P12.2 RUC-2 Model Analysis Soundings as a Surrogate for Observed Soundings in Supercell Environments

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1. INTRODUCTION

Proximity sounding studies have focused on the environments of severe and tornadic thunderstorms, with the goal of identifying environmental characteristics associated with various severe thunderstorm phenomenon. However, many obstacles present themselves when considering observed proximity soundings. First, there is the nontrivial question of which time and space scales are most appropriate to represent the storm "environment" (Brooks et al. 1994). Numerical simulations by Weisman et al. (1998) demonstrated that supercells may exert influence on low-level shear and buoyancy profiles up to 30 km away from the storm, effectively altering what had been the pre-storm environment. Apparent storm impacts on local environments have been documented during formal field experiments (Markowski et al. 1998), and have been observed by storm chasers across the Great Plains since the 1970s.

Other concerns include sounding sample size and storm characteristics. Maddox (1976) estimated that several hundred years may be necessary to accumulate a large sample of close proximity soundings for tornadic storms. Kerr and Darkow (1996) applied rather stringent proximity criteria (15 minutes before to 105 minutes after tornado time, and within 80 km), though coarse WSR-57 radar archives precluded association of tornadoes with specific storm types. A larger sounding sample was collected by Rasmussen and Blanchard (1998; hereafter; RB98). They considered all 00 UTC soundings from 1992, and associated each sounding with significant tornadoes, severe weather reports, or lightning strikes and no severe weather. RB98 relied on two inch diameter or larger hail as a proxy for supercells, and their time and space limitations were rather broad (up to 400 km in inflow sector of storms, along with a time window spanning from six hours prior to three hours after storm time). As a test of the RB98 supercell classification technique, we examined Storm Data for two inch or larger hail reports from April and July of 2000. Of these hail reports, 90 percent could be attributed to supercells documented by Thompson et al. (2002). However, less than two-thirds of the documented supercells during those two months produced hail two inches or larger. Therefore, based on this smaller sample, RB98 likely missed a large number of supercells in their sounding classification. Most recently, Craven et al. (2002) have completed an examination of thousands of proximity soundings for most of the period from 1957 to 1999. While they have created sample sizes in the thousands, their proximity criteria (185 km and 3 hours) still allow much uncertainty for individual severe events, and little is known about the characteristics of the storms that produced the severe weather.

This work is an attempt to refine these past studies by narrowing the spatial and temporal proximity criteria, while maintaining a reasonably large sample size and utilizing information that is readily available to forecasters throughout the day and night. Additionally, we limited our examination to documented supercells. To accomplish our goals, we have collected observed and RUC-2 analysis/forecast soundings in regional supercell environments. Herein we document the accuracy of the RUC-2 analysis soundings, and make recommendations regarding the utility of the RUC-2 analyses in assessing environmental characteristics associated with supercells.

2. DATA AND METHODOLOGY

The following supercell definitions and proximity criteria were utilized during real time data collection from 1999-2001:

1) To be categorized as a supercell, each storm must have displayed one or more characteristic radar reflectivity structures (such as hook echoes, inflow notches, etc; Browning 1964, Lemon 1977), a WSR-88D peak cyclonic azimuthal shear of 20 m s^{-1} or greater within a distance of 10 km (similar to the Mesocyclone Detection Algorithm described in Stumpf et al. 1998), and persistence of the cyclonic shear for at least 30 minutes.

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2) Based on availability of hourly RUC-2 model analysis grids, a sounding was interpolated for each supercell at the nearest surface hourly observing site. This resulted in soundings that were generally within 30 minutes and 40 km of each supercell.

Following these guidelines, a nationwide sample of 458 supercells and associated RUC-2 model analysis soundings were gathered for the period from April 1999 through June 2001. When any of these supercells occurred within three hours of a standard sounding time (00 or 12 UTC), the nearest observed sounding was archived if it had 1) surface-based parcel CAPE (Doswell and Rasmussen 1994), 2) complete data below the equilibrium level, and 3) no obvious contamination from nearby thunderstorms. For each observed sounding meeting these criteria, a RUC-2 analysis sounding valid at the time and location of the observed sounding was generated to determine how accurately the RUC-2 depicts the regional supercell environment. RUC-2 model proximity soundings were constructed from grids with 25 mb vertical resolution and 40 km horizontal resolution.

One potential advantage of the RUC-2 analysis soundings is their availability every hour. The RUC-2 analyses contain asynoptic data from profilers, surface observing network, satellite winds, etc. However, the quality of these soundings can be questioned given the lack of synoptic scale three dimensional observations of temperature, moisture and winds between the twice daily soundings at 00 and 12 UTC. To examine the accuracy of these asynoptic soundings, we chose 1-hour forecasts from 2300 (1100) UTC valid at 0000 (1200) UTC for the collected observed soundings. Our working hypothesis is that the 1-hour forecast, based on a RUC-2 analysis 11 hours after the time of the previous synoptic soundings, should be the least accurate of the day.

Sounding errors were computed by taking the difference between the analysis and observed value, or the forecast and observed value. Hence, positive (negative) errors mean that the analysis or forecast value was greater (less) than the observed value. Confidence intervals about the mean error were computed based on the t-statistic. The error distributions do not deviate grossly from a normal distribution, though the error distribution tails tend to be slightly heavier than what is expected from normally distributed errors. Therefore, our 95% confidence intervals may be a little too narrow.

Errors in bulk properties (such as CAPE, etc.) were computed in the same manner as the basic sounding values (such as temperature). However, these errors are clearly not normally distributed. The error distribution tends to be a function of the parameter in question, and it may be partly due to the nature of some parameters. For example, CAPE cannot be negative. Hence, the median was used to estimate the overall error because it is more robust than the mean and resistant to outliers.

3. RESULTS AND DISCUSSION

The profile of temperature errors for the 0-hour RUC-2 analysis soundings (Fig. 1) shows that the zero error is generally within the 95% confidence interval from about 850 to 400 mb. Temperature errors are larger near the ground, with strong tendency for model surface temperatures to be about 0.5 C too cool. Mixing ratio errors (Fig. 2) were largest near the ground with a tendency for the RUC-2 analyses to over estimate the mixing ratios by 0.1 to 0.2 $g\ kg^{-1}$ immediately above the surface. The small errors above 400 mb are somewhat misleading since mixing ratios aloft tend to be limited by cold temperatures, thus

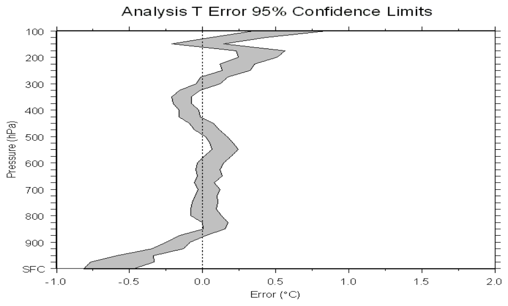

Figure 1. Vertical distribution of the 95% confidence interval (shaded region) about the mean temperature error based on a t-test, for a sample of 149 0-hour RUC-2 analysis soundings. Positive errors indicate analysis (0-hour) values greater than the observed value, and vice versa. The vertical dashed line is 0 error. When the shaded region contains the 0 line, the error is insignificant at the 95% confidence level. Values are available every 25 mb. In all cases, the surface value is that for the particular sounding, regardless of the surface pressure.

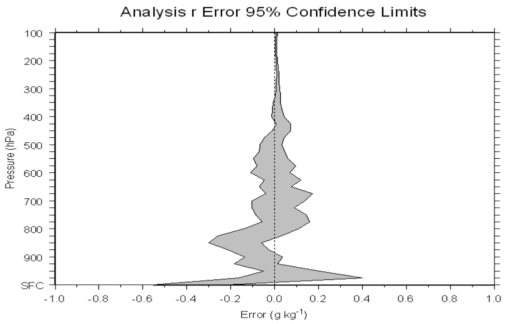

Figure 2. Same as Fig. 1, except for 0-hour mixing ratios.

absolute error magnitudes are necessarily small. Dew point temperature errors (not shown) were largest from 400-100 mb.

The vertical profile of 0-hour wind speed errors is shown in Figure 3. The zonal (u) errors (not shown) lie within the 95% confidence interval from the surface to 100 mb, and the width of the confidence interval suggests that zonal wind components are typically within 0.5 m s^{-1} of the observed values. Meridional (v) wind components (not shown) reveal a tendency for wind speeds to be about 1 m s^{-1} too strong from the south near the surface, and about 1 m s^{-1} too weak from the south near 200 mb. Throughout the remainder of the troposphere, the 95% confidence interval includes the zero error. The net result was that RUC-2 analysis wind speed tended to be about 1 to 2 m s^{-1} too strong from the surface to 600 mb.

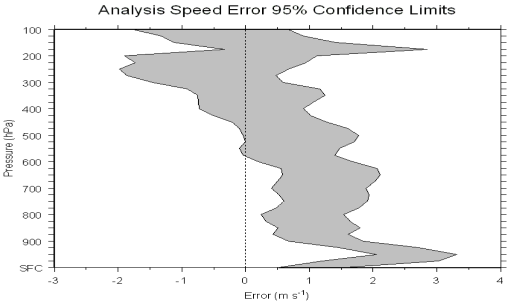

Figure 3. Same as Fig. 1, except for 0-hour wind speed errors.

Vertical temperature errors for the 1-hour RUC-2 forecast soundings (Fig. 4) were substantially larger than for the 0-hour soundings, with pronounced over forecasts (roughly 0.5 C) from the surface to 800 mb, and near 200 mb. The 1-hour forecast mixing ratio errors (Fig. 5) were generally around 0.2 to 0.3 g kg^{-1} too large near 900 mb, though surface values were too low by roughly the same amount. The profiles of u and v wind component errors for the 1-hour forecast soundings (not shown) are consistent with the 0-hour analysis soundings, with the zero error generally within the 95% confidence interval. However, there is some skew in the profiles such that the zonal (westerly) and meridional (southerly) wind components are over-forecasted by 0.5 to 1 m s^{-1} in the layer from the surface to about 600 mb. This resulted in the over-forecasted wind speeds illustrated by Fig. 6. Overall, the 1-hour forecast sounding errors covered a wider range of values than the 0-hour analyses. The larger errors are not surprising given that these forecast soundings are well removed from the synoptic sounding times.

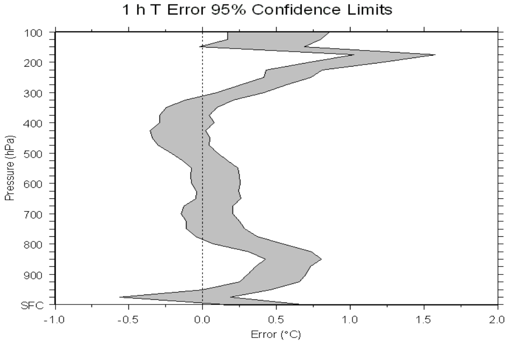

Figure 4. Same as Fig. 1, except for a sample of 127 1-hour RUC-2 forecast soundings.

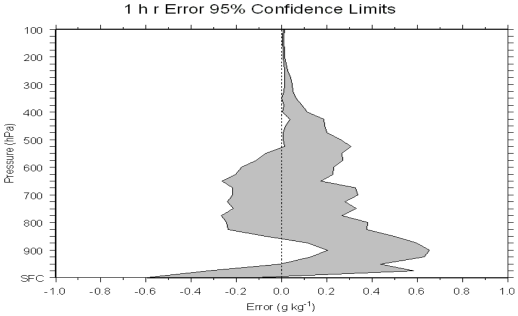

Figure 5. Same as Fig. 4, except for 1-hour forecast mixing ratio errors.

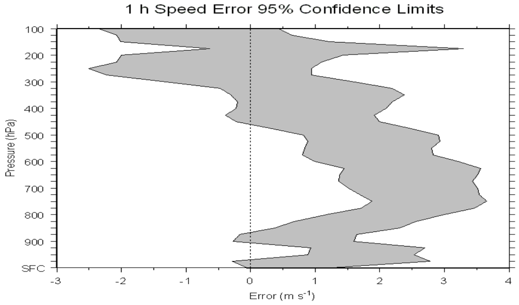

Figure 6. Same as Fig. 4, except for 1-hour forecast wind speed errors.

Several bulk supercell sounding parameters were also examined for both the analysis and 1-hour forecast soundings. In general, the surface-based (sb) CAPE values tended to be under estimated by 100 to 500 J kg^{-1} within the middle 50% of the distributions for both the 0-hour and 1-hour forecast soundings (Fig. 7), owing to the tendency for surface temperatures to be a little too cool (see Fig. 1). Errors for 0-hour 100 mb mean parcel (ml) CAPE were more evenly distributed around zero error, while the 1-hour forecast values were too large as a result of temperatures and mixing ratios being too high within the lowest 100 mb (see Figs. 4 and 5). Vertical shear parameters such as storm-relative helicity (SRH) and measures of deeper layer shear (0-6 km vector shear, BRN shear term) were more uniformly distributed than the CAPE errors. The 95% confidence interval for median values of 0-1 and 0-6 km shear (Fig. 8) includes zero error in each layer for both the 0-hour analyses and 1-hour forecasts. Similar error distributions were also documented for the 0-1 km and 0-3 km SRH (not shown).

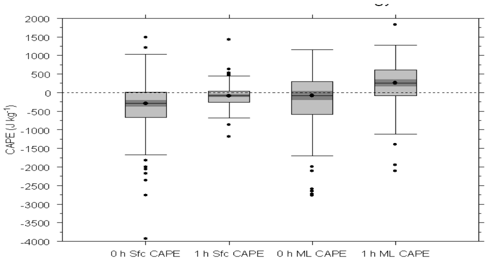

Figure 7. Box and whisker plot showing the distribution of sbCAPE and mlCAPE errors for the 0-hour analysis and 1-hour forecast soundings. The line transecting the central dot indicates the median value, while the 95% confidence interval for that value is shown by the dark gray bar. The upper quartile spans the region from the median to the op of the box, while the lower quartile spans the region from the median to the bottom of the box. The whiskers are drawn to the nearest value not beyond 1.5 times the interquartile range from the quartiles; points beyond (outliers) are drawn individually.

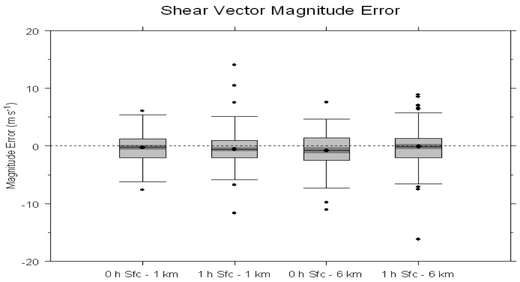

Figure 8. Same as Fig. 7, except for 0-1 and 0-6 km vector shear magnitude error.

4. SUMMARY

Analysis of a sample of RUC-2 model analysis (0-hour) and 1-hour forecast soundings suggests that the RUC-2 profiles are a reasonable proxy for direct observations in the regional supercell environment. Errors in the analysis and forecast soundings are generally within 0.5 C for temperatures, 0.2 g kg^{-1} for mixing ratios, and 1 m s^{-1} for wind speed. Larger errors have been documented in bulk sounding parameters, such as the relatively common CAPE errors up to 500 J kg^{-1} (see Fig. 7), owing primarily to temperature and mixing ratio errors near the surface. Though these errors are of concern to forecasters, approaches such as the hourly objective analysis scheme at the Storm Prediction Center (see Bothwell et al. this volume) can at least partially correct for RUC-2 biases near the surface. Since analysis and forecast errors tend to increase in time from the standard synoptic soundings (e.g., 1-h forecasts from 23 UTC have larger errors than 00 UTC RUC-2 analyses), forecasters will need to carefully compare available observations to the RUC-2 analyses to identify important errors in the analysis soundings.

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