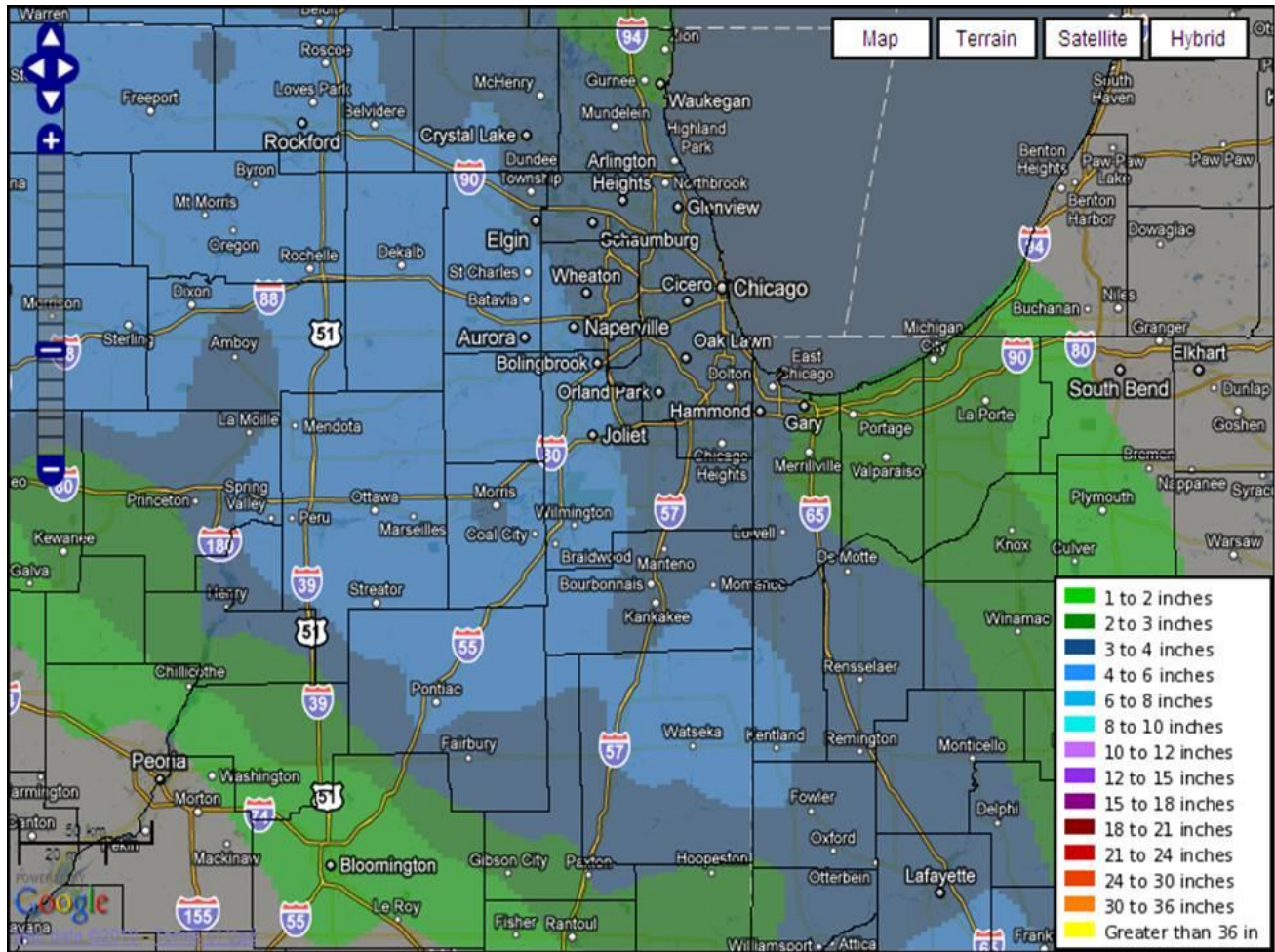


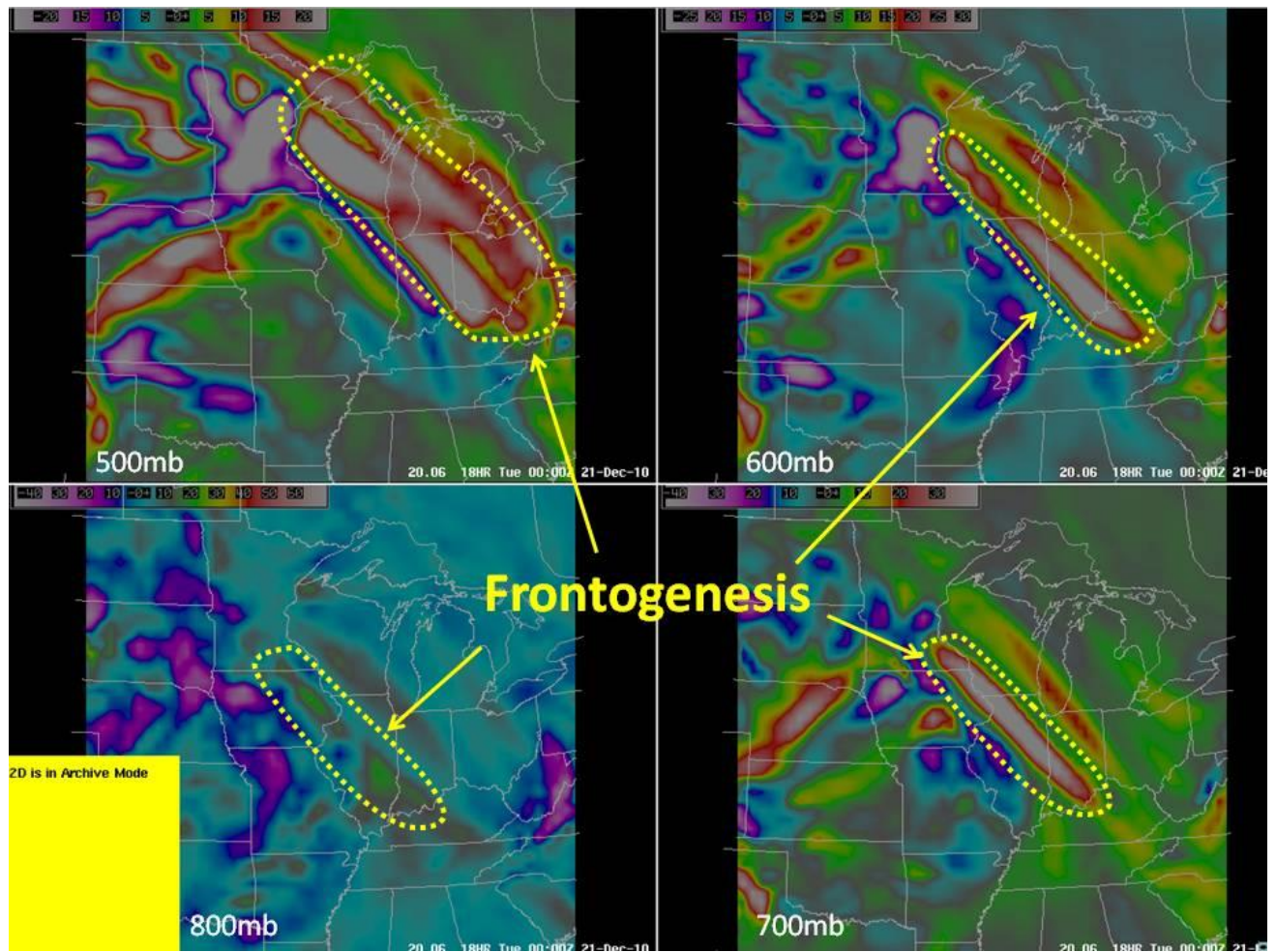
National Weather Service Weather Forecast Office Chicago, IL

Thundersnow 101...A Scientific Review of the December 20th Thunder-Snow Event

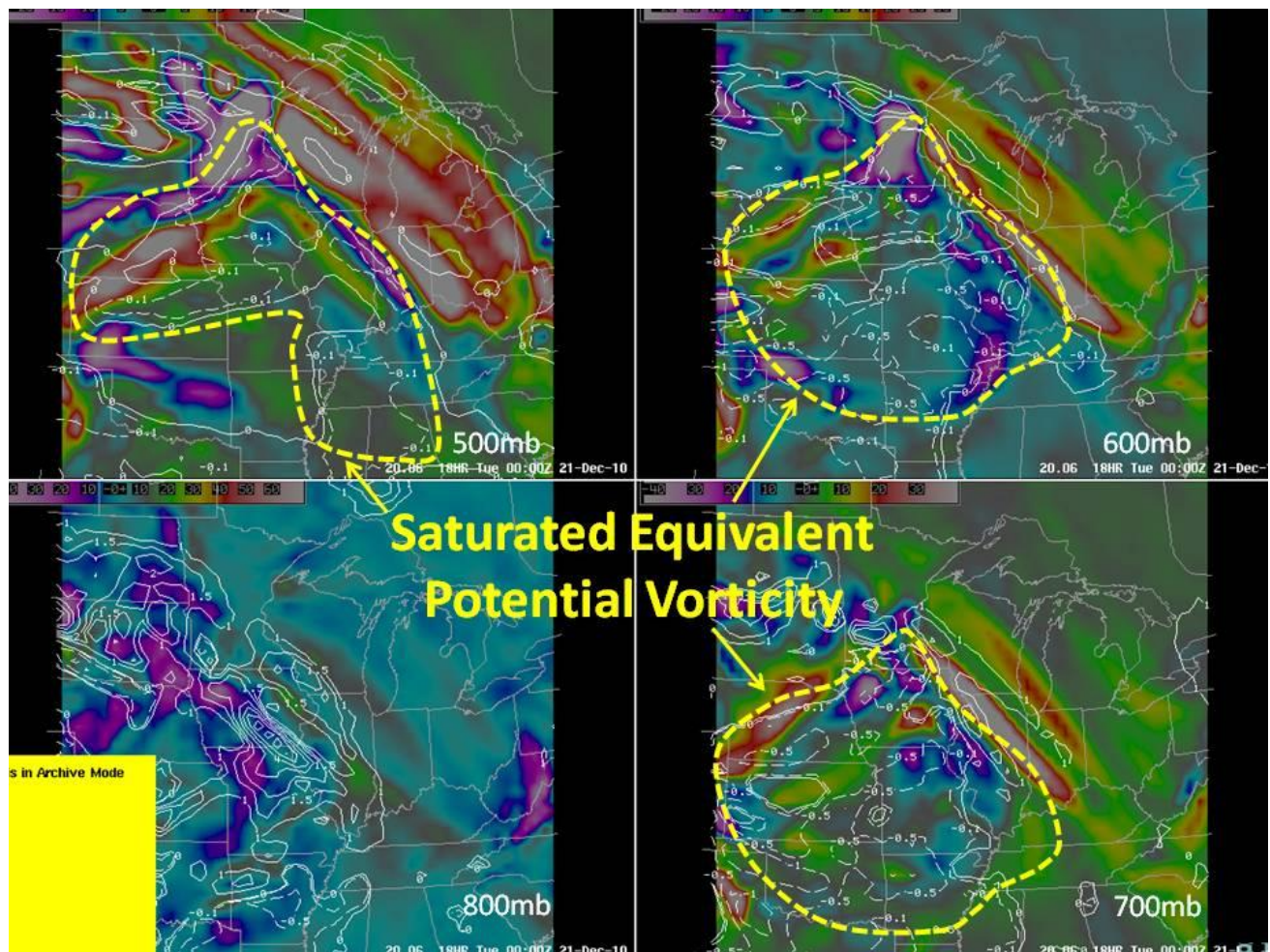
A band of snow moved across northern Illinois and northwest Indiana during the afternoon and evening hours of Monday December 20th. Snow within the band was heavy at times reducing visibilities to one quarter mile or less, with snow-producing thunderstorms forming along the back edge of the snow. Despite the intensity of the snow, total snow accumulations across the area were generally between 3 and 5 inches as the snow didn't last for a particularly long time in any one area.



One of the primary mechanisms that caused the band of heavy snow to form is what is known as frontogenesis, which is the scientific term for the strengthening of a front (or temperature contrast). In the case of this snow event, the strongest frontogenesis which was responsible for the heavy snow took place well above the surface, between 700 mb-500 mb (roughly 10,000-18,000 ft above the ground). The image below is a 4 panel depicting the area of strongest frontogenesis at various levels in the atmosphere as was forecast by a computer program, or model (the Global Forecast System, or GFS) the night before the event.

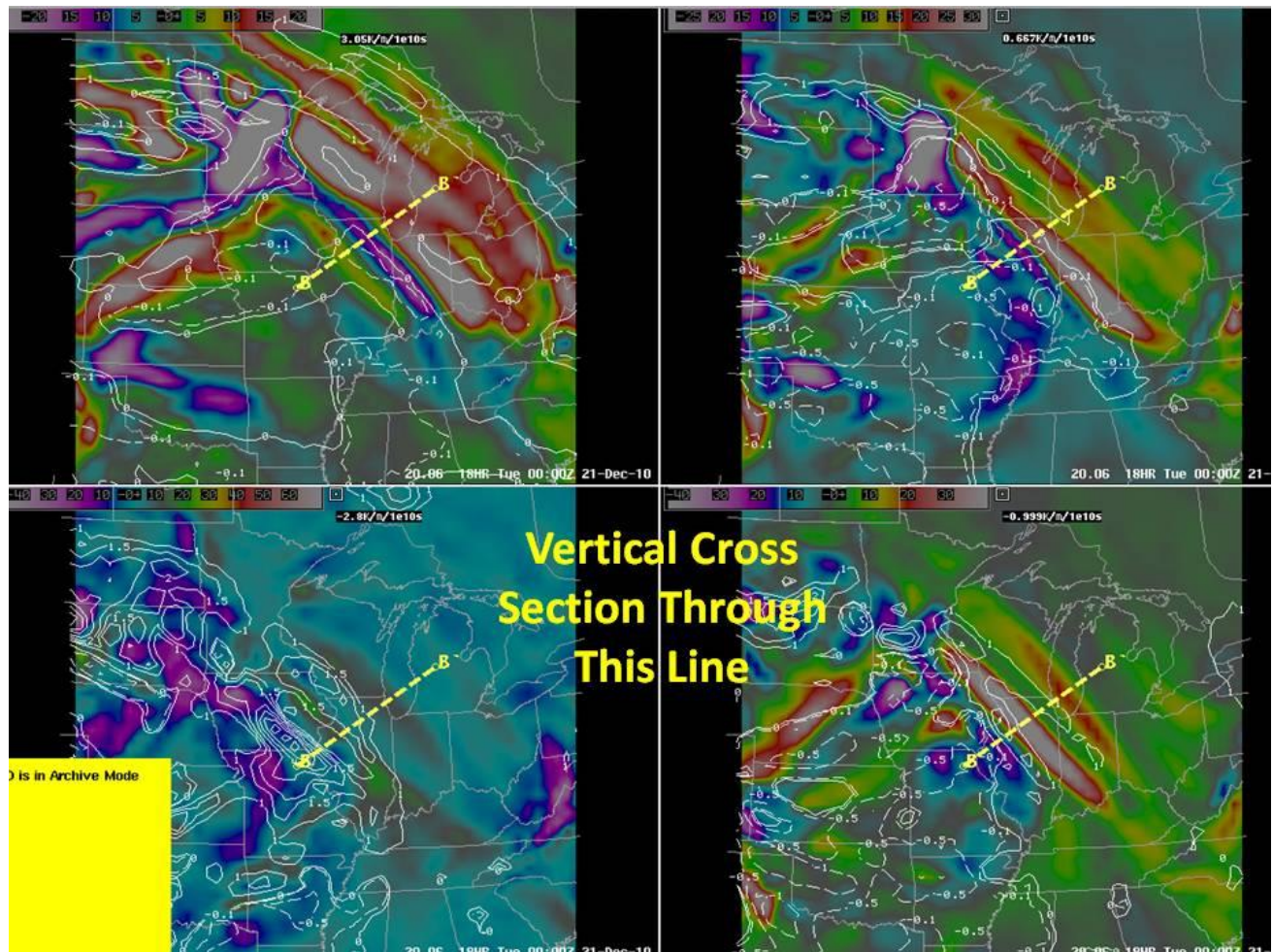


In addition to the strengthening front aloft, there was also a more unstable airmass aloft moving in behind the advancing mid level front. The image below depicts areas of negative saturated equivalent potential vorticity (saturated EPV), which can be used to identify regions of instability. The image below shows the large region of negative saturated EPV moving NE behind the advancing front.

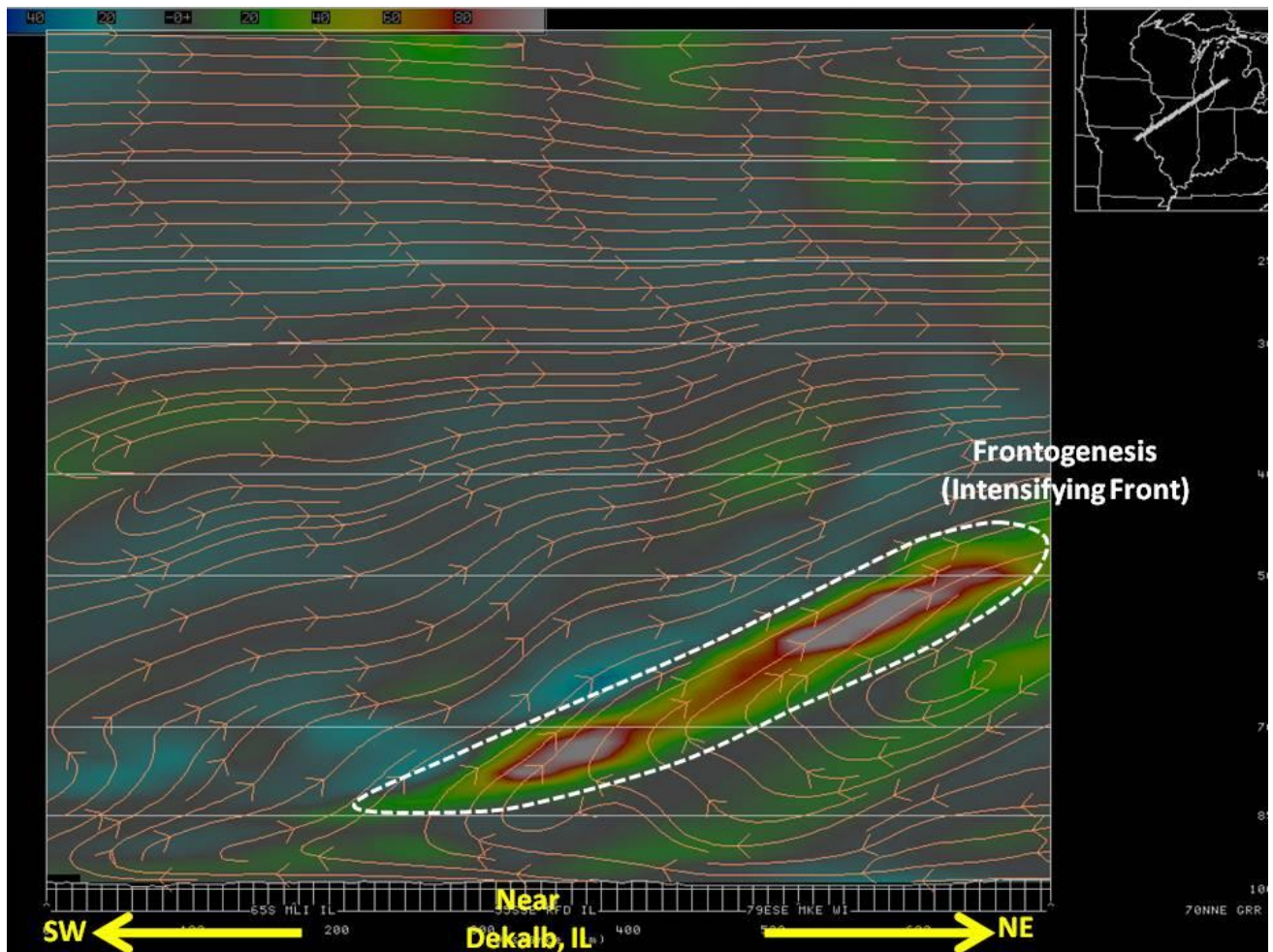


One of the advantages of using saturated EPV to measure instability is that it can depict areas favorable for the formation of both upright convection (typically found with thunderstorms) as well as areas favorable for what is known as slantwise convection. The type of instability associated with slantwise convection is known as conditional symmetric instability (CSI). When CSI exists the air rises and accelerates along a slantwise surface, sometimes resulting in thunderstorms.

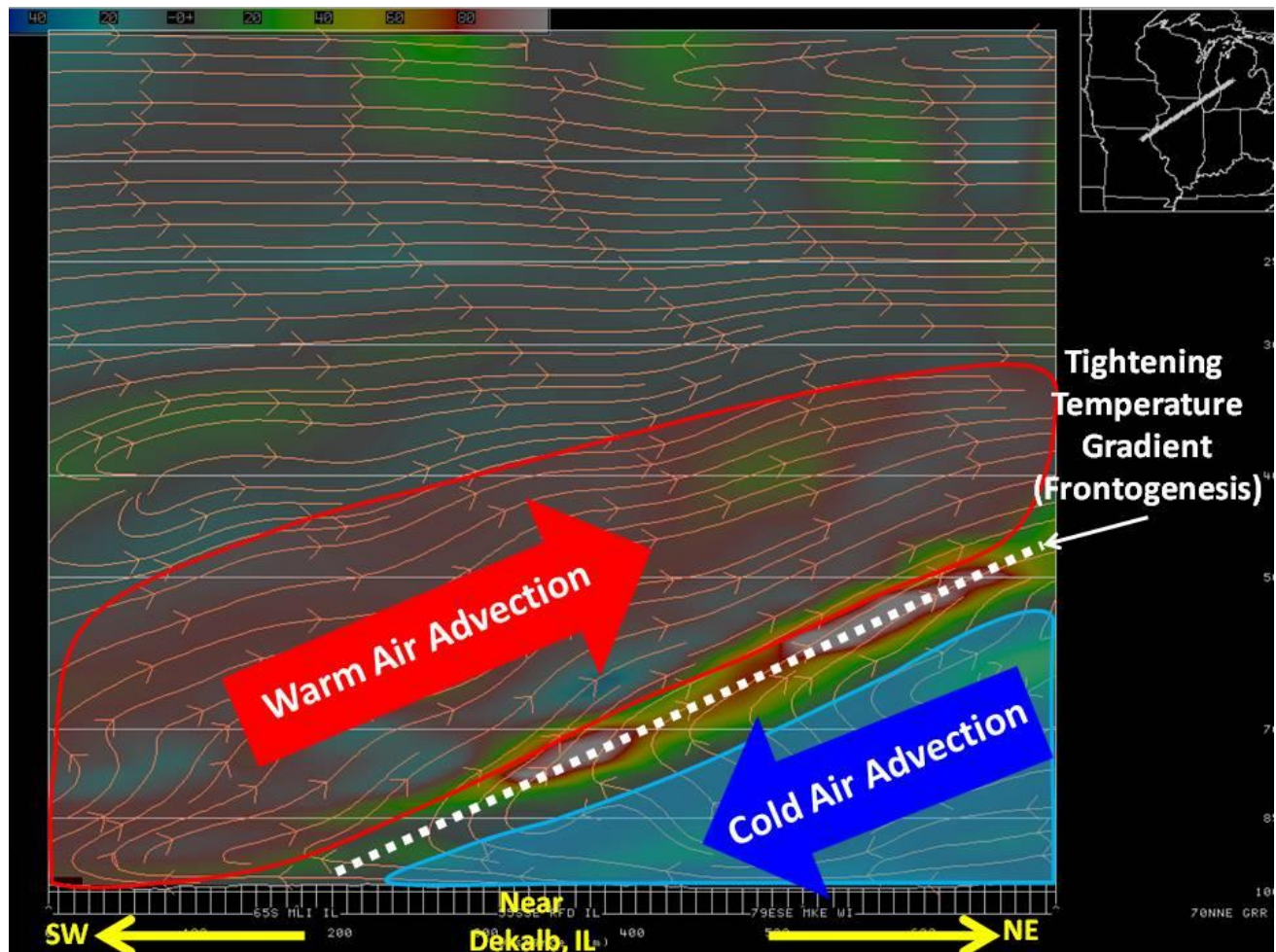
A good way to visualize frontogenesis and the resultant rising motion is by looking at vertical cross sections of the atmosphere, so to visualize this case we will look at a vertical cross section along the line labeled "B" in the image below.



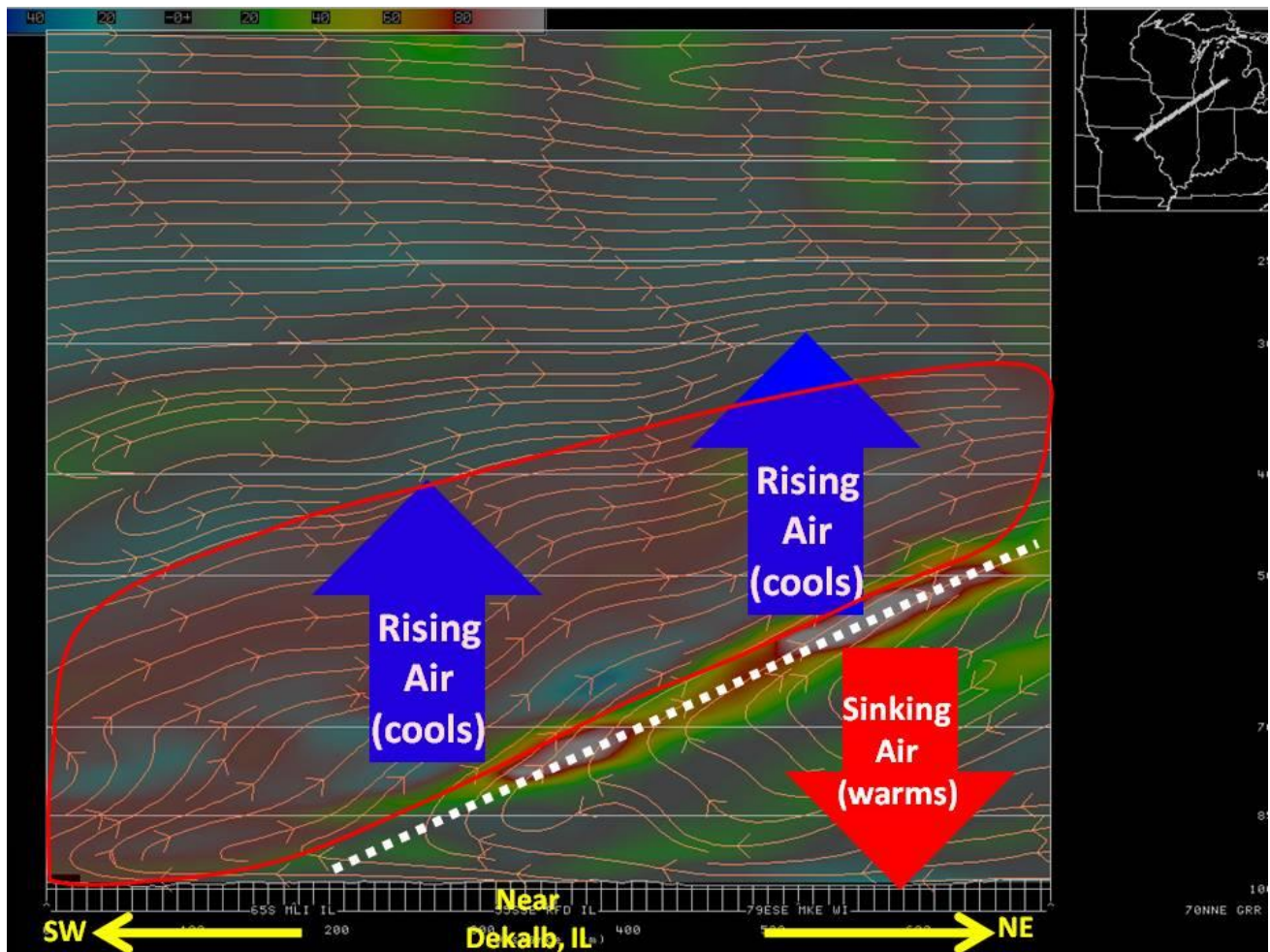
The vertical cross section depicts the slope of the warm front quite nicely in the image below, including the arrows showing vertical motions taking place.



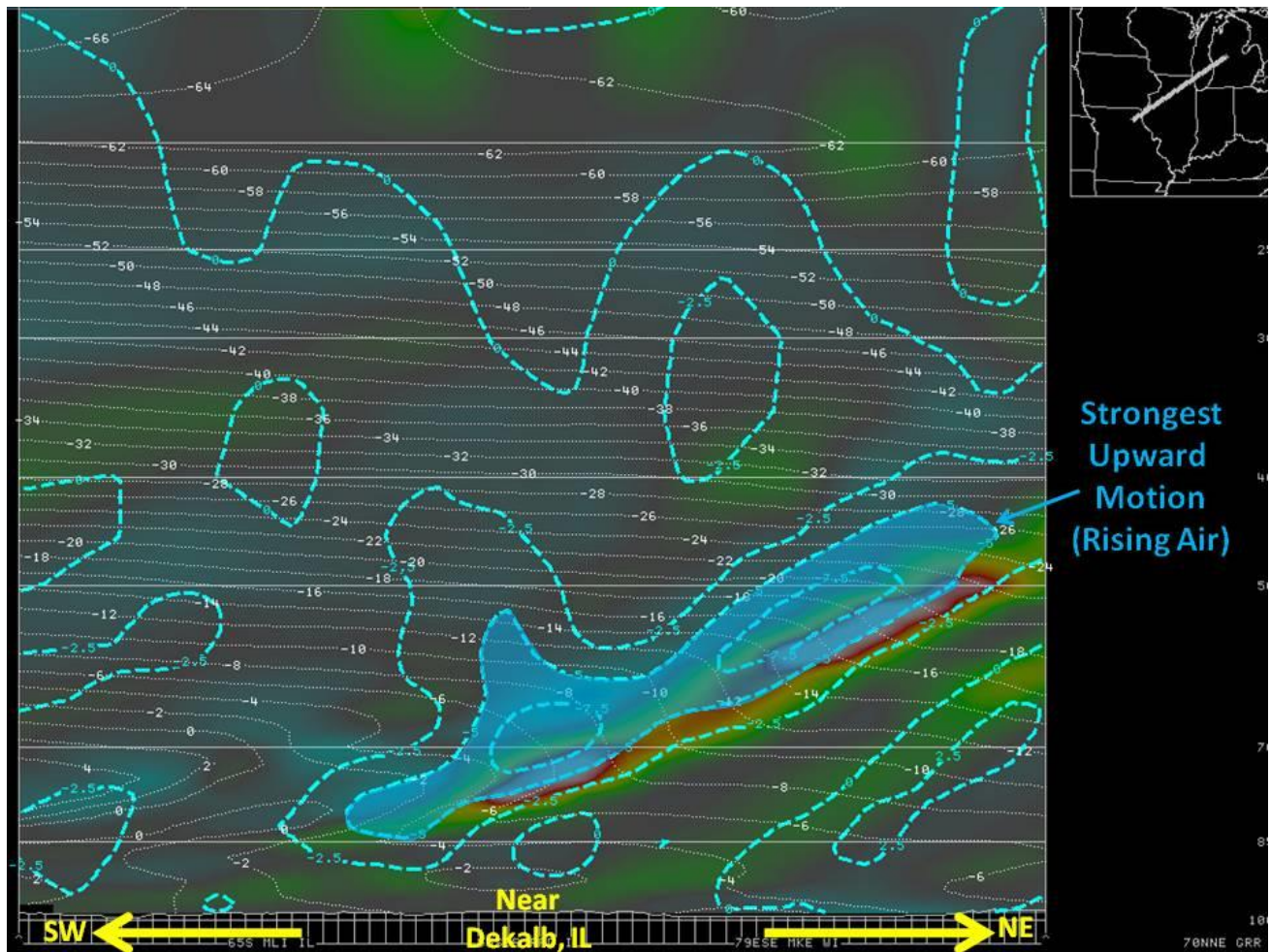
Since cold air is denser than warm air, a warm front is typically sloped upward into the cold air. The image below shows how the less dense warm air is forced up and over the top of the denser cold air. In this particular case, the gradient between the cold air and warm air aloft was increasing and the frontal boundary aloft was strengthening (frontogenesis).



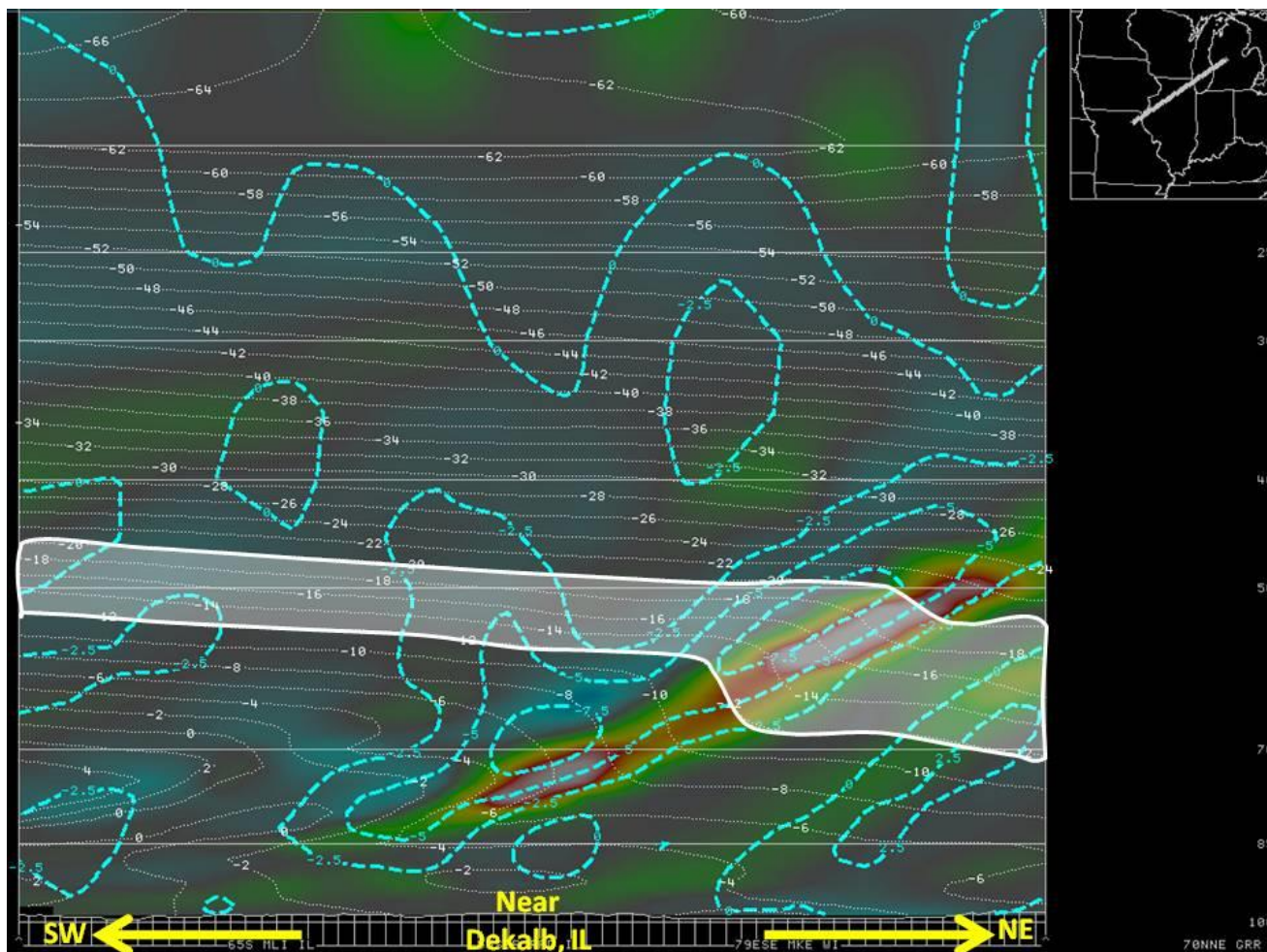
In general, the atmosphere is going to try to “fix” imbalances such as large temperature gradients, and one of the ways this occurs is through rising and sinking air. When air rises it cools and conversely, sinking air will warm as it sinks. So in regions of frontogenesis, a vertical circulation will often form with air tending to rise (and cool) on the warm side of the intensifying front and sink (thereby warming) on the cooler side.



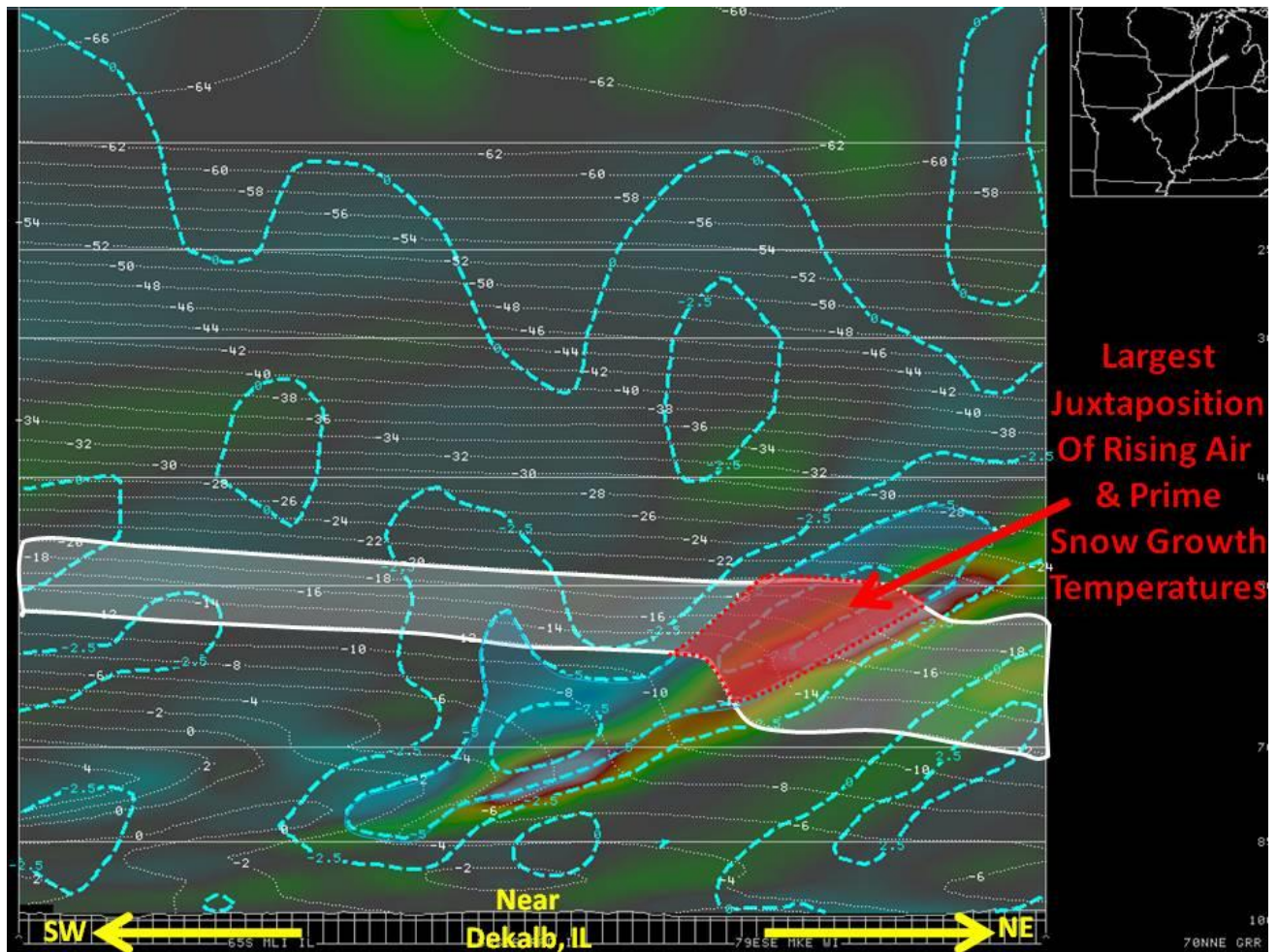
The rising and sinking air within this vertical circulation is very important in forecasting, since rising air is needed to produce precipitation. Identifying areas of rising air ultimately helps meteorologists identify areas where precipitation may form. Notice in the image below that the strongest (fastest) upward motion is occurring on the immediate warm side of the intensifying front.



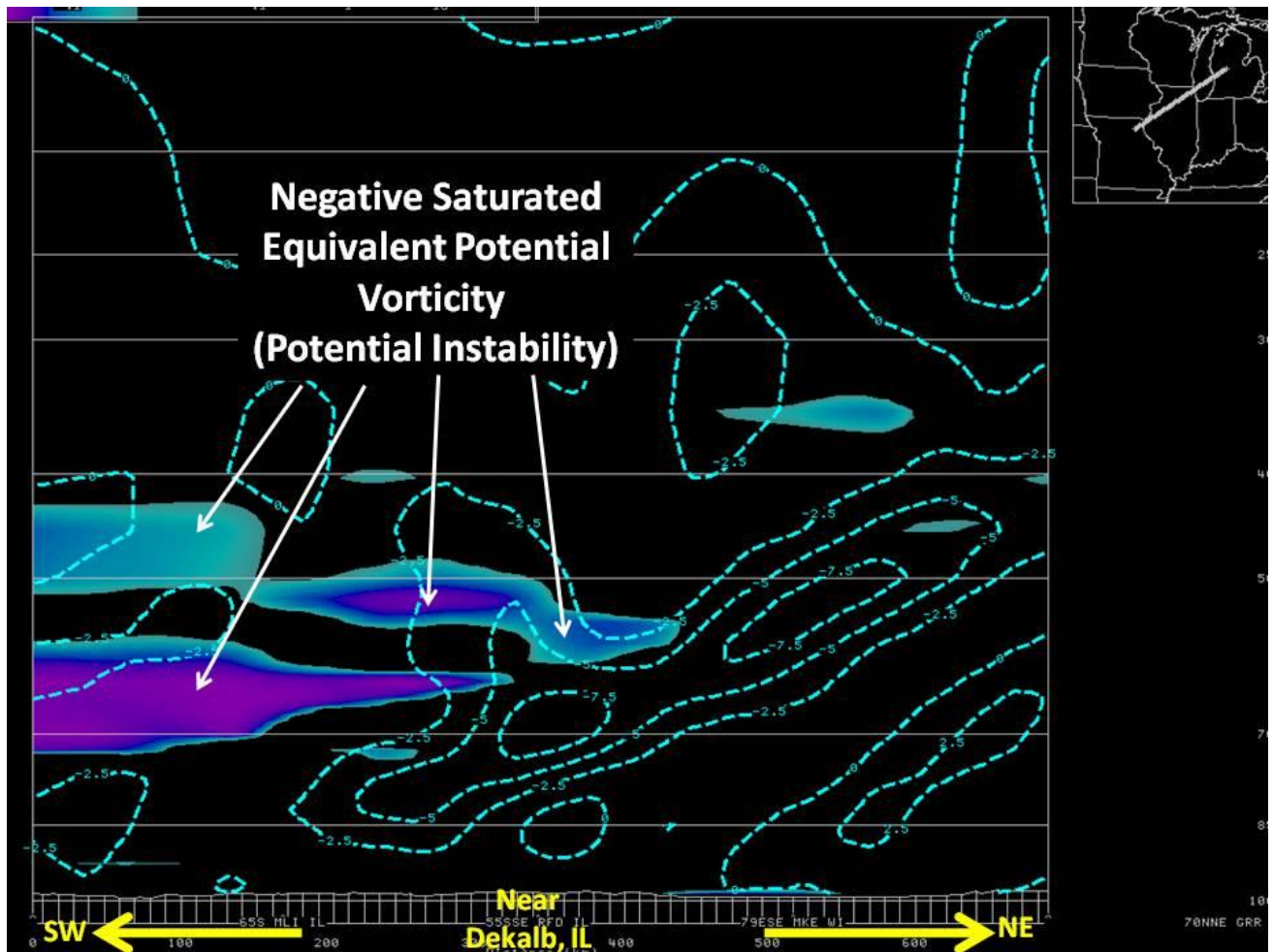
When forecasting snowfall, one of the important ingredients in determining the amount of snowfall one might eventually see is the temperature aloft. Snowfall tends to form most readily when the strongest rising motion occurs where temperatures aloft are between -12C and -20C. This forecasted temperature range is highlighted in the image below.



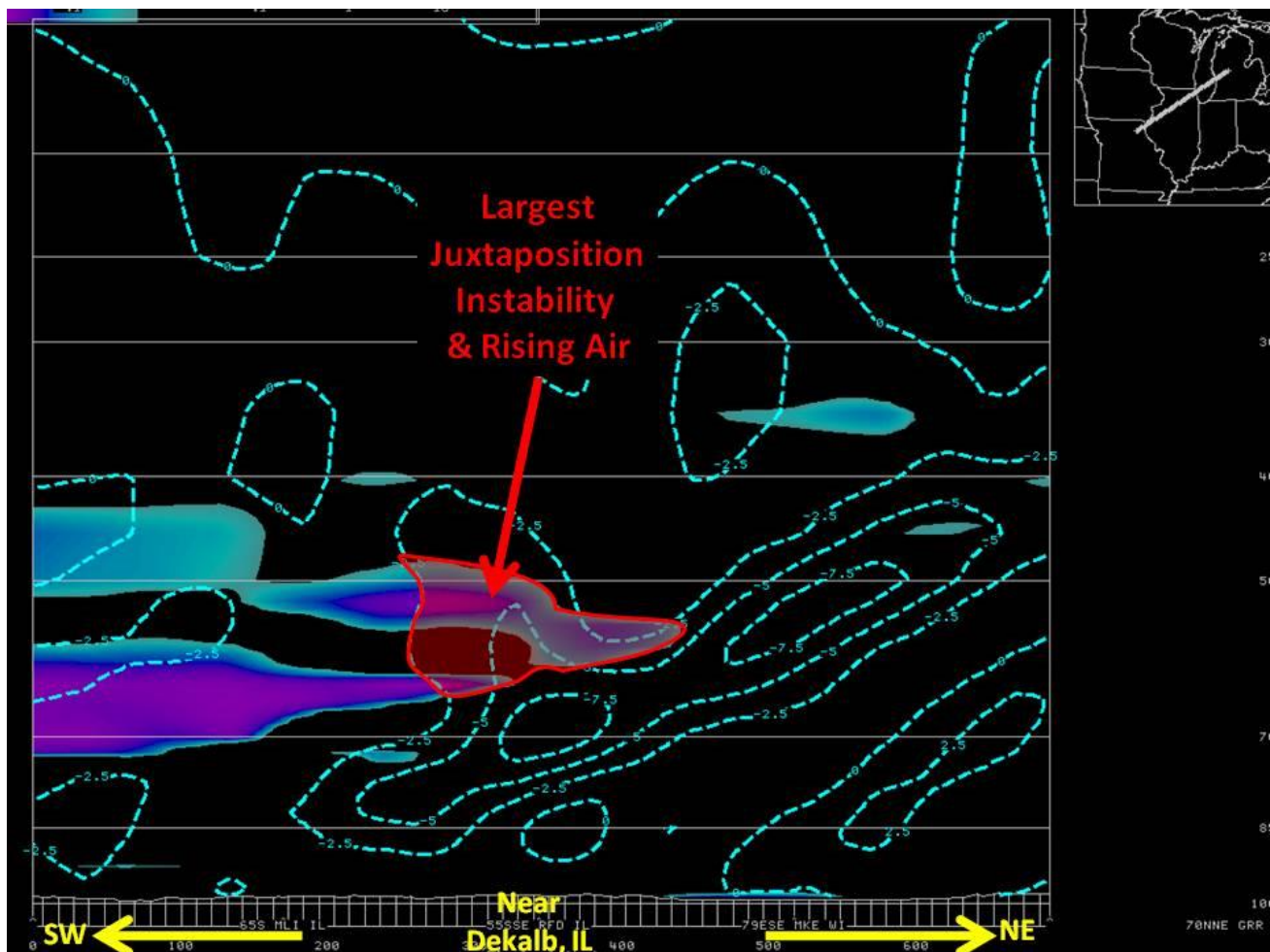
Notice in the cross section below that the area where the fastest rising motion and most ideal temperatures for heavy snow coincide is over the eastern portion of the intensifying front aloft. This model forecast would suggest that the heaviest snowfall would be most likely to occur along the leading edge of the band of snow, which was indeed the case Monday.



To diagnose the potential for convection and possibly thunderstorms, it is helpful to examine where the regions of negative saturated EPV exist with respect to the frontal circulation. This is shown in the image below.

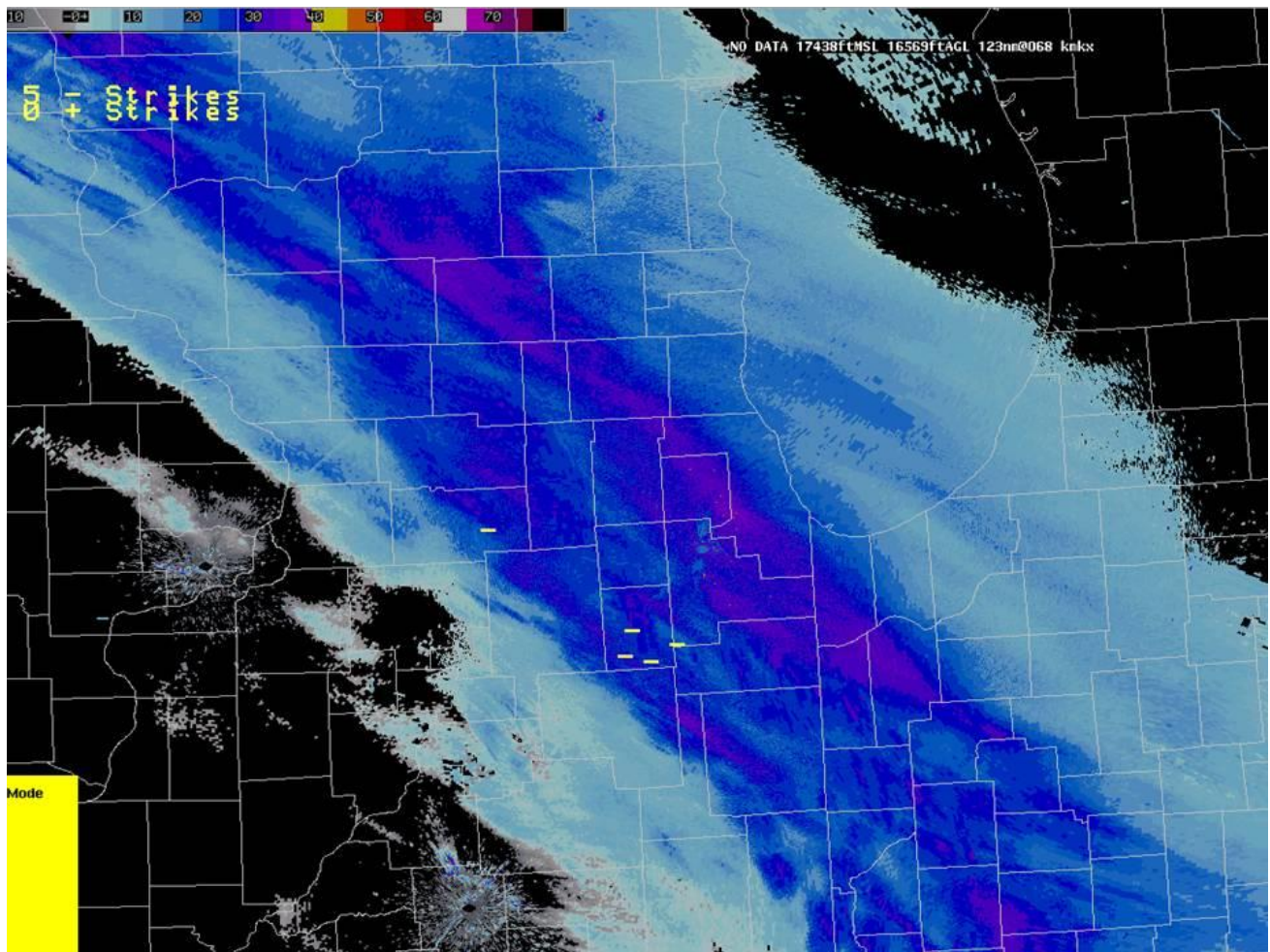


In the image below the GFS model forecasts suggested that the best juxtaposition of saturated negative EPV (instability) and strongly rising air was located along the trailing (western) edge of the frontal circulation and likely area of snowfall. This would be the area that forecasters would key in on for the potential for convection and thunderstorms.

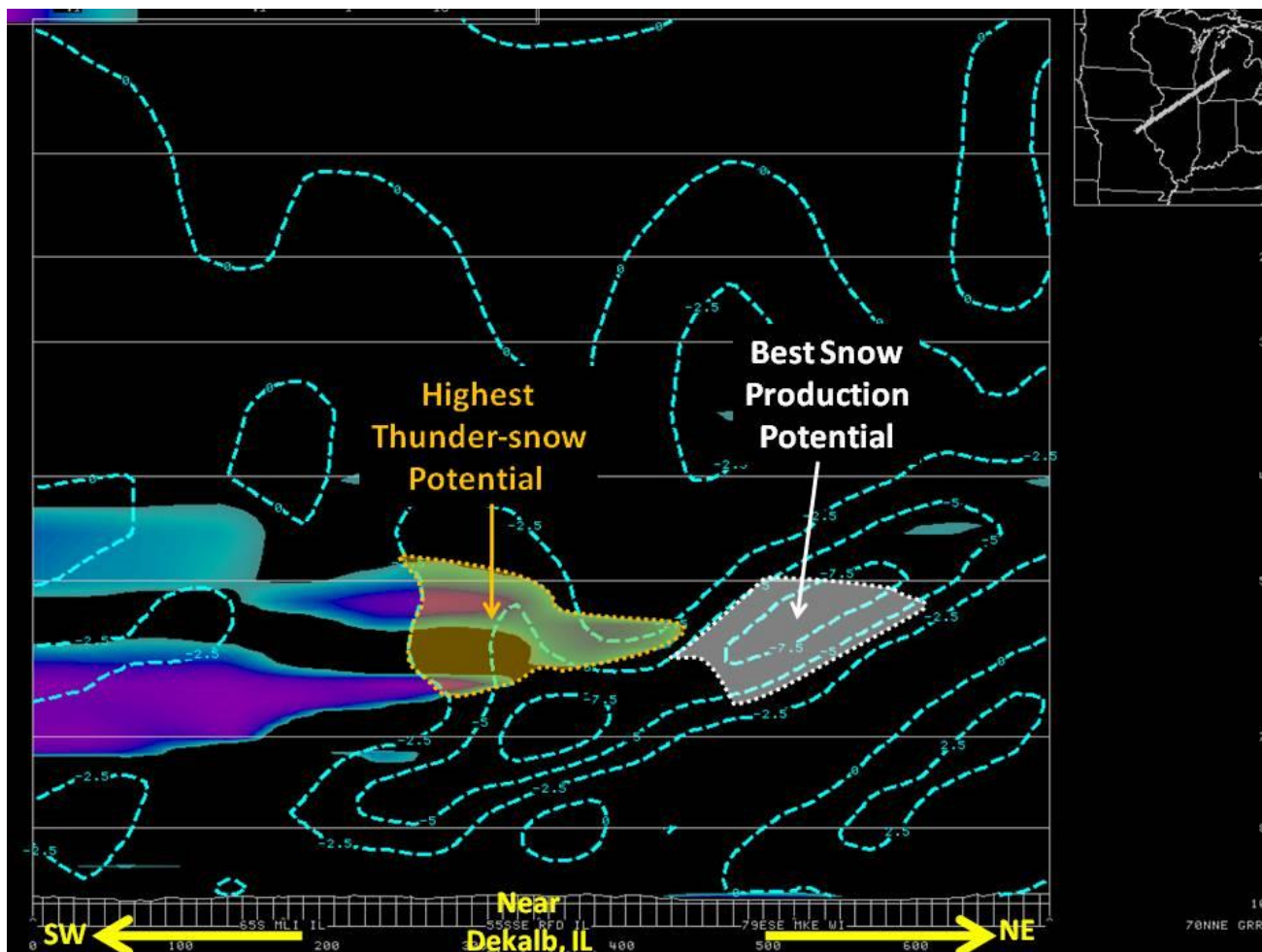


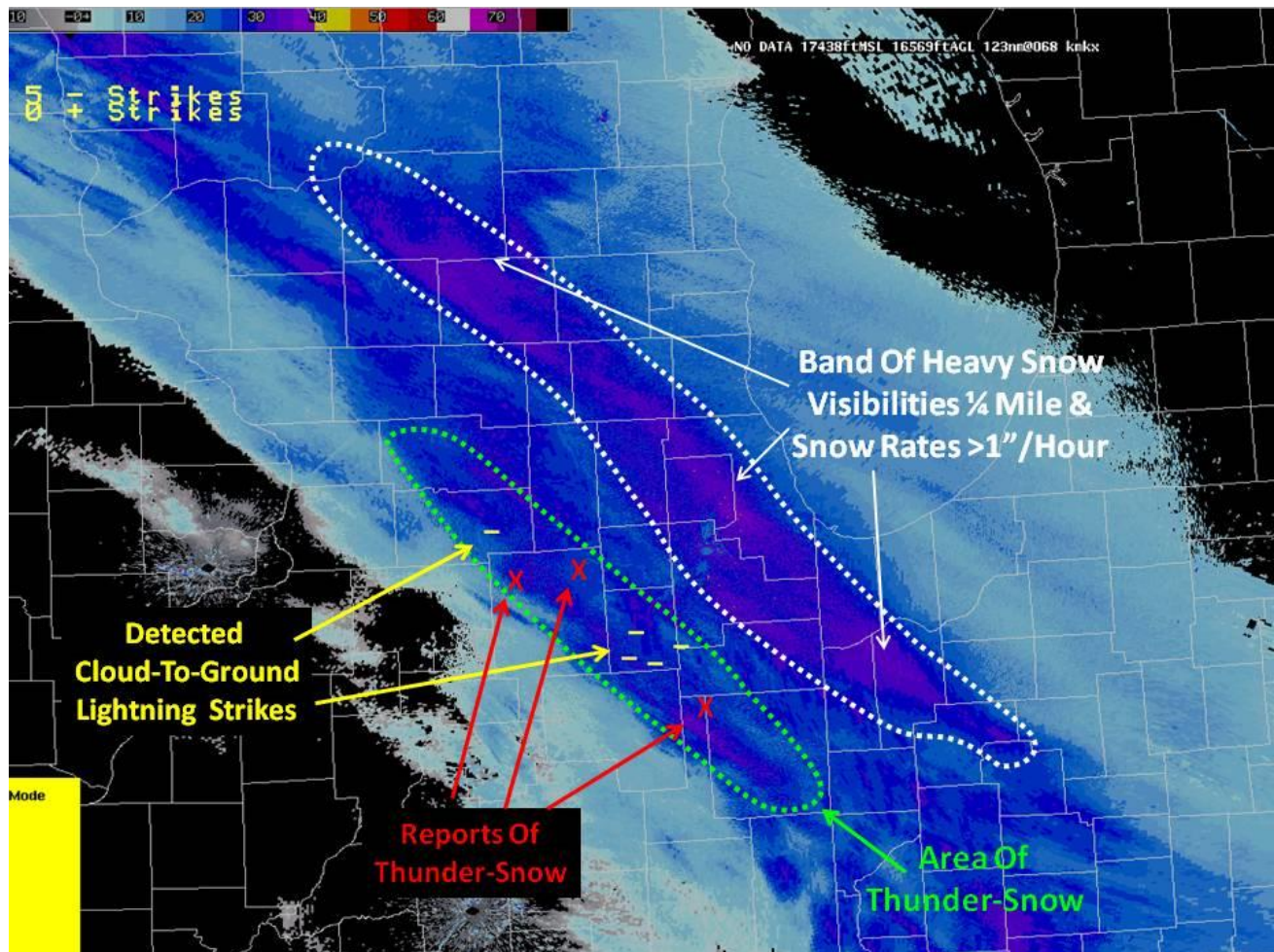
Unfortunately, forecast models will depict very similar set ups and many times no slantwise convection or thunderstorms occur. In addition, there will be times it can occur even though model forecasts don't accurately depict the set up. This is an area that challenges forecasters and means that many times thundersnow will not be in the forecast well in advance of it occurring.

In this case, the model that the images above were taken from did a surprisingly good job in depicting what actually happened. The radar image below, taken from roughly the same time as the model forecasts for the images above were for, shows the large band of snow moving across region.



Not only did the model accurately forecast a broad band of snow associated with the intensifying frontal circulation aloft, but comparing the cross section and radar images below suggest that the model accurately was able to capture both the band of heavy snow along the leading edge as well as the thundersnow that developed along the trailing edge of the precipitation.





In this case, the heavy snow and thundersnow was moving at a fairly quick pace, so even though snowfall was heavy and had crippling impacts on the evening rush hour in Chicago, the snowfall totals were not particularly heavy.

Another scenario where frontogenesis and instability aloft can result in heavy snowfall is to the north of the track of strong low pressure systems as warm air gets wrapped up and around the low. This is sometimes referred to by meteorologists as a TROWAL (trough of warm air aloft). Frontogenesis occurs as the warm air gets entrained into the large cyclonic circulation of the cyclone and pulled into the “cold” part of the storm resulting in a tightening of the temperature gradient (frontogenesis). In these situations, it’s not uncommon for heavy banded snowfall (and occasionally even thundersnow) to be less progressive and persist in one area for an extended period of time producing very heavy snowfall totals.