P2.12 SEVERE WIND-DRIVEN HAIL EVENTS: DEPENDENCE ON CONVECTIVE MORPHOLOGY AND LARGER-SCALE ENVIRONMENT

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1. Introduction

Prior studies have examined both the near-storm environments (e.g. Rasmussen and Blanchard 1998) and convective morphologies most likely to be associated with either severe wind events or hail events (e.g., Duda and Gallus 2010), but relatively little work has been done to understand the conditions favorable for severe wind-driven hail events. Some recent cases such as the Eldora Iowa event in August 2009 where hail of 3 inch diameter was blown by winds exceeding 90 knots, have demonstrated how tremendously damaging and dangerous a thunderstorm can be when severe wind and large hail occur together. The present study uses the approach followed in Duda and Gallus (2010) to examine the convective morphologies associated with severe wind-driven hail events. In addition, a brief overview is provided for two such events.

2. Methods

The present study follows the approach of Duda and Gallus (2010), using storms from 2007 and assigning morphologies based on Gallus et al. (2008). The morphologies used were IC – isolated cells, CC – cluster of cells, BL – broken line of cells, NS – squall line with no stratiform precipitation, TS – trailing stratiform precipitation, PS – parallel stratiform precipitation, LS – leading stratiform precipitation, BE – bow echo, and NL – non-linear convective system with storm motion from left to right. Examples of these morphologies are illustrated in Fig. 1. Unlike the earlier studies, the present study focuses on severe wind-driven hail events.

To determine a wind-driven hail event the National Climatic Data Center's (NCDC) Storm Data publication was used. Since Duda and Gallus (2010) used 2007's storm reports and classified the morphologies of all convective systems in a 10-state region from April through August, that same dataset was used for this study. Wind-driven hail events were noted if severe hail and severe wind were reported within five miles of each other and within the same thirty minute period. Although in 2007 0.75 inch diameter hail was used to define a severe hailstone, because that minimum criterion has now changed, we used the new one inch diameter criterion except in special circumstances. When the description in the Storm Data report called attention to simultaneous occurrence of the wind and hail, we then allowed the 0.75 inch diameter events to be included in the dataset.

In all, 72 wind-driven hail events were found in the 10 state region during this portion of the 2007 warm season, occurring on 34 different days. After this dataset of cases was built, the location and date of the events were compared to the dataset of convective morphologies from Duda and Gallus (2010) to assign a morphology.

3. Cases and Results

3.1 Wind and Hail from Duda and Gallus (2010)

In Duda and Gallus (2010) storm reports for wind, hail, tornado, and flooding were classified

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according to the convective morphology of the system responsible for producing the report. For large hail events (Fig. 2) PS was the largest producer in 2002 while BL was largest in 2007. In 2007 the number of NS events was much larger than the 2002 amount. Otherwise, CC and IC also contributed significantly to reports of hail larger than two inches in diameter. For all hail in 2002 the top three morphologies were BL, BE, and PS, and in 2007 BL, CC, and PS were the top three. For high wind events greater than 65 knots, BE events were largest in 2002, followed by TS, while in 2007, BE events again were largest but followed by BL (Fig. 3). For all severe wind events BE were most followed by TS, and both BL and PS were close.

3.2 Morphologies for 2007 Wind-Driven Hail

For cases of wind-driven hail, squall lines contributed the greatest share, with TS and NS combined accounting for 36% of all events. IC and CC events also contributed substantially to the total, with 16% and 15%, respectively (Fig. 4). As for changes in percentage compared to the 2007 non wind-driven hail events, TS had a twelve point increase, NS an eight point increase, and IC a six percent increase. These results imply squall lines have a relatively higher risk of severe wind-driven hail compared to other morphologies than they do for hail or wind alone. On the other hand, CC events had an eighteen percent decrease, with BL and NL having a three percent decrease.

Monthly totals for each morphology are shown in Fig. 5 for all systems in 2007 (from Duda and Gallus 2010) as well as wind-driven hail events. For CC, BL, BE, and NL systems, the month with the most wind-driven hail events for a particular type of system differed from the month with the most of those systems. For IC, NS, PS, and TS systems, these months were the same. Of note, no wind-driven hail events occurred in LS systems, a result not surprising since Duda and Gallus (2010) found very few LS events occurred in 2007. For most morphologies, the months most active for wind-driven hail were early in the warm season (April, May), but for IC systems, the peak was later (July).

A comparison of Figs. 2 and 3 with the total number of wind-driven hail events in Fig. 5 suggests that although some morphologies such as BL and BE events produce large amounts of hail alone or wind alone storm reports, they more rarely produce wind-driven hail, while IC events in particular have a relatively large number of such events associated with them compared to the number of hail or wind events alone.

3.3 June 20, 2007 Kalvesta, KS

To gain some preliminary insight into the characteristics of the near-storm environment, two cases were studied in more detail. In the first case, occurring in southwest Kansas on June 20, a cold front was moving slowly southward into southwest Kansas around 00 UTC (Fig. 6), and the atmosphere was very unstable with lowest 100 mb mixed layer CAPE values of 4000-5000 J/kg near the storm (Fig. 7). Effective helicity values were maximized in this region, exceeding 250 m^2/s^2 (Fig. 7). Aloft, a ridge was located over the Rockies with flow generally under 30 knots in much of the region, although a short wave trough was affecting southwest Kansas, which can be seen in the 500 mb data (Fig. 6). The strong east component of the low-level winds helped to result in sufficient 0-6 km shear to allow the environment to support supercells. This system was assigned a CC morphology when the event occurred before evolving into a TS by the time it moved southeast into Oklahoma (Fig. 8).

The 3D volume scan from GR2Analyst for this event (Fig. 12) is shown with the 50 dBZ echo as suggested in Donavon and Jungbluth (2007) as one indication for very large hail. In this event, hail was as large as 4.25 inches in diameter, and occurred concurrently with wind of 70 knots.

3.4 May 29, 2007 Sturgis, SD

In the second event analyzed in more detail, a weak cold or stationary front was located across South Dakota around 00 UTC May 29 (Fig. 9), and conditions were somewhat unstable with lowest 100 mb mixed layer CAPE values reaching 2000 J/kg near the storm (Fig. 10).

Although effective helicity was low over much of South Dakota, a small region near the front did have values exceeding 200 m^2/s^2 (Fig. 10). At higher levels, a fairly intense trough was digging into the northern Rockies, with southwesterly flow exceeding 30 knots at 500 mb spreading over western South Dakota (Fig. 9). This event showed a NL type of morphology at the time of the event (Fig. 11).

A 3D volume scan from GR2Analyst for this case (Fig. 13) shows that the 50 dBZ echo isosurface does not cover as large an area as it did for the Kalvesta case. As might be expected from the difference in the radar echoes, the Sturgis event had a smaller peak hail size, 1.5 inch diameter, but did have similar 70 knot gusts to that other event.

4. Conclusions

An analysis of severe wind-driven hail events found a few differences in the types of morphologies most likely to produce severe wind-driven hail in 2007 compared to hail or wind reports alone. Squall line morphologies such as TS and NS tended to have the most concurrent severe wind and hail reports, but the IC and CC events seemed to be responsible for more extreme events with larger hail and higher wind speeds. We speculate that these types of events may be associated with larger CAPE and helicity values than other morphologies, although more study will be needed to verify this theory. Storms capable of producing severe wind-driven hail are not restricted to areas of unusually large CAPE and helicity, as seen from the conditions present in the Sturgis, SD case.

5. Future Work

In the future, we will compute average values for some parameters typically used for severe weather prediction, such as helicity and CAPE, for the full sample of wind-driven hail events. These averages will be compared to averages for hail and wind events alone. We would also like to expand the analysis to include cases from different years, such as the exceptionally severe 2009 Eldora, IA event.

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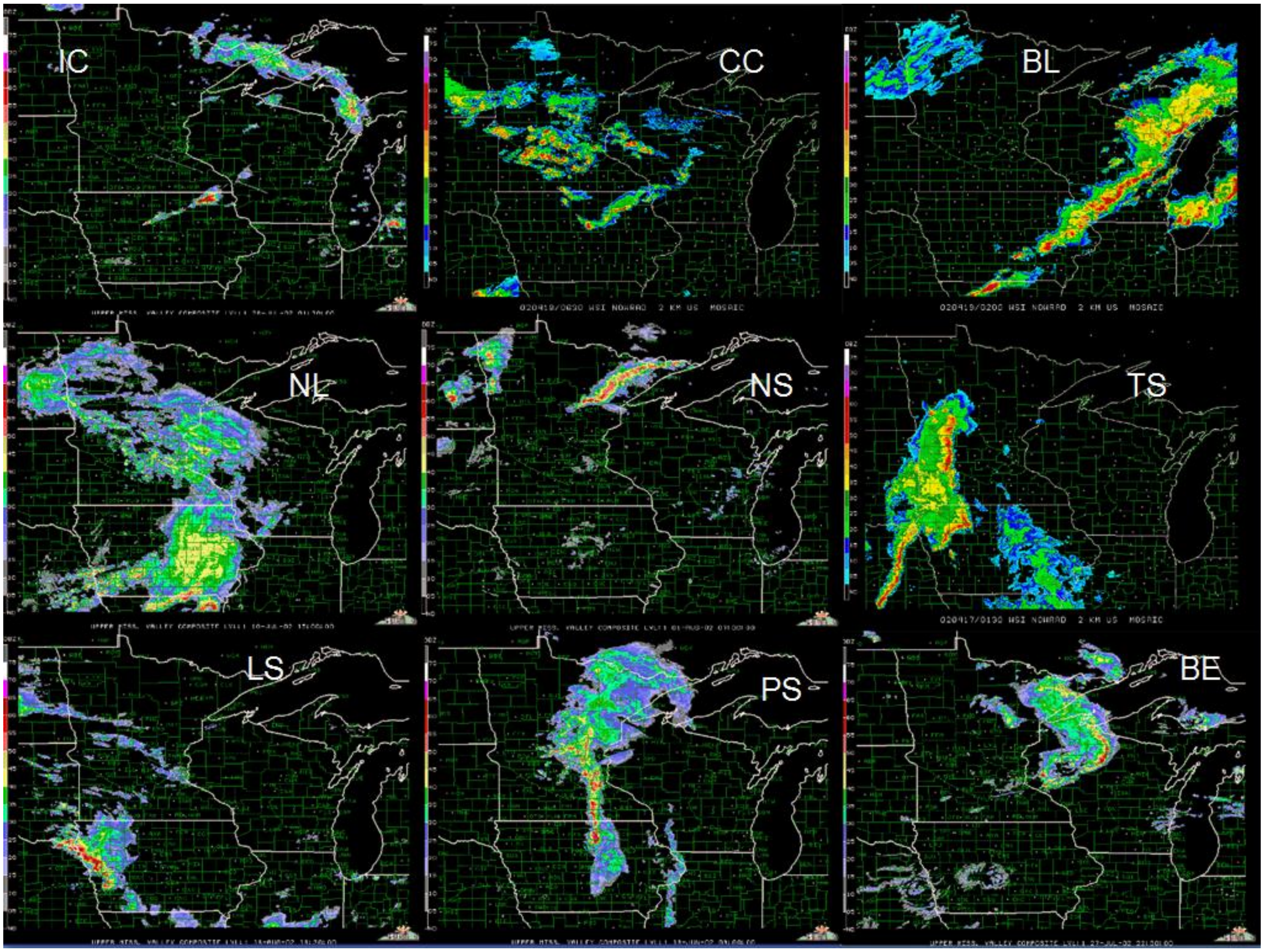

Figure 1: The morphologies used in the present study, taken from Duda and Gallus (2010) with: IC – isolated cells, CC – cluster of cells, BL – broken line of cells, NS – squall line with no stratiform precipitation, TS – trailing stratiform precipitation, PS – parallel stratiform precipitation, LS – leading stratiform precipitation, BE – bow echo, and NL – non-linear convective system with storm motion from left to right.

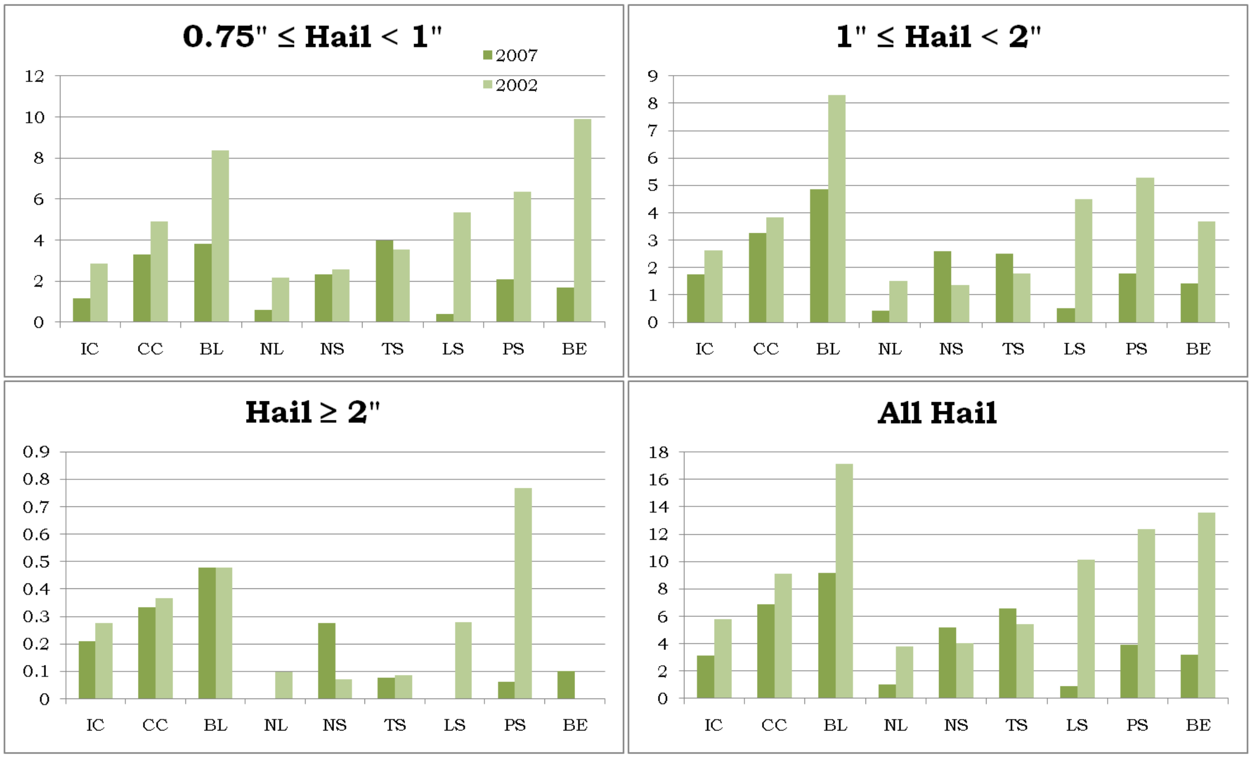

Figure 2: Severe hail reports (sorted by size) as a function of convective morphology, taken from Duda and Gallus (2010).

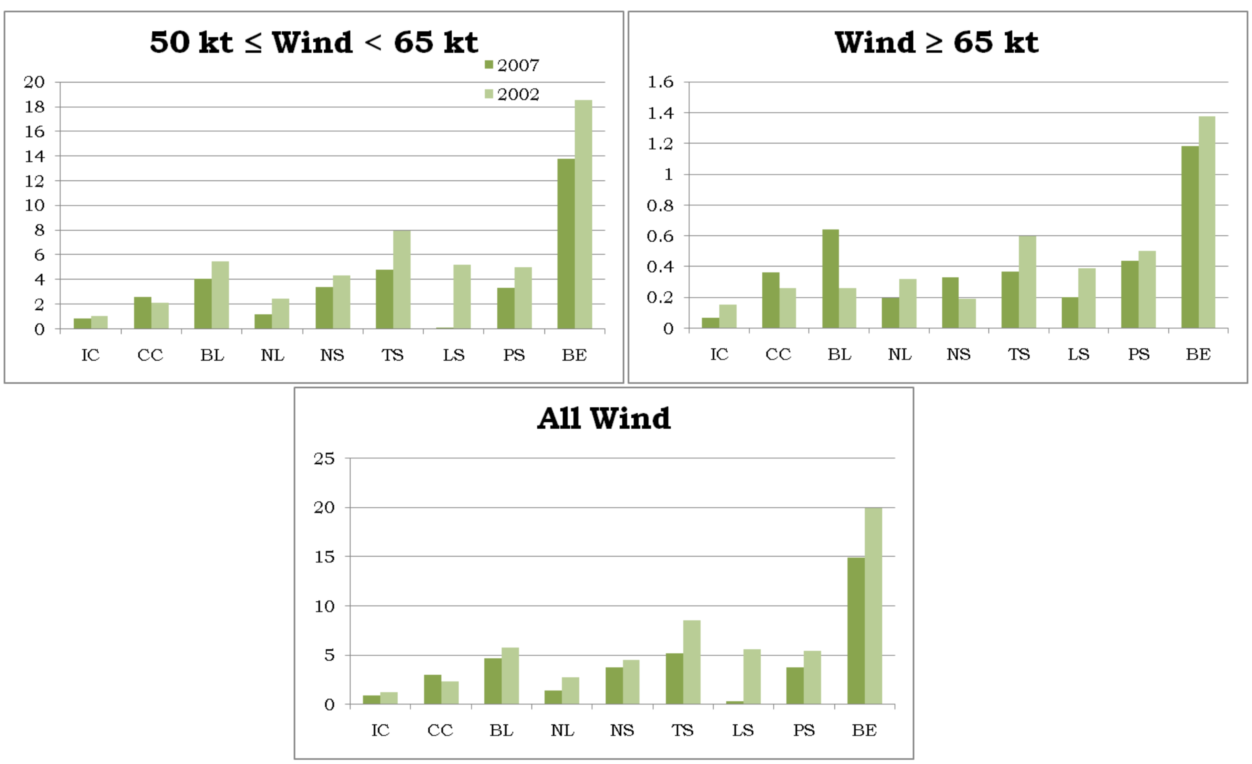

Figure 3: Severe wind reports (sorted by speed of wind in knots) as a function of morphology, taken from Duda and Gallus (2010).

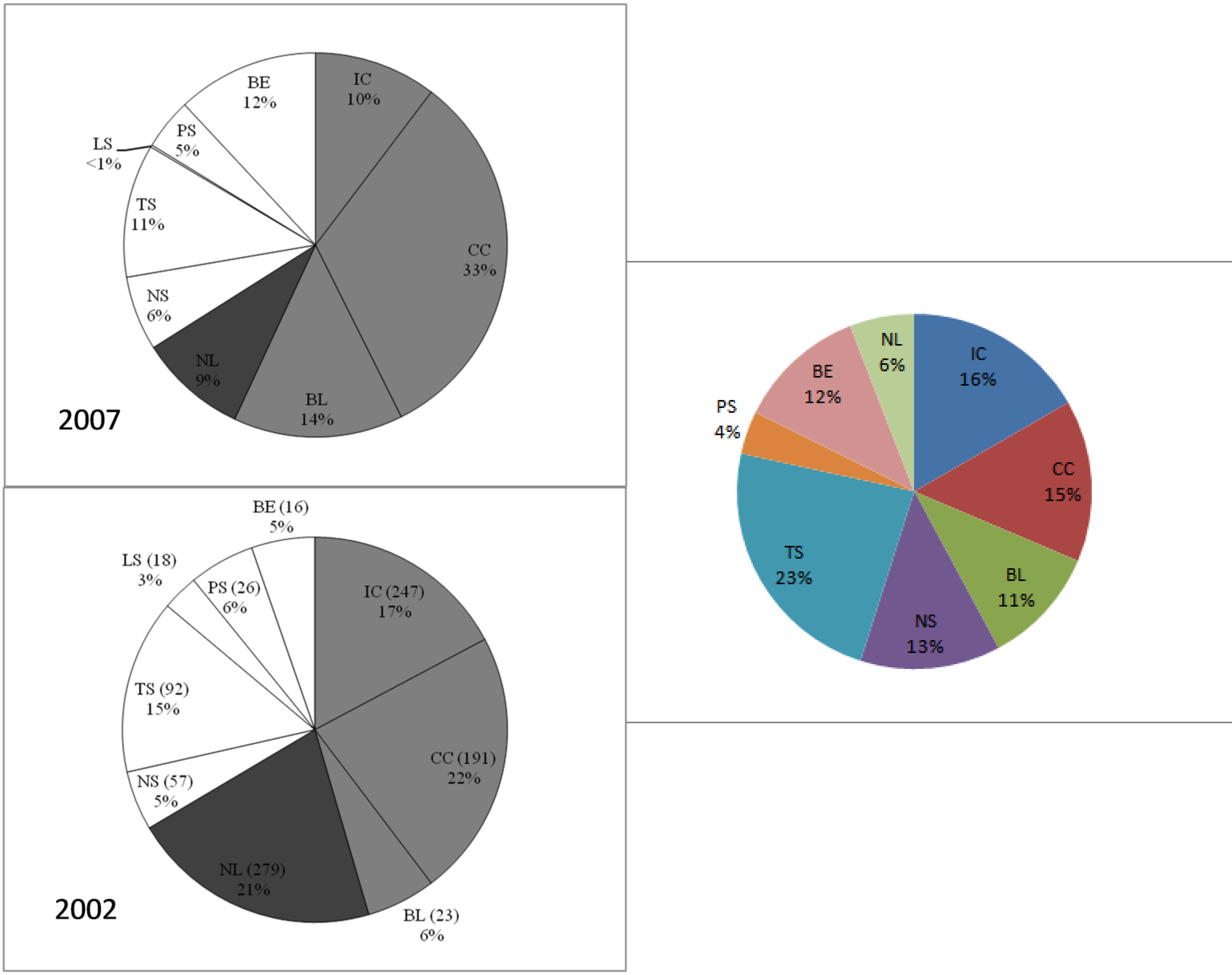

Figure 4: The percentage of convective morphologies in the data sample from 2002 and 2007 from Duda and Gallus (2010) on the left, and the percentage of convective morphologies for wind driven hail events in 2007 on the right.

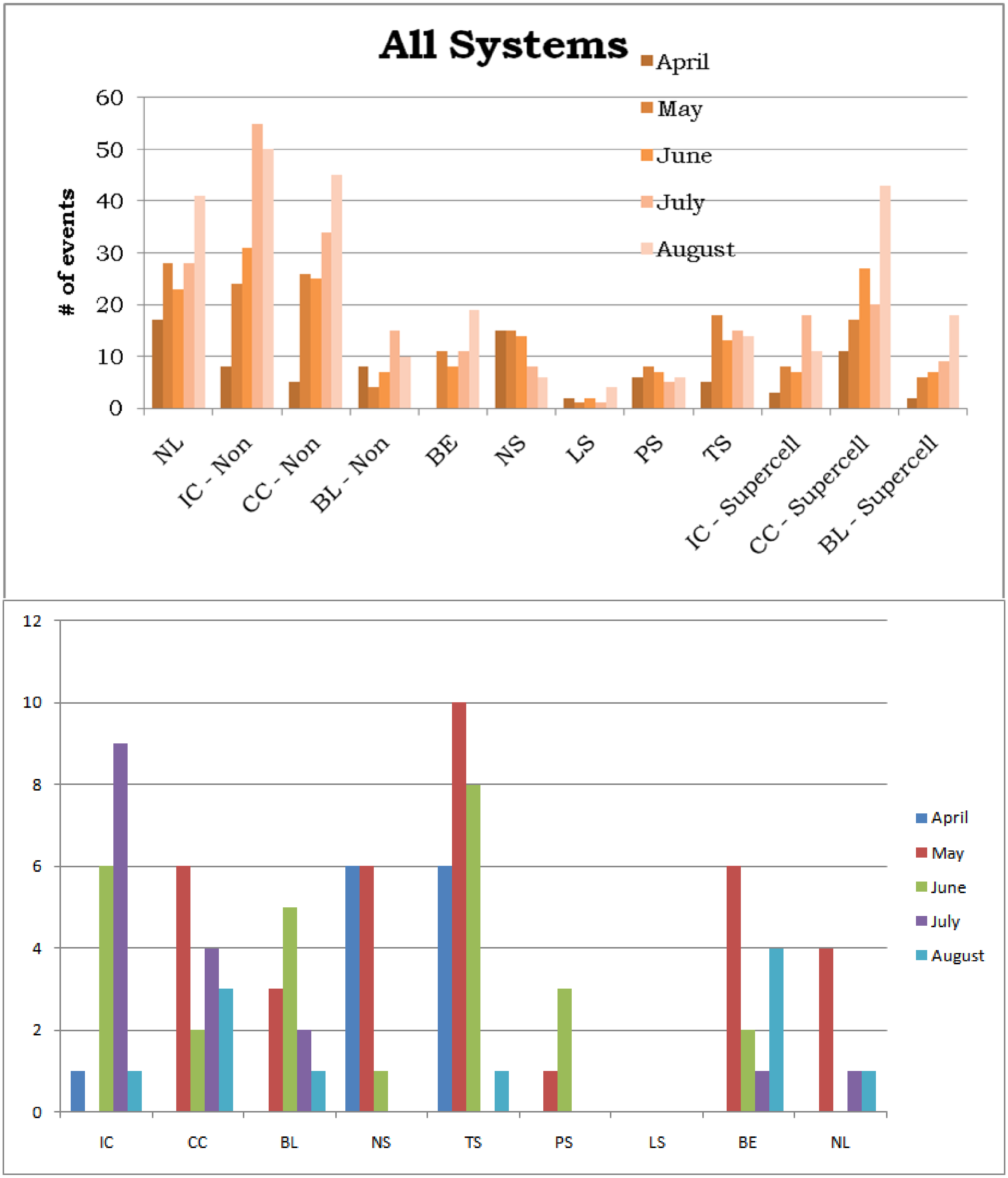

Figure 5: The number of systems of each morphology in 2007 based on the month of occurrence (on top, from Duda and Gallus 2010) and wind driven hail events on the bottom.

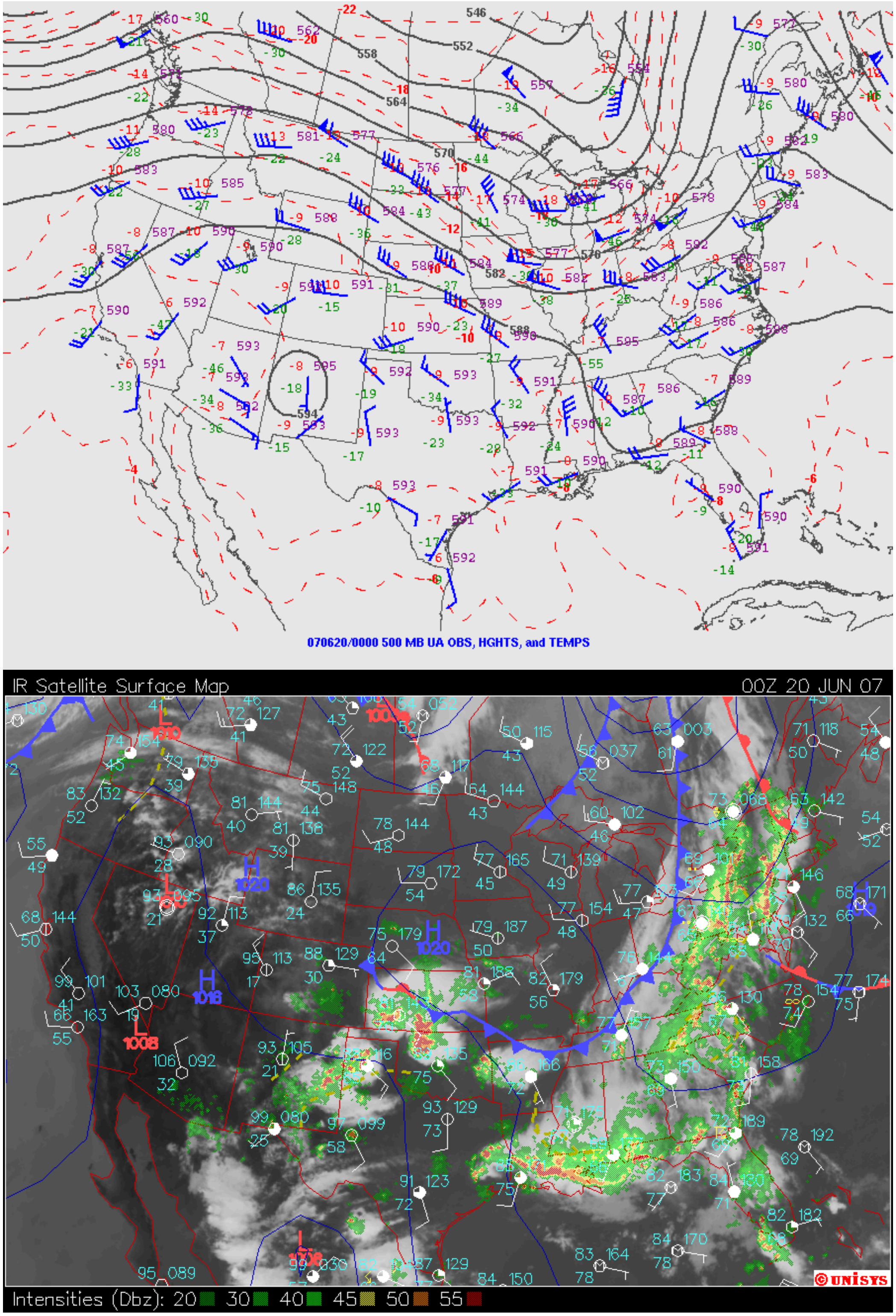

Figure 6: Analyses at 500 mb from SPC (top) and surface (bottom) on June 20, 2007, around the time of the Kalvesta, KS case (00 UTC).

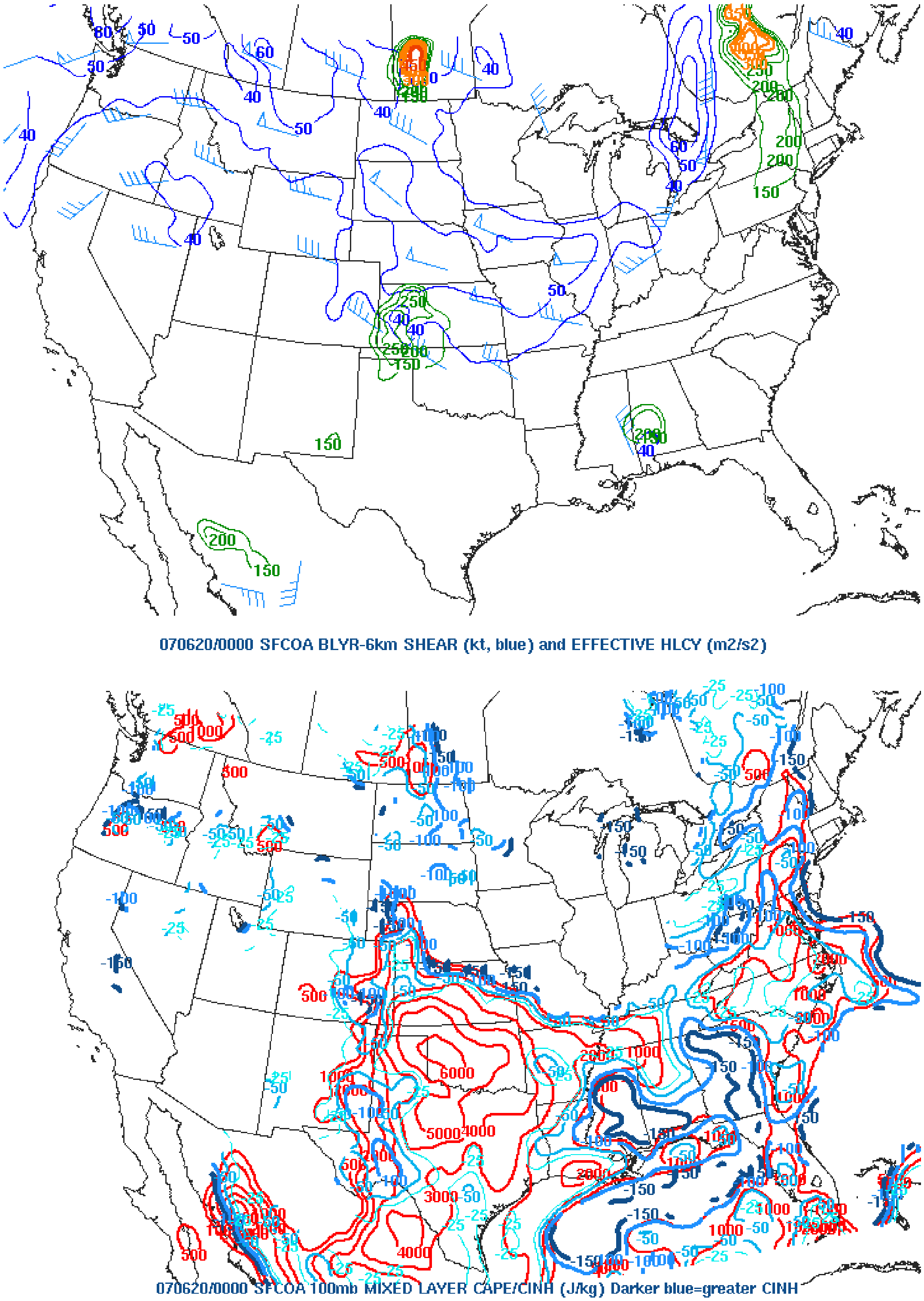

Figure 7: Effective storm relative helicity and sfc-6km shear (top) and 100 mb mixed layer CAPE and CINH (bottom) for 00 UTC June 20, 2007 (from SPC archive).

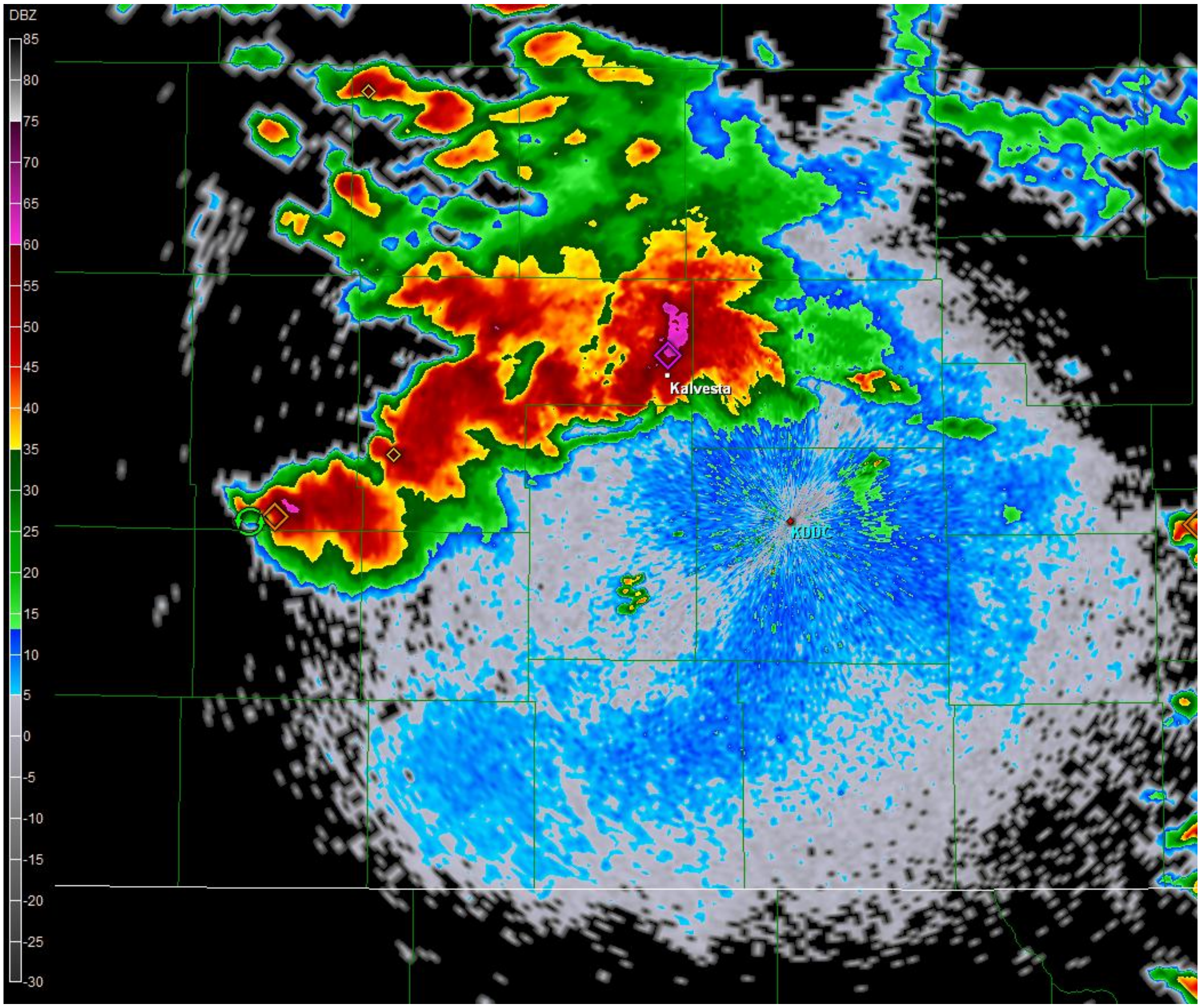

Figure 8: Radar image from Dodge City, KS at 2353 UTC June 19, 2007

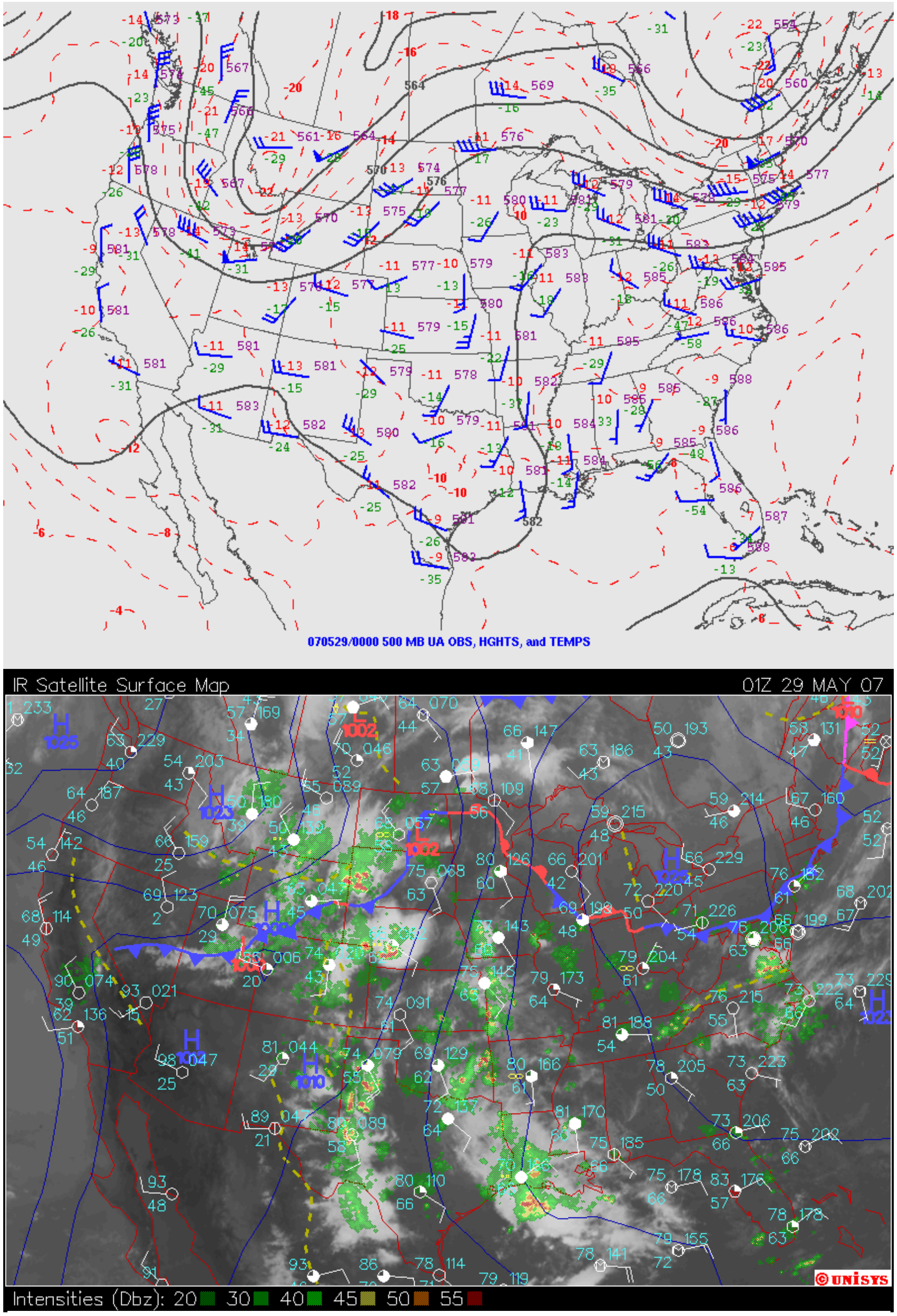

Figure 9: Analyses at 500 mb (top) from SPC and surface (bottom) for the Stugis, SD case at 00 UTC May 29, 2007.

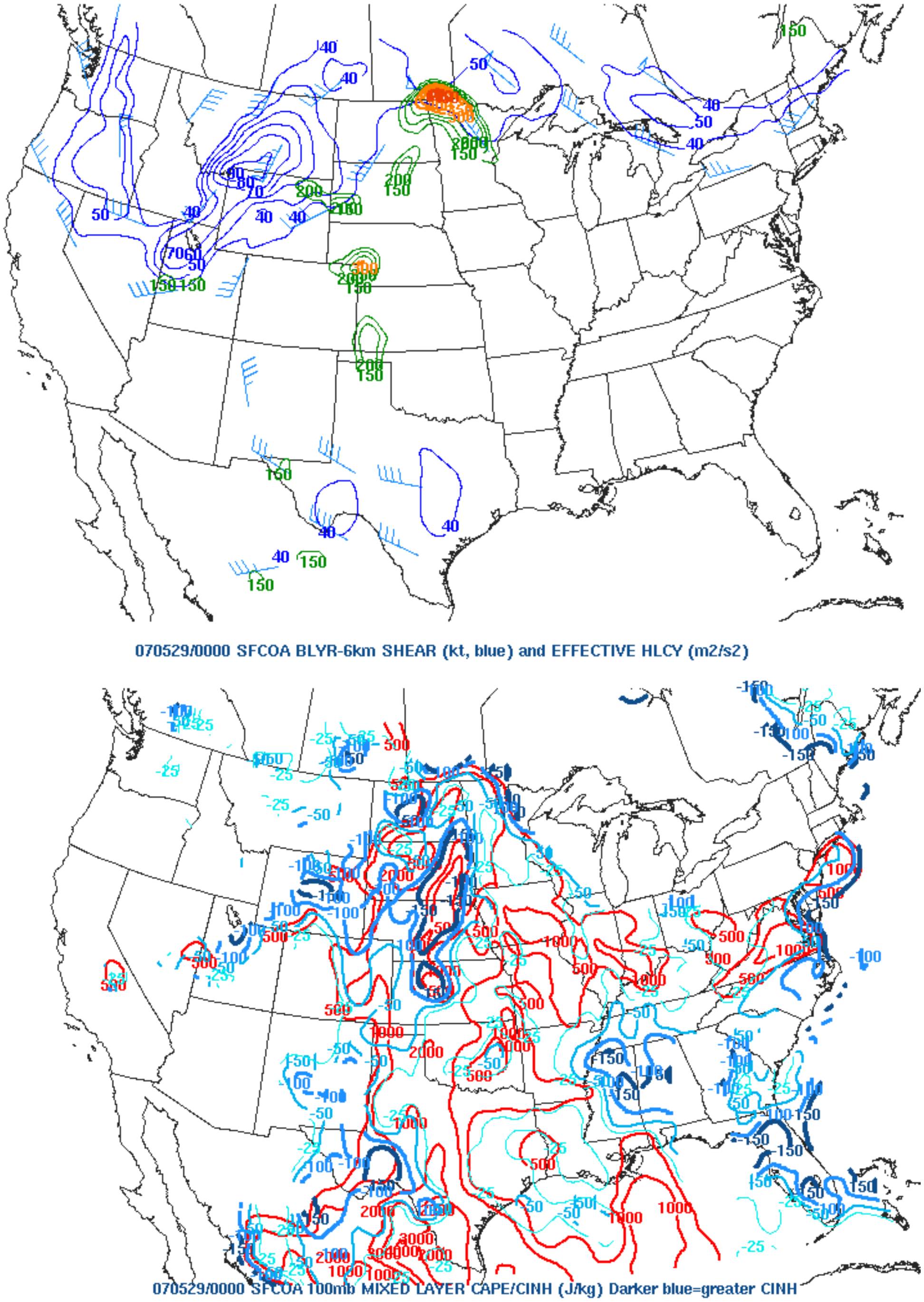

Figure 10: Effective storm relative helicity and sfc-6km shear (top) and 100mb mixed layer CAPE and CINH (bottom) at 00 UTC May 29, 2007 (from SPC archive).

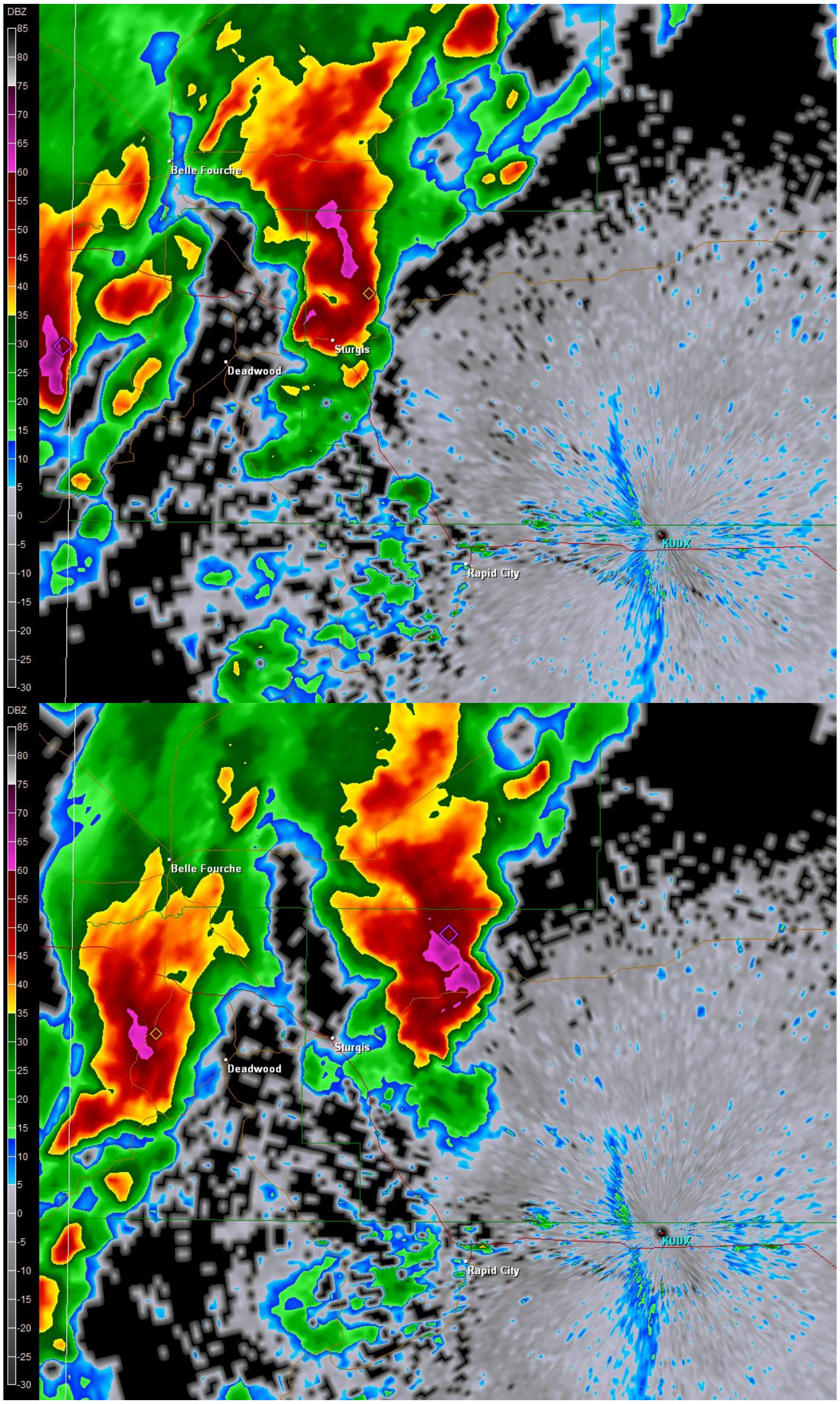

Figure 11: Radar from Rapid City, SD at 0020 UTC on top and 0040 UTC on the bottom corresponding to the two reports.

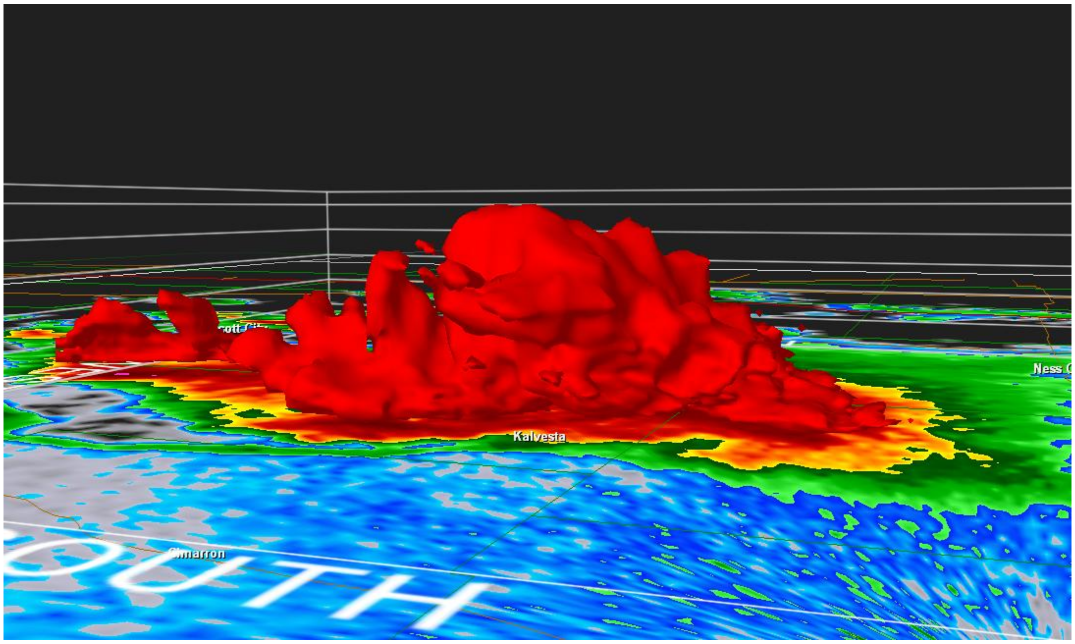

Figure 12: The 50 dBZ echo during the Kalvesta, KS event from GR2Analysts 3D volume tool.

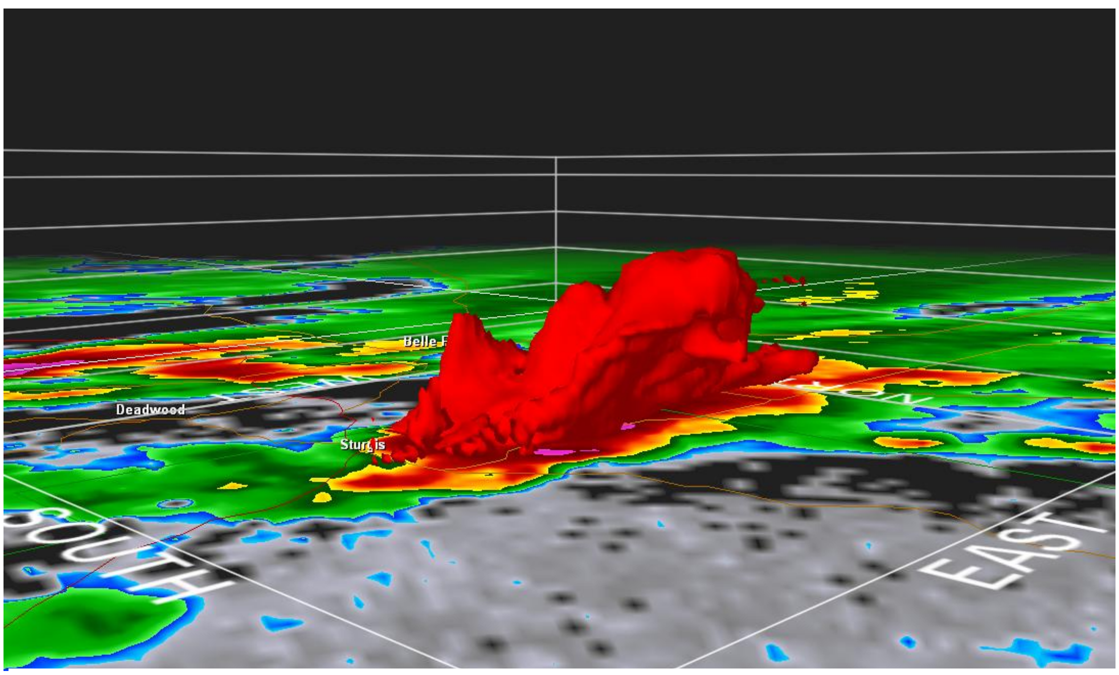

Figure 13: The 50 dBZ echo during the Sturgis, SD event from GRAnaylst's 3D volume tool.