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[1]PATTERN RECOGNITION AND THE MILWAUKEE FLASH FLOOD OF AUGUST 6, 1986

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1. Introduction

Five or more inches of rain occurs almost daily somewhere in the U.S. during the warm season (April-September). Hurricanes and mesoscale convective complexes (MCCs) are obvious excessive rainfall producers. However, Spayd and Scofield (1983) documented SHARS, a subtle heavy rainfall signature (satellite) consisting of 'warm-topped' (low equilibrium level) convection embedded in the northeast quadrant of a synoptic scale cyclonic circulation (surface-500 mb). This is quite different from the three basic meteorological patterns (synoptic, frontal, mesohigh) defined by Maddox et al. (1979) that generate flash floods in the eastern two-thirds of the U.S.

On August 6, 1986 between 1700 and 2000 UTC (noon and 3:00 p.m. CDT) warm topped convection spilled six inches of rain onto downtown Milwaukee, Wisconsin. The subsequent flash flood resulted in one fatality and nearly $30,000,000 in damage.

This study forwards the hypothesis that pattern recognition could have been used based on the National Meteorological Center's (NMC) numerical models to call attention to the possibility of heavy rain somewhere in the lower Great Lakes region. In order to test the hypothesis, the study addresses the following questions:

(1) How well did the surface and upper air patterns of August 6th over the Midwest compare with SHARS composite cyclonic circulation?

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(2) How well were the flash flood patterns forecast by the nested-grid model (NGM) and limited area fine-mesh model (LFM)?

(3) How often does this pattern produce heavy rainfall?

2. Data and Procedures

Data used for this study were observations and model products. Observations were from National Weather Service (NWS) first-order stations, flight service stations, Coast Guard stations, buoys in Lake Michigan, and RAOBs from throughout North America. Initial and forecast model analyses were courtesy of NMC. Six seasons (1981-1986) of archived initial analyses including surface, upper air and 24-hour rainfall were provided by NMC's Forecast Branch.

The study proceeded as follows. First, the initial analysis of 12Z August 6th was compared with the SHARS composite. Second, the LFM's and NGM's 24-hour forecasts from the 12Z run of August 5th were compared with the initial analysis. Finally, SHARS cyclonic circulation patterns over the past six summer seasons (June 1st through September 15th) were examined to see how many were associated with 24-hour rainfalls of five inches or more.

The comparison was done without using satellite imagery because the SHARS composite offers forecasters the opportunity for pattern recognition well in advance of the event (12-24 hours). Satellite imagery is best suited for confirming the event plus or minus three hours of occurrence.

3. Results

3.1 August 6th 12Z analysis

In this section the 12Z August 6th upper air and surface patterns are compared to the composite of Spayd and Scofield. The composite was an average of five flash flood cases over the eastern two-thirds of the U.S.

Figure 1 is the analysis and composite at 500 mbs. A trough in the streamline pattern is seen in both. The maximum vorticity associated with this trough is $16 \times 10^{-5}\ s^{-1}$. The vorticity fields are circular and MKE is located to the northeast of the vorticity center in the preferred region of flash flood potential as outlined in the composite. At 850 mbs (Fig. 2), the 12Z analysis shows the jet axis southeast of MKE. This is similar to the composite, where the jet is south and east of the preferred region of flash flood potential. As stated in Spayd and Scofield, this is different from the Maddox et al. (1979) flash flood composites where the 850 mb jet is nosed directly into the region of flash flood potential. Dewpoints are near $10^{o}C$ over MKE and greater than $10^{o}C$ over much of the flash flood region in the composite.

At the surface (Fig. 3), the 12Z analysis shows a weak low near Moline, Illinois with MKE north of the surface trough. Similarly, the composite shows the flash flood potential region to be north of the surface low and trough.

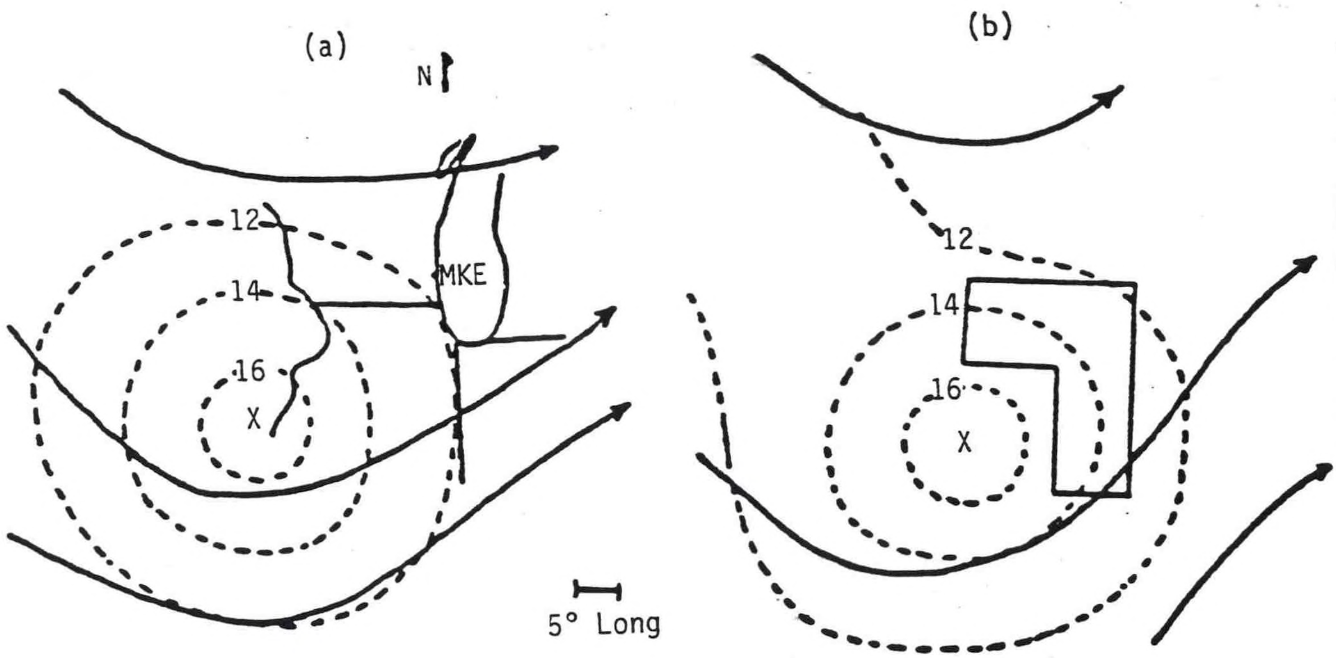

Fig. 1. (a) 500 mb analysis at 12Z August 6th and (b) 500 mb SHARS composite. Streamlines are solid arrows and dashed lines are isopleths of absolute vorticity.

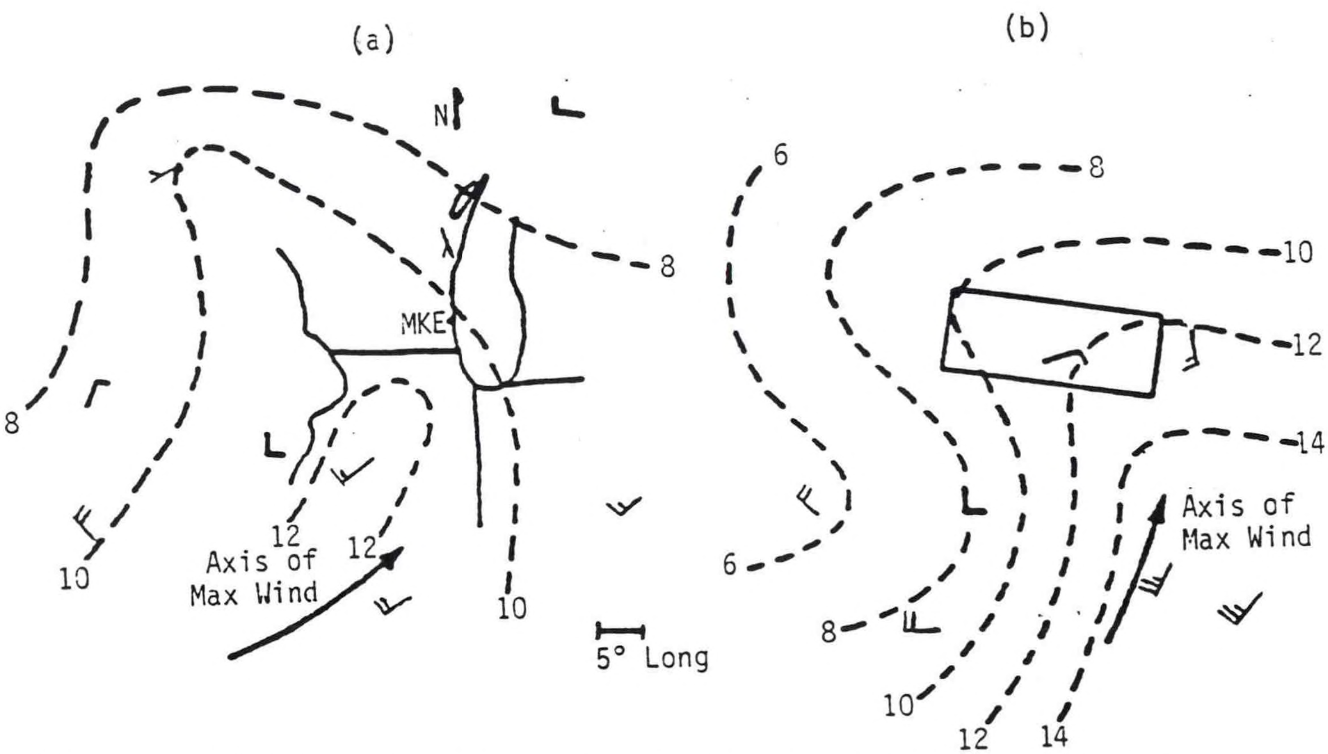

Fig. 2. (a) 850 mb analysis at 12Z August 6th and (b) 850 mb SHARS composite. Arrow depicts axis of maximum winds and isodrosotherms are dashed in units of °C. Wind speeds are in knots.

The 12Z vertical profiles from observations and from the composite are shown in Figure 4. The profile for MKE is an average of PIA and GRB except at the surface where only MKE data is used. Similar characteristics were found in this average profile compared to the composite, particularly at the surface where the temperature and dewpoint are nearly identical.

3.2 The model forecasts

In order to assess how well the weather patterns were forecast by the NMC models, the 24-hour 500 mb forecasts (12Z run of August 5th) of the LFM and NGM (Fig. 5) were compared with the 12Z August 6th analysis. Both models accurately predicted a substantial circular vorticity maximum to the southwest of MKE.

Figure 6 displays the 24-hour surface forecasts. The LFM depicted a trough across south central Wisconsin with its axis north of MKE. On the other hand, the NGM forecast the trough across northern Illinois close to the verified position. The NGM also predicted a low pressure center near Moline, Illinois. While the LFM did not isolate a low center, one could infer a weak center somewhere in the 'baggy area' of low pressure over eastern Iowa and southwestern Wisconsin.

Historically, the models quantitative precipitation forecasts (QPF) have been one of the weaker elements of NMC guidances (Keyser and Uccellini, 1987) especially during the summer convective season when subtle low-level surface boundaries focus convection. The addition of the NGM to the array of models has been helpful in alerting forecasters to the potential for vigorous convection. This is especially true during the first 24 hours of the models run. A fundamental goal of this model was to improve forecasts of heavy precipitation out of 48 hours (Technical Procedures Bulletin 345). A by-product of the model has been a more realistic depiction of high/low relative humidity corridors and strong vertical velocity fields.

In Figure 7, the 36-hour LFM and NGM 12-hour accumulation of rainfall (QPF) ending on 00Z August 7th are compared. This time period includes the time of the flash flood. The NGM, while not predicting six inches of rain, out performed the LFM by forecasting amounts four times of those predicted by the LFM.

3.3 Recent climatology

A survey was done in which the past six (1981-1986) summer seasons (June 1-September 15) were checked for SHARS cyclonic circulation characteristics. After isolation of SHARS events based on 500 mb, 850 mb and surface charts, precipitation analyses were examined to determine whether the events were associated with heavy rainfall. For this exercise, a SHARS cyclonic circulation heavy rainfall event was defined with respect to the movement of the 500 mb vorticity center where at least one station in the left-forward quadrant (see Fig. 8) reported a 24-hour rainfall of five inches or greater.

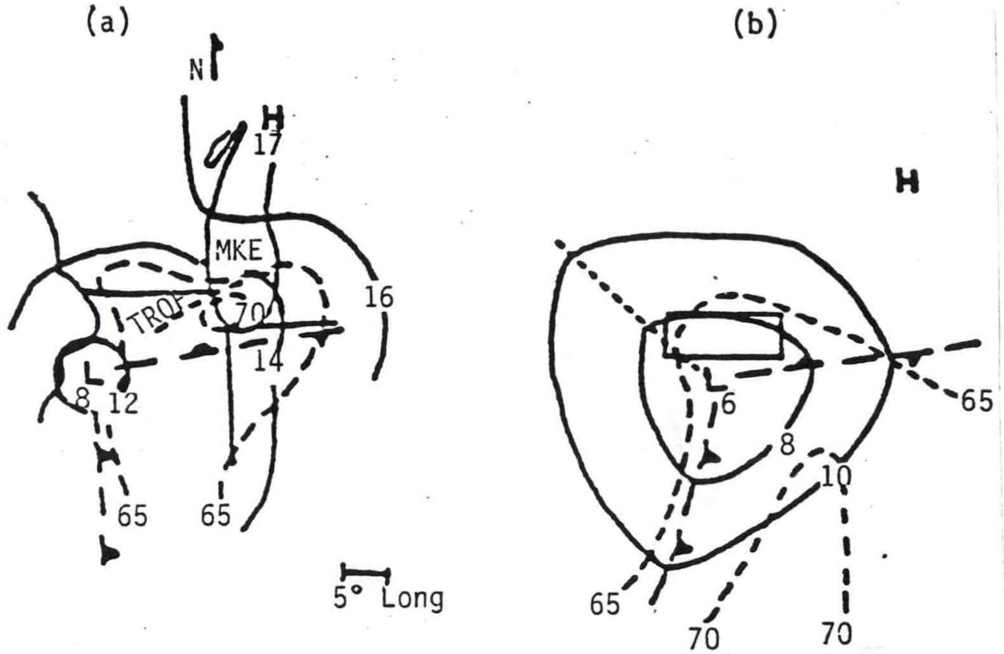

Fig. 3. (a) Surface analysis at 18Z August 6th and (b) surface SHARS composite. Isodrosotherms are dashed in units of °F, isobars are solid in units of mbs + 1000.

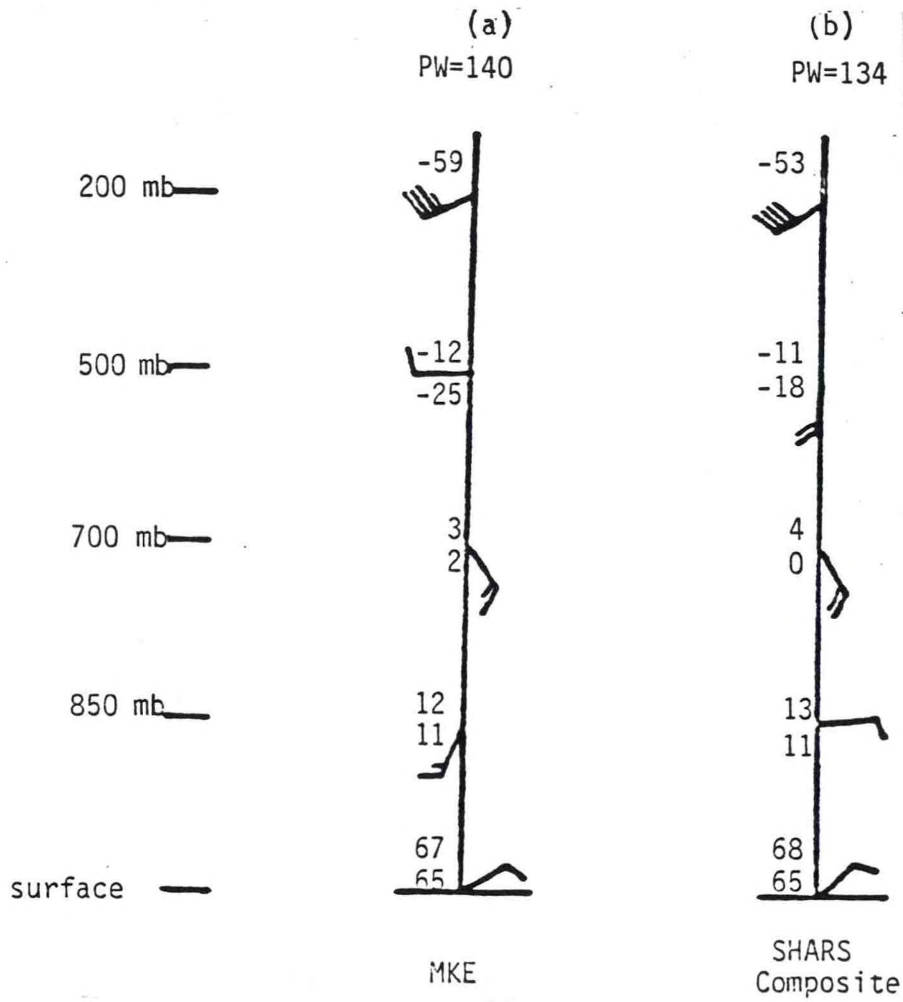

Fig. 4. (a) Averaged vertical profile between GRB and PIA except at the surface where data from MKE are used and (b) vertical profile of SHARS composite. Temperatures and dewpoints are in °C except at the surface where they are in °F. Wind speeds are in knots.

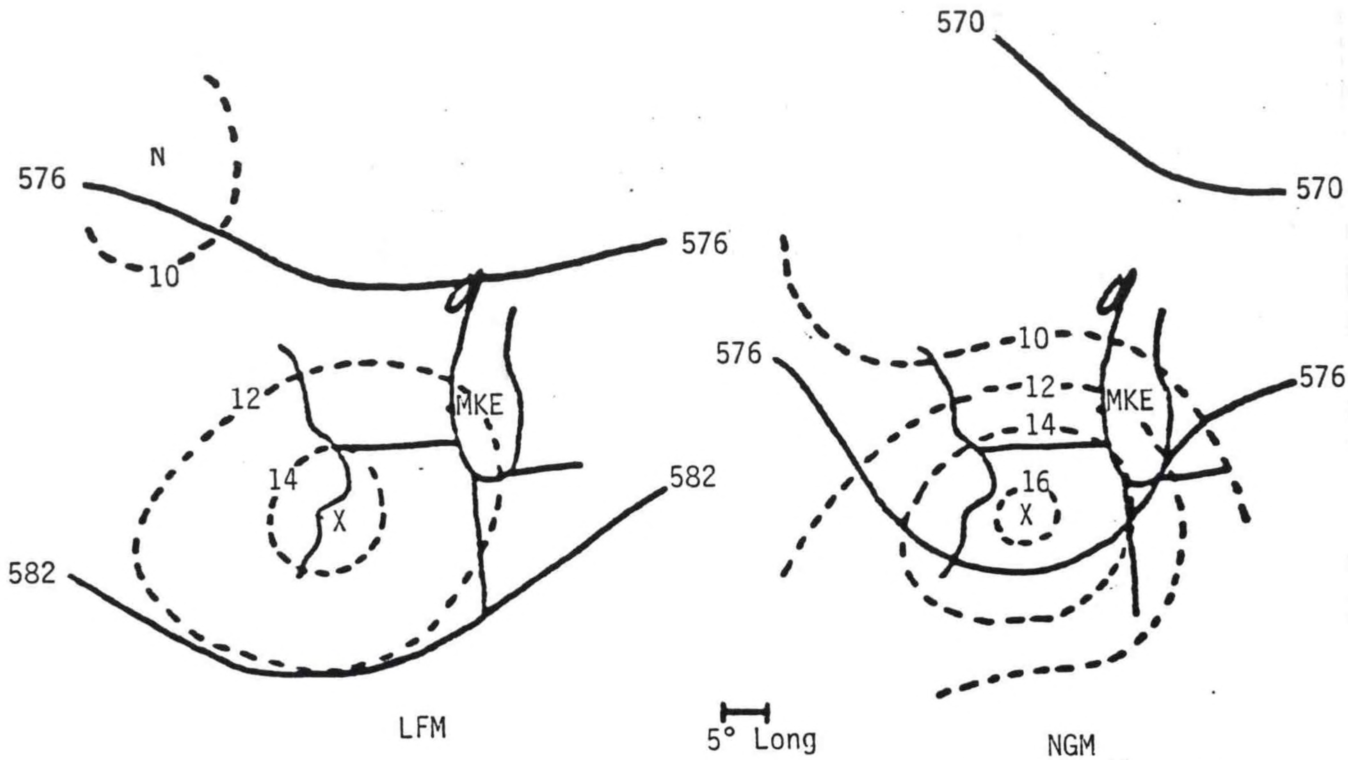

Fig. 5. 24 Hour 500 mb forecasts of heights and vorticity valid at 12Z August 6th from the LFM (left) and NGM. Contours are solid lines labeled in dm and isopleths of vorticity are dashed lines.

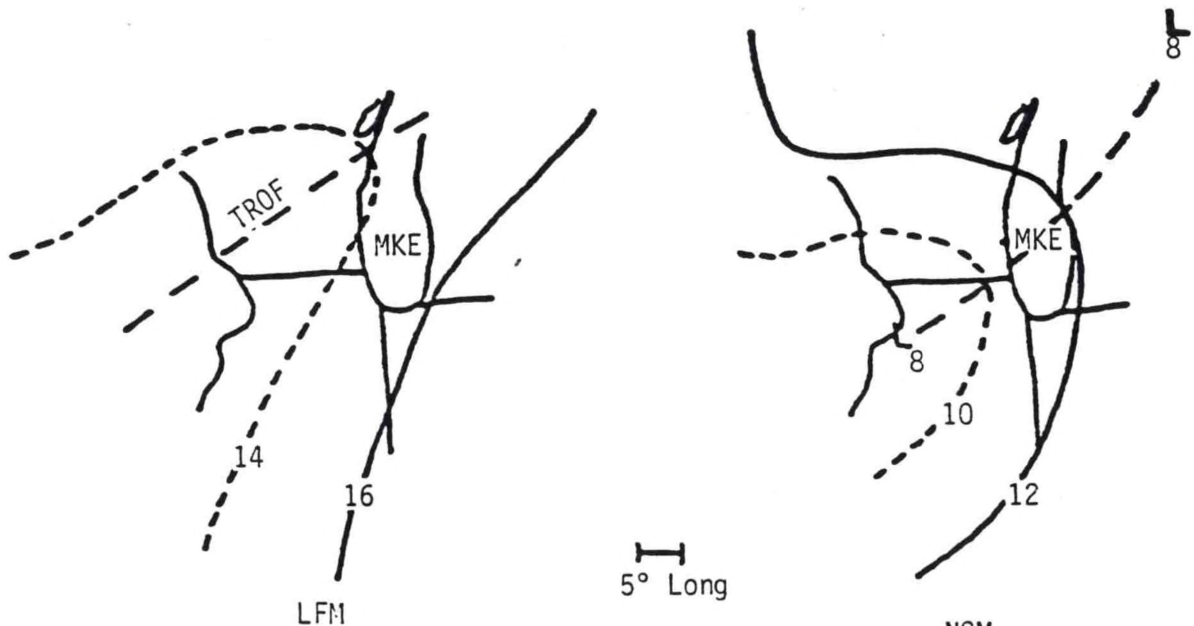

Fig. 6. Same as Fig. 5, except surface forecasts. Isobars are solid in units of mbs + 1000. The trough axis is depicted with a dashed line.

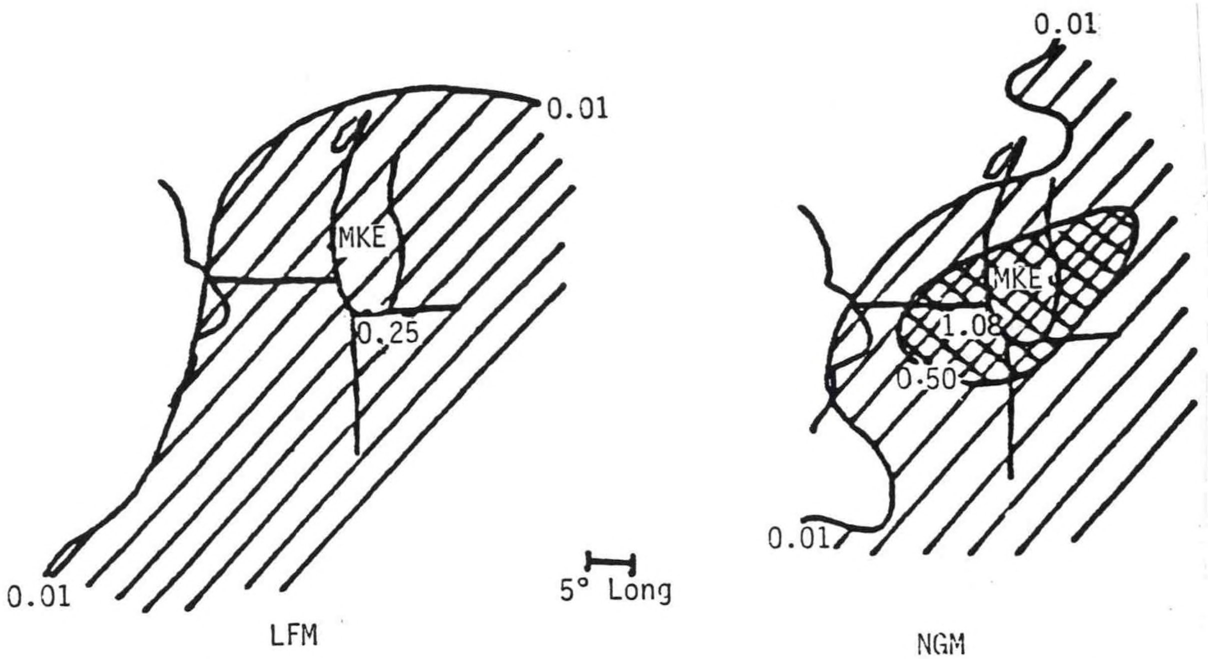

Fig. 7. 36 Hour forecasts of 12-hour accumulated precipitation valid at 00Z August 7th from the LFM (left) and NGM. Hatched area indicates a forecast of 0.01" or greater and shaded area indicates a forecast of 0.50" or greater.

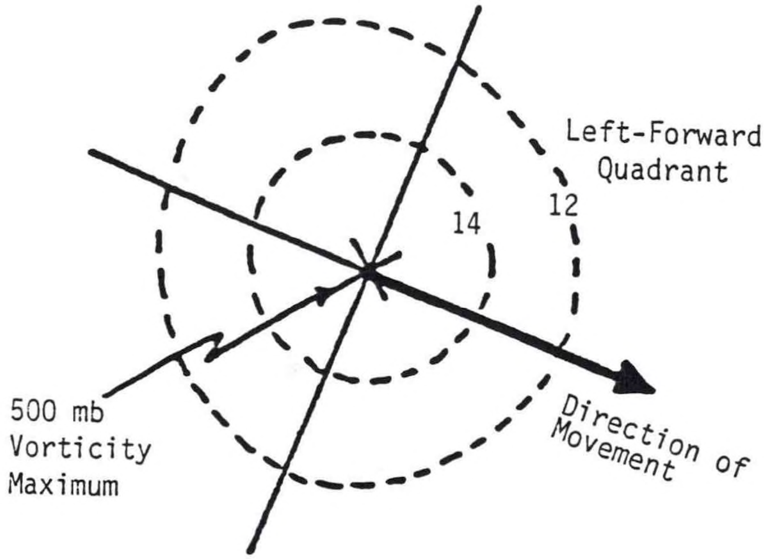

Fig. 8. Coordinate system used in the selection of SHARS circulation cases. Thick arrow indicates direction of movement of the vorticity center. Solid lines delineate the quadrants.

Screening for SHARS events was done as follows. Initially potential cases were isolated based on the 500 mb flow. The following criteria were used. The system:

(1) It had to be east of the Rockies,

(2) had to have a minimum height no lower than 5700 m,

(3) had to be analyzed with one circular vorticity isopleth of 14 units or greater,

(4) could not have any westward movement of the vorticity maximum, and

(5) could not be associated with a tropical disturbance.

Cases accepted based on the 500 mb criteria were then checked at 850 mbs and the surface. Cases were eliminated which did not have a 850 mb low nearby or which had 850 mb dewpoints less than 10°C. At the surface, cases were eliminated which did not have a trough and which had dewpoints less than 18°C.

The screening technique used the SHARS composite pattern as a starting point. However, it was not limited to eastward or northeastward moving systems or particular translational speeds. Results of this survey show that during the past six summer seasons, ten of the 17 cases (59%) which were SHARS cyclonic circulation systems produced at least five inches of rain somewhere in the left-forward quadrant with respect to the movement of the 500 mb vorticity maximum. Six of those ten resulted in flash flood episodes as documented in Storm Data.

4. Summary and Discussion

This study was a comparison of the weather patterns similar to that which produced the Milwaukee flash flood of August 6, 1986. Comparisons were made with the SHARS composite of Spayd and Scofield (1983) and with NMC's numerical model forecasts. Also included was a review of the past six summer seasons to determine the frequency of heavy rainfall associated with SHARS cyclonic circulation systems.

The Milwaukee flash flood fit the classic pattern of the SHARS composite. Model forecasts accurately predicted the SHARS patterns 24 hours in advance of the flood. Results of the recent climatology survey showed that even though, according to the strict criteria used, a SHARS event is rare on a given summer day, when it occurs it is often (about 60% of the time) associated with heavy rainfall somewhere immediately to the left and ahead of the 500 mb vorticity maximum track and the 850 mb low track. An interesting point and perhaps one which deserves further study is that this same synoptic scale circulation that produces heavy rain in summer is often responsible for heavy snow in winter.

The survey of summer seasons was necessarily done in a subjective manner for the following reasons. Time was not available to do exhaustive research since the survey was performed by the principal investigator in an operational environment. The goal was to look at SHARS cyclonic circulation systems from the perspective of a forecaster who among her/his duties has to make briefly thought-out decisions. Pattern recognition is an extremely useful tool in focusing a forecasters attention to this particular problem.

5. Acknowledgements

The authors would like to express their sincere gratitude to Frank Brody, LeRoy Spayd and Jim Belville for their helpful comments and encouragement during the course of this research.

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