STORMTIPE-95: Results from a Convective Storm Forecast Experiment

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(Manuscript received 17 April 1996, in final form 22 April 1997)

ABSTRACT

During the spring of 1995, an operational forecast experiment using a three-dimensional cloud model was carried out for the north Texas region. Gridpoint soundings were obtained from the daily operational numerical weather prediction models run at the National Centers for Environmental Prediction, and these soundings were then used to initialize a limited-domain cloud-resolving model in an attempt to predict convective storm type and morphology in a timely manner. The results indicate that this type of convective forecast may be useful in the operational environment, despite several limitations associated with this methodology. One interesting result from the experiment is that while the gridpoint soundings obtained from the NCEP models generally overforecast instability and vertical wind shear, the resulting convective storm evolution and morphology in the cloud model was often similar to that of the observed storms. Therefore the "overforecast" of mesoscale environment's instability and vertical wind shear still resulted in a thunderstorm-scale forecast that provided useful information to operational forecasters.

1. Introduction

As the National Weather Service moves toward prediction on the meso- and convective scales, the operational use of numerical weather prediction models that can explicitly resolve individual thunderstorms may be possible within the next decade (Brooks et al. 1992). The computational feasibility of using such models in an operational environment is rapidly approaching as computer speeds increase. During the spring of 1995, a numerical cloud model was used in an operational mode to predict convective storm type and behavior. This experiment, the Storm Type Operational Research Model Test Including Predictability Evaluation for 1995 (STORMTIPE-95, hereafter denoted as ST-95), was conducted as a collaboration between the Department of Meteorology at Texas A&M University and the National Weather Service Forecast Office in Fort Worth, Texas. This experiment was similar in many ways to the original STORMTIPE experiment (Brooks et al. 1993a, hereafter denoted as ST-91). The basic concept of the STORMTIPE methodology is to input a single sounding that is representative of the afternoon environment into a three-dimensional cloud-scale model, trigger convection, and use the resulting convective storm evolution from the simulation to indicate to the forecaster what type of convection that sounding is capable of supporting (i.e., supercell, multicell, pulse convection, or none). STORMTIPE forecasts were also used to assess the likelihood that convection would produce damaging surface winds and/or significant mesocyclones. The advantage of the STORMTIPE methodology is that it is an inexpensive and simple way to perform storm-scale forecasting and lends itself toward performing ensemble forecasts. The disadvantage is that nonhomogeneous features, such as fronts, outflow boundaries, or drylines, are not present in the model. Therefore the convection in the STORMTIPE simulation is not initiated and does not interact with any mesoscale features. These limitations must be taken into account when using STORMTIPE forecasts.

The experiment was run from 24 March 1995 through 19 April 1995. As in ST-91, there are two basic categories of forecast error in the experiment. The first category of error (type I) is associated with the accuracy of the forecast mesoscale environment by the large-scale model. The second category of error (type II) is associated with the accuracy of the forecast of the convective storm type by the model, given that the input sounding is representative of the observed environment. An important difference between ST-91 and ST-95 is that ST-95 did not use a human forecaster to generate the afternoon soundings, which were then used to initialize

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the cloud model. Using the 1200 UTC operational forecast models produced at the National Centers for Environmental Prediction (NCEP), ST-95 forecasters predicted the location where the most severe convection was expected to develop during the day. A forecast sounding was then obtained for that location using the NCEP model's 12-h forecast fields. This methodology is similar to one reported by Brooks et al. (1993b), where gridpoint soundings generated by a regional mesoscale model were used to initialize a cloud model. The use of hand-generated soundings in ST-91 made it difficult to determine whether sounding errors were due to an inaccurate NCEP model forecast or due to the interpretation of the situation by individual forecasters. By directly using the NCEP model's gridpoint soundings, it is believed a more quantitative evaluation of both type I and type II errors would be possible. Some individual biases would remain, however, since different forecasters were accessing each particular situation and subsequently choosing the sounding locations.

In this paper we will present the results from ST-95. Section 2 discusses how the ST-95 forecasts were generated. Section 3 presents the overall results for the experiment, with the results from two of the forecasts presented in some detail. Section 4 summarizes the findings.

2. Forecast procedures

Figure 1 shows the procedure used to create a ST-95 forecast. The forecast cycle would begin in the morning with forecasters at Fort Worth assessing the likelihood of severe convection occurring in north Texas during the day. If severe convection was expected, a sounding would be obtained for this location from the NCEP model's 12-h forecast fields (valid at 0000 UTC). All ST-95 soundings were obtained from the Eta Model, except for the 10 April forecast where the sounding was obtained from the rapid update cycle (RUC) model. While obtaining sounding data from just one model would have been preferred, the RUC model output was used because output from the Eta Model, obtained via the Internet, was occasionally unavailable at Texas A&M.

The gridpoint sounding would then be used to initialize the cloud model domain to create horizontally homogeneous wind, temperature, and moisture fields in the model. This initialization procedure omits any mesoscale or nonhomogeneous features (fronts, drylines, jet streaks, short waves, etc.) from the domain. Therefore STORMTIPE forecasts are most applicable to situations when the convection is isolated and not significantly interacting with outflow boundaries or other mesoscale features. The lack of mesoscale features also means that the convection must be triggered in some artificial way. The philosophy employed here is to introduce a warm thermal into the domain of such size and magnitude that the thermal will rise to at least the lifted condensation level where the effects of latent heat

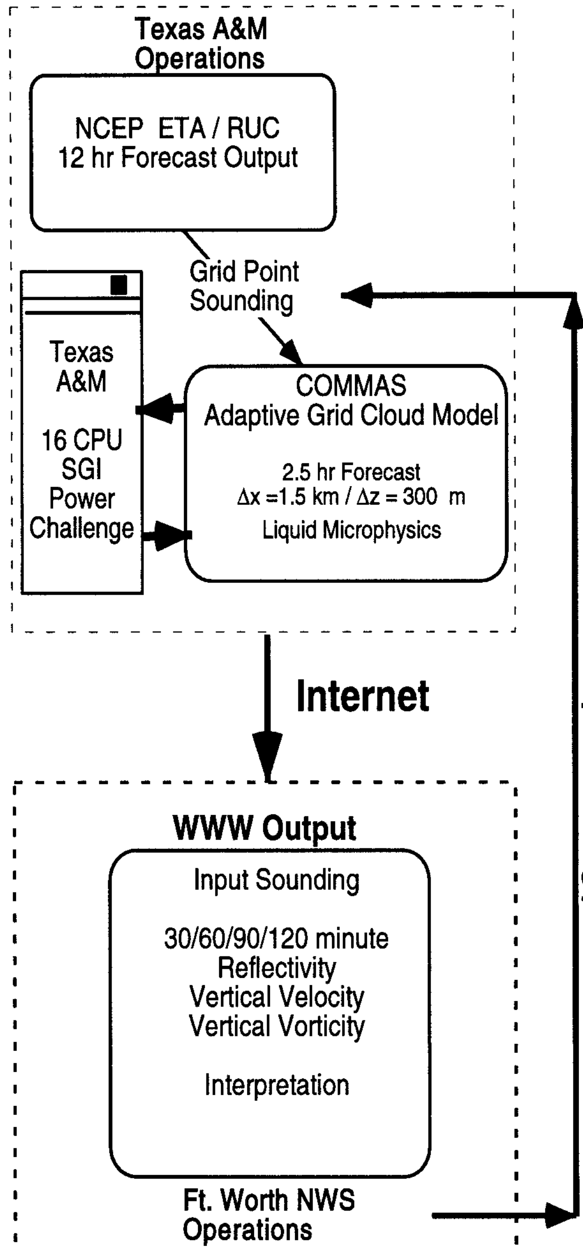

FIG. 1. Flow chart describing how a STORMTIPE-95 forecast was created.

release, entrainment, precipitation, etc. can then determine the subsequent evolution in the model. No effort was made to "match" the amount of lifting present in the thermal to the vertical motion predicted by the operational model. Therefore the STORMTIPE forecast assumed there would be sufficient lifting in the actual atmosphere to initiate clouds.

In each simulation, a single elliptical thermal was placed in the middle of the domain centered 1500 m above the surface. The thermal bubble had a maximum temperature excess of 4 K with a horizontal radius of

10 km and a vertical radius of 1500 m. Brooks (1992) has shown that large variations in thermal shapes and temperature excesses do impact the resulting storm's evolution, on both short ($\sim$10 min) and long ($>$1 h) timescales. Therefore the solution generated by the cloud model using a single specification of the thermal may not be representative of the average set of solutions if a variety of simulations were initialized with different thermals. However, Brooks's results and our experiences indicate that if the convection is triggered with a thermal having at least the size and temperature excess described here, then the resulting simulation would very likely be representative of an ''average'' solution from a set of simulations using somewhat different thermal initializations. Since STORMTIPE forecasts attempt to qualitatively forecast the characterstics of the convection—for example, supercell versus multicell, mesocyclone versus no mesocyclone—then we believe that solution sensitivities due to the specification of the initial thermal are small enough to be ignored.

The cloud model used for this experiment was the Collaborative Model for Mesoscale Atmospheric Simulation (COMMAS, Wicker and Wilhelmson 1995). The vertical grid consists of 35 levels with the vertical grid resolution of 300 m near the surface increasing to 700-m resolution at the top of the domain at 17.5 km. A unique aspect of the forecast procedure is that during ST-95, COMMAS used its automatic adaptive grid capabilities (Skamarock and Klemp 1993). The adaptive gridding algorithm automatically places higher-resolution grids over regions in the domain where convection is developing. To the authors' knowledge, this is the first time *automatic* grid refinement has been used in a quasi-operational setting. In ST-91, computational constraints forced the use of a small domain. Consequently, the user had to choose which convective storm to follow in this domain. In ST-95, a 240 km by 240 km domain with a horizontal grid resolution of 4 km was used for the outer domain. This size is sufficient to keep the convection in the domain for several hours. The adaptive grids, each having a horizontal grid spacing of 1.3 km, are then used to track and resolve all the convective storms that form during the simulation. During the integration, the solution is checked every 10 min to determine where the convection is located and whether the existing adaptive grids adequately cover those areas. The determination is made based on a set of user criteria that is chosen before the integration begins. If new convection is forming near the edge or outside an existing adaptive grid, new grids are generated automatically to capture the storms. Figure 2 shows the placement of higher-resolution grids over the region of active convection within the large domain after 2 h of integration from the 3 April 1995 simulation.

Using the COMMAS model, a forecast would be generated on Texas A&M's SGI Power Challenge computer using 12 dedicated processors. Depending on the complexity of the resulting convection in the domain, a 2-h forecast would require between 15 and 25 min of wall-clock time to integrate. Due to the significant increase in CPU time needed when ice microphysics is included, the simulations used Kessler (liquid water only) microphysics. While the lack of ice microphysics is not preferable, previous experience with convective storm simulations indicates that the impact of ice on the resulting storm evolution is usually not enough to change the convective mode. Simulated convective storms with and without ice microphysics almost always behave qualitatively the same; for example, both simulations will produce storms that are supercells, multicells, etc. Previous simulations indicate that the only environments that produce convection sensitive to the inclusion of ice microphysics are those having large instability and low relative humidity in the boundary layer. These environments usually occur during the late spring and early summer in the high plains, and none of the soundings used in the ST-95 had such characteristics. Therefore the lack of ice microphysics in the experiment should not significantly impact the results. Unfortunately this limitation means that no guidance could be given regarding the potential for large hail.

Once the simulation was completed, plots of low-level (z = 1 km) reflectivity with overlays of vertical velocity and vertical vorticity contours were generated. A hypertext document containing these plots, an interpretation of the simulation from either L. Wicker or M. Kay, as well as other useful information was automatically generated and placed on the World Wide Web server at the Texas A&M Meteorology Department. In this manner, forecasters at Fort Worth could quickly and effectively access ST-95 forecasts.[1] These ST-95 products were then used in the mesoscale briefing conducted by the forecast office severe weather team.

Verification of the 12-h forecast NCEP soundings used to initialize the cloud model domain was done using the 0000 UTC NCEP gridded analysis data. The sounding errors were computed using forecast and analysis data from the same model; that is, Eta analyses were used to verify the soundings forecasted by the Eta Model. This methodology was the only way to quantify type I errors associated with gridpoint soundings not coincident with the synoptic sounding stations.

3. Results

a. Overview

ST-95 was run for six cases during the period 24 March 1995 through 19 April 1995. Figure 3 displays a map from the north Texas region indicating the positions of the six ST-95 forecasts. The dots indicate the position at which NCEP model soundings were obtained

[1] The complete set of ST-95 forecasts are currently available online at http://hesston.tamu.edu.

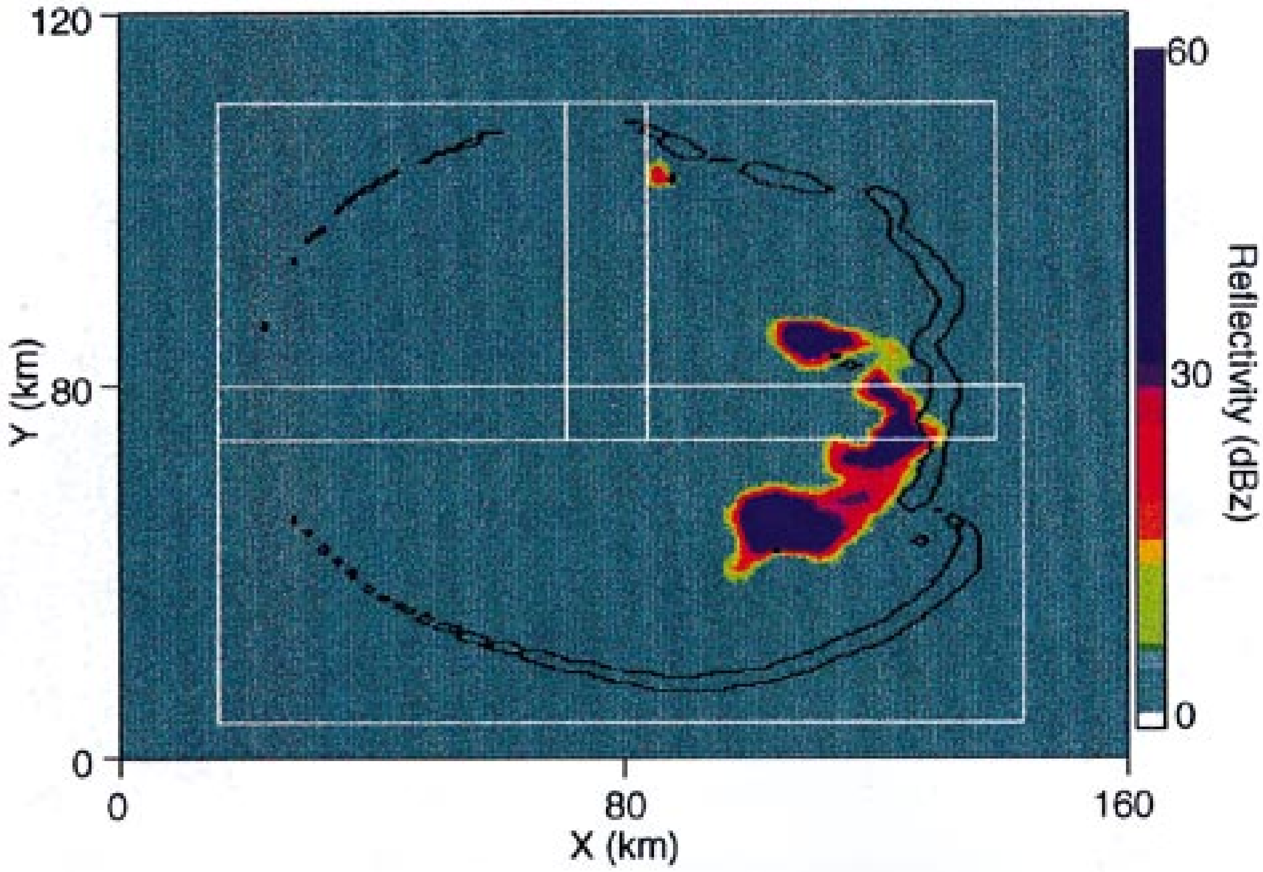

FIG. 2. Low-level horizontal plot showing the adaptive gridding used in making the 3 April 1995 forecast. The three white rectangles indicate the positions of the $\Delta x = 1.3$ km grids. The radar reflectivity is the color image, and vertical velocities greater than 2 m s^{-1} at $z = 1$ km are shown as the black contour line.

and then used to initialize the cloud model domain. Table 1 summarizes each ST-95 forecast as well as listing the most severe storms that did occur near the target area. There are several inherent ambiguities when trying to verify storm-scale forecasts. Often during severe storm events, there are dozens of observed storms to ''verify'' against. Similar to ST-91, the ST-95 forecasts are evaluated using the information that appears most relevant, that is, whether convection forms, the type of convection, and whether the model correctly predicts the most severe storm observed near the forecast area. The forecasts are focused toward the ''worst case'' scenario. Similar to ST-91, one of the focuses of this experiment was to determine whether ST-95 added value to the forecasts by indicating the type of convective mode, that is, high-precipitation, or ''HP,'' supercells versus classic supercells (Moller et al. 1990); low-level mesocyclone intensity; etc. On three of the six forecast days, the model's prediction of convective storm type and some specific behaviors appeared to be very representative of the most severe convection observed.

The forecast for 24 March was made for the region just to the south of Childress, Texas (CDS). The forecast sounding for that area had a strong capping inversion at 750 hPa. This sounding was used to initialize the cloud model domain, and the resulting simulation failed to produce any significant convection. This information was communicated to the forecasters at Fort Worth. Some convection did form in the Childress area in the late afternoon, with 1-in. hail being reported 8 mi north of Childress at 1740 CST. No other reports of severe weather, however, were received on this day. Storm-chasers reported the convection as being rather disorganized and short lived. Severe convection was also expected on 25 March. Due to problems obtaining the NCEP model output on this day, the sounding for the evening of 25 March was taken from the 36-h forecast from the 1200 UTC Eta Model run on 24 March (see Fig. 3 for the location). The 36-h forecast indicated that a significant shortwave trough and a dryline/cold front would move across the north Texas region during the afternoon. The forecast evening sounding for the north Texas region had large convective available potential energy (CAPE) and strong vertical wind shear present, indicating the potential for supercell thunderstorms. The ST-95 simulation did produce a classic supercell with

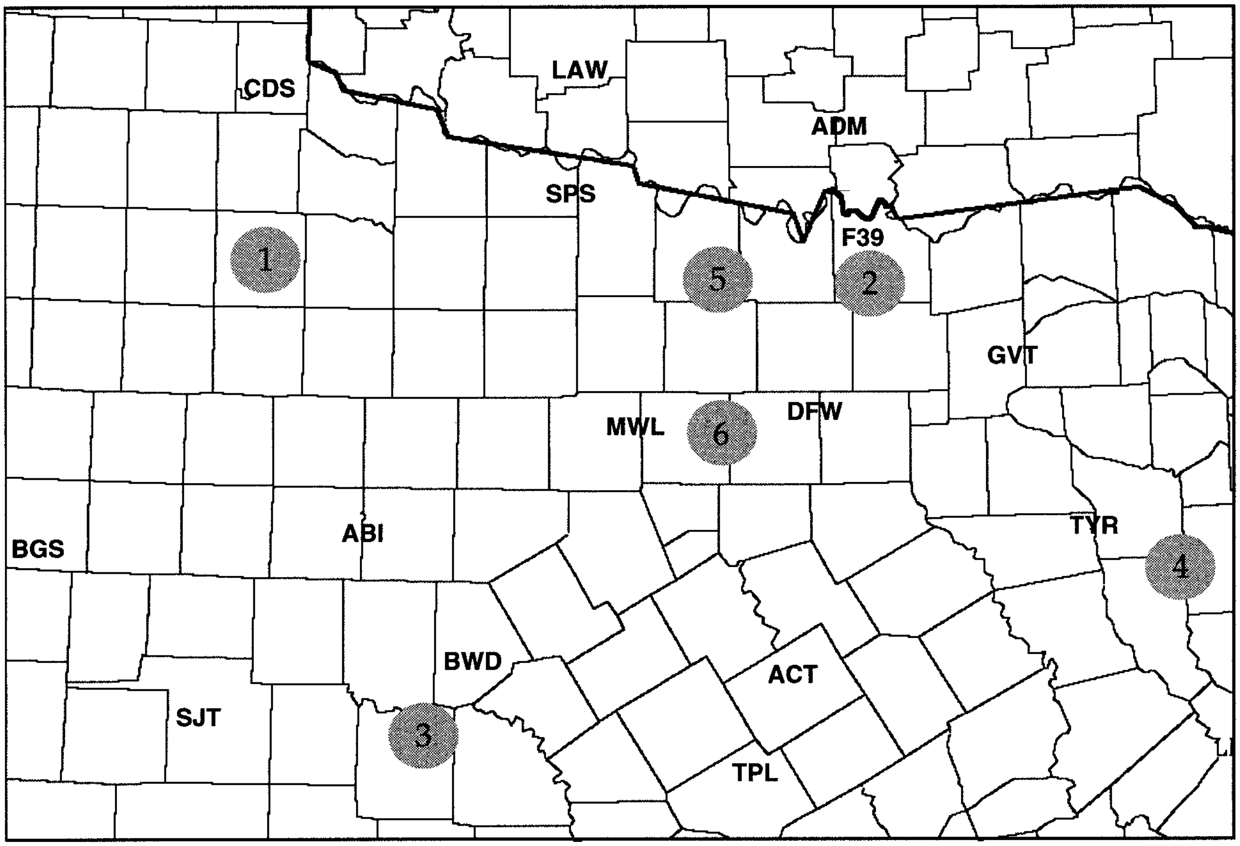

FIG. 3. Positions of the ST-95 forecasts: 1) 24 March 1995, 2) 25 March 1995, 3) 3 April 1995, 4) 10 April 1995, 5) 17 April 1995, and 6) 19 April 1995.

a moderately strong low-level mesocyclone. Unfortunately, the Eta Model underforecast the eastward motion of the shortwave, such that widespread multicell convection developed during the morning hours throughout north Texas and southwestern Oklahoma. Several reports of large hail and damaging winds were received from these storms, but the environment in which these storms formed had considerably less CAPE than the forecast sounding due to the reduced daytime heating. During the afternoon, a narrow region of instability developed behind this convection in the eastern Texas panhandle, and a tornado was reported north of Canadian, Texas. The sounding in this region was considerably different than the one used to produce the ST-95 forecast. Therefore the rather large (type I) error makes it difficult to access the quality of the convective scale forecast.

On 10 April, a forecast was made for eastern Texas southeast of Tyler, Texas (TYR). The 12-h forecast from the RUC model[2] forecasted significant midlevel warming during the day in this region, and a formidable cap at 750 hPa was present in the gridpoint sounding valid at 0000 UTC. Due to the large convective inhibition present in the sounding, the simulation failed to produce any convection. The 0000 UTC RUC analysis indicated that the forecast sounding was 5 K too warm at 750 hPa. During the evening hours, a strong squall line did develop and move into northeastern Texas where quarter-sized hail and damaging winds were reported.

The forecast for 17 April was made for a point north of the area between Mineral Wells (MWL) and Fort Worth (FTW). A strong shortwave was forecast to move over north Texas from New Mexico by 0000 UTC. The progged sounding contained a weak capping inversion, a CAPE of 2305 J kg^{-1}, and a storm relative helicity of 330 J kg^{-1} (Davies-Jones et al. 1990) is computed using an estimated storm motion. The ST-95 forecast is initially a classic supercell with moderate low-level rotation. After 1 h, smaller cells develop on the flanks of the original supercell. The supercell then takes on HP characteristics for the rest of the simulation. After transitioning to its high-precipitation phase, very weak low-level rotation is present in the supercell. During that afternoon severe convection developed to the southwest of Wichita Falls, Texas. One of the storms evolved into an intense and long-lived HP supercell, which produced

[2] As indicated earlier, this was the only ST-95 forecast made using the RUC model.

TABLE 1. Summary of ST-95 forecasts and observed thunderstorm behavior.

Date	ST-95 forecast	Error type*	Observed storm behavior
24 Mar 1995	No convection.	G	Storms form near CDS and then dissipate.
25 Mar 1995	Isolated, long-lived supercell with moderate low-level rotation.	I	Severe storms in the eastern Texas panhandle.
3 Apr 1995	Multicellular convection.	G	Short-lived single-cell storms near Brownwood.
10 Apr 1995	Strong cap prevents storms from developing.	I	Strong squall line in east Texas during evening hours.
17 Apr 1995	Initial supercell storm with some moderate rotation develops into HP/bow echo structure by 2 h.	I, II	Several supercell storms develop near SPS; one significant HP supercell produces several tornadoes across southern Oklahoma.
19 Apr 1995	A squall line forms with an HP supercell embedded in the middle of the line. Supercell has a persistent and strong low-level mesocyclone.	G	Intense north–south line of strong cells develops in the early evening. An HP supercell within the line produces an F2 tornado in the Dallas–Fort Worth area.

* I indicates type I error, II indicates type II error, and G indicates a good forecast.

numerous tornadoes as well as wind and hail damage as it tracked northeast into Oklahoma. The ST-95 forecast appeared to have correctly predicted the convective mode of the HP supercell. The simulation, however, failed to predict that significant low-level mesocyclones would develop and persist.

Figure 4 shows the average errors for potential temperature, mixing ratio, u and v winds for the six forecast days. The average error here is defined as forecast minus observed. Positive values then indicate an overforecast of temperature, moisture, wind, etc. Figure 4a shows that at low levels, the potential temperature was overforecast by more than 3 K, and in the upper troposphere, temperatures were too cool by more than 2 K. The mixing ratio was also 1–2 g kg^{-1} too high near the surface. Further aloft, the 700-hPa temperatures were consistently forecast to be too cool, leading to an underforecast of the convective inhibition in the soundings. The errors in these soundings at low and upper levels generated an overforecast of the available convective instability in the NCEP soundings. The vertical wind shear was also consistently forecast to be too large at low levels in the NCEP soundings. Figures 4c and 4d indicate that the winds at the ground were forecast to be more southeasterly than what was observed. This led to an overforecast of vertical wind shear and storm-relative helicity.

b. Two case days

Two of the ST-95 forecasts will be discussed in more detail. On 3 April, severe thunderstorms were expected to develop between San Angelo (SJT) and Waco, Texas (ACT). The Eta Model forecast sounding from this region (Fig. 5a) had a CAPE of 1764 J kg^{-1} with little or no convective inhibition. The wind shear in the lowest 4 km of the sounding was marginal for supercell storms, with wind speeds less than 10 m s^{-1}. During the first hour of the ST-95 forecast, the initial storms split and a weak right-moving supercell formed (Fig. 5b). After 1 h, the supercell weakens and evolves into a broken multicellular line after 2 h. This was indicated by the four reflectivity cores distributed over a 50-km north–south line at 2 h. Figure 5b indicates that several discrete gust front updrafts are also present at 2 h, displaced 5–15 km away from the reflectivity cores, indicating that the storms are collapsed and ''gusted out.'' Figure 6 shows the WSR-88D radar from Fort Worth during the afternoon and evening. The initial storm forms as an isolated cell near Big Springs, Texas (BGS, Fig. 6a). The shape of the echo is very similar to that of the ST-95 simulation at 1 h (Fig. 5b). An hour later (Figure 6b), several more convective cells have formed in several short lines. Several reports of large hail were received between Big Springs and Brownwood (BWD). The verification sounding from this region had CAPE and wind shear values that are approximately half as large as the forecast sounding (Fig. 5a). The bulk Richardson number (Weisman and Klemp 1982), however, is nearly the same for both soundings. The simulation appears to have correctly forecasted the type and severity of the convection, even though the forecast sounding from the Eta Model overforecast the instability and vertical wind shear.

Another strong shortwave lifted out across north Texas and Oklahoma on the evening of 19 April. The 12-h Eta Model forecast sounding is taken from the area between Forth Worth and Mineral Wells (Fig. 7a). The sounding has virtually no convective inhibition and had a CAPE of 2269 J kg^{-1}. The storm-relative helicity for a right-moving supercell was 269 J kg^{-1}. During the first hour of the ST-95 simulation, the initial storm cell grows and then collapses, creating an intense gust front. Along this gust front, a large squall line then forms and moves eastward. At around 90 min into the simulation, a very strong low-level mesocyclone develops in conjunction with one of the cells in the center of the squall line (Fig. 7b). This mesocyclone persists for nearly 30 min before weakening. Figure 8a shows the low-level storm-relative flow, reflectivity, and vertical velocity field at 90 min. A strong circulation is present near the center of the gust front east of the storm. Figure 8b

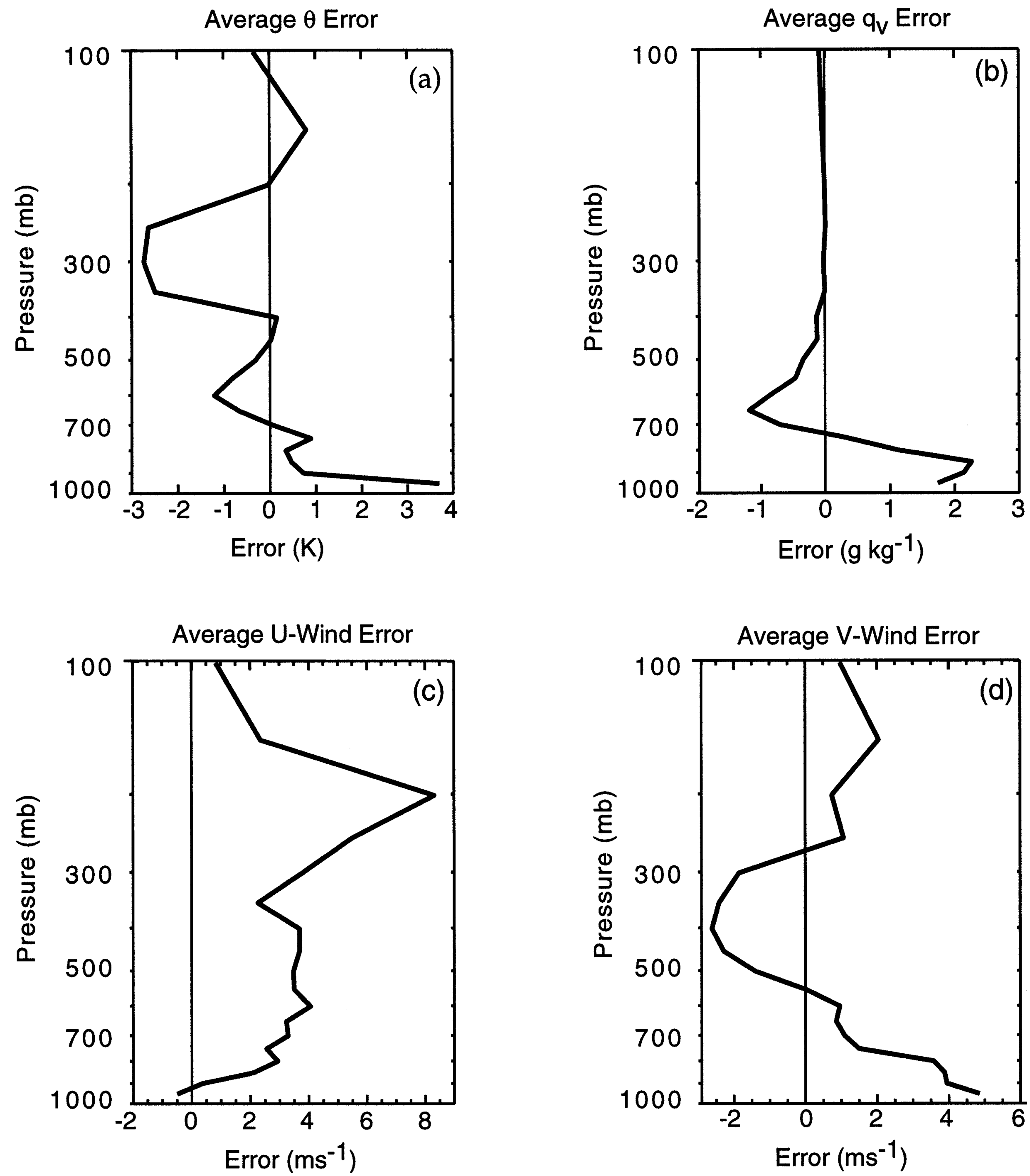

FIG. 4. Average errors (forecast observed) for the ST-95 soundings: (a) potential temperature, (b) mixing ratio, (c) *u* wind, and (d) *v* wind.

shows the radar reflectivity from Fort Worth that evening. A large squall line develops southeast of Wichita Falls (SPS), Texas, and then moves eastward toward Fort Worth. As the line approached Fort Worth, a significant inflow notch, associated with a strong low-level mesocyclone, develops. This mesocyclone moved into the Dallas–Fort Worth area and produces several tornadoes. Several more inflow notch or bow echo features develop later as the squall line moved across east Texas and into Louisiana by 0700 UTC. Figure 7a shows the verification sounding for this case. The forecast temperatures between 850 and 500 hPa are several degrees

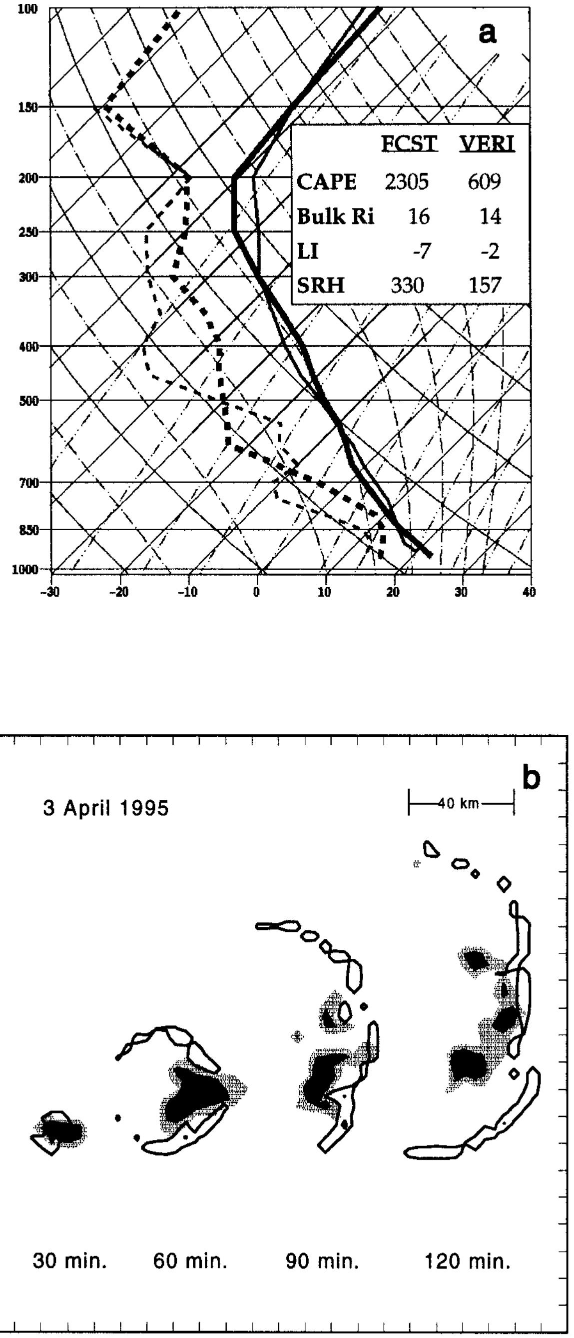

FIG. 5. (a) Twelve-hour forecast and verification sounding from the Eta Model for 0000 4 April 1995. Thick line is the forecast sounding, thin depicts the verification sounding. (b) Reflectivity and vertical velocity at $z = 1$ km for 30, 60, 90, and 120 min from the ST-95 model simulation. The 10- and 30-dBZ reflectivities are light and dark shading, respectively, and the vertical velocity is plotted using 1 and 5 m s^{-1} contours. Tick marks on the grid are spaced at 10-km intervals

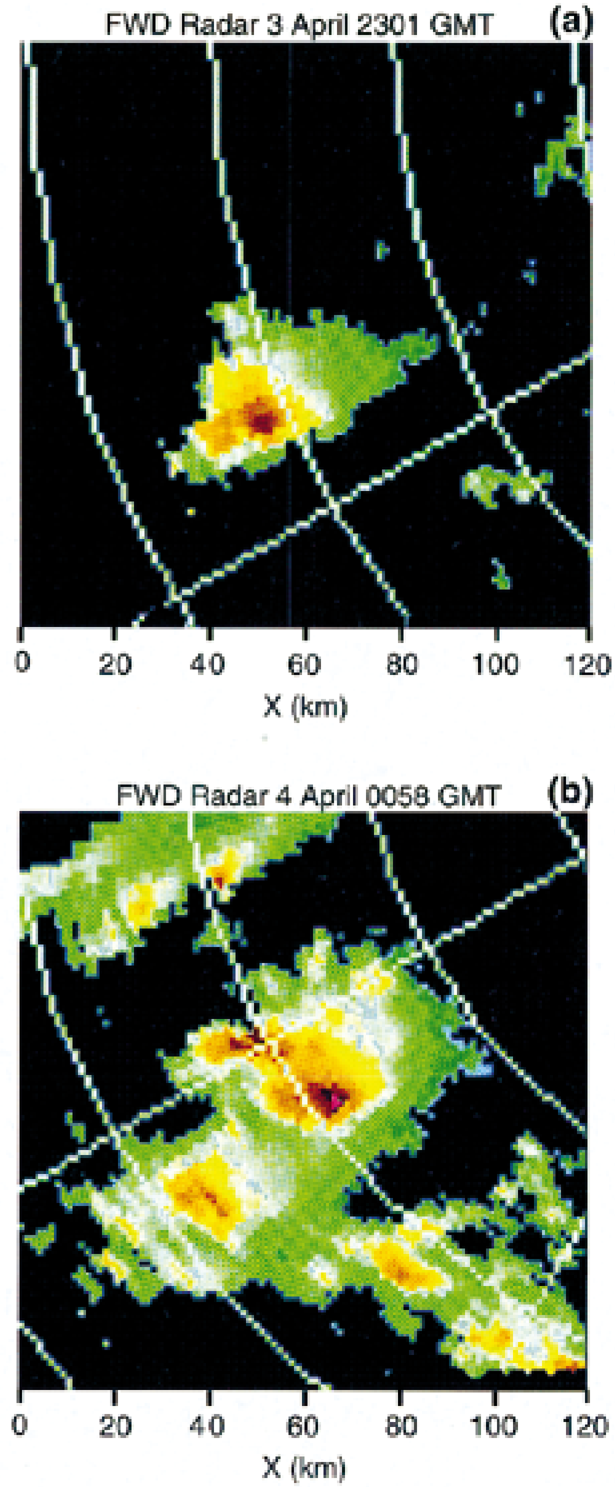

FIG. 6. Radar data from FWD on 3–4 April 1995. Shown is reflectivity at 0.5 degrees of elevation. Reflectivity greater than 10 dBZ is shaded green, reflectivity greater than 30 dBZ is shaded yellow, and reflectivity greater than 50 dBZ is shaded red. (a) Reflectivity at 2301 GMT. (b) Reflectivity at 0058 GMT.

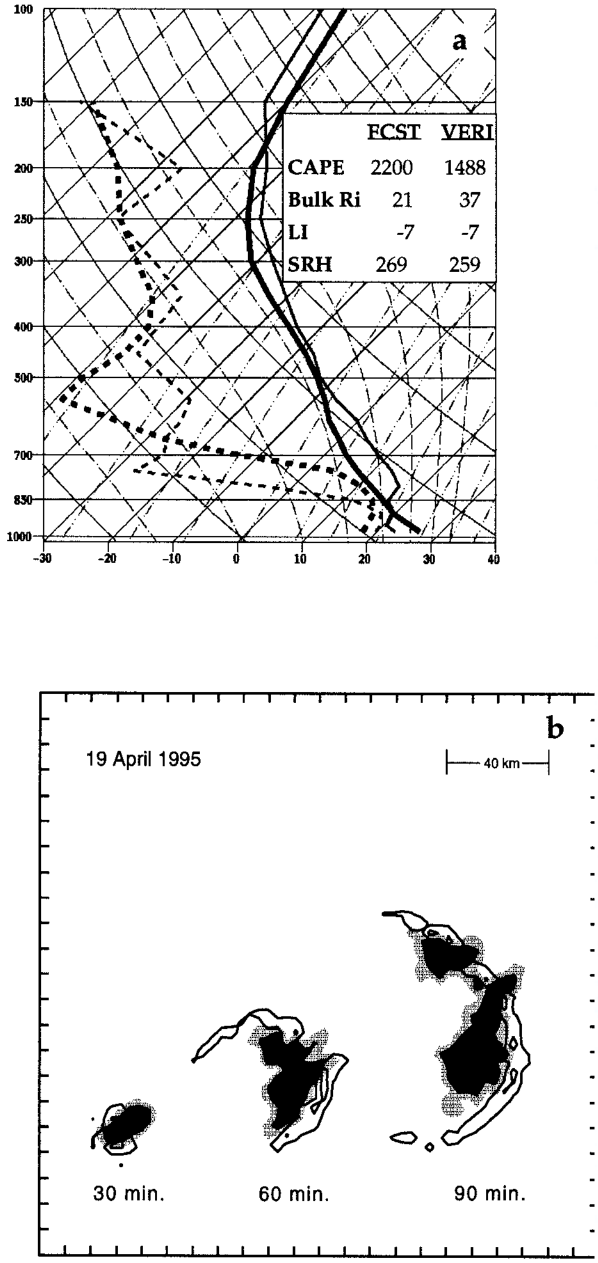

FIG. 7. (a) Twelve-hour forecast and verification sounding from th Eta Model for 0000 20 April 1995. Thick line is the forecast soundin thin depicts the verification sounding. (b) Reflectivity and vertic velocity at $z = 1$ km for 30, 60, and 90 min from the ST-95 mod simulation. The 10- and 30-dBZ reflectivities are light and dark shad ing, respectively, and the vertical velocity is plotted using 1 and m s^{-1} contours. Tick marks on the grid are spaced at 10-km interval

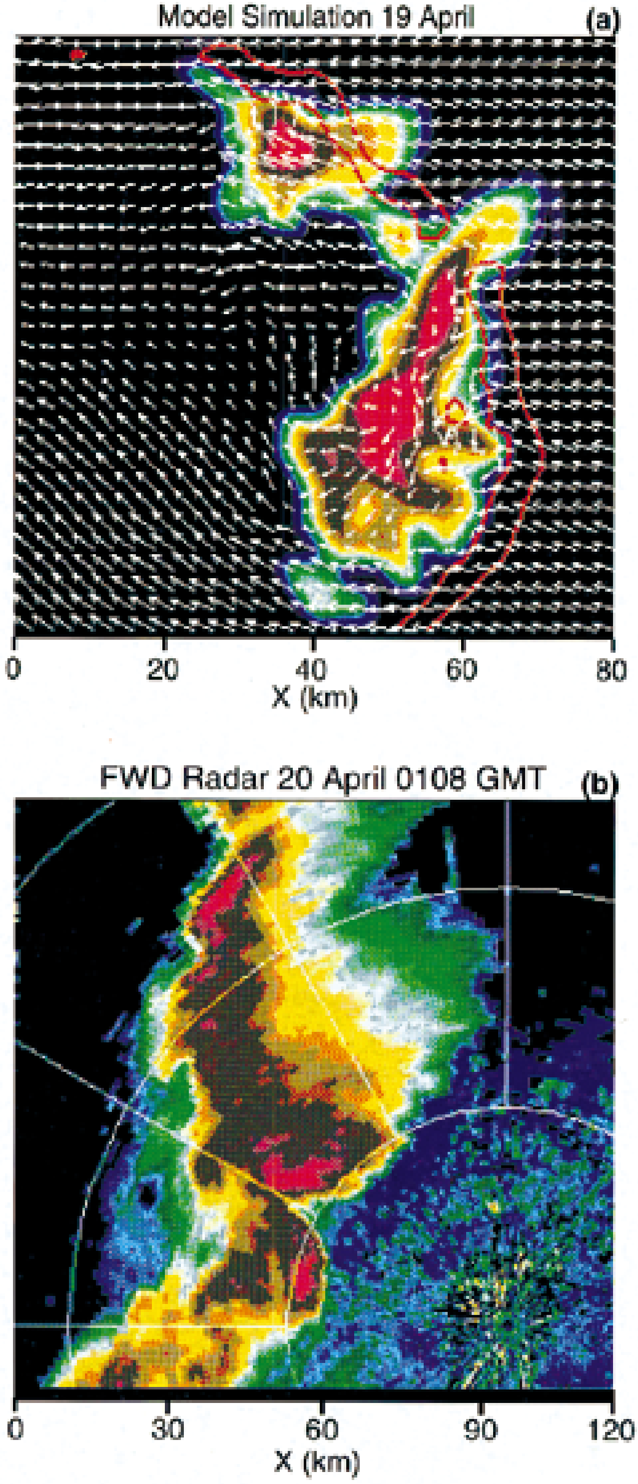

FIG. 8. (a) ST-95 model simulation at 90 min. Shown are the $z =$ 1 km reflectivity, vertical velocity, and the storm-relative horizontal velocity field. Reflectivity color scheme is the same as in Fig. 6. Vertical velocity greater than 1 m s^{-1} is shown as the single red contour. Maximum wind speeds are 25 m s^{-1}. (b) Radar data from FWD on 19 April 1995. The elevation angle and reflectivity color scheme is the same as in Fig. 6.

too cool, leading to an overforecast of instability by about 50%. The hodographs (not shown) are qualitatively similar in shape, except that the observed hodograph displayed somewhat weaker winds below 3 km, and the surface winds are not as backed as forecast. Nevertheless, the behavior observed in the ST-95 forecast was strikingly similar to the behavior observed in the actual storms that evening.

4. Conclusions

ST-95 was run for 6 days during the spring of 1995. When the gridpoint sounding had convective indices similar to those observed, then the storm-scale forecasts demonstrated skill in predicting the mode of convection as well as other characterstics of the convection. These results are similar to the results from the ST-91 experiment. Under these circumstances, the STORMTIPE forecast then provided useful information to forecasters in Forth Worth about the potential for severe convection during the afternoon and evening hours. The use of forecast gridpoint soundings from the NCEP models was a better methodology than using the forecaster-generated soundings as in the ST-91 experiment. Sounding errors were considerably more systematic, as consistent biases were found. The only sounding that contained too little instability was the 10 April case, and this sounding was obtained from the RUC model. In the four out of the five other case days, the Eta Model's soundings overforecast the amount of instability and wind shear to be present at 0000 UTC. This overforecast of the environmental conditions then created an ''overforecast'' of the convective storm intensity in the cloud model. A positive aspect of the overforecast of instability and shear is that it may have helped to alert the forecasters to the worst-case possibility of severe weather. While the sample size and the error analysis performed here are clearly insufficient to draw any firm conclusions, the biases in the operational model-predicted soundings should be examined more rigorously in future studies. Aside from the standard synoptic sounding sites, there exists an increasing number of field program datasets, such as sounding data from the Verifications of the Origins of Rotation in Tornadoes Experiment (Rasmussen et al. 1994), which have a large number of asynoptic soundings that could be used to analyze gridpoint soundings in operational models. The results from both the ST-91 and ST-95 experiments suggest that if a sounding indicative of the mesoscale environment can be accurately predicted by larger-scale models, useful forecasts of convective storm characteristics using the STORMTIPE methodology may be possible.

The success of the ST-91 and ST-95 forecast experiments remains somewhat surprising since the use of a homogeneous environment and the crude method of triggering the convection in the cloud model are clearly not a realistic representation of mesoscale processes responsible for thunderstorm development and evolution. Perhaps the results from this experiment can be partially explained by considering that if both instability and vertical wind shear are overforecast, the bulk Richardson number remains roughly the same. Several of the case days had similar bulk Richardson numbers in the forecast and observed soundings, even though the CAPE and vertical shear were much smaller in the observed environment than in the forecast environment. A recent study by Jahn and Droegemeier (1996) indicates that the bulk Richardson number may be the best indicator of storm morphology. Therefore the resulting convection in these simulations may have had similar characteristics to the observed storms because the model environments had nearly the same bulk Richardson number as was present in the actual environment.

In the future, another STORMTIPE experiment is planned, this time using a Monte Carlo–type approach to the convective forecasts as advocated by Brooks et al. (1992). Increased computational capability will allow the generation of 5–10 convection storm simulations for operational forecasters. There are a variety of possibilities available as to how to generate such a set of simulations. For example, soundings from several locations or even different models could be used to initialize the domain. A variety of different triggering mechanisms could also be used to generate the convection. The orientation and intensity of mesoscale features might be incorporated into the domain as well. By obtaining a wide variety of realizations for a given severe storm environment, a more robust evaluation of the convective storm forecast and its sensitivity to the mesoscale variability present will be possible.

Acknowledgments. This research was supported by the National Weather Service's Southern Region Scientific Services Division under NOAA Contract NA37WA0543 through the Cooperative Institute of Applied Meteorological Studies at Texas A&M University and by the National Science Foundation under Grant ATM-9318914. The authors appreciate the helpful comments from the three anonymous reviewers. The Texas A&M Supercomputer Center generously provided high-priority access to their SGI Power Challenge machine, which was necessary for timely forecasts.

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