirrus forecast by the model off the Sierra Nevada range of California, the Lewis range in Montana, the Absaroka and Big Horn ranges in Wyoming and the Front range of Colorado late in the loop.

22. This is the corresponding synthetic water vapor imagery. Increase the loop speed and rock it back and forth will allow you to readily identify regions of orographic cirrus, in particular where we see regions of subsidence along the mountains such as the Sierra Nevada range of California, the Lewis range of Montana and the Front range of Colorado.

23. This is the verifying GOES imagery. By mentally subtracting the erroneous long lines of clouds from the synthetic imagery and focusing on the orographic cirrus, we can see the model does a reasonable job of depicting orographic cirrus.

24. Where can you view the synthetic imagery? The WRF-ARW imagery we've been showing is part of the GOES-R proving ground products that are available in AWIPS via the central region LDM, if you're outside of central region and desire this data in AWIPS, please contact us . The imagery is available on the web at CIRA at this URL, select the synthetic imagery from the suite of other GOES-R proving ground products. CIMSS also makes the imagery available at the URL shown. CRAS output is also available in AWIS via the LDM. Finally, if you're interested in model output fields from the WRF-ARW model, it's available at the URL shown here.

25. Analyzing synthetic imagery for orographic cirrus does have advantages compared to only looking at model fields in that you're looking for what appears to be orographic cirrus, and you have higher temporal resolution data. The best approach is to look at multiple sources of synthetic imagery to readily identify regions of orographic cirrus, then look more carefully at those regions utilizing multiple models to gain confidence in the occurrence and timing of orographic cirrus, and most importantly, what effects that will have on the temperature forecast.

26. If you have any questions, feel free to email myself or Dan Lindsey. If you're a NOAA employee that would like credit for having completed this training, take the quiz on the LMS.