Multi-day severe event of 18-22 May 2013

By
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Abstract:

A relatively slow moving Trough over the western United States and a ridge over the eastern United States setup a relatively persistent pattern from 18-22 May 2013. This pattern produced a period of enhanced severe weather over the United States from 18-22 May 2013. Relative to the month of April 2013 this was an extremely active 4 day period which in fact produced more severe weather reports than were reported during the entire month of April 2013.

The key features associated with the active severe weather of 18-22 May 2013 included a slow moving Trough over the western United States and a ridge over the eastern United States. The resulting enhanced southerly flow, the evolution of a strong LLJ, between these two systems allowed warm moist air from the Gulf of Mexico to move into the central United States from Texas to the Great Lakes. This led to increased values of CAPE in close proximity to strong shear. The result was a multi-day period of enhanced severe weather with three successive days of 300 or more reports of severe weather from 19-21 May 2013 (Table 1). These data show that despite previous conditions, a rapid change in the pattern can rapidly produce significantly different weather.

A very dry air mass over the southwestern United States showed up as a region of below normal precipitable water from 18-22 May 2013. This dry air, as it moved off the higher terrain of New Mexico and west Texas produced an elevated mixed layer and a loaded gun sounding over portions of Oklahoma including the period of the deadly New Castle and Moore, Oklahoma tornado.

1. Overview

After a relatively quiet start to the 2013 severe weather season, the pattern over North America changed dramatically in mid-May with a surge of total severe reports (Table 1) from 18 to 23 May 2013. There was also a rapid increase in tornado activity to include the deadly 20 May New Castle and Moore, OK EF5 tornado. The total number of severe weather reports of 1434 from 18-22 May exceeded the 1381 severe weather reports for the entire month of April 2013.

The larger scale pattern (Fig. 1) showed a slow moving mid-tropospheric trough (Fig. 1) which moved across the central United States from 18 to 22 May 2013. As this system reached the plains the trough had -1σ height anomalies with a strong gradient between the trough to the east and ridge to the east. In the 4-day mean pattern (Fig. 2) there was strong westerly jet over the southwestern United States (Fig. 2a) with an implied jet entrance region over southern Canada; trough over the central United States with a strong ridge to the east (Fig. 2b); 850 hPa temperatures were above normal from Texas into the Great Lakes (Fig. 2c) and there was a surge of high precipitable water (PW:Fig. 2d) air into the Plains and into the eastern United States. The PW field also showed a sharp north-south boundary of dry air with -1s below normal PW over western Texas and Oklahoma. On a larger scale, the climate forecast system (CFS) analyzed a synoptic scale dry-line (Carlson and Ludlam 1968;Carlson et. al 1983) over the southern Plains which persisted for several days.

The dry-line and implied dry air over the southwestern United States and Mexico is a means to produce an elevated mixed layer (EML: Fawbush and Miller 1954; Carlson and Ludlum 1968;Banacos and Ekster 2010) over a warm moist boundary layer over the lower southern plains to the east. The result is a "*capping inversion*" over the relatively warm moist planetary boundary layer (PBL) with a well-mixed layer of air originally from the elevated regions of the southwest in the mid-troposphere. The sounding from Normal, OK at 1200 UTC 20 May 2013 (Fig. 3) shows an example of the classic "*loaded gun*" sounding (Fawbush and Miller 1954). The larger scale conditions (Fig. 2) captured the set-up of the dry-line on a synoptic scale that produced the sounding. Producing conditions favoring severe weather over several days requires a unique set of conditions. It will be shown that there were 3 successive days of severe weather over the southern Plains from 18-20 May 2013. Then the severe weather moved eastward (Table 1).

This paper will document the larger scale pattern over the United States during the active severe weather period of 18-22 May 2013. The focus is on the key features that produced a favorably active period of severe weather after a relatively quiescent period in April 2013.

2. Data and Methods

The larger scale pattern was reconstructed using the Climate Forecast System (Saha et. 2010). The means and standard deviations were used based on the method described by Hart and Grumm (2001) suing the NCEP/NCAR reanalysis data (Kalnay et al. 1996). Daily values of raw CFS data were compared to the 21-day centered means and standard deviations.

Storm reports were obtained from the Storm Prediction Center. Processed SPC data was used to overlay on the anomalies and the base SPC images were used.

3. Pattern over the region

The larger scale 500 hPa pattern (Fig. 1) showed the evolving 500 hPa trough and implied deep southerly flow between the trough to the west and the ridge over the eastern United States. The evolution of the PW (Fig. 4) field at 0000 UTC 17-22 May 2013 showed the persistent dry-line with areas of above normal PW at times over the southern Plains into the Great lakes. The deepest plume of above normal PW in the southern Plains was at 21/0000 UTC (Fig. 3e).

The plume of moisture was associated with a strong low-level jet (LLJ) at 850 hPa (Fig.5). The low-level southerly winds increased over the period from 18/0000 through 22/0000 UTC with the strongest southerly jet at 20/0000 UTC. The 3 strongest late afternoon peaks were from 19-21 May, implying the strongest LLJ over the southern plains and plains on the afternoon hours of 18-20 May 2013. At 20/0000 and 21/0000 UTC there were relatively strong westerly winds at 850 hPa and aloft (Fig. 1a) which may have aided in advecting the warm dry air over the elevated terrain over southwestern United States over the warm moist PBL in the southern Plains, producing the EML (Fig. 3 & Fig. 6). The elevated EML was present in some form at 0000 UTC for 3 days at Norman, OK (Fig. 6).) Though not shown, west of the dry-line, locations such as Amarillo had extremely dry profiles below about 700-600 hPa with several days of an implied invert-V sounding from 18-21 May 2013.

In the warm moist air, the CFS analyzed surface available convective energy (CAPE: Fig. 7). CAPE values over 2400JKg-1 were present over region of the southern Plains from 18 to 21 May 2013. The severe reports from 18-21 May 2013 (Fig. 8) show the evolution of the pattern of the severe weather. The area of high CAPE, strong southerly flow, and moisture played a critical role in the increase in severe weather during this period. The tornado activity in the southern Plains appears to be linked more to the strong dry-line and clearly, in Oklahoma, the tornadoes during the afternoon hours of 19 and 20 May were related to the same general ingredients and the dry-line and EML.

4. Radar of the southern Plains severe weather Moore supercell

The convection during the afternoon and early evening hours of 19 May 2013 at 2200 UTC showed a line of severe storms in Kansas and several large discrete storms in Oklahoma (Fig. 9 upper) . Based on Figure 8 there were other locations of severe weather (not shown) into the western Great Lakes. A similar pattern of the convection was evident 24 hours later as with a broken line of thunderstorms and discrete storms in Oklahoma. Though not shown, the convection moved well to east on the 21st as implied in the severe reports from the Storm Prediction Center. The supercell which produced the deadly EF5 tornado in New Castle and Moore, OK had a very distinct signature in the hook echo near showing a nearly circular field in the hook itself at 2016 UTC 20 May 2013. This storm will likely be well studied over the next 1-2 years.

5. Summary

A relatively slow moving Trough over the western United States and ridge over the eastern United States setup a relatively persistent pattern from 18-22 May 2013. This pattern produced a period of enhanced severe weather over the United States from 18-22 May 2013 (Table 1). Relative to the month of April 2013 this was an extremely active 4 day period which in fact produced more severe weather reports than were reported during the entire month of April 2013.

The key features associated with the active severe weather of 18-22 May 2013 included a slow moving Trough over the western United States and a ridge over the eastern United States. The resulting enhanced southerly flow, the evolution of a strong LLJ, between these two systems allowed warm moist air from the Gulf of Mexico to move into the central United States from Texas to the Great Lakes. This led to increased values of CAPE in close proximity to strong shear. The result was a multi-day period of enhanced severe weather with three successive days of 300 or more reports of severe weather from 19-21 May 2013 (Table 1). These data show that despite previous conditions, a rapid change in the pattern can rapidly produce significantly different weather.

The strong LLJ and instability, combined with a dry-line and an EML in the southern Plains to produce several days of destructive tornadoes. The dry air over the southwestern United States (Fig. 2) showed up in the CFS mean PW field, over western Oklahoma and Texas just west of the deep moist southerly flow to the east. The increasing westerly winds as the trough moved eastward likely pushed this warm dry air over the moist PBL setting up several days with an EML over eastern Oklahoma and the loaded gun soundings which were present during both of the tornadic events in Oklahoma (Figs. 3 & 6).

6. Acknowledgements

Dana Tobin for image production in GR2 analyst of the Norman, OK tornado.

7. References

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Date(DTG)	All severe	Tornadoes	General region of most reports
5/1/2013	24	0	
5/2/2013	8	1	
5/3/2013	0	0	
5/4/2013	5	1	
5/5/2013	1	0	
5/6/2013	19	1	
5/7/2013	26	0	Kansas
5/8/2013	105	7	Plains
5/9/2013	87	4	
5/10/2013	99	0	
5/11/2013	25	0	
5/12/2013	1	0	
5/13/2013	23	0	
5/14/2013	20	0	
5/15/2013	60	7	
5/16/2013	34	4	Texas
5/17/2013	80	7	Dakotas
5/18/2013	186	16	Southern Plains
5/19/2013	426	29	Southern Plains to western Lakes
5/20/2013	356	32	Southern Plains to Great Lakes
5/21/2013	315	0	Texas to Ohio Valley
5/22/2013	151	0	Eastern States
5/23/2013	137	5	West Texas

Table 1. list of severe weather reports by date and the number of tornadoes reported in the total severe weather reports. Data from Storm Prediction Center as of 28 May 2013. Return to text.

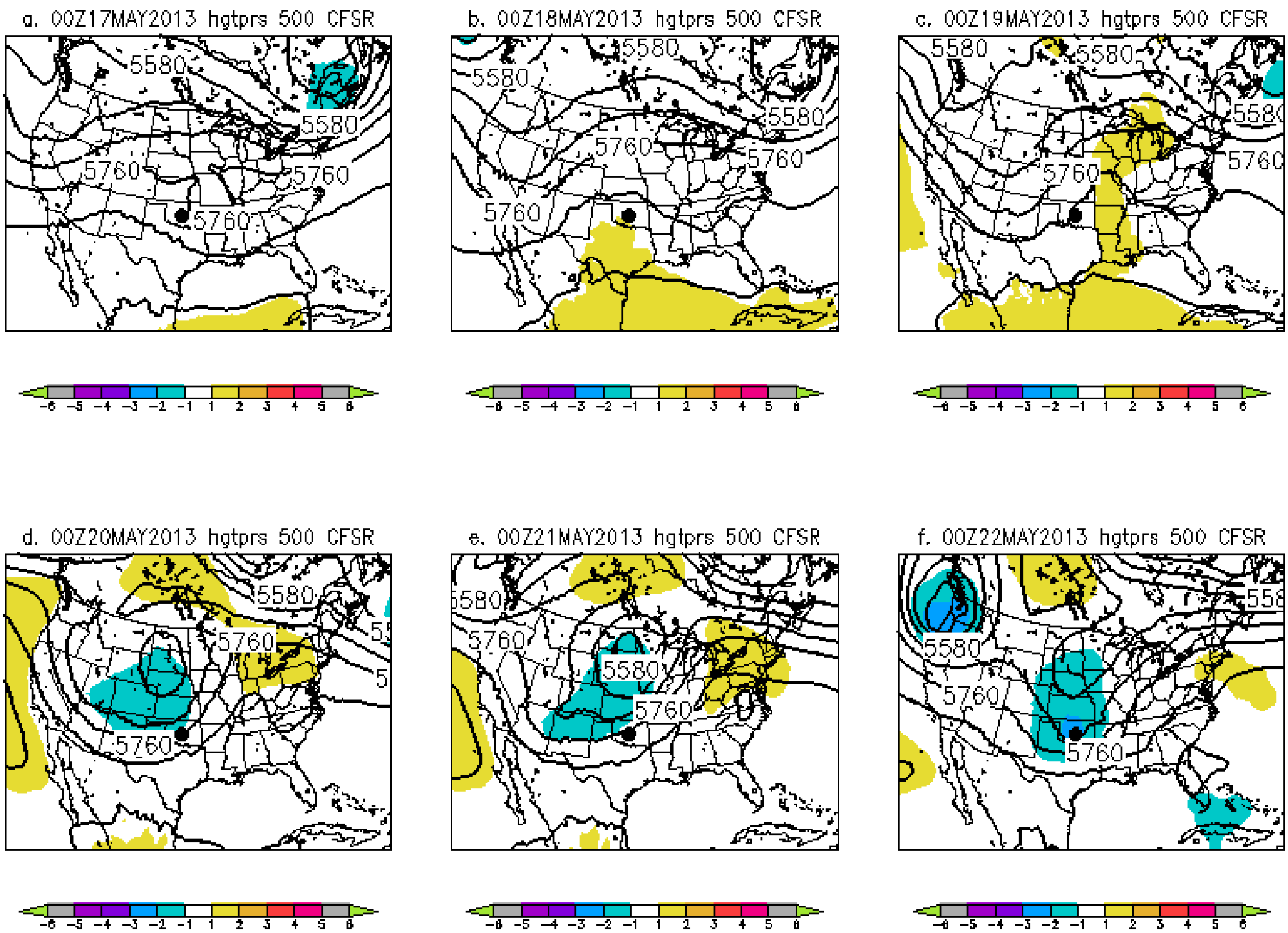


Figure 1. CFS analysis of 500 hPa heights and 500 hPa height anomalies over the United States in 24 hour increments from a) 0000 UTC 17 May 2013 through f) 0000 UTC 22 May 2013. The black dot is the approximate location of Moore, OK. **Return to text**.

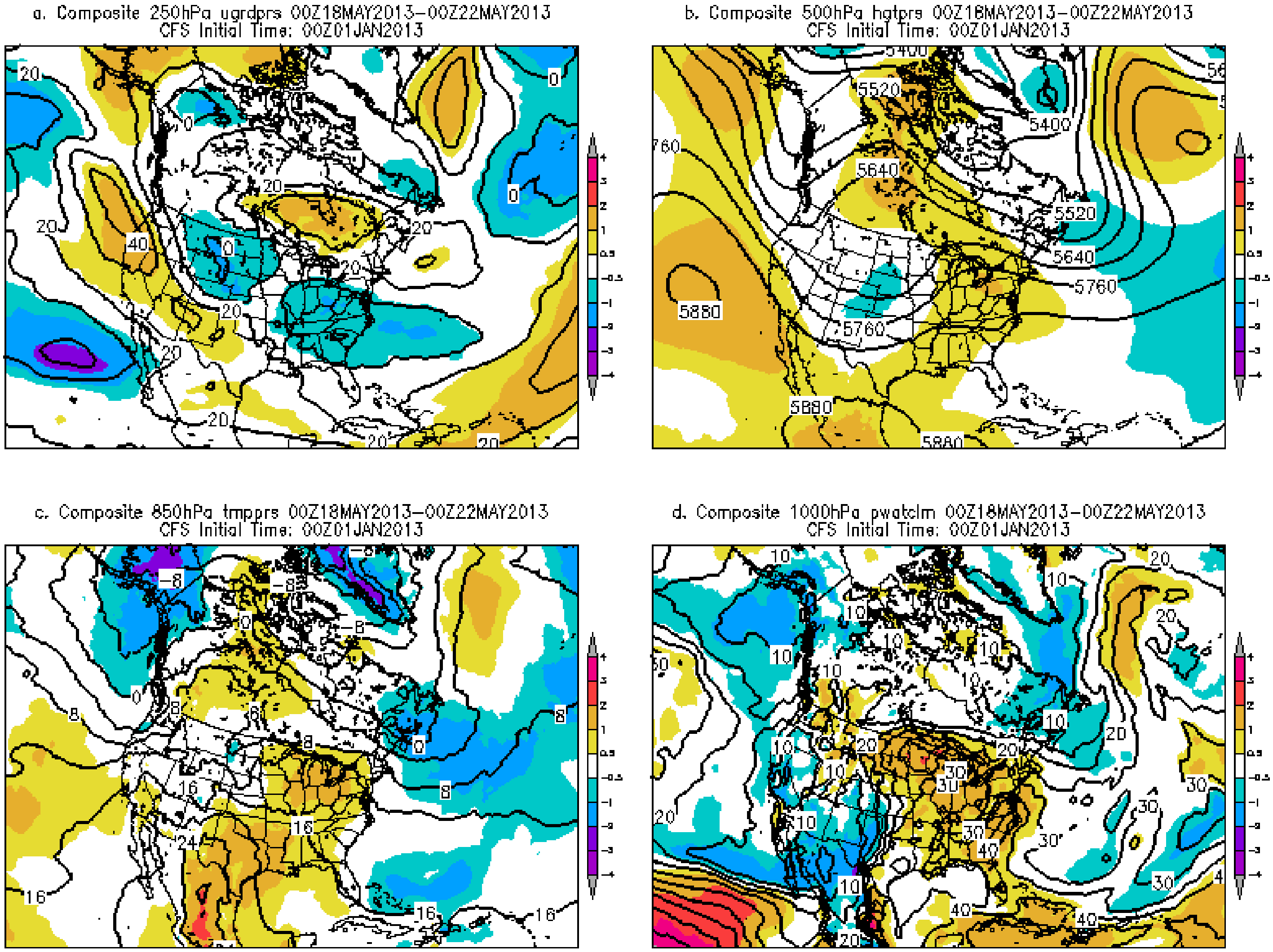


Figure 2. CFS composite mean pattern and anomalies computed from 6-hourly data from 0000 UTC 18 through 0000 UTC 22 May 2013. Data shown include a) 250 hPa u-wind and u-wind anomalies, b) 500 hPa heights and height anomalies, c) 850 hPa temperatures and temperature anomalies. And d) precipitable water and precipitable water anomalies . **[Return to text.]**

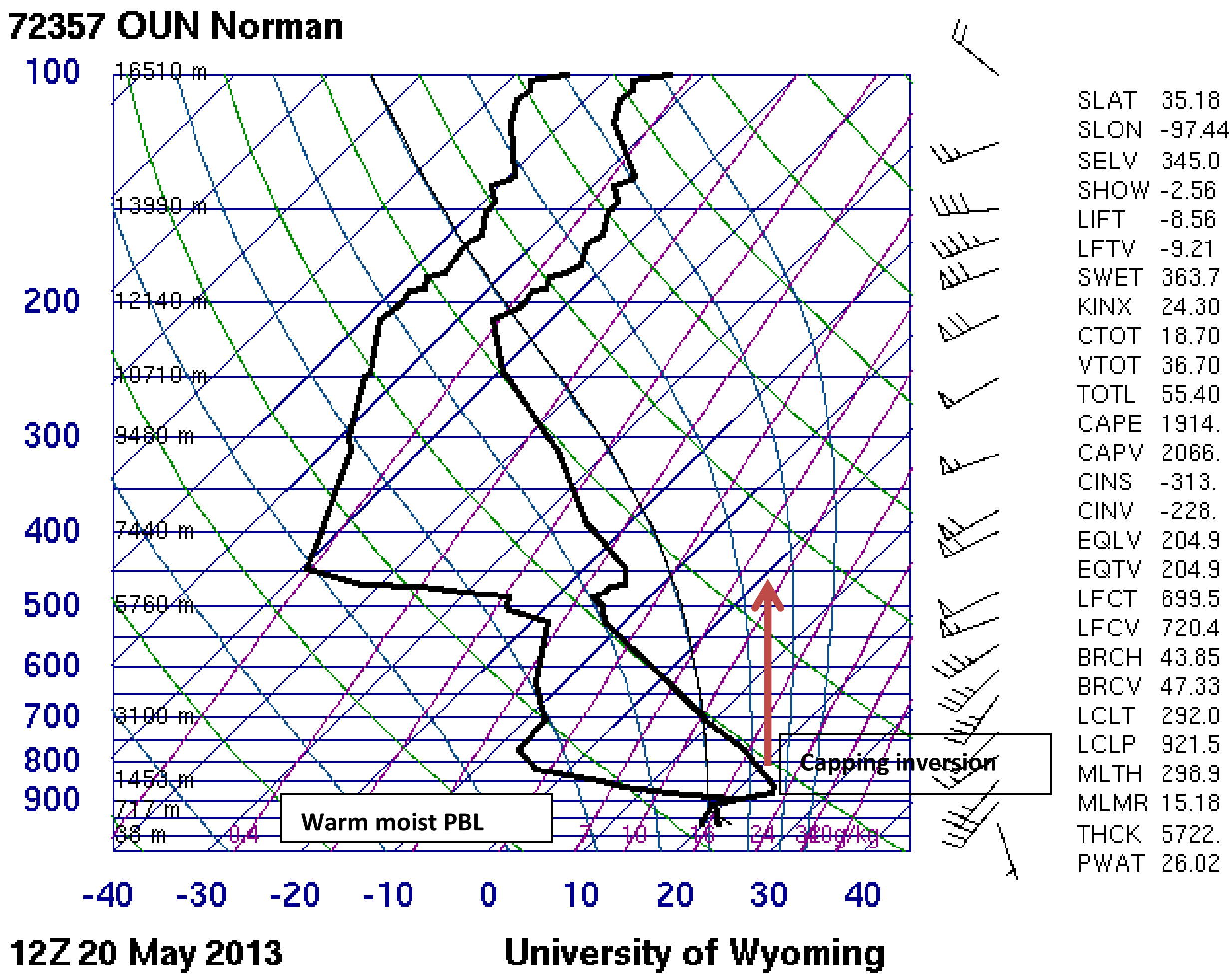


Figure 3. Norman, Oklahoma sounding at 1200 UTC 20 May 2013. Courtesy of the University of Wyoming sounding archive site. The moist boundary layer, capping inversion and EML (red arrow above the inversion) are labeled. **Return to text.**

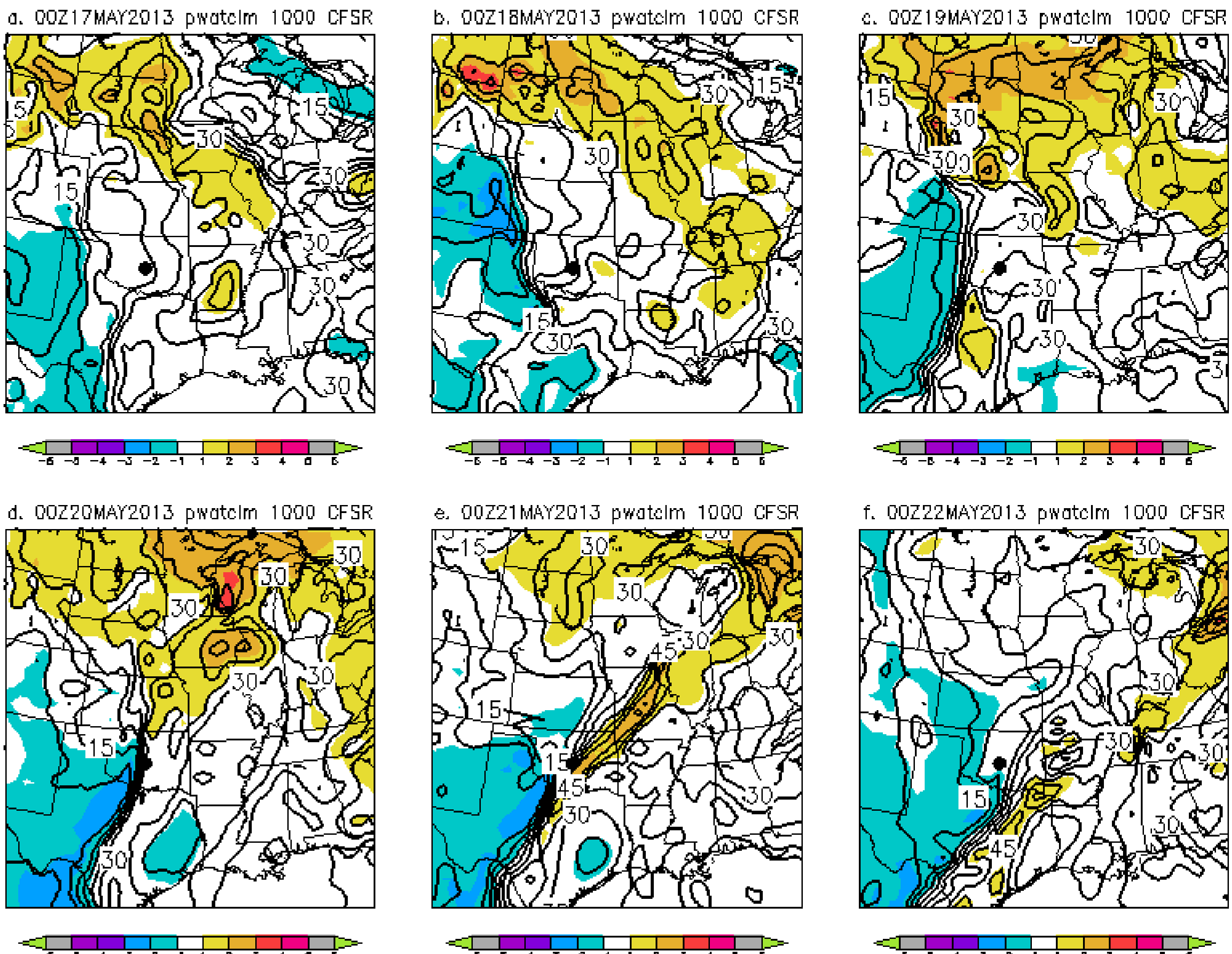


Figure 4. As in Figure 1 except for precipitable water in 24 hour increments from a) 0000 UTC 17 through f) 0000 UTC 22 May 2013. **Return to text.**

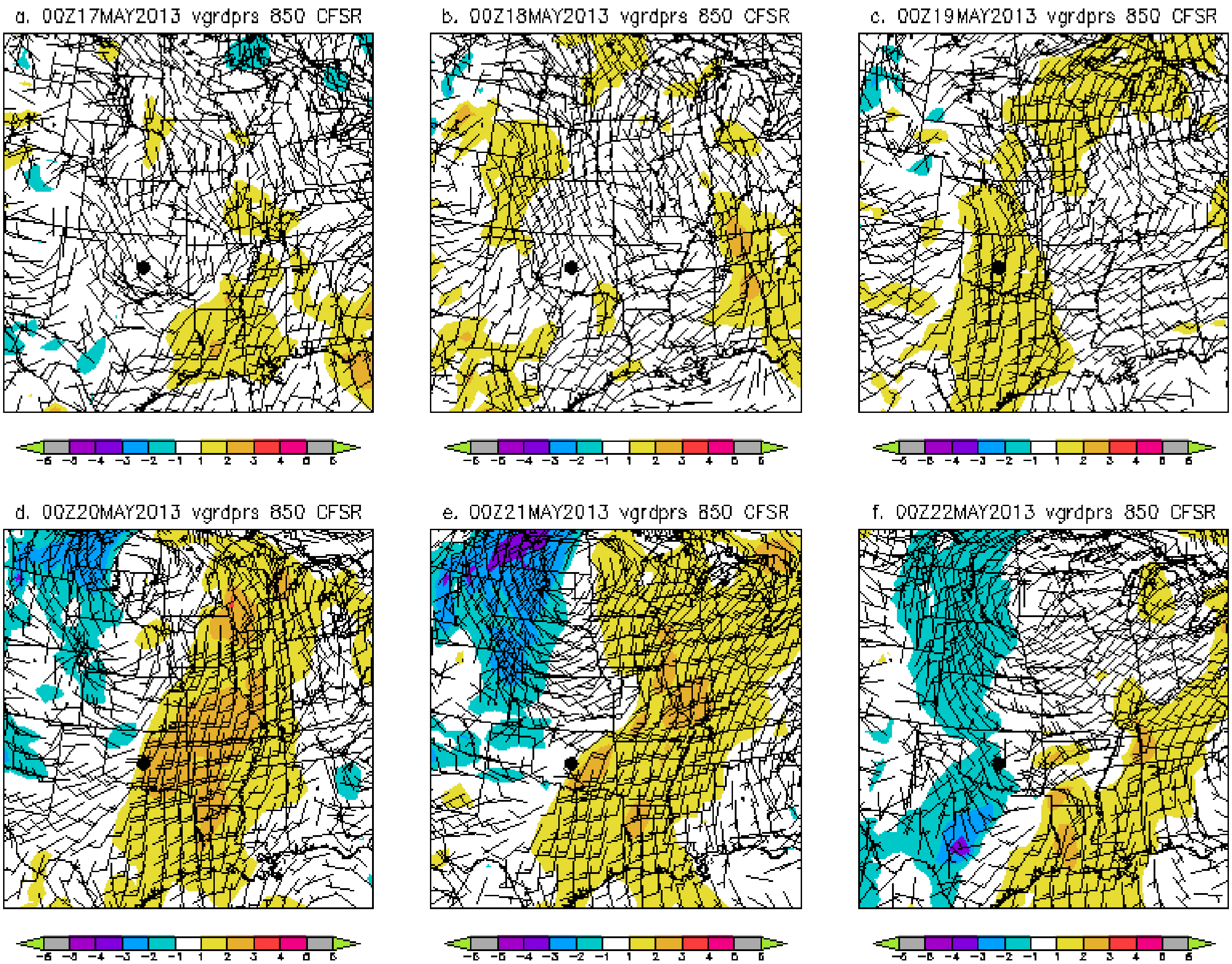


Figure 5. As in Figure 4 except for 850 hPa winds and 850 hPa v-wind anomalies. **Return to text.**

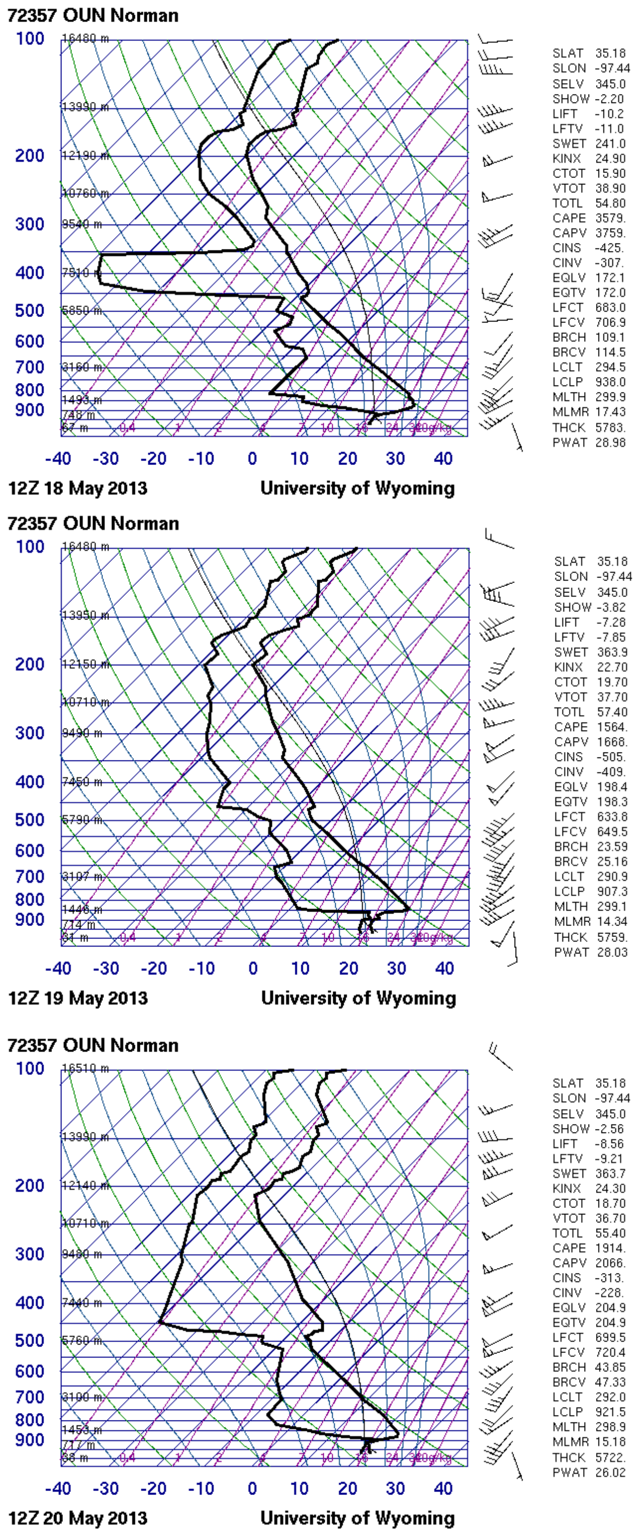


Figure 6. As in Figure 3 except for valid 1200 UTC 18,19 and 20 May 2013. Return to text.

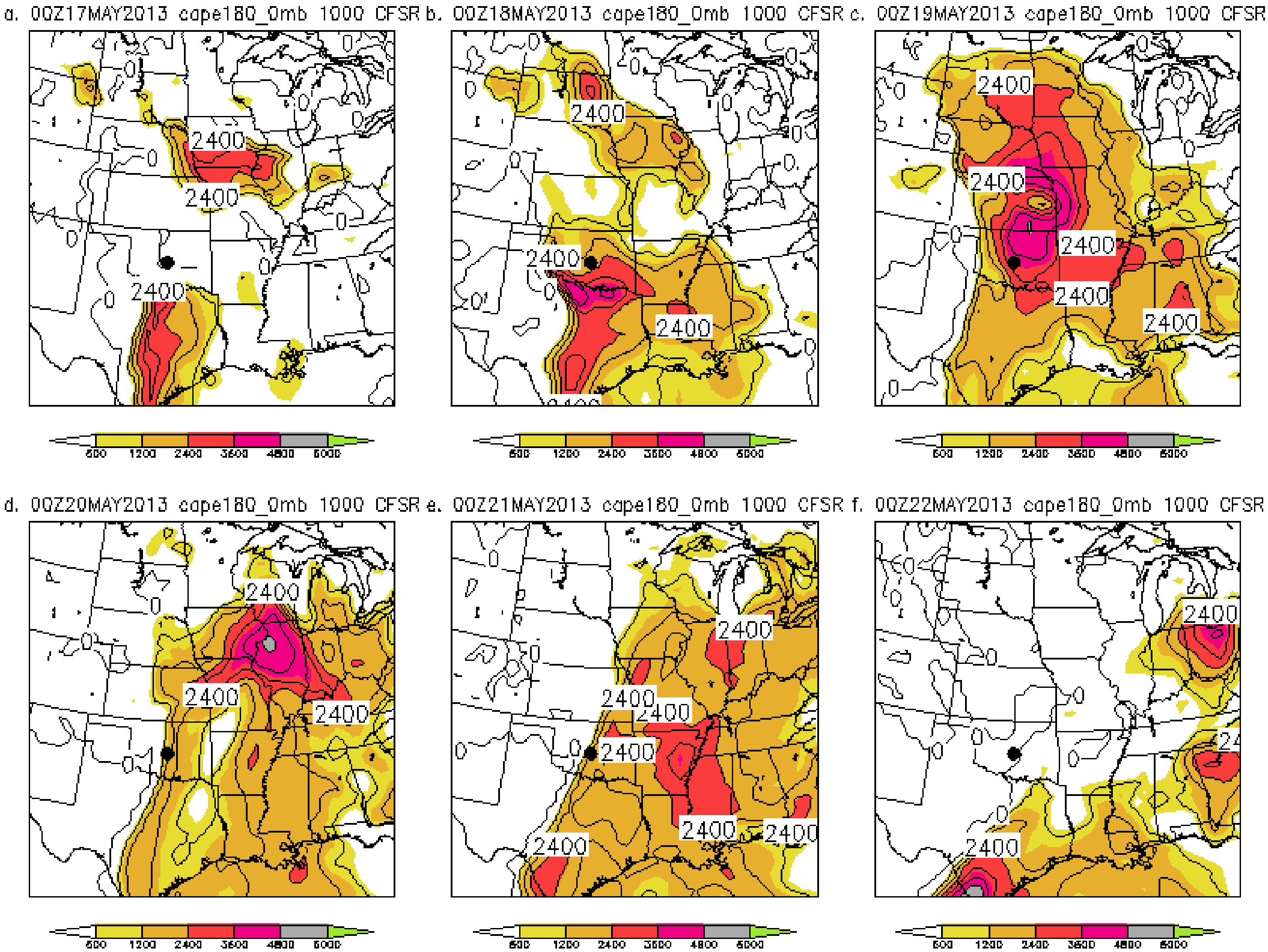


Figure 7. As in Figure 5 except for CFS based CAPE in joules per kilogram shaded as in color bar. **[Return to text.]**

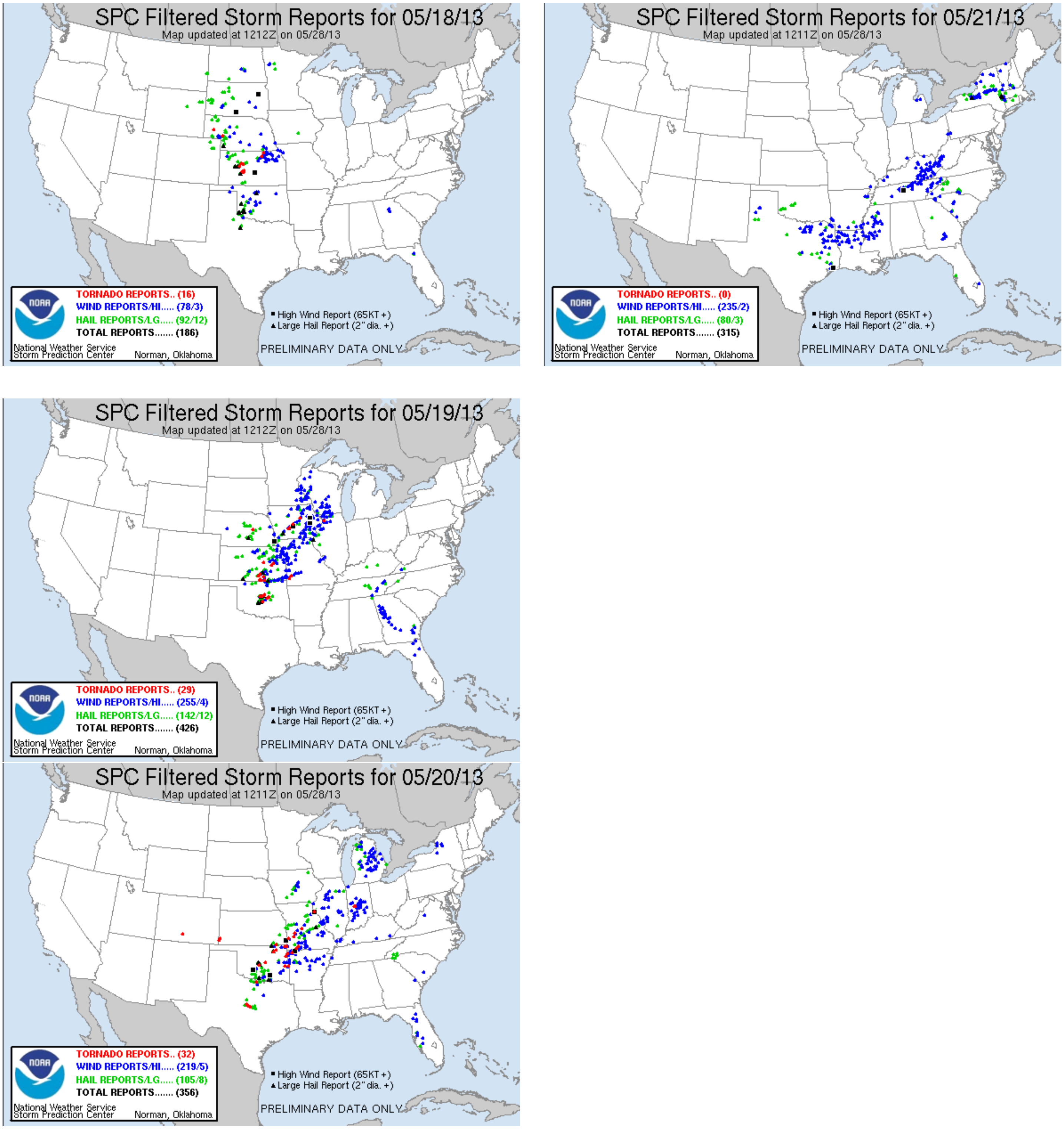


Figure 8. Severe weather reports by type from the Storm Prediction Center (SPC) for 18,19, 20, and 21 May 2013. **Return to text.**

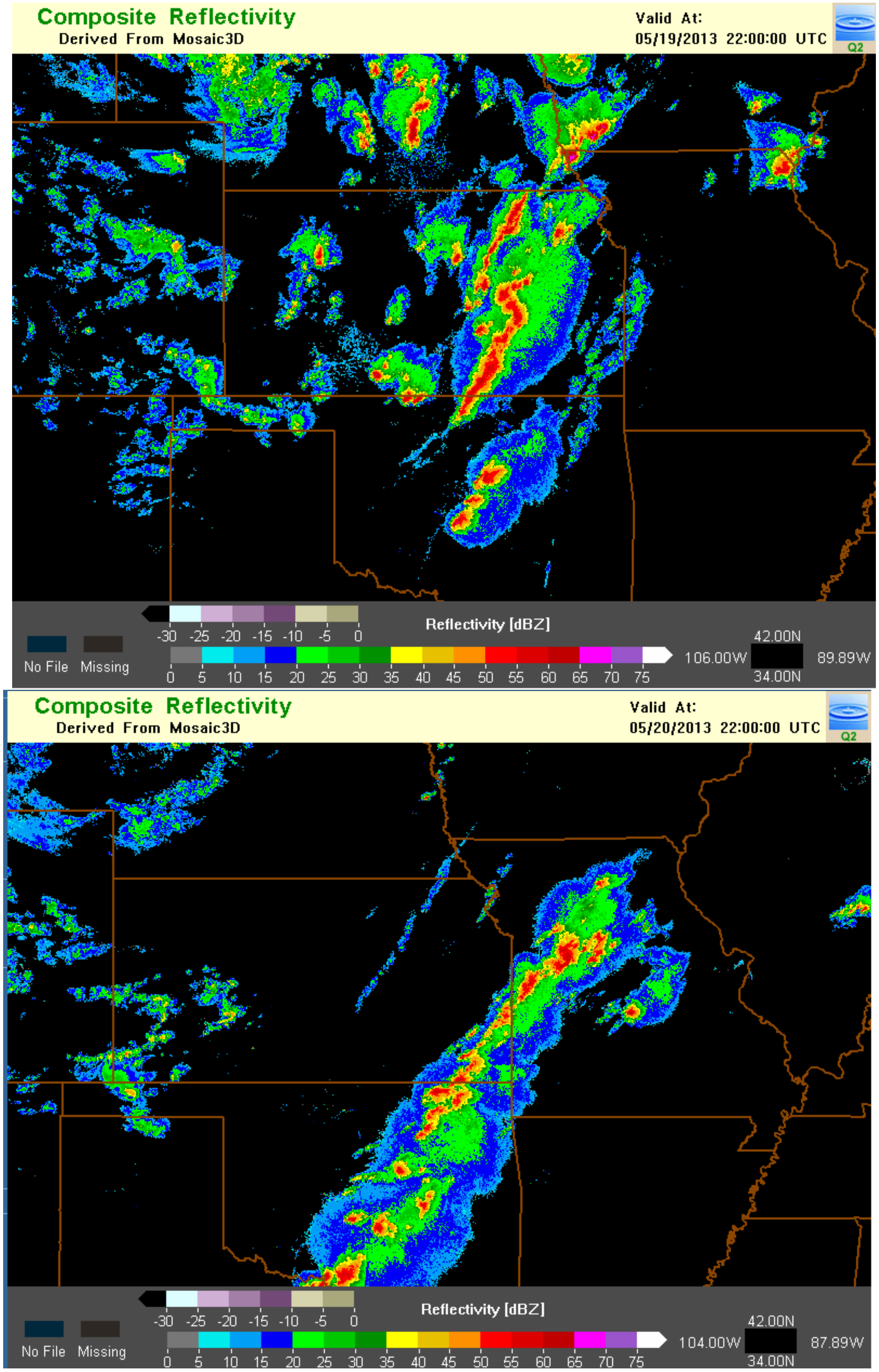


Figure 9. Composite reflectivity at 2200 UTC (upper) 19 May 2013 and (lower) 20 May 2013. Data from the NMQ Q2 site. **Return to text.**

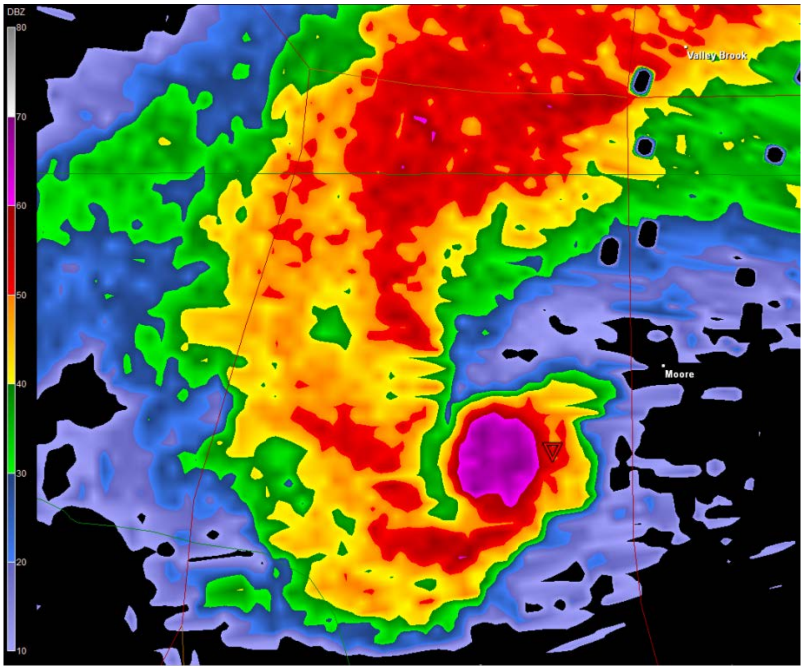
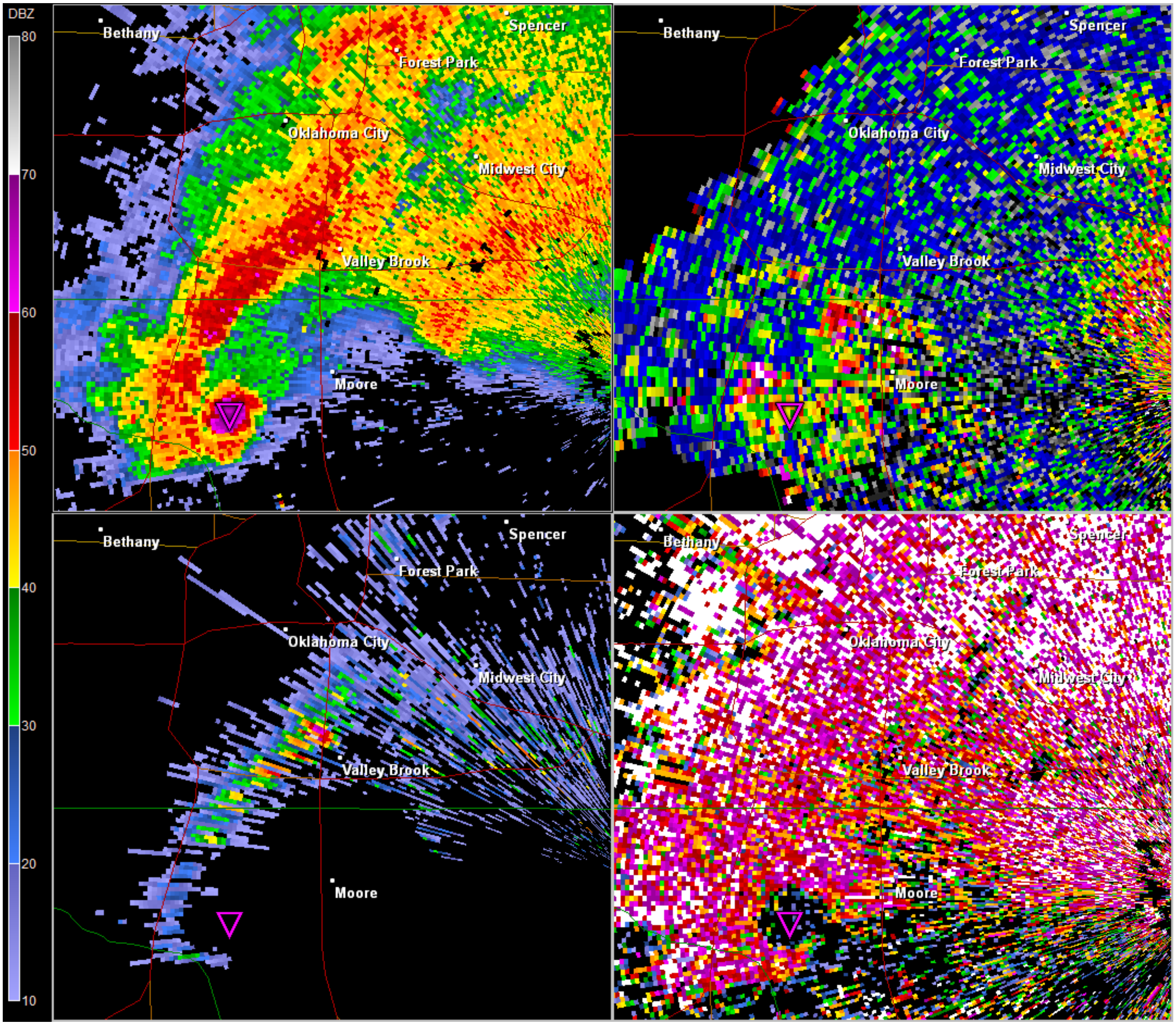


Figure 10. Base reflectivity at 2016 UTC 20 May 2013 showing the hook echo and approximate tornado near Moore, OK . **Return to text.**


DBZ
80
70
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40
30
20
10
Bethany
Spencer
Forest Park
Oklahoma City
Midwest City
Valley Brook
Moore