

Talking points for “Utilizing Synthetic Imagery from the NSSL 4-km WRF-ARW model in forecasting Severe Thunderstorms”.

1. This training session is part of a series that focuses on applications of synthetic imagery from the NSSL 4-km WRF-ARW model. In this training session we'll consider applications of the synthetic imagery towards severe weather events. The primary motivation for looking at synthetic imagery is that you can see many processes in an integrated way compared with looking at numerous model fields and integrating them mentally.

2. Synthetic imagery is model output that is displayed as though it is satellite imagery. Analyzing synthetic imagery has an advantage over model output fields 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), it uses WSM6 microphysics. This is a 1-moment package, meaning the model predicts only the mass, and not the number concentration, of each hydrometeor species. Hydrometeors include cloud water, cloud ice, snow, graupel, and rain. Certain model output fields, including the hydrometeors in addition to temperature, pressure, heights, water vapor, and canopy temperature are sent to CIRA and CIMSS.

3. Those fields are used as inputs into a model that generates simulated satellite brightness temperatures. Gaseous absorption (by water vapor, primarily) is calculated for cloud-free grid columns, and Modified Anomalous Diffraction Theory is used to obtain scattering and absorption by the cloud particles. Cloud water and cloud ice are the only hydrometeors having a non-negligible effect on the resulting brightness temperatures.

4. Given the 1-moment microphysics, particle number concentration must be guessed at. Since particle size is proportional to the ratio of the mass to the number concentration, the uncertainty in the number concentration leads to uncertainty in the particle size, which in turn leads to errors in the cloud optical depths. This is most often manifested by thin cirrus having brightness temperatures that are too cold. For more information on the details of synthetic imagery generation, refer to the references on the student guide webpage.

5. Hourly output is generated for the 9 to 36 hour forecast, valid 09Z of Day 1 to 12Z of Day 2. The synthetic imagery is ready to view by about 10:00 UTC. The model outputs brightness temperatures for a number of satellite bands. 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. In this training session, we're only going to focus on the 10.35 um IR band and 2 of the 3 available water vapor bands. We will be discussing the water vapor channel you are used to looking at, 6.5 or 6.7 um depending on whether you are considering GOES-East or GOES-West, and we'll also be looking at the 7.4 um water vapor channel which is available on the GOES sounder. Next, we'll look at the differences between these two water vapor channels.

6. The weighting function profile gives us a clear indication of what level in the vertical the channel is seeing. Here are the weighting function profiles based on a sounding at North Platte, NE for the 6.9 um and 7.3 um wavelengths. The maximum values for the 6.9 um channel are around 400 to 500 mb. Think of this as the net temperature of the layer of moisture the channel

sees peaks around 400 to 500 mb, with decreasing values above and below that layer. Let's contrast that with the 7.3 um curve shown in purple which sees the moisture at lower-levels and over a broader depth. Note that the layer the channel sees is variable, and depends on the thermodynamic profile. The advantage of looking at the 7.4 um channel is detecting vertical motions through a deeper layer as well as detection of mid-level jet streaks.

7. We now begin looking at cases. We'll start each case by looking at the SPC storm reports. For this case from June 21, 2010 note the numerous severe weather reports across Wisconsin, Illinois and Iowa, while further west, we see numerous reports in Montana and Colorado.

8. Here is the WRF-ARW synthetic imagery for the 6.95 μm water vapor channel. This is from the 00 UTC 21 June 2010 model run, so we're looking at the 12 to 30 hour forecast during this loop as the imagery is labeled 12 UTC to 06 UTC. Note the region of convection during the morning hours in Illinois moving towards Indiana. MCS's appear much smaller in the synthetic imagery compared to observations for reasons we'll discuss later. Note the darker region of warmer brightness temperatures that appears to be associated with a shortwave. Convection develops in response to this shortwave in the Iowa, Wisconsin, Illinois region from the afternoon hours and moves eastward through the evening. Further west, we see a cutoff low over western Montana. We see a jet streak that moves from Arizona into Colorado as depicted by a region of relatively fast moving area of cooler brightness temperatures. This visual comparison of a jet streak with how it would show up in the water vapor imagery makes comparison between model output and GOES imagery even easier. We see convection develop in response to the cutoff low over Montana and further south across Colorado to the northern Texas panhandle in response to the jet streak. Visually, we can readily see the mid to upper level features in the synthetic imagery that can lead to convection which makes for an easy comparison with water vapor imagery.

9. Here is the GOES water vapor imagery for the same period as the synthetic imagery. First, note the morning MCS across Illinois moving into Indiana. It does appear much larger in GOES compared to the synthetic imagery because the synthetic imagery typically underdoes the areal extent of the anvil cirrus. MCS's will almost always appear too small in the synthetic imagery for this reason. Note in the GOES imagery that the MCS persists longer than the synthetic imagery showed. This is another common thing to look for in the synthetic imagery, in that it is typically too quick to dissipate the convection. The model did a pretty good job with the convection associated with the shortwave as it moved across Iowa, Wisconsin and Illinois. In the west we can readily identify the cutoff low in Montana and the convection associated with it. The model did a very good job with the jet streak as it moved from Arizona into Colorado. Brightness temperatures in the synthetic imagery will typically be warmer than observed in GOES imagery, which is why we see the jet streak show up in the GOES imagery as a larger region of colder brightness temperatures. The storms associated with this jet streak have a much larger anvil cirrus than the synthetic imagery showed. This is a known bias so you will just need to keep this in mind when identifying thunderstorms in the synthetic imagery. In review, we see some areas where the forecast convection timing and location looked good, other areas, not as good. Remember we are looking at model output, and not even considering low-level features such as visible imagery and surface observations. The main utility of the synthetic water vapor imagery is identifying shortwave and jet streaks that may play a role in the initiation, maintenance and intensity of convection.

10. Here is the WRF-ARW synthetic IR imagery for the same time period. During the SPC spring experiment, the sector was over this region so we will be looking at the central US for this reason. The advantage to this channel is that low-level features will show up. This is useful when analyzing cloud cover, to see if clouds will dissipate and allow for sufficient insolation to warm up the surface. Note the morning clouds in eastern Colorado that are forecast to dissipate by late morning. Outflow boundaries from the forecast thunderstorms are seen as lighter (colder brightness temperatures), there is an example in northern Missouri. These kind of details are usually beyond the ability of the model to accurately represent, however it's important to note their presence and what effect that might have in the near future in the model.

11. Here is the GOES IR imagery for the same time period. The most obvious difference between the synthetic imagery and the GOES imagery is that the storms in the synthetic imagery appear smaller, that is the cloud tops are not as cold as they should be and, more apparently, the areal coverage of the colder cloud tops is underdone. Remember that the model will perform best regarding convection in situations with relatively strong synoptic forcing, such as shortwaves and jet streaks that become juxtaposed with low-level convergence boundaries. Note the model does relatively well with the convection in Illinois, Iowa and Wisconsin since it's associated with a shortwave. Note the region of cirrus associated with the jet streak mentioned before as its moving from Arizona into Colorado. The timing of that cirrus as it becomes juxtaposed with a low-level convergence boundary near Denver seems to correspond quite well to convective initiation. Note the early cloud cover in eastern Colorado does dissipate as was forecast by the model, this is one utility of the synthetic IR imagery that you would not use the synthetic water vapor imagery for.

12. SPC storm reports for May 12, 2010

13. Here is the WRF-ARW synthetic water vapor imagery. Note the representation of the MCS early on in Missouri, Iowa, Illinois and Indiana. This is typical for the model in that there are many holes in the clouds compared to an MCS appearance in GOES imagery with a uniform canopy of cold cloud tops. The model shows a trough in the west, so that there is strong southwest flow across the plains. The model develops afternoon convection in Iowa at the leading edge of a dark region, and further south in Kansas although it is difficult to see in the imagery. Notice the extensive region of higher clouds that are forecast to develop in the southern plains, this can play a key role in where the model predicted thunderstorms will develop. Note that the storms in central Kansas are close to where they were forecast, but the model storms appear much smaller. This is typical of the model, so at times it may be difficult to pick out on the imagery storms that are developing, let's look at the zoomed in IR imagery to help us out.

14. Here is the WRF-ARW synthetic IR imagery for May 12, 2010. Cloud coverage would definitely be a key forecast question here, not only the high clouds that are forecast to develop over the southern plains, but also the low-level clouds. The model has quite a bit of low clouds from central Kansas northward, and high clouds south of there into Oklahoma. The model has thunderstorms developing in between those two regions along a boundary in central Kansas, again, note how small they appear, don't expect large storms with extensive cirrus canopies in the model. Note the long streaks associated with the high clouds in Texas and Oklahoma, they don't appear natural. The long streaks of high clouds are optically thicker in the model than observed, expect to see this fairly often when analyzing what appear to be high level cirrus in the model. The best approach is to compare the GOES imagery with the forecast images during the morning to early afternoon hours, note if the model appears to be doing well or not and this will

gauge how much confidence you should have in the synthetic imagery for the late afternoon and evening hours.

15. Here is a comparison of the synthetic IR imagery versus the GOES IR imagery through 1800 UTC. Note the imagery around 12 UTC depicting the MCS across Missouri, Iowa, Illinois and Indiana. In the same location as was forecast, but with a different appearance. Remember, the model output MCS's will appear small and sometimes be full of holes in the canopy cirrus. The model does pick up on the high cloud cover development across Texas and Oklahoma by this time. The model has a good handle on the low cloud cover over Kansas. Let's look at the higher resolution visible imagery next.

16. Here is the corresponding GOES visible imagery through 1732 UTC. There is clearing in the warm sector region south of the cold front in Kansas, so confidence in thunderstorms developing in that region should increase. Further south in Oklahoma, the cirrus can be seen developing in Texas and advecting towards Oklahoma, however there is a region in western Oklahoma along a dryline that appears it will not be impacted by the cirrus.

17. Here is the corresponding GOES visible imagery after 1732 UTC. The model did pretty well with the area of clearing that developed in central Kansas, where thunderstorms initiated along a cold front, and north of the cirrus shield. Recall, the model did not have convection further south in Oklahoma, but by monitoring trends in the IR and visible imagery we can gain confidence in convective initiation near the dryline in Oklahoma as insolation occurred there.

18. SPC storm reports for August 4, 2010.

19. Here's the WRF-ARW synthetic water vapor imagery for August 4 2010. Note the convection that develops across Ohio around 20-21 UTC. It appears to originate just north of a dark zone along a line of higher clouds, this could be from an earlier MCS across Illinois that the model dissipated too quickly. The model forecast convection in Ohio moves southeast, experiences upscale growth and merges with convection along a line in Kentucky into West Virginia. The convection continues to move southeast towards Virginia and is then forecast to dissipate.

20. Here's the corresponding GOES water vapor imagery. We look back further to 04 UTC through the overnight hours to see that there was an MCS over Illinois around 11 UTC that moved east where new convection developed along the MCS boundary in Indiana. Afterwards, it was a fairly similar depiction to what was forecast in the model with upscale growth and movement to the southeast, this is when there were numerous severe wind reports.

21. SPC storm reports for May 18, 2010.

22. Here's the WRF-ARW synthetic water vapor imagery for May 18, 2010. The model shows an elongated trough in the west with storms forecast ahead of this feature from Montana to Texas. The model has a rather well defined jet streak moving across New Mexico moving towards the Texas panhandle where it forecasts convection over the dryline. Remember, this is a situation the model tends to have more skill in since there is an associated synoptic scale feature.

23. Here's the corresponding GOES water vapor imagery. The model did a good job with the evolution of the jet streak across New Mexico into the Texas panhandle and the associated convective initiation. The model appeared to do well in Montana as well, with the usual caveat of underdoing the anvil cirrus. Next, we'll look at more details with the IR imagery.

24. Here's the WRF-ARW synthetic IR imagery for May 18, 2010. One thing that may strike you is that the storms in the Texas panhandle appear more intense than the storms further north in Colorado and into Wyoming since they have a greater areal extent of colder brightness

temperatures and colder brightness temperatures in general. Although it may work out that way on a given day, in general it's best not to interpret the model output in that way and you're better off looking at environmental data such as the magnitude of CAPE, shear, the simulated radar reflectivity and so forth.

25. Here's the corresponding GOES IR imagery. This example shows why one shouldn't conclude anything about storm intensity by looking at the synthetic imagery alone, the storm in the Texas panhandle was intense in that there were tornadoes associated with it, but there were also tornadic storms in northern Colorado near the Wyoming border as well. Analyze near-storm environment data when assessing storm intensity, a better use of the IR synthetic imagery would be cloud cover trends.

26. SPC storm reports for May 19, 2010. Note the numerous reports in Oklahoma.

27. The WRF-ARW synthetic imagery for May 19 shows an elongated trough centered around Colorado and Wyoming. Note the dark region that appears to be a shortwave rotating around the trough from New Mexico, moving towards the Texas panhandle followed by western Oklahoma. The model develops convection in response to this shortwave in Oklahoma.

28. Here's the corresponding GOES water vapor imagery which shows a good agreement with that model in initiating storms along the leading edge of the shortwave.

29. WRF-ARW 7.34 μm synthetic imagery for May 19. This band has a weighting function that peaks lower in the atmosphere than the 6.95 μm band we just looked at, usually around 600 mb. This band can give us indications of mid-level jets, and since we're looking lower into the atmosphere, may provide details about the characteristics of the environment associated with the dark zone. There is a well defined dark zone at the southern end of the trough that moves eastward and expands during the day. Convective initiation occurs at the leading edge of this dark zone during the afternoon in Oklahoma.

30. Corresponding GOES sounder 7.4 μm imagery. The resolution is greater than 10 km, but you can detect the dark region we discussed in the previous slide. Remember that in general, the synthetic imagery has warmer brightness temperatures than observed on GOES. This actually makes it easier to identify the dark zones in the synthetic imagery, then we can go to the GOES imagery and identify it there. In this example, convection develops along the leading edge of the dark zone in Oklahoma, very similar to the depiction in the synthetic imagery. It's important to understand what you're looking at in the imagery when you see a dark zone, next we'll look at this in more detail.

31. Here's the visible imagery with the surface observations shortly before convective initiation. The key boundaries are an outflow boundary and an approaching cold front. The afternoon convection develops along these boundaries and where the leading edge of the dark zone on the 7.4 μm imagery exists.

32. Here is the sounding from Amarillo, Texas before and after the passage of the GOES 7.4 μm dark zone. After the dark zone passage, lapse rates steepen due to temperatures aloft getting colder. These are key ingredients for destabilization which likely explain the dark zone's role in assisting in convection initiation and maintenance.

33. SPC storm reports for June 17, 2010. We'll be discussing the Minnesota to North Dakota region.

34. Here is the WRF-ARW synthetic water vapor imagery. An upper level low exists over Montana with a strong southwesterly jet just southeast of the low setup over South Dakota, North Dakota and moving towards Minnesota. Note the convection that develops along the leading edge of a dark region in North Dakota, eastern South Dakota and into Minnesota.

35. Here is the corresponding GOES water vapor imagery. The model did a reasonably good job developing convection along the leading edge of the dark (or warm) zone from North Dakota into Minnesota.

36. Here is the WRF-ARW synthetic imagery for the 7.4 μm band. In this example we can see the development and movement of this dark / warm region from western Nebraska and South Dakota move northeast towards North Dakota and Minnesota with convection developing along the leading edge.

37. Here is the corresponding GOES sounder 7.3 μm imagery. Recall, this band allows us to see lower into the atmosphere and generally peaks around 600 mb. As you might suspect, the dark region is associated with a hot / dry airmass behind the dryline with origins off the higher terrain of the Rockies. Let's look a little more closely at the airmass associated with the dark / warm region by inspecting the soundings from Aberdeen which is located in northeast South Dakota where the dark region passed through.

38. Soundings for Aberdeen, SD on June 17, 2010. The first frame shows the 1800 UTC sounding, the low-level airmass is still moist as the winds are from the south. Now advance to the next frame at 0000 UTC which corresponds to after the dark region passed through and note the changes that took place. Above approximately 700 mb the sounding is generally warmer, which is consistent with the warmer brightness temperatures observed in the 7.4 μm imagery. At low-levels, the airmass is much drier as the winds are now strong southwesterly and the lapse rates are dry adiabatic from the surface to 780 mb. The inversion around 680 mb corresponds to the top of the deep, mixed layer with a source region over the elevated terrain of the Rockies. Although the dewpoint is missing above about 700 mb you can get the impression that it's much drier at mid-levels.

39. Lets overlay some model output to get more insight into this dark region. The 500 mb heights from the GFS depict the low over Montana and we see that the dark region of interest is associated with a shortwave trough. The 600 mb winds from the GFS show a jet associated with this dark region. Another useful application of the 7.4 μm imagery is that mid-level jets generally correspond to these fast moving dark regions, and can be confirmed with other observational data or model output.

40. SPC storm reports for June 25, 2010. We'll focus on Minnesota for this case.

41. Here is the WRF-ARW synthetic water vapor imagery for June 25, 2010. A ridge is located over the southeast to south central US with a trough to the west so the strongest flow is north of the ridge which is situated across the northern Plains and Minnesota. There are indications of an early MCS in Minnesota, remember, it will appear much less obvious in the synthetic imagery compared to the GOES imagery. The model develops what appears to be intense convection later in the afternoon in the wake of the MCS. We say "intense" because we see relatively large area of cold clouds tops and anvil cirrus, along with a dark zone signature in the forecast imagery, which you see at times in the vicinity of intense storms as you get strong subsidence around a strong updraft.

42. Here is the corresponding GOES water vapor imagery. We see a relatively good forecast in that there was a morning MCS, convection developed in the wake of the MCS and appeared quite intense in the GOES water vapor imagery as well with a noticeable dark zone signature induced by the storm caused by compensating subsidence in the vicinity of a strong updraft.

43. Here is the WRF-ARW synthetic IR imagery for the same time period. The morning MCS in southern Minnesota leaves behind a boundary of low-level clouds (cooler brightness temperatures) that is east-west oriented and appears to be an outflow boundary. This can be

compared with visible imagery during the late morning to early afternoon hours to see if this is evolving similar to the way the model forecast. Thunderstorms are forecast to develop along the MCS outflow boundary by 21 UTC in southern Minnesota. Interestingly enough, the next image at 22 UTC shows what appear to be intense storms, with an enhanced-v signature on the dominant storm. The thunderstorm activity continues through the evening hours as they move southeast towards Iowa.

44. Here is the corresponding GOES IR imagery. This would be considered a successful forecast of an early MCS in Minnesota, with later convective development along the MCS outflow boundary. Convective initiation occurred between 20 and 21 UTC, as the model predicted. The storms did appear quite intense, recall there were a number of tornado reports. We also observed an enhanced-v signature in the GOES imagery, as was also depicted in the synthetic imagery. Cases such as this show the potential of utilizing synthetic imagery in forecasting, just keep in mind that not every case will be forecast this well as we are looking at model output with its familiar limitations.

45. SPC storm reports for July 22, 2010.

46. WRF-ARW synthetic water vapor imagery for July 22. This case is somewhat similar to the case we just looked at in that there's a morning MCS across Minnesota and Wisconsin that moves off to the east with later thunderstorm development in Minnesota, Iowa and into Wisconsin. Also similar to the last case is the storm-induced dark zone signature around the later convection, which could indicate fairly intense storms. You would want to assess environmental data and the simulated radar reflectivity to assess storm intensity.

47. Corresponding GOES water vapor imagery. The late afternoon convection in the wake of the morning MCS develops further east than what the model forecast (in Wisconsin rather than Minnesota). Let's look at the IR imagery to see if we can figure out why.

48. WRF-ARW synthetic IR imagery for July 22. After the passage of the morning MCS, we still see considerable forecast cloud cover across Wisconsin, even by 1900 UTC. Storms are forecast to develop further west in Minnesota and Iowa.

49. Corresponding GOES IR imagery. Thunderstorms initiate further east than forecast, over Wisconsin, then later in Iowa. Let's look at the higher resolution visible imagery for more details.

50. Corresponding GOES visible imagery. By 1900 UTC, the MCS outflow boundary can be traced from Wisconsin back towards northern Iowa. Sufficient clearing takes place in the warm sector south of the MCS outflow boundary. Monitoring trends in the visible imagery enable you to assess confidence in the synthetic imagery.

51. SPC storm reports for June 5, 2010.

52. Here is the WRF-ARW synthetic water vapor imagery. Early on we see what appears to be an MCS over Iowa and Illinois, and an additional area of early convection in Massachusetts and Connecticut. Both areas of convection move east, and by afternoon new convection is forecast to develop in Ohio and Massachusetts. By late afternoon (22-23 UTC) new convection develops in Iowa and moves into Illinois. Around this same time, notice the forecast convection in south central Colorado that is forecast to dissipate in the 01-02 UTC time frame, not long after it developed. Meanwhile, in the southeast notice the strong southwest flow and apparent jet streak that is forecast to move from the Gulf of Mexico towards Alabama, Mississippi and Georgia, developing convection in response to this feature.

53. Here is the corresponding GOES water vapor imagery, with an earlier start time (around 0830 UTC) to highlight the origins of the MCS in the midwest. By 12 UTC, we see the MCS in

Iowa / Illinois as forecast, and we see the convection in Massachusetts that was also forecast. The convection in Ohio that appears to be related to the MCS appears to be forecast well as it moves east/southeast, as does the convection in Massachusetts. The late afternoon convection in Iowa moving into Illinois appears to be well timed, although more convection extends further south into Missouri than forecast. The convection in south central Colorado persists much longer than forecast dissipation, this is something to anticipate since it's a known bias. The jet streak moving into the southeast from the Gulf of Mexico, assisting in thunderstorm development in Alabama, Mississippi and Georgia seems to be well forecast.

54. Here is the WRF-ARW synthetic imagery. What are some of the additional features we can see in the IR that we could not see in the water vapor band? Low-level clouds and outflow boundaries are evident across Illinois, in fact the late convection that develops in Iowa appears to be at the intersection of the MCS outflow boundary and cold front. Sometimes the model is correct in identifying this, other times it is not, it's useful information to know what the model may be "picking up on" so to speak so that you may monitor this in the visible imagery in real-time.

55. Here is the corresponding GOES IR imagery. The late afternoon convection in Iowa does appear in response to a shortwave juxtaposed with a cold front at the surface. An MCS outflow boundary is not apparent in the imagery. Notice that convection does develop further south along the cold front in Missouri than what was forecast.

56. SPC storm reports for June 18, 2010.

57. Here is the WRF-ARW synthetic water vapor imagery. Early on, the model has convection across Illinois moving southward then dissipating. Later, the model has new development in Iowa and Missouri, the model quickly dissipates the convection in Iowa as it moves into Illinois. Further south, it does hold together the convection as it moves southward into Missouri.

58. Here is the corresponding GOES water vapor imagery. The most noticeable event is that the later convection does not dissipate quickly as it moved east towards Illinois. We'll look more carefully at the storms in the IR imagery next. Notice the gravity waves on the later storms in south central Iowa.

59. Here is the WRF-ARW synthetic IR imagery. An interesting question might be, why does the later convection in Iowa dissipate so quickly as it moves towards Illinois? Perhaps it's moving into a region stabilized by an earlier MCS, nevertheless, trends in visible imagery and surface observations can be monitored to see if it really evolves this way.

60. Here is the corresponding GOES IR imagery. The early MCS across Illinois holds together longer than forecast, and moves eastward, producing severe weather all the way to Michigan before finally dissipating. The later convection in Iowa clearly persists longer than forecast as it is still going strong as it moves into Illinois. This case is a classic example of a known bias of the model – dissipating convection too soon.

61. SPC storm reports for June 20, 2010. For this case, we'll focus on the region from Montana to Colorado.

62. The WRF-ARW synthetic water vapor imagery shows an upper low over Oregon with a strong jet to its southeast from Utah to Wyoming to Montana. The model has quite a bit of convection, from Montana southward into the Plains. The earliest convection occurs in Montana where strong forcing near the upper low exists. Storms in Wyoming and northeast Colorado seem to be associated with the upper level jet moving through the region.

63. Here is the WRF-ARW synthetic IR imagery. Note the low-level clouds at 14 UTC in Nebraska nosing into portions of northeast Colorado. There are also low-level clouds across Wyoming. Both areas of low clouds are forecast to dissipate leading to afternoon insolation then followed by convection. Across Iowa, an early MCS moves east, there is clearing behind the MCS and later convective initiation near Omaha.

64. Here is the corresponding GOES IR imagery. Note that the majority of the low-level clouds in Wyoming dissipate, leading to clearing and isolated afternoon severe storms. In northeast Colorado, the low-level clouds look much more widespread than forecast, pushing all the way to the Front Range, thus the lack of insolation appears to be responsible for the lack of thunderstorms in this region. Further east in Iowa, we see considerable cloud cover and additional convection during the day, and thunderstorms do not initiate in this area as the model forecasted.

65. Here is the corresponding GOES visible imagery. The visible imagery can be monitored to check to see if cloud coverage trends forecast by the model are taking place. For example, in this case the low-level clouds across northeast Colorado are covering a larger area than forecast and are not dissipating during the day, this played a key role in limiting the insolation and thus thunderstorm development probabilities.

66. SPC storm reports for May 24, 2010.

67. The WRF-ARW synthetic imagery shows a meridional trough in the west that is forecast to move northeast during the day. On the 1800 UTC image, you can clearly see a line in the imagery north-south oriented running from northeast Wyoming southward through the Nebraska panhandle to eastern Colorado to the western Texas panhandle. Within a few hours, thunderstorms are forecast to develop along this line, which most likely would correspond with the location of the dryline at the low-levels. Notice the dark region further south as well as the well defined jet streak moving from the 4 corners towards southwest Kansas.

68. The GOES water vapor imagery shows the majority of the convection near the upper low to be close to what was forecast. Strongly forced synoptic events will likely be better handled by the model than weakly forced events. The line that appeared in the synthetic imagery across the high plains that we said is likely the dryline, also shows up on the GOES imagery.

69. The WRF-ARW synthetic IR imagery shows low cloud development shortly prior to convective initiation across the dryline. The dryline shows up at certain times, during the daytime the cooler brightness temperatures are on the moist side of the dryline, with warmer brightness temperatures on the dry side of the dryline. Generally, the dryline shows up better in the GOES imagery than in the synthetic imagery.

70. Here is the GOES IR imagery, which shows a general agreement with convection near the upper low and along the dryline.

71. 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 LDM. Let us know if you're interested in obtaining synthetic imagery in your AWIPS, our contact information is provided on the last slide of this training session. 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. Finally, if you're interested in model output fields from the WRF-ARW model, it's available at the URL shown here.

72. Conclusions (1).

73. Conclusions (2).