JP3.12 ANALYSIS OF FORECAST PERFORMANCE FOR HIT, MISS, AND FALSE ALARM THUNDERSNOW EVENTS DURING *ROCS*

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1. INTRODUCTION

Thundersnow (TSSN) is a mesoscale event that is typically associated with large amounts of precipitation and both in-cloud and cloud-to-ground lighting. TSSN is most often seen in the northwest and northeast sectors of dynamic mid-latitude cyclones (Market et al. 2002). Starting in 2002, the Research on Convective Snows (ROCS) group began issuing TSSN outlooks each day during the cold season for the area of the United States pictured in Fig. 1. The outlooks were issued at 1800 UTC and expired at 1800 UTC the following day. The purpose of the outlooks was to inform users on whether TSSN should be expected in the central U.S. during the ensuing 24-hour period and for what location, if applicable. The issuance of daily outlooks continued for five seasons from 2003 through 2008. Although these TSSN outlooks had been issued for some time, there has never been any significant verification performed on these forecasts. This paper will look at three different TSSN cases and determine the reasons for either a successful or unsuccessful forecast.

2. METHODOLOGY

Of the cases selected for analysis, three are chosen for further discussion in this paper. Each case had a different forecast outcome; and either fell into the category of being a "hit" forecast, a "missed" forecast, or a "false alarm" forecast. There is another category of outcomes called "correct rejections", but those cases consist of a forecast of no TSSN with no TSSN occurring. A "hit" forecast means that the forecasters predicted TSSN and TSSN did occur. The "hit" case occurred on 01 December 2006. A "false alarm" forecast means that the forecasters predicted TSSN would occur and TSSN did not occur. The "false alarm" case occurred on 20 January 2007. Finally a "missed" forecast means that the forecasters predicted that no TSSN would occur and TSSN did occur. The "missed" case occurred on 13 February 2007. Table I shows the standard 2×2 contingency table (SWPC 2007) that was employed for the verification of these TSSN cases.

		TSSN Observed	
		Yes	No
TSSN Forecast	Yes	A	B
	No	C	D

Table I. 2×2 contingency table for TSSN events: Table entry "A" indicates "hit" forecasts, table entry "B" indicates "false alarm" forecasts, table entry "C" indicates "missed" forecasts, and table entry "D" indicates "correct rejections".

It is important to note, too, that the emphasis on the analyses that follow is on the assessment of stability. In each of the cases examined, sufficient moisture and adequate forcing for ascent were present to generate clouds and precipitation. Therefore, a careful examination of the thermodynamic profiles (e.g., Brown 1993; Market et al. 2006) in each event is the key, to understanding why a given atmosphere did (or did not) become unstable and create convection.

3. DATA

Data for the analysis of lightning in the TSSN cases came from a National Lightning Detection Network feed provided by Vaisala, Inc. The thermodynamic profiles were assessed using output from the Rapid Update Cycle (RUC) initial fields, which had been thinned to a 40-km grid (widely available in real-time when the forecasts were being created). As such, we are making an assumption that the soundings from the RUC initial fields are the best available representation of the sounding profiles for the stated times and locations. (Plan-view synoptic analyses originate from the thinned 80-km RUC 211 grid).

4. ANALYSIS

4.1 Case Study Analysis (01 December 2006)

For the "hit" case that occurred on 01 December 2006 the TSSN outlook was created on 30 November

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2006 at 1800 UTC and expired on 01 December 2006 at 1800 UTC. The outlook included a graphic that identified the location of any TSSN for the next 24 hours (Fig. 2) and a written forecast discussion (not shown). Fig. 2 shows that TSSN was forecasted to occur in a swath from extreme north Texas to Michigan. Fig. 3 depicts the actual storm-total snowfall amounts for the forecast area.

The area of focus for the "hit" case was Jefferson City, MO (KJEF). The surface analysis (Fig. 4) shows a strong surface low located to the southeast of Missouri. Temperatures were right on the cusp between sleet development and snow development, but later sounding analysis depicts colder temperatures for snow formation. Q vector divergence (Fig. 5) shows that there is adequate mid-level forcing for accent. Fig. 6 shows the relative humidity from 950 to 500 millibars and indicates that moisture is plentiful for the forecast location.

The sounding profiles for KJEF are shown in (Fig. 7). Fig. 7(a) is a sounding from 0400 UTC on 01 December 2006 and depicts the development of a typical TSSN sounding (Market et al. 2006). Lapse rates are starting to increase and winds at lower levels are turning with height from the southeast to the northwest. Fig. 7(b) shows a sounding from 0600 UTC on December 01 2006. This is the period where TSSN is occurring. The sounding shows a similar profile to Fig. 7(a), but with steeper lapse rates which indicate greater instability. Fig. 7(c) shows the event wrapping up and decreasing lapse rates.

4.2 Case Study Analysis (20 January 2007)

The "false alarm" case was forecasted from 1800 UTC on 19 January 2007 to 1800 UTC on 20 January 2007. TSSN was expected to occur in northern Texas and the majority of Oklahoma (Fig. 8). Fig. 9 is the map of the snowfall that actually occurred from the case. For this case we must look at the written forecast discussion to understand why the forecasters thought that TSSN would occur in northern Texas and Oklahoma:

> "….Once this system enters the main jet core in the southern plains, it is progged to spread into the central US by 18Z on the 20th bringing with it the chance of additional snowfall. Ample moisture coupled with strong forcing and **freezing temperatures develop over Northern Texas and Southern Oklahoma by late day 1… Soundings from northern Texas and Southern Oklahoma show temperature profiles within the desired 0 C to -10 C temp range** for lightning production with saturated profiles and strong omega (-16 ub/s) values. Cross sections from HHF to LBF in northern TX reveal a well saturated atmosphere with regions of elevated (700-500 mb) CSI surrounded by additional CI and PI… However, once the system is influenced by the low level jet pumping additional moisture in from the Gulf, and with all the other necessary elements present in this system, some lightning activity in the cold air is possible."

The focus area for the "false alarm" case was Wichita Fall, TX (KSPS). The surface analysis (Fig. 10) depicts lower surface pressure in the southwestern United States near Arizona and New Mexico. Fig. 11 shows Q vector divergence and indicates forcing for accent. Fig. 12 shows relative humidity from 950 to 500 mb. As with the "hit" event there was ample moisture for TSSN to occur.

For this case the *hourly* sounding profiles were taken from KSPS and are depicted in (Fig. 13). Hourly soundings are show, as the 1900 UTC dataset (to make a 1500-1700-1900 UTC 2-hourly time series) was not available. Fig. 13(a) is the 20 January 2007, 1600 UTC sounding. The sounding shows veering with height of the lower winds, marginal lapse rates, but the big problem is that the sounding is a sleet sounding and not a snow sounding. Fig. 13(b) is the 20 January 2007, 1700 UTC sounding from the case and even though we do see some convective available potential energy (CAPE), the sounding is still too warm for snow production. Fig. 13(c) finishes out the stability profiles for this event with the sounding from 20 January 2007, 1800 UTC. We no longer see any CAPE and the sounding remains too warm. Another problem with these soundings is that they are stable in the preferred lightning region.

4.3 Case Study Analysis (13 February 2007)

The final event is the "missed" case that was forecasted for 1800 UTC on 12 February 2007 to 1800 UTC 13 February 2007. TSSN was not expected to develop anywhere in the specified area of Fig. 1 (Fig. 14 is the identical outlook graphic for the event). We must again look at the written forecast discussion to understand why the forecasters made the decision that TSSN would not occur.

> "….These dynamics, however, are all confined to the warm sector of the system with the 5400 thickness gradient extending from Kansas through northern Missouri, Illinois, Indiana, and Ohio. **The majority of instability for this system also seems to remain confined to the southern portion of this system where rain will be the only type of precipitation.** A few pockets of moisture with adequate forcing are present in IA between 06 - 12Z Tues, but a closer look at soundings in the area indicate weak vertical velocities (less than 5 ubars/sec) and lapse rates of only 4.5 C/km."

Fig. 15 shows the snowfall map, which includes the areas that actually experienced TSSN, even though it was not forecasted. The ensuing *plan-view* analyses are for ~18 hours prior to the development of the TSSN event, yet we show these for two reasons: 1) these plan-view analyses were valid at the time that the outlook was created, and 2) the synoptic situation did not change appreciably in the ensuing 17-18 hours.

For the "missed" case the focus was the Olathe, KS (KIXD) area. Early surface analysis (Fig. 16) shows a strong low pressure center located near the borders of Colorado, Texas, and New Mexico. As with the other two events, Q vector divergence in Fig. 17 shows good forcing for ascent, and 950mb to 500mb relative humidity in Fig. 18 shows deep moisture.

Sounding profiles for this event were taken from KIXD (Fig. 19) and valid *at the time of* the event. Fig. 19(a) is the first sounding of interest for 13 February 2007. The time of the sounding is 0200 UTC. The sounding shows very steep lapse rates and temperatures cold enough for snow production. The sounding from 13 February 2007 at 0400 UTC (Fig. 19(b)) shows even greater lapse rates, temperatures still cold enough for snow production, and even some CAPE. The final sounding from 13 February 2007 with a time of 0600 UTC (Fig. 19(c)) still shows good temperatures and lapse rates, but there is no longer any CAPE.

5. SUMMARY AND CONCLUSIONS

In the three forecast cases, moisture and forcing were all present, and the associated extratropical cyclones were dynamic in nature. The forecast outcomes were dictated by the stability of the systems. The "hit" forecast case developed the way it was predicted. Model outcomes were correct and interpreted correctly. Stability analysis showed that TSSN would occur and it did. The "false alarm" forecast case was just too warm for snow to occur. Sleet fell instead, which was indicated by the RUC soundings. Also, the atmosphere was too stable in the preferred lightning region for TSSN. The reason for the error by the ROCS forecasters were that model runs were showing colder temperatures in the forecast region than actually occurred. Finally the "missed" forecast case had model runs indicating weak lapse rates in the forecast area, so ROCS forecasters did not issue an outlook for TSSN. CAPE was present at one time during the event, temperatures were cold enough for snow development, and lapse rates were steeper compared to earlier model output. These conditions along with the presence of moisture and upward vertical motion lead to the development of TSSN.

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Space Weather Prediction Center, 2007: *Forecast Verification Glossary*. Accessed on 20 April 2009. http://www.swpc.noaa.gov/forecast_verification/Glossary.html.

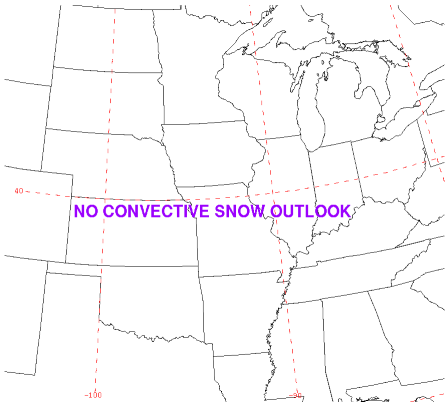


Figure 1. Indicates the region for which the ROCS group created thundersnow outlooks.

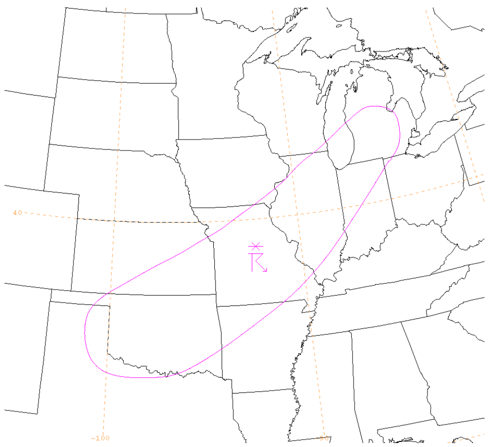


Figure 2. Indicates the location of forecasted TSSN from 1800 UTC on 30 November 2006 to 1800 UTC on 01 December 2006. Thundersnow symbol approximates the sounding location (KJEF).

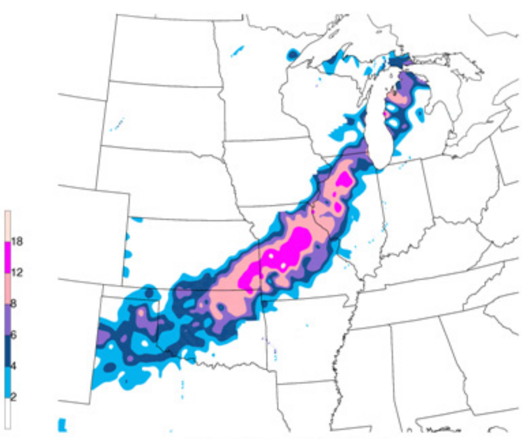


Figure 3. Snowfall (inches (in)) accumulated over a 48 hour period ending at 1200 UTC 01 December 2006.

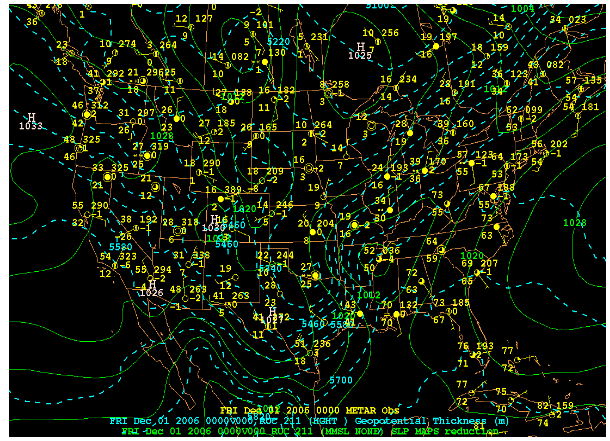


Figure 4. Surface analysis with METAR observations (yellow), geopotential thickness (every 60 gpm, dashed blue line) and mean sea level pressure (every 4 mb, solid green line) for 01 December 2006 at 0000 UTC.

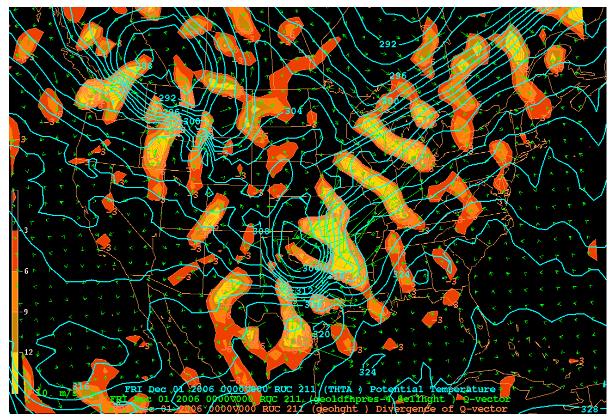


Figure 5. Q vector divergence (convergence is shaded) and Q vectors (green arrows) for the 400-700-mb layer; 550-mb potential temperature (every 2 K; solid blue line); all valid at 0000 UTC 01 December 2006.

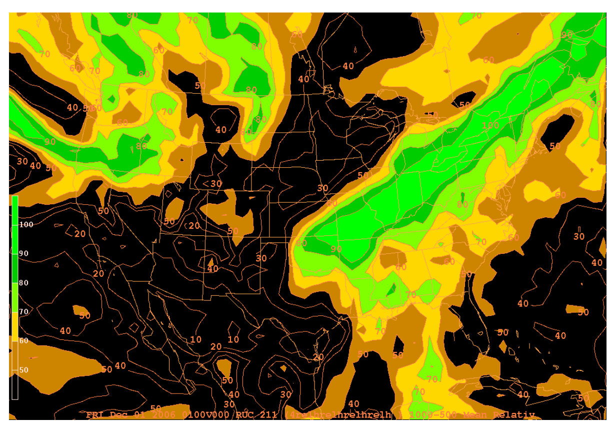
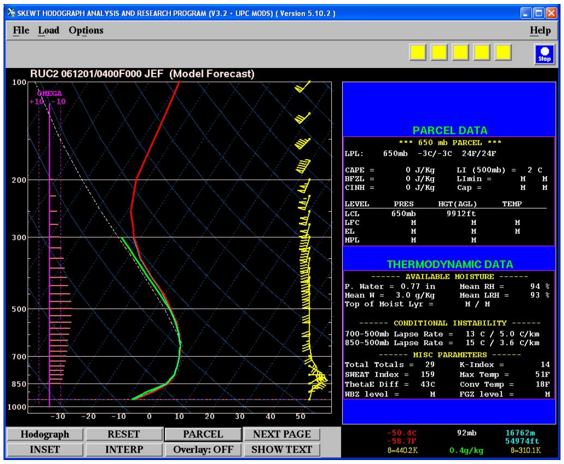


Figure 6. Mean relative humidity (every 10%, shaded over 50%) in the layer from 950 mb to 500 mb (*not* 1000-500 mb as depicted in the figure) valid at 0000 UTC 01 December 2006.



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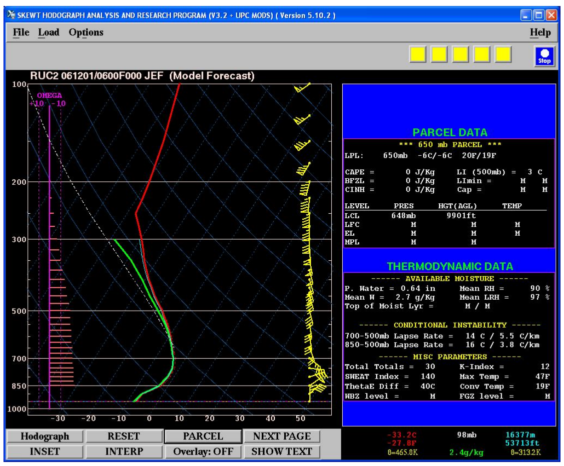

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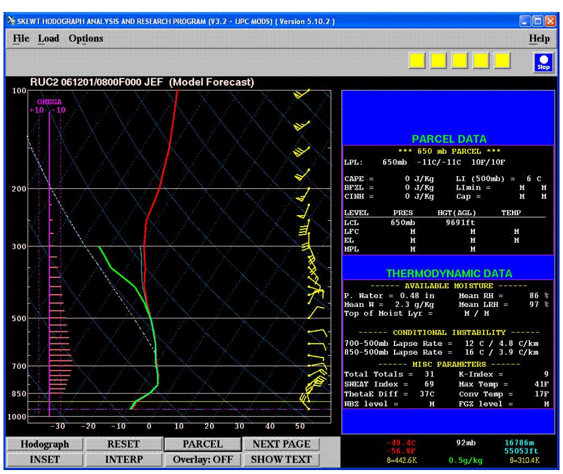

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Figure 7. RUC model initial field soundings for Jefferson City, MO (KJEF) valid on 01 December 2006 at *a*) 0400 UTC, *b*) 0600 UTC, and *c*) 0800 UTC.

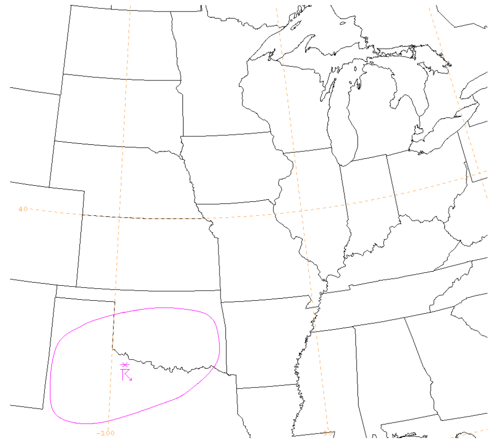


Figure 8. Indicates the location of forecasted TSSN from 1800 UTC on 19 January 2007 to 1800 UTC on 20 January 2007. Thundersnow symbol approximates the sounding location (KSPS).

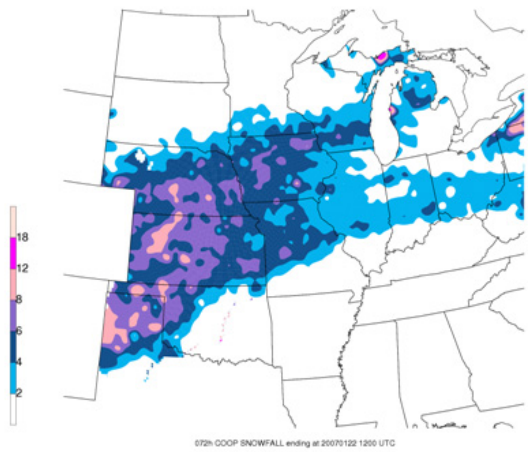


Figure 9. Snowfall (inches (in)) accumulated over a 72 hour period ending at 1200 UTC 22 January 2007.

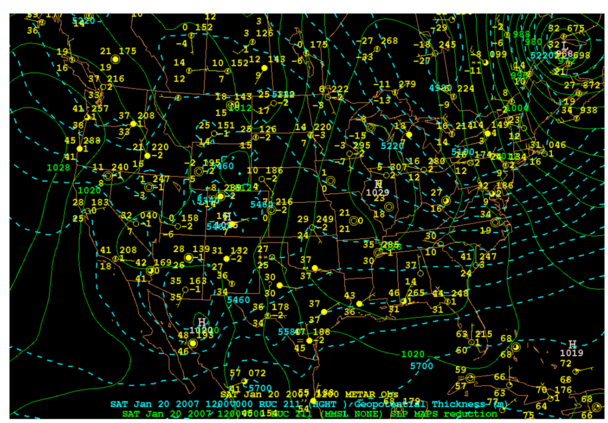


Figure 10. Surface analysis with METAR observations (yellow), geopotential thickness (every 60 gpm, dashed blue line) and mean sea level pressure (every 4 mb, solid green line) for 20 January 2007 at 12 UTC.

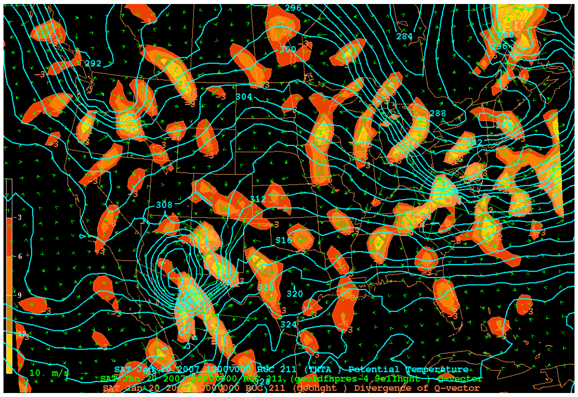


Figure 11. Q vector divergence (convergence is shaded) and Q vectors (green arrows) for the 400-700-mb layer; 550-mb potential temperature (every 2 K; solid blue line); all valid at 20 January 2007 at 1200 UTC.

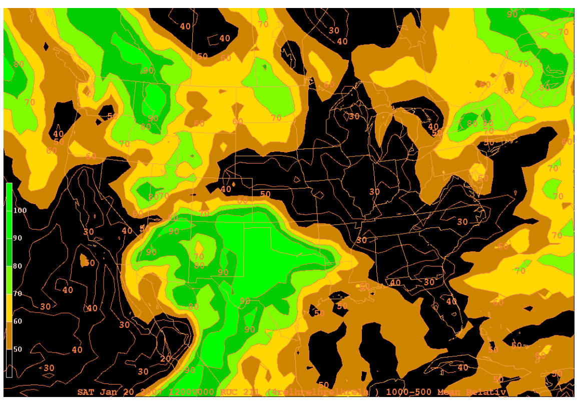
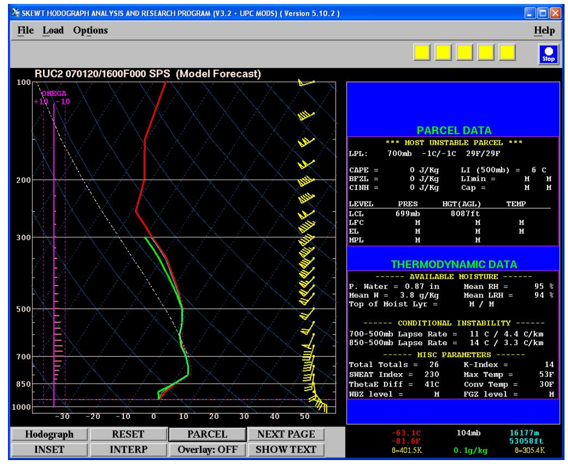


Figure 12. Mean relative humidity (every 10%, shaded over 50%) in the layer from 950 mb to 500 mb (<u>*not*</u> 1000-500 mb as depicted in the figure) valid at 1200 UTC 20 January 2007.



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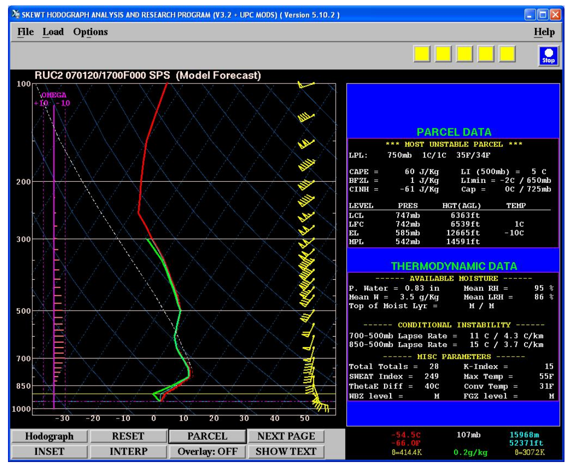

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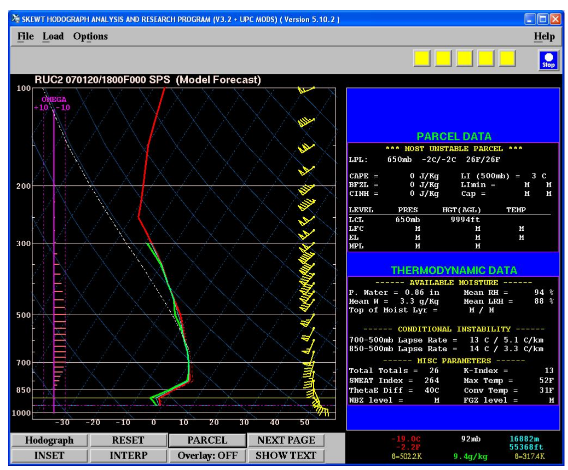

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Figure 13. RUC model initial field soundings for Wichita Falls, TX (KSPS), valid on 20 January 2007at *a*) 1600 UTC, *b*) 1700 UTC, and *c*) 1800 UTC.

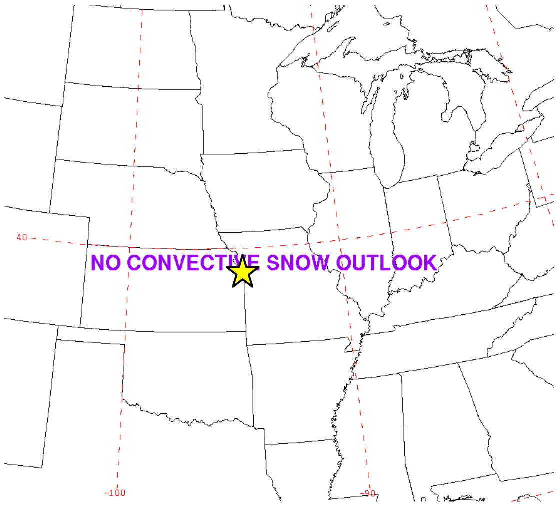


Figure 14. The "no convective snow" outlook from 1800 UTC on 12 February 2007 to 1800 UTC on 13 January 2007. Star symbol approximates the sounding location (KIXD).

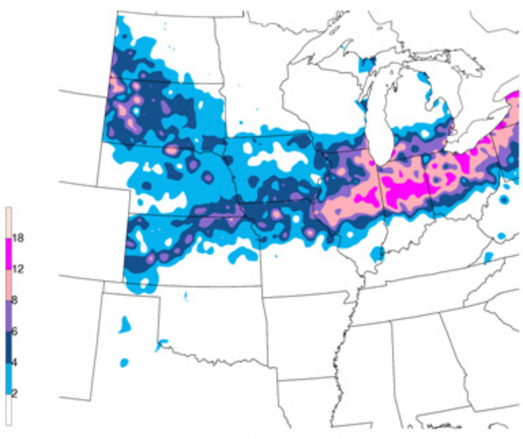


Figure 15. Snowfall (inches (in)) accumulated over a 72 hour period ending at 1200 UTC 14 February 2007.

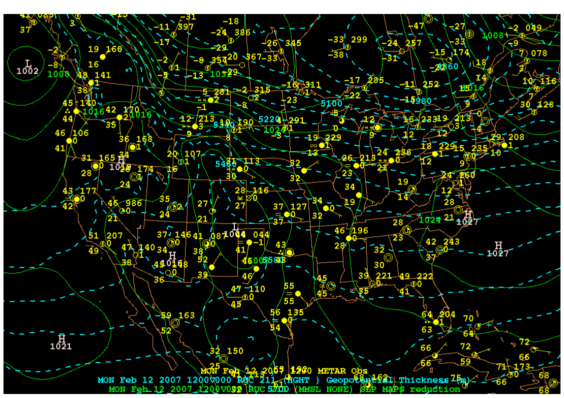


Figure 16. Surface analysis with METAR observations (yellow), geopotential thickness (every 60 gpm, dashed blue line) and mean sea level pressure (every 4 mb, solid green line) for 1200 UTC 12 February 2007.

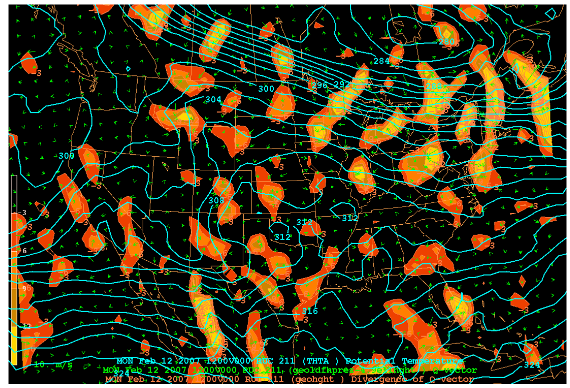


Figure 17. Q vector divergence (convergence is shaded) and Q vectors (green arrows) for the 400-700-mb layer; 550-mb potential temperature (every 2 K; solid blue line); all valid at 1200 UTC 12 February 2007.

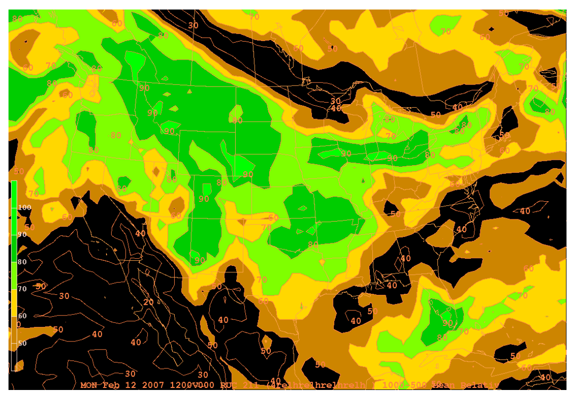
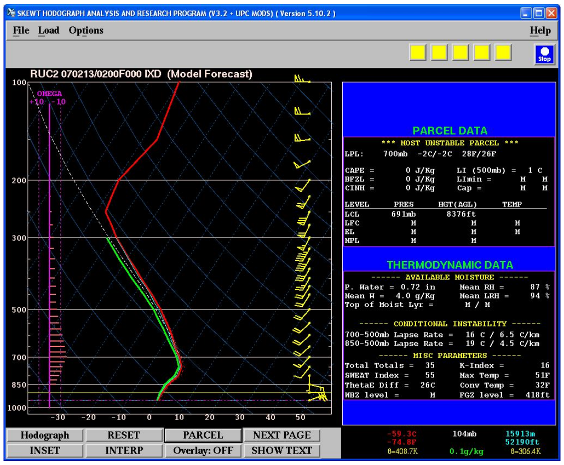


Figure18. Mean relative humidity (every 10%, shaded over 50%) in the layer from 950 mb to 500 mb (***not*** 1000-500 mb as depicted in the figure) valid at 1200 UTC 12 February 2007.



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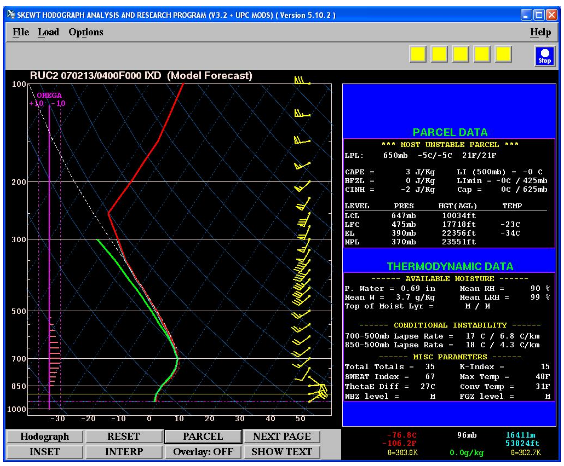

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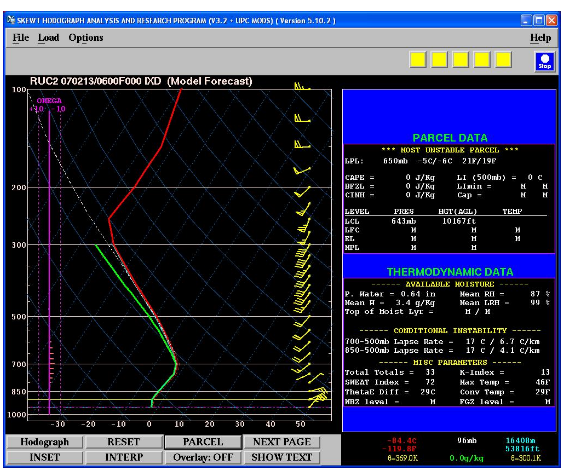

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Figure 19. RUC model initial field soundings for Olathe, KS (KIXD), valid on 13 February 2007at *a*) 0200 UTC, *b*) 0400 UTC, and *c*) 0600 UTC.