P 5.2 **THE SUPER OUTBREAK: OUTBREAK OF THE CENTURY**

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1. INTRODUCTION

The Super Outbreak of tornadoes of 3-4 April 1974 remains the most outstanding severe convective weather episode of record in the continental United States (Figure 1). By nearly every metric imaginable, the outbreak far surpassed previous and succeeding events in severity, longevity and extent. A sampling of statistics only partially conveys its enormity:

148 TORNADOES
…95 F2s or stronger
…30 F4s or F5s

48 KILLER STORMS
…335 dead
…More than 6000 injured

PATH LENGTHS UP TO 90 miles (145 km)
…Total path length > 2500 mi (4000 km)

F2s OR GREATER PRESENT FOR EACH THREE HOUR PERIOD BETWEEN 12 UTC / 3rd AND 15 UTC / 4th

AT ONE POINT, 15 TORNADOES IN PROGRESS AT SAME TIME

TEN STATES DECLARED FEDERAL DISASTER AREAS

Further appreciation for the phenomenal nature of the Super Outbreak may be gleaned from Figure 2, which depicts the maximum, week-long running total of F2 or greater tornadoes since 1875. Entire years noted for their prominent tornado counts (e.g. 1953 and 2003) pale in comparison to the 18-hour period that began around midday on 3 April 1974. Twenty-five F3 or greater long track (>25 miles (40 km)) tornadoes occurred during the same period, more than triple the annual average of such events since 1880 (C. Broyles, personal communication).

Thirty years have passed since the Super Outbreak inflicted its unprecedented human and physical toll on the Midwest and the Ohio and Tennessee Valleys. Despite its breadth and intensity, comparatively little has been written regarding the event's synoptic and mesoscale meteorological evolution. In particular, only limited attention has been given to understanding

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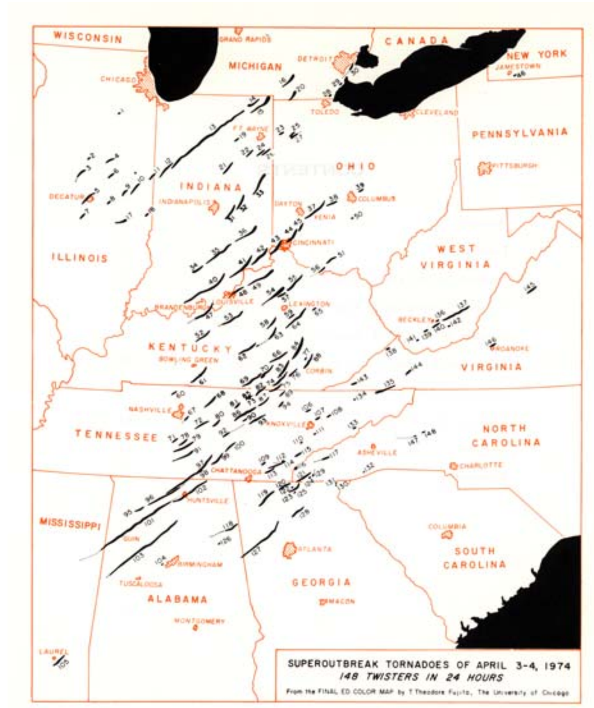

Figure 1. Tracks of the 148 Super Outbreak tornadoes documented by Fujita (1975).

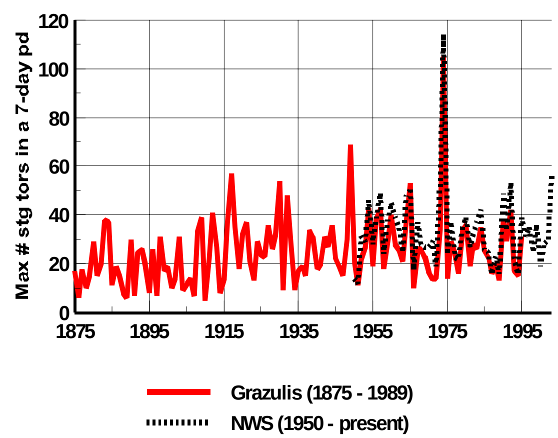

Figure 2. Maximum, week-long running total of F2 or stronger tornadoes per year since 1875. Data in red from Grazulis (1993); dotted black, NWS/SPC database (Courtesy of R. Schneider)

why so many significant, long-lasting tornadic storms occurred.

In the present paper, the surface and upper air analyses contained in Hoxit and Chappell (1975), and additional data are used to present an updated synoptic and subsynoptic overview of the 1974 Super Outbreak. Emphasis will be placed on (1) identifying the major factors that contributed to the development of the three main convective bands associated with the event, and (2) identifying the conditions which may have contributed to the outstanding number of intense and long-lasting tornadoes. In addition, output from a 29 km, 50 layer version of the Eta forecast model using data from the NCEP/NCAR reanalysis grids (Kalnay et al. 1996) will be presented to assess the model's skill in depicting synoptic and mesoscale aspects of the outbreak.

2. SYNOPTIC ENVIRONMENT

2.1. *Tue 2 April*

The morning of Tuesday 2 April 1974 was characterized by a broad, low amplitude large scale trough over the continental United States (Figure 3a). Embedded in the trough were two moderately strong shortwave disturbances, one of which was located over the Ohio Valley, and the other just entering the Great Basin. The latter impulse was associated with 500 mb wind speeds in excess of 100 kts (50 ms^{-1}) across southern California, while downstream speeds were less than 50 kts (25 ms^{-1}) over the southern Plains. The eastern shortwave was deamplifying at this time and was associated with a weakening surface low over the eastern Great Lakes.

By late in the day, the Great Lakes low was over Quebec, with a cold front that curved from off the New England coast across southern Virginia into the northwest Gulf of Mexico (not shown). Surface dewpoints south of the boundary were moist for the time of the year, ranging from the low 60s (16 C) in north Florida to the low 70s (21C) over coastal Louisiana. The western part of the front began to return northward as a warm front Tuesday evening as increasing westerly mid level flow and the eastward advance of the Great Basin impulse induced strong lee cyclogenesis east of the central Rockies. This cyclogenesis was also fostered by the presence of strong, along-stream variation of the upper level flow in the exit region of the western states speed maximium (Uccellini and Johnson 1979); 300 mb speeds at this time ranged from nearly 140 kts (70 ms^{-1}) in southern Nevada to less than 80 kts (40 ms^{-1}) in Oklahoma and north Texas.

The jet maximum associated with the Great Basin shortwave trough continued to propagate east southeast Tuesday evening as a weak disturbance in the flow reached central Oklahoma (not shown). At the same time, the lee cyclone deepened to less than 984 mb and edged east into Kansas. As warm advection increased over the southern Plains, scattered high-based thunderstorms developed across north Texas and eastern Oklahoma ahead of the Pacific cold front trailing south from the Kansas low. This activity soon organized into a forward propagating MCS that continued east into Arkansas early Wednesday.

The thermodynamic environment across the south central United States late Tuesday was characterized by a broad swath of steep low to mid tropospheric lapse rates that extended from the southern and central Rockies east to the Mississippi Valley (Figure 4a). Lapse rates were close to dry adiabatic over much of western Texas and Oklahoma. While plumes of mixed layer air originating over the high plateau of the southwestern United States and Mexico are commonly observed in soundings taken over the Plains and Mississippi Valley prior to spring tornado outbreaks, the extent of the potential instability in this case is notable. Nevertheless, because of the absence of substantial boundary layer moisture, significant surface-based convective available potential energy (CAPE) was confined to areas along the front near the Gulf Coast (Figure 5a).

2.2 *Early morning, Wed 3 April*

The combination of potent dynamic forcing and favorably timed diurnal factors promoted substantial strengthening and broadening of the south southwesterly low level jet over the lower Mississippi Valley early Wednesday. During the pre-dawn hours, 850 mb wind speeds increased to more than 50 kts (25 ms^{-1}) across Louisiana, Mississippi and Alabama as the Kansas low deepened to 980 mb. The associated northward transport of moisture resulted in rapid warm sector destabilization from the Gulf Coast to the Tennessee Valley. By 1200 UTC, CAPE of 1000 J/kg was present as far north as the Ohio River (Figure 5b) as the Gulf Coast warm front redeveloped northward (Figure 3b). However, because of the presence of the elevated mixed layer plume (Figure 4b), most of the CAPE was "capped" to unassisted deep surface-based convection.

While the elevated mixed layer plume prohibited the development of deep convection over much of the warm sector, the favorable thermodynamic environment for cold downdraft production, in conjunction with increasing moisture inflow, fostered continued intensification of the Arkansas MCS. By dawn, the convective system extended in a broken band from southern Illinois across far western Kentucky into central Arkansas. The line of storms produced severe weather at several locations, and was the first of the three, supercell-containing convective bands that would affect the east central states that day.[1]

[1] In this paper, the term "convective band" will be favored over "squall line" to emphasize that the predominant convective mode remained quasi-cellular rather than linear throughout the event

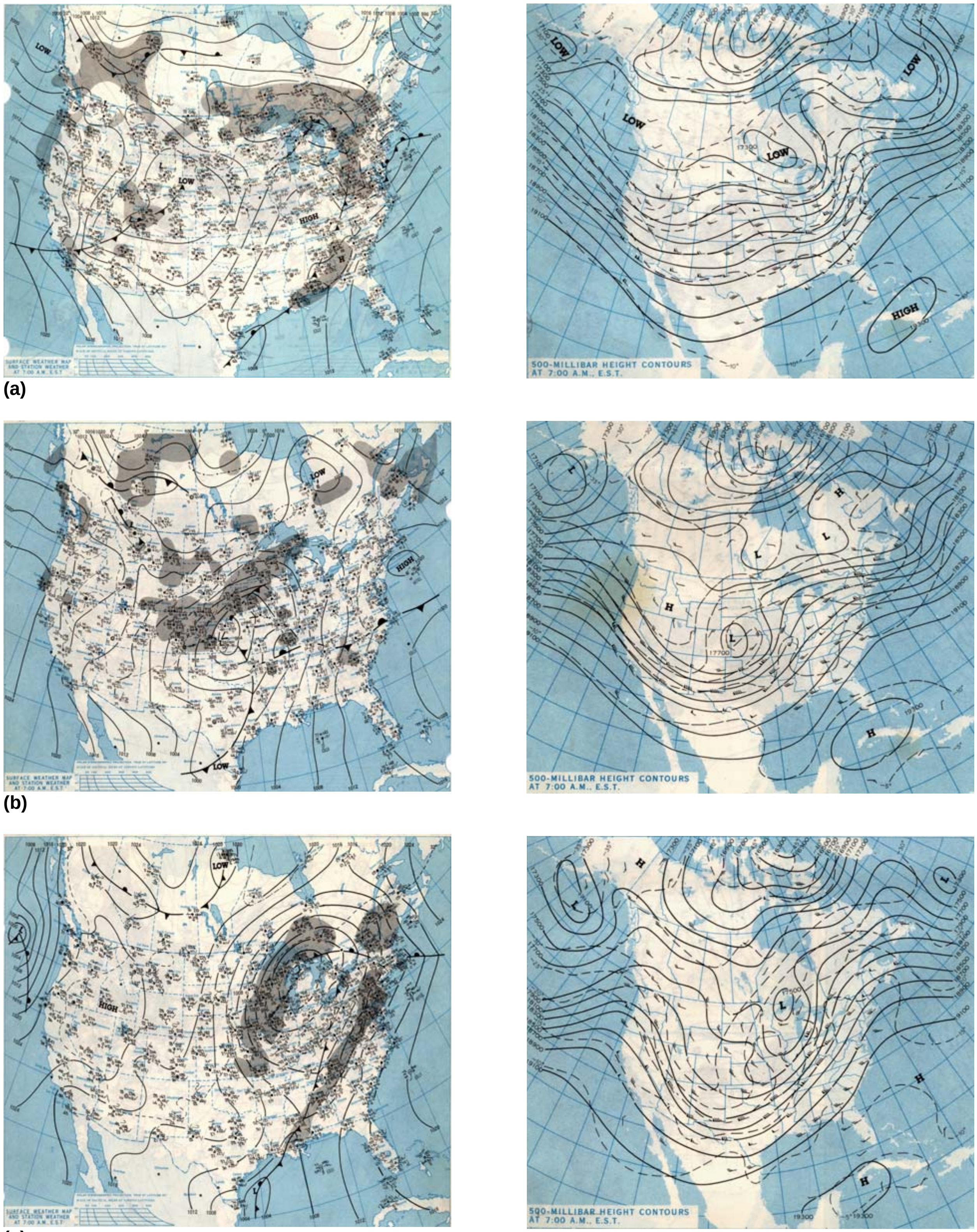

Figure 3. 1200 UTC Surface (left) and 500 mb (right) Daily Weather Map analyses from (a) 2 April, (b) 3 April and (c) 4 April 1974. Surface pressure in mb; contour interval 4 mb. Standard abbreviated station plots, with English units. 500 mb height contours in feet; contour interval 200 ft. Wind speed in knots. Half barb = 5 kts (2.5 ms^{-1}), full barb = 10 kts (5 ms^{-1}), and flag = 50 kts (25 ms^{-1}).

Because a thermal gradient was present at 700 mb west of the Arkansas MCS at 1200 UTC (not shown), one might conclude that the system was associated with an elevated frontal zone or "cold front aloft" as described by Locatelli et al. (1989). However, the thermal gradient was not well-defined at the time of storm initiation over the southern Plains, and temporal and spatial continuity of the feature as revealed by the radiosonde data is not sufficient to confirm the presence of an elevated front. Similar thermal gradients have been attributed to elevated fronts in the vicinity of other forward-propagating convective systems when, in fact, they actually reflected localized corridors of evaporatively-cooled air in the wake of the rear-sloping MCSs (e.g., Rose et al. 2002).

It does appear, however, that the Arkansas MCS was in some manner related to a gravity wave or bore-like structure that moved east across the Ohio and Tennessee Valleys during the late morning and early afternoon on the 3rd, more or less in phase with the convective band. Early morning visible data satellite loops clearly depict an eastward-moving arc of mid-level clouds that seems to emanate from the vicinity of the MCS and is oriented parallel to it. The cloud arc extends south to near the Gulf Coast, well beyond the southernmost radar echo in northern Mississippi. As the arc moves east, parts of the original squall line remain active northeastward into western Pennsylvania, while the convective band develops south into Mississippi and Alabama coincidental with passage of the arc (Figure 6).

Miller and Sanders (1980) present data in which a persistent, small-scale pressure perturbation moves eastward in conjunction with the convective band from western Arkansas to the western slopes of the Appalachians. Miller and Sanders also identify nine other perturbations in the wake of the first. These did not, however, bear any consistent relationship with meso-alpha scale convective system development.

Locatelli et al. (2002) present output from a mesoscale model simulation of the Super Outbreak that depicts a structure having characteristics of an undular bore (Locatelli et al. 1998). The feature moves east across the Ohio and Tennessee Valleys in unison with the Arkansas MCS. They propose that the feature is initiated when the Pacific cold front associated with the Kansas surface low encounters the stably stratified ("loaded gun" type) thermodynamic environment over the southern Plains. This seems plausible, as the bore is oriented parallel to the front and, as previously noted, the cloud arc seen in satellite imagery immediately precedes subsequent convective development in Mississippi and Alabama.

2.3 *Late morning/early afternoon, Wed 3 April*

The onset of diurnal heating, occurring nearly simultaneously with the arrival of substantial low level moisture, resulted in continued destablization across a much of the east central and southeastern United States late Wednesday morning. As Figure 5c shows, by 1800 UTC surface-based CAPE in excess of 2500 J/kg was present from the lower Ohio and Mississippi River Valleys south and east to the Gulf Coast.; values were greater than 3500 J/kg over parts of Alabama, Mississippi, Tennessee and Kentucky. In addition, because of the seasonably rich nature of the boundary layer moisture inflow (dewpoints in the mid to upper 60s), values of mean mixed layer CAPE were nearly as great (not shown).

The Illinois/Kentucky/Arkansas convective band (hereafter referred to as Convective Band One) continued east across the Tennessee and Ohio Valleys at an average speed of 60 kts (30 ms^{-1}) through mid afternoon. It reached the western slopes of the Appalachians around 2100 UTC. The system broke into two parts around 1500 UTC, with the split centered over eastern Kentucky (Figure 6a). Hoxit and Chappell (1975) attribute this split to the band's movement into a zone of large scale subsidence centered over eastern Kentucky at 0000 UTC 4 April. They calculate vertical motion using a kinematic method based on the observed radiosonde data. An area of subsidence is not, however, depicted over Kentucky in plots of Q-vector forcing for vertical motion computed for various layers using the present study's re-run of the 29 km Eta model (not shown).

The break up of Convective Band One may simply reflect that synoptic scale forcing for ascent was stronger north of the Ohio River than it was to the south. This may have fostered downwind cell development (i.e., forward propagation) at the northern end of the convective band despite the fact that surface-based instability was less in this region relative to points south. Such behavior by strongly-forced forward-propagating convective systems is commonly observed by forecasters at the Storm Prediction Center.

The northern third of Convective Band One produced scattered damaging wind gusts and marginally severe hail in Ohio, in addition to a tornado in Indiana, before weakening over Lake Erie and northwest Pennsylvania late in the afternoon. The southern half, meanwhile, continued to intensify as it developed south across Mississippi and Alabama and reached north Georgia early in the afternoon (Figure 6b). An F2 tornado with a 15 mile (24 km) path length occurred in extreme northern Georgia around 1800 UTC. Satellite loops suggest that the band (and/or the gravity wave structure associated with it) enhanced existing thunderstorms as the system encountered convection that had formed earlier in the day near the stalling cold front over the southern Appalachians. However, given the timing of the band's arrival with diurnal heating and the return of boundary layer moisture, a causal relationship cannot be made with certainty.

In the wake of the first convective line, a second area of thunderstorms, hereafter referred to as Convective Band Two, formed around 1400 UTC in northeast Arkansas and southeast Missouri. This activity appears to have been initiated as surface heating and

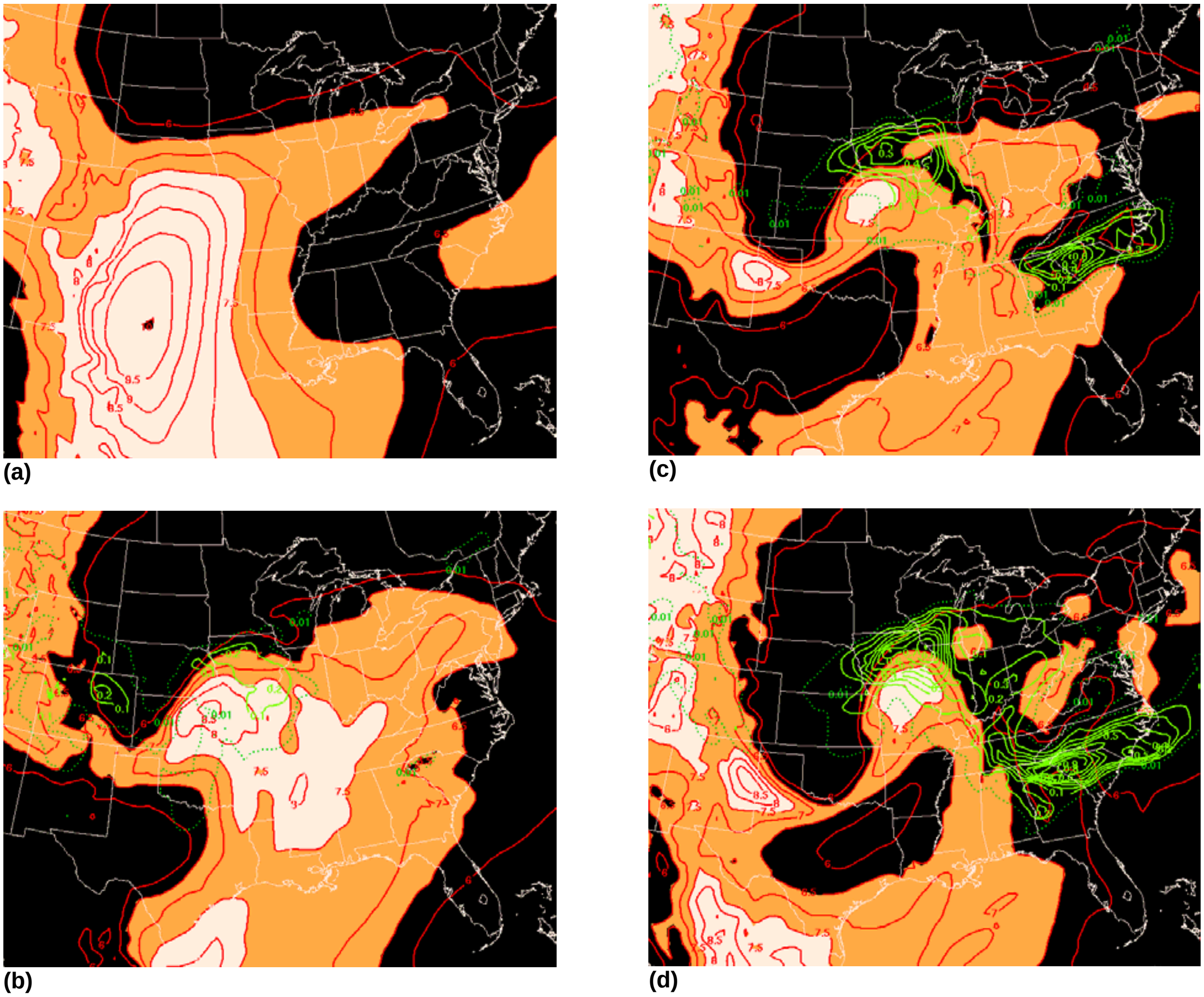

Figure 4. Sequence of 29 km Eta 850-500 mb lapse rates (red) and 12-hour accumulated convective rainfall (green) valid for (a) 0000 UTC 3 April, (b) 1200 UTC 3 April, (c) 1800 UTC 3 April, and (d) 0000 UTC 4 April 1974. Lapse rate contour interval one half degree C per km (red); lapse rates greater than 6.5 degrees C per km shaded. Precipitation contour interval one tenth of one inch. Model initialized at 0000 UTC / 3 April.

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strong boundary layer moisture transport destabilized an axis of convergence along the surface dry line. The dry line had become discernible the previous evening over central Texas and Oklahoma, just ahead of the Pacific cold front (not shown). It reached southern Arkansas and northwest Louisiana around 1200 UTC Wednesday. The boundary accelerated northeastward later Wednesday morning and reached southeastern Missouri around midday, following the onset of diabatic heating and enhanced boundary layer mixing.

The degree of destabilization that occurred in the wake of Convective Band One is especially apparent upon examination of the sequence of soundings made at Nashville, TN presented in Figure 7. The sequence shows vividly how a combination of surface heating, moisture inflow and sustained large scale ascent weakened and ultimately eliminated the convective inhibition present at 1200 UTC (also see Figures 5c and d). The corresponding wind profiles and hodographs illustrate how the kinematic environment became increasingly favorable for tornadic supercells as winds strengthened downstream from the approaching upper level jet streak. Using an average observed storm motion of 230 degrees at 45 kts (22 ms^{-1}), storm relative helicity at 1800 UTC in middle Tennessee was more than 750 m^2/s^2!

Given the environment of very strong (70 kt (35 ms^{-1})) 0-6 km southwesterly shear and great instability (surface-based CAPE of 2000 to 3000 J/kg), the Arkansas/Missouri storms quickly became supercells. By noon, cloud tops within Band Two had attained heights of more than 50,000 ft (15.2 km), well above the regional tropopause level of 38,000 ft (11.6 km). Reflecting the orientation of the axis of strongest flow aloft (from northeast Arkansas to northern Indiana at 1800 UTC), the northern part of Band Two moved rapidly northeastward, while the trailing southern end edged only slowly east across west Tennessee. As the convective band moved generally east, it also

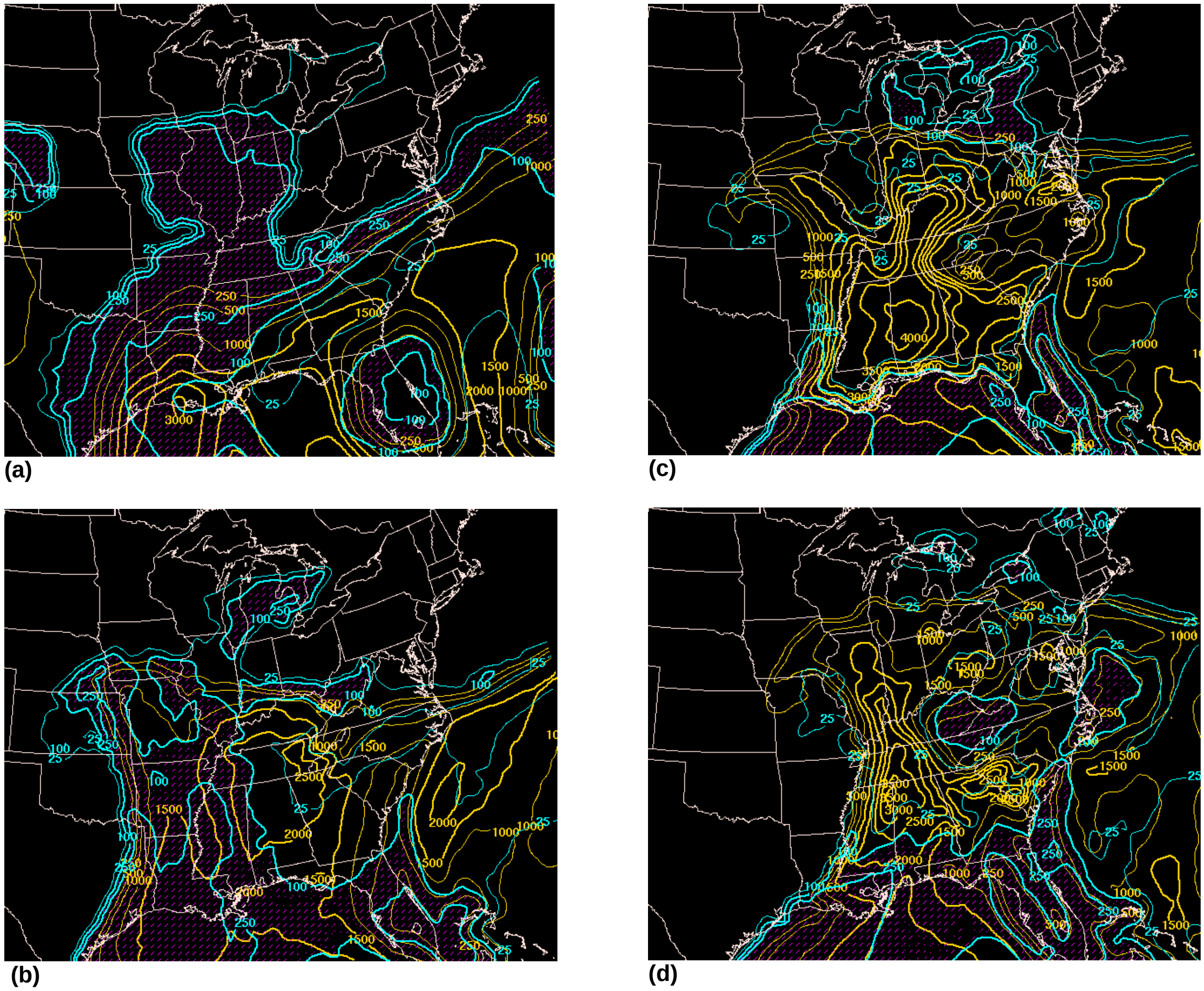

Figure 5. Sequence of 29 km Eta surface-based CAPE (yellow) and CIN (blue) valid at (a) 0000 UTC 3 April, (b) 1200 UTC 3 April, (c) 1800 UTC 3 April, and (d) 0000 UTC 4 April 1974. CAPE contoured at intervals of 500 J/kg, except 250 J/kg contour added for resolution below 500 J/kg. CIN contoured at 25, 100 and 250 J/kg. CIN greater than 100 J/kg stippled purple. Model initialized at 0000 UTC / 3 April.

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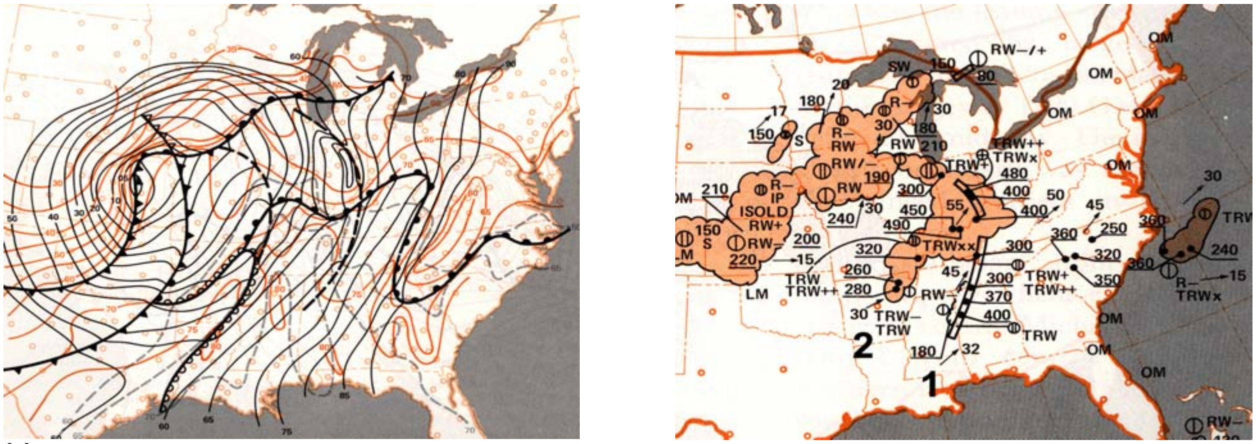
expanded preferentially to the north, so that by early afternoon it extended from near Fort Wayne, IN to Memphis, TN. Examination of model-derived vertical motion fields (not shown) and 1800 UTC radiosonde data suggests that the presence of stronger synoptic scale forcing for ascent and weaker capping were likely responsible for the north bias.

Shortly after Convective Band Two arose in Arkansas and southeast Missouri, a third broken line of storms developed around 1600 UTC from near St Louis northward into west central Illinois. Surface, satellite and model derived data suggest that Band Three formed in a zone of strong differential positive vorticity advection in the exit region of the 120 Kt (60 ms^{-1}) 300 mb jet streak progressing northeast across rkansas. As capping was quite weak (per 1800 UTC Salem, Illinois radiosonde data and Figure 5 c) and convergence was pronounced near the intersection of the dry line and Pacific cold front (Figure 6b), storms formed as soon as the convective temperature was attained (about 74 F or 23 C). Supercells within Band Three produced baseball-sized hail in central Illinois around 1720 UTC.

2.4 *Mid-afternoon, Wed 3 April through early morning, Thu 4 April*

The Super Outbreak began in earnest around 1900 UTC (1400 CDT) as all three convective bands began producing damaging tornadoes nearly simultaneously (Figure 8). Within the next two hours, devastating tornadoes would strike Brandenburg, KY, Depauw, IN and Xenia, OH, all with Band Two. The violence increased after 2100 UTC, as tornadoes associated with all three convective bands touched down in numerous communities from Alabama and Tennessee northward into Illinois, Indiana and Ohio. The metropolitan areas surrounding Birmingham, AL, Cincinnati, OH and Louisville, KY were also hit. In northern Indiana, Band Three spawned a half mile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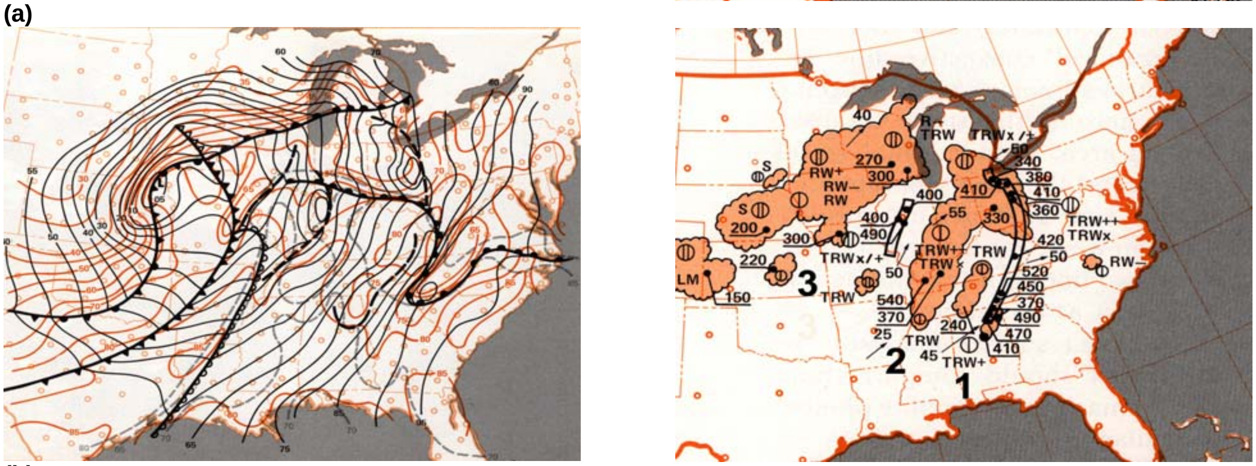
(a)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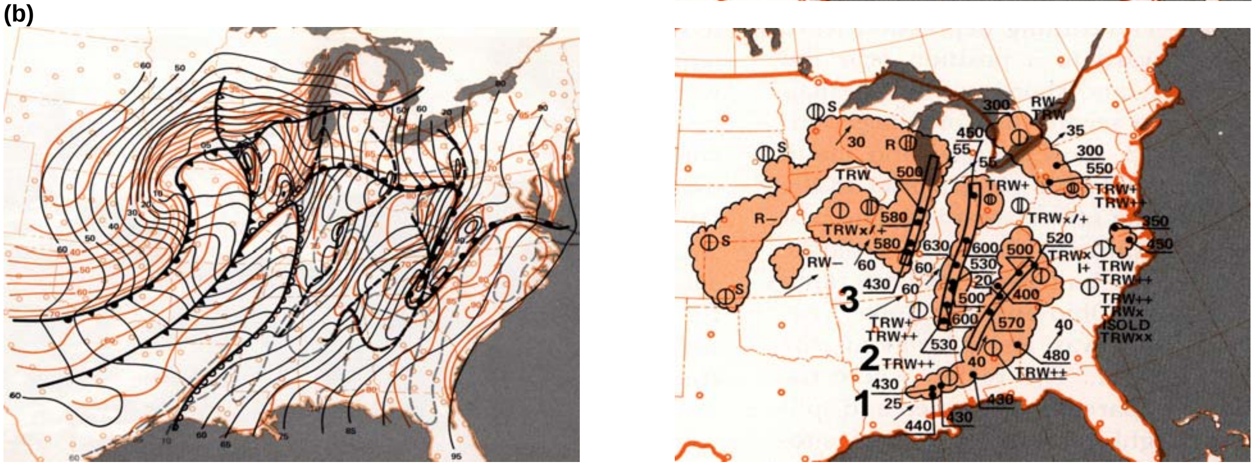
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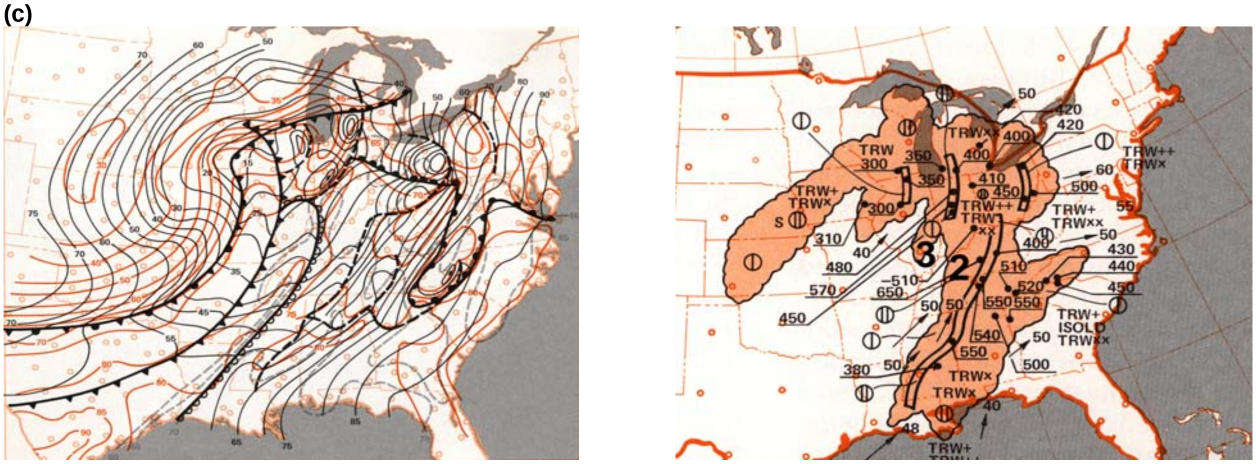
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(d)

Figure 6. (Previous page) Surface analyses (left) and National Weather Service (NWS) radar summary charts (right) for (a) 1500 UTC 3 April, (b) 1800 UTC 3 April, (c) 2100 UTC 3 April and (d) 0000 UTC 4 April 1974. Temperatures (orange) and dewpoints (grey) in 5 degree F increments; altimeter settings (black) in inches of mercury. Frontal symbols conventional. Dashed lines denote convective bands (numbered in bold 1, 2, 3), troughs and/or outflow boundaries. Radar data depicted using conventional NWS format. After Hoxit and Chappell (1975).

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wide F4 which struck the town of Monticello around 2215 UTC. This tornado had a path length of nearly 109 miles, the longest of any in the Super Outbreak. Hail up to the size of softballs accompanied Band Two in northern Kentucky, where radar cloud tops were as high as 65,000 ft (19.8 km).

The Kansas surface low began to fill slightly as it tracked slowly northeast to near Kirksville, MO by 0000 UTC Thursday (Figure 6d). The low was situated in the exit region of 300 mb jet streak of 125 kts (62 ms^{-1}) centered over Arkansas. At 500 mb, southwesterly winds exceeded 100 kts (50 ms^{-1}) from northeast Texas to southern Illinois. Mid level temperatures south and east of the jet streak, in the general area of Convective Band Two, warmed by 3-5 degrees C during the course of the day. Hoxit and Chappell (1975) attribute this warming to a combination of diabatic processes (latent heat release), advection and subsidence on the equatorward side of the upper jet. The warming is not consistent with the concept of a cold front aloft, and does not support the notion that Band Two was "directly connected" with an upper front as proffered by Locatelli et al. (2002).

By 0000 UTC the northern part of Convective Band One had long since dissipated over New York and Pennsylvania. The southern part, meanwhile, had become indistinguishable after having interacted with existing supercell storms along the stalled front over the western Carolinas. Farther west, Band Three continued east across Illinois, Indiana and western Kentucky, where individual radar-observed cell motion reached 60 kts (30 ms^{-1}). The system also developed north into southern Michigan, where two tornadoes occurred in a region of backed low level flow near the surface warm front around 0030 UTC. Band Three remained very strong through the evening and did not show appreciable weakening until it encountered rain-cooled air over Ohio and central Kentucky around 0600 UTC Thursday.

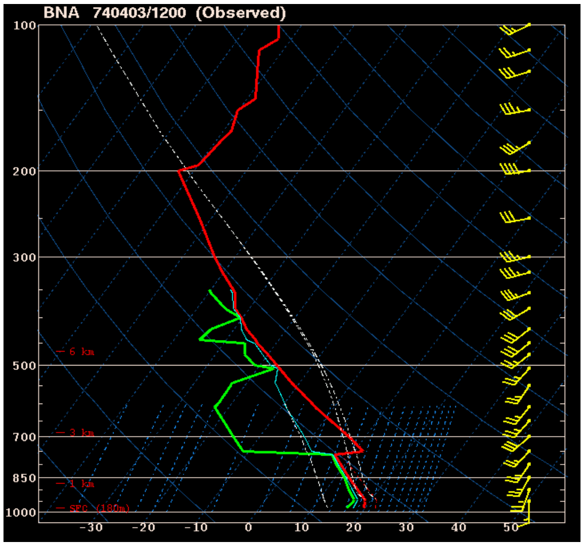
While severe weather continued in conjunction with Band Three well into Wednesday night, after 2300 UTC, the most intense activity shifted to areas south of the Ohio River in association with Band Two. In far northern Alabama, a tornado which reached F5 intensity and that had a path length of 85 miles (136 km) severely damaged several communities in Lawrence, Limestone and Madison counties between 0000 and 0030 UTC. A second tornado, following almost directly in the path of the first storm, had a path length of 20 miles. These storms remained intense as they moved into southern Tennessee. Elsewhere, major tornadoes struck areas north and west of Birmingham as rich moisture inflow continued beneath an environment of intense (80 kt (40 ms^{-1}) deep shear at the southern end of Band Two. Between 0100 and 0200 UTC in middle Tennessee, Band Two also spawned another cluster of violent tornadoes that swept northeast into southern Kentucky. The last tornado in Kentucky occurred around 0430 UTC, but severe weather continued in Tennessee beyond midnight Central Time (0500 UTC) as storms associated with Band Two encountered the rising terrain in the far eastern part of the state. Embedded supercells continued to produce damaging winds and additional tornadoes until nearly dawn (1000 UTC) Thursday northward into southern West Virginia and western Virginia. The events in the latter two states were extremely unusual considering not only the time of day but also the relatively low incidence of severe weather of any kind in those areas at that time of the year.

3. ETA MODEL OUTPUT

As previously noted, output from a 29 km, 50 layer version of the Eta forecast model was examined to assess the model's skill in depicting synoptic and mesoscale aspects of the outbreak. The model was initialized with synoptic scale data valid at 0000 UTC 3 April provided by the NCEP/NCAR reanalysis fields (2.5 deg x 2.5 deg grid and 17 levels). A goal was to investigate how well the model would depict mesoscale features when initialized with coarse initial conditions.

In Figure 9, the 24-hour surface and 500 mb model forecast fields valid at 1200 UTC 4 April are compared to the corresponding analyses. The Eta29 has clearly performed very well in depicting major features at both levels. The intensity and location of the surface low, as well as the speed and direction of the 500 mb jet streak are all well forecast. And, as shown in Figure 10, the 24-hour total precipitation forecast bears a strong resemblance to the observed data. In particular, the model correctly places the axes of heavier precipitation over both the southern Appalachians (associated with the stalled cold front) and the upper Mississippi Valley (in the region of sustained large scale ascent north of the surface low). The Eta does, however, show somewhat less skill over the Ohio Valley.

To more closely examine the model's convective precipitation forecasts, plots of three-hourly accumulated model precipitation were compared to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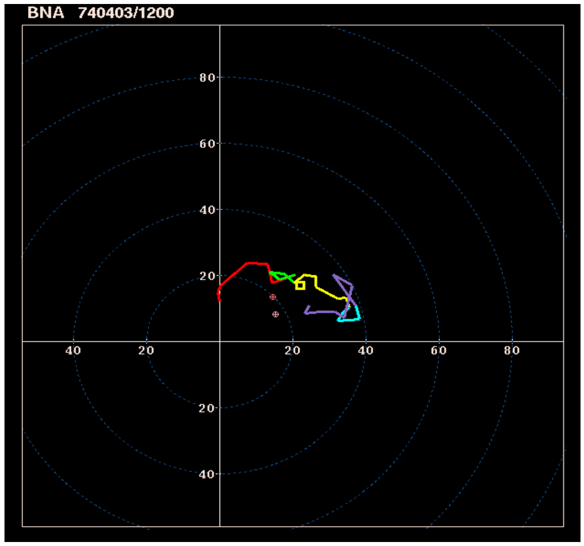
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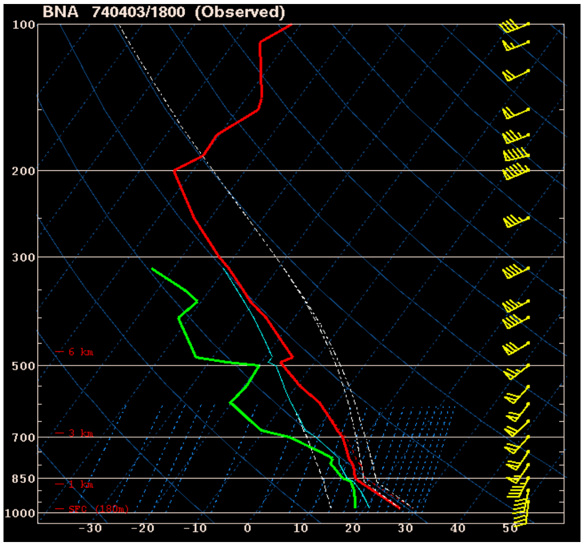
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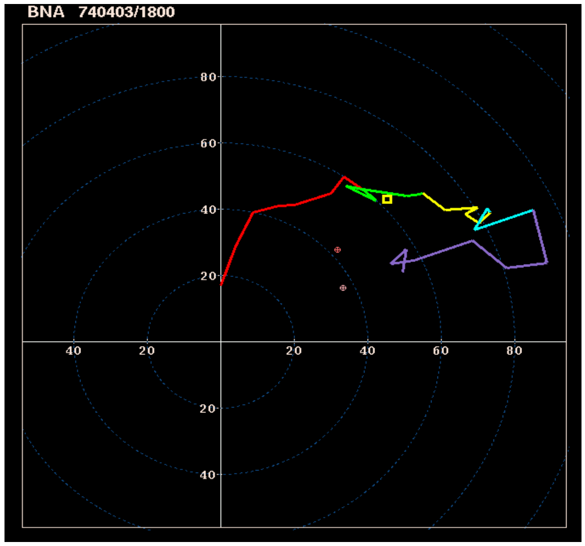
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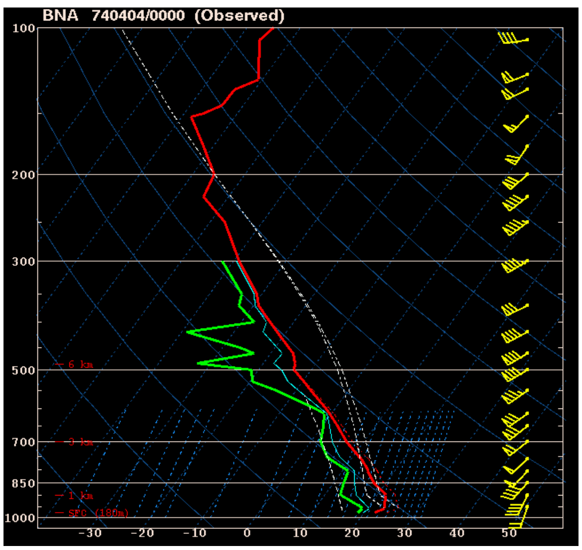
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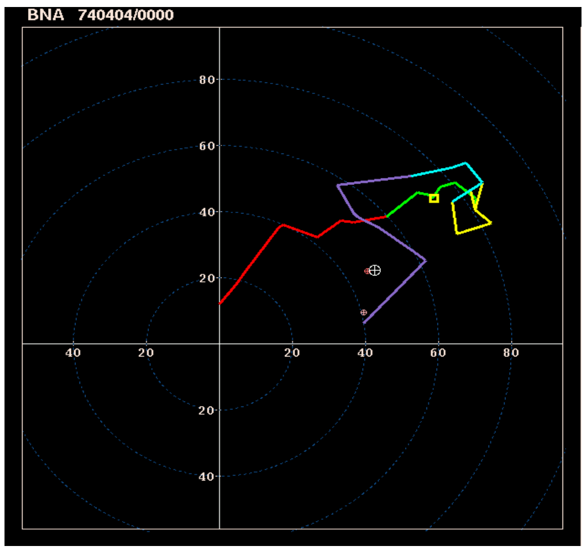
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Figure 7. (Previous page) Radiosonde (left) and hodograph (right) plots for Nashville, TN at (a) 1200 UTC 3 April, (b) 1800 UTC 3 April, and (c) 0000 UTC 4 April 1974. Sounding depicts temperature in red and dewpoints in green. Hodographs color coded for height (0-3 km, red; 3-5 km, green; 6-9 km, yellow; 9-12 km, blue; greater than 12 km, purple). Wind speeds on sounding and range rings on hodographs are in knots.

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the radar positions of convective bands given in Figure 6. It is readily apparent that at best the Eta29 is only minimally skillful in providing useful information regarding the location and timing of mesoscale convective features. While the model does indicate likelihood for afternoon convection in the Ohio and Tennessee Valley, it fails to depict Convective Band One, and only hints at the presence of Band Three. The Eta also over-forecasts activity near the stalled front in the Appalachians. The location, intensity and timing errors of the model's convective precipitation forecasts affect, in turn, its handling of various thermodynamic fields. For example, forecast lapse rates and CAPE are erroneously weakened over middle and eastern Tennessee as a result of the over forecasting of convective rainfall in the adjacent southern Appalachians (Figures 4d and 5d).

In summary, the Eta29, initialized with synoptic scale data, provided a reasonable forecast of the large scale environment conducive to severe convective storms. But the model was less skillful in anticipating convective initiation and location. This likely reflects both the low resolution of the input data, and the model's incomplete parameterization of processes related to convective development.

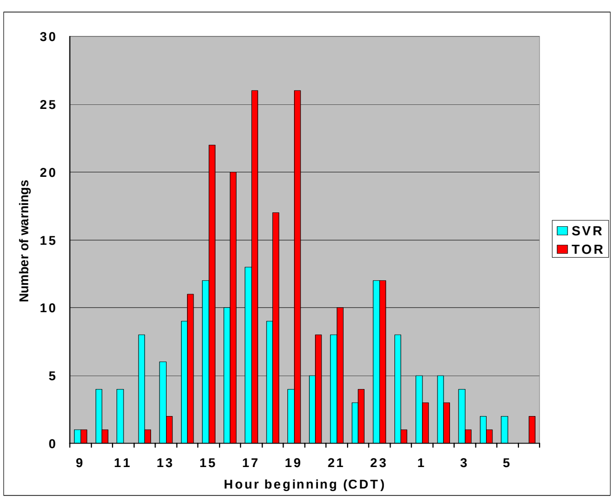

Figure 8. Number of severe thunderstorm (blue) and tornado (red) warnings issued per hour by local National Weather Service offices during the Super Outbreak. Time in CDT (add 5 for UTC). Data from U.S. Department of Commerce (1974).

4. CONCLUDING THOUGHTS

This paper has presented an updated synoptic and mesoscale overview of the 3-4 April 1974 Super Outbreak of tornadoes. The Outbreak was clearly singular in terms of the intensity, longevity and scope.

It might be expected that an event of such magnitude would be associated with a correspondingly rare, readily recognized synoptic scale signature. But such is not the case.

For example, while the Colorado-Kansas lee cyclone which formed prior to the Super Outbreak was rather impressive, such storms are far from unprecedented; two or three such developments might occur each decade. Jet streaks in excess of 120 kts (60 ms^{-1}) similarly are also not rare. And CAPE frequently exceeds 2000 J/kg over the Ohio and Tennessee Valleys in spring. What then likely contributed to the unusual nature of the Super Outbreak?

Instead of a single "smoking gun," it appears that several factors which came together more or less by chance were largely responsible for the Super Outbreak. Not to be discounted, the unusually strong upper level jet streak associated with the progressive Great Basin trough certainly set the stage for a severe weather event by creating large scale conditions favorable for expansive lee cyclogenesis. The jet maximum not only provided the necessary shear for intense, sustained supercells, but also helped focus the mesoscale areas of ascent that assisted in convective initiation.

At the same time, the warm sector during the Super Outbreak was not only very broad but also unusually warm and moist for early April. These characteristics were established, in part, when the trailing frontal system associated with the previous shortwave impulse failed to effect a significant air mass change over the Southeast. This enabled simultaneous occurrence of both dry line storms ("Band Two") and jet exit region activity ("Band Three") as the Great Basin disturbance progressed east northeast into the Plains. Oftentimes, because of the limited aerial extent of surface-based instability, severe weather episodes associated with "ejecting" lee cyclones are limited to dry line/lee trough activity on the initial day of ejection, and jet exit region storms on the succeeding one.

Climatological data suggest another factor that may have contributed to the "quality" of the warm sector boundary layer over the southeastern states on 3 April 1974. Mean constant pressure charts for the previous few weeks (not shown) depict the presence

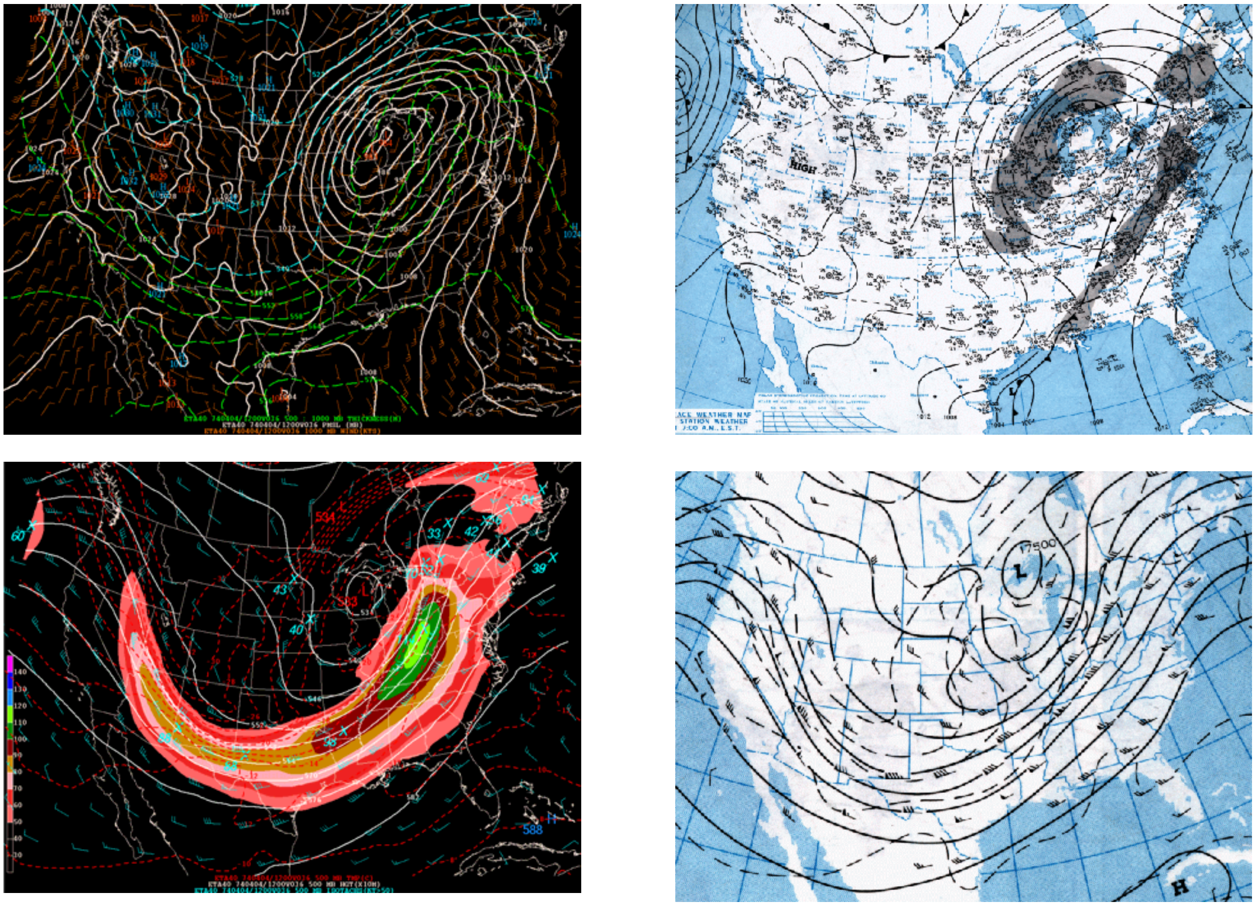

Figure 9. Comparison of 36-hour Eta29 forecast fields (left) with observed data (right). Surface pressure (top) in mb, with 1000-500 mb thickness field dashed green (model field only). 500 mb heights in dm; temperatures in degrees C (dashed) and wind speed in knots. Eta central surface pressure 983 mb; observed pressure 988 mb. Eta maximum 500mb wind speed 114 kts; observed 120 kts.

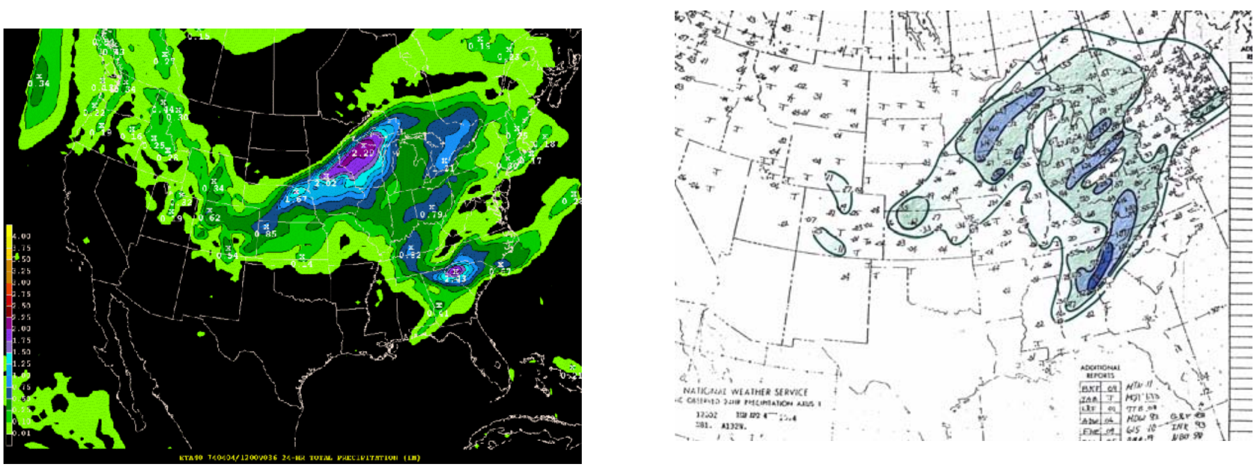

Figure 10. Comparison of 36-hour Eta29 12-hour total precipitation forecast (left) with observed (right). Amounts in inches; contour interval in model field, .25 inches; in observed field, variable (.10, .50., 1.00 and 2.00 in.).

of a persistent upper level ridge over the Caribbean Sea and southern Gulf of Mexico. The ridge had restricted cold frontal penetrations into the region for much of the month of March. This may have allowed a warmer and moister boundary layer to evolve over the Gulf than is usual for the time of year.

Yet another factor which set the Super Outbreak apart was the well-defined gravity wave or bore which provided a "bonus" third source of organized uplift. This feature helped initiate deep convection in areas that may otherwise have remained capped to development. The bore, in conjunction with daytime heating, also helped rejuvenate existing storms in Georgia and the Carolinas.

Returning to the kinematic environment, it is important to note that the ***fast but low amplitude nature of the upper jet pattern*** was also influential in the event. This pattern not only (1) allowed for rapid, undiluted advection of the elevated mixed layer plume eastward from the Plateau into the Mississippi, Ohio and Tennessee Valleys, but also (2) delayed / discouraged storm evolution toward linear convective modes. By enabling storms to remain discrete for a maximum period of time, the potential for both tornado development and longevity were enhanced. The low amplitude flow also likely limited the coverage of high level, "warm conveyor belt" clouds which often restrict diabatic heating in more highly amplified regimes. Low amplitude, fast flow patterns have been associated with other significant severe outbreaks in recent years (e.g., Arkansas, 21 January 1999; Tennessee and Ohio Valleys, 10 November 2002).

Finally, it is worth noting that the diurnal cycle was favorably timed with respect to the arrival of rich boundary layer moisture and the intensification of deep shear over the Ohio and Tennessee Valleys during the Super Outbreak.

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