ANNUAL SUMMARY

Mesoscale Convective Complexes over the United States during 1982

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ABSTRACT

An important class of convective weather system, the mesoscale convective complex (MCC), presents many challenges and problems to both the research and operational communities. In addition, these very large and long-lived thunderstorm systems have a significant social and economic impact resulting from associated severe weather phenomena and widespread beneficial rain. Enhanced infrared satellite images were surveyed to document MCCs which occurred over the United States during 1982. Thirty-seven convective mesosystems were identified that displayed satellite-observable characteristics which satisfied the MCC criteria described by Maddox. Details of the life cycles of the 37 cases are given and several specific cases are discussed. Current and proposed future research will focus on what are perceived to be key questions surrounding these important weather systems. This annual summary is offered as a starting point for scientists interested in pursuing studies of mesoscale convective weather systems.

1. Introduction

Mesoscale convective complexes (MCCs) have been documented and their meteorological and social importance have been discussed in recent literature (Maddox, 1980; Bosart and Sanders, 1981; Maddox *et al.*, 1982). The definition of MCC is reproduced in Table 1 (Maddox, 1980). This definition describes characteristics, observable in enhanced infrared satellite imagery, which were used to identify long-lived meso-α scale[2] convective systems. This satellite-based definition was developed to aid studies of significant convective mesosystems; in addition, it has stimulated interest in and drawn attention to mesosystems in middle latitudes. However, the definition is not meant to uniquely describe all examples of organized convective mesosystems nor does it attempt to describe or classify the internal structure or physical processes associated with MCCs.

Mesoscale convective complexes are often significant weather events for a number of social, economic, and meteorological reasons. During their typical 12–15 hour life cycle, MCCs often produce a variety of "weather". This may include tornadoes, large hail, torrential downpours, and damaging wind gusts from severe thunderstorms and "super cell" storms often present during early stages of MCC evolution. In addition, MCCs typically produce broad areas of light to moderate rainfall and more concentrated regions of flash flooding, urban street flooding, and vigorous lightning activity. The resulting economic effects of just a single MCC can be enormous in terms of deaths and injuries, property and crop damage, interruptions to flight operations, power outages, etc. (see for example Maddox and Fritsch, 1982). The fact that very large mesosystems (MCCs) occur 30–40 times a year (based on the last 5 years) indicate that they likely supply a major portion of growing-season rain to the wheat, corn, and cotton belts (Fritsch *et al.*, 1981). Due to their large size and long duration, important mesoscale/large-scale interactions take place, seriously impacting the accuracy of the operational numerical forecast models (Fritsch and Maddox, 1980, 1981; Maddox *et al.*, 1981; Maddox and Heckman, 1982). The effects of an MCC can persist 24–36 h as thunderstorm-produced surface mesohighs and outflow boundaries provide mechanisms to influence subsequent weather (Purdom, 1979). Johnston (1981) has identified, again from satellite imagery, remanent low-to-midtropospheric mesoscale cyclonic vorticity centers (MVCs) in the vicinity of a decaying MCC after the active convection of the MCC has ceased. In many cases, these MVCs appeared to initiate or enhance convection long after dissipation of the generating MCC.

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[2] Denotes horizontal dimensions on the order of 0.2–2 ($\times 10^3$) km (Orlanski, 1975).

TABLE 1. Mesoscale convective complex (MCC) (based upon analysis of enhanced IR satellite imagery).

	Physical characteristics
Size	A—Cloud shield with continuously low IR temperature ⩾ 100 000 km^2 B—Interior cold cloud region with temperature ⩾ −52°C must have an area ⩾ 50 000 km^2
Initiate	Size definitions A and B are first satisfied
Duration	Size definitions A and B must be met for a period ⩾ 6 h
Maximum extent	Contiguous cold cloud shield (IR temperature ⩾ −32°C) reaches maximum size
Shape	Eccentricity (minor axis/major axis) ⩾ 0.7 at time of maximum extent
Terminate	Size definitions A and B no longer satisfied

Recent studies at the Environmental Protection Agency indicate that mesoscale convective systems also have a dramatic impact on regional distributions of planetary boundary layer (pbl) pollutants, visibility and acid rain. Because of large horizontal and vertical mass transports associated with MCCs, broad areas of the polluted pbl are vented. Sulfates and oxidants are ingested into updrafts and carried to the middle and upper troposphere. Boundary layer air is replaced by "cleaner" entrained midtropospheric air carried to the surface as downdrafts. Much of the pollutants serve as cloud condensation nuclei; some falls as rain while substantial amounts are injected into the free atmosphere in the cirrus cloud shield. Thus, mesoscale convective precipitation systems have been linked to episodes of acid rain deposition as well as "wash-out holes" of greatly increased visibility and significantly depleted ozone levels in the surface mesohigh region. Additionally, MCCs may constitute a previously underestimated significant sink of pbl pollutants through relocation to the upper troposphere and dispersion to distances as great as several states in divergent anvil outflow (Lyons and Colby, 1983). These findings may have important ramifications to air pollution transport modeling efforts.

Therefore, in light of these important aspects of mesoscale convective complexes, the following annual summary has been prepared. The authors hope that it will serve as a starting point for scientists in various disciplines interested in researching the causes and consequences of these important weather systems.

2. 1982 MCCs

The MCC season of 1982 lasted from late March through early September. During this period, 37 MCCs were identified from enhanced infrared satellite imagery. Table 2 provides details of the life cycles of each system including associated severe weather reports. Figs. 1a–1e depict the paths followed by the centroid of the satellite-observed cold cloud shield of each MCC. The track spans the period from first storms to dissipation.

Compared to the 23 cases documented during 1981 (Maddox *et al.*, 1982), 1982 provided an eventful season. Each one of the 37 cases resulted in reports of severe weather[3] (according to the monthly NOAA NESDIS publication *Storm Data*). Associated severe weather phenomena caused the loss of several hundred million dollars in property and crop damage, 13 deaths, and over two hundred injuries. Vast areas of the central United States were repeatedly visited by beneficial growing-season rains as well as severe and damaging weather produced by the MCCs. Detailed rainfall statistics were not compiled for this summary, however 27 of the 37 cases were associated with heavy rain and/or flood reports. Most of the deaths and injuries resulted from these floods.

The average 1982 MCC life span covered more than 14 hours from initial deep convection [identified by the first appearance of medium gray −32°C enhancement on the satellite image, using the MB enhancement curve (NOAA, 1976)] to the decay of the cold cloud shield below the size criteria in Table 1. Similar to past cases, these events showed a strong nocturnal tendency. While there was considerable variation from case to case, typically the first thunderstorms developed in midafternoon (local time), grew and/or merged to MCC proportions (refer to Table 1) by late evening, reached a maximum extent of cold cloud shield around 0200 LST, then weakened and decayed by sunrise (Table 2). Measurements of the cloud shield at maximum extent yielded an average size of 2.81×10^5 k m^2 which is almost equal to the combined areas of Iowa and Illinois.

One of the most destructive and violent cases in 1982 occurred on 11–12 May (case 6, Figs. 1a, 2). It began with thunderstorms which developed along the Caprock Escarpment of the Texas Panhandle within the warm sector of a relatively strong synoptic weather system. The initial thunderstorms grew vigorously in a region of strong low-level warm, moist advection. Much of the damage occurred early in the MCC development as intense thunderstorms passed over southwest Oklahoma producing 18 tornadoes, large hail (described as having size and shape resembling charcoal briquettes), and numerous funnel clouds. Two people were killed and 59 injured by tornadoes. Altus Air Force Base and the town of Altus sustained over $200 million in damages. Later in its life cycle, the mesosystem produced over 12 cm of rain, resulting in flash floods and one more death. Oklahoma suffered additional severe weather four days later as two more MCCs moved over the same region (cases 7, 8, Figs. 1a, 1b).

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[3] Severe weather in this context denotes tornadoes, hail ⩾ 2 cm, wind speeds ⩾ 25 m s^{-1}, lightning damage, and/or flash flooding.

TABLE 2. Mesoscale convective complexes during 1982.

Case number	Date	Time (GMT) First storms	Time (GMT) Initiate	Time (GMT) Maximum extent	Time (GMT) Terminate	Duration (hours)	Cloud top area at maximum extent (×10³ km²) ≤ −32°C	Cloud top area at maximum extent (×10³ km²) ≤ −52°C	Significant weather*
1	19 Mar	0000	0600	0800	1300	13.0	467	279	T, W, L, R, F
2	17 Apr	0000	0600	0900	1500	15.0	400	349	T, H, W, L, R, F
3	19–20 Apr	1415/19	2200/19	0200/20	1000/20	19.75	288	224	T, H, W, L, R, F
4	20–21 Apr	1230/20	1500/20	2030/20	0330/21	16.0	385	313	T, H, W, L, 1K
5	10–11 May	2045/10	0145/11	0415/11	1130/11	14.75	198	99	T, H, W, R, F
6	11–12 May	1930/11	0600/12	0915/12	1315/12	17.75	210	189	T, H, W, R, F, 3K, 59I
7	16 May	0100	0630	1415	2100	20.0	286	196	T, H, W, R, F
8	16–17 May	2000/16	0030/17	0430/17	0730/17	11.5	435	242	T, H, W, F
9	07 Jun	0500	0830	1200	1900	14.0	328	201	T, H, W, R, 8I
10	08 Jun	0545	1015	1431	2200	16.25	235	188	H, W, L, R, F, 1K
11	08–09 Jun	1200/08	1845/08	0100/09	1000/09	22.0	294	216	T, H, W, R, F
12	09–10 Jun	2045/09	0100/10	0330/10	0730/10	10.75	268	188	T, H, W, F
13	10–11 Jun	1600/10	2030/10	0115/11	0415/11	12.25	243	133	T, H, W, L, F, 1K, 24I
14	10–11 Jun	1900/10	2245/10	0830/11	1530/11	20.5	439	240	T, H, W, L, F
15	14 Jun	0200	0800	0930	1700	15.0	252	196	H, F, 1K, 3I
16	14–15 Jun	1800/14	0300/15	0430/15	1030/15	16.5	434	303	T, H, W, F, 1K, 150I
17	15–16 Jun	1930/15	0130/16	0530/16	0800/16	12.5	321	193	H, W, L, F
18	26–27 Jun	1900/26	0800/27	1230/27	1400/27	19.0	188	113	T, H, W, L, F
19	28–29 Jun	1230/28	2230/28	0215/29	0430/29	16.0	179	122	T, W, L, 1K
20	29–30 Jun	2030/29	0030/30	0430/30	0800/30	11.5	275	201	H, W, R
21	01–02 Jul	2015/01	0115/02	0345/02	0830/02	11.75	158	106	W, R, F
22	04–05 Jul	2200/04	0045/05	0745/05	1200/05	14.0	450	329	T, H, W, L, 3I
23	06–07 Jul	2215/06	0530/07	1100/07	1300/07	14.75	279	172	L, F
24	13–14 Jul	2130/13	0145/14	0515/14	0945/14	12.25	194	118	H, W, R, F
25	18 Jul	0330	0630	0800	1630	13.0	289	145	H, W, L, R, F
26	18–19 Jul	2300/18	0400/19	0800/19	1130/19	12.5	189	106	H
27	24–25 Jul	2215/24	0245/25	0415/25	1115/25	13.0	168	86	T, H, W, R, F
28	04–05 Aug	2200/04	0300/05	0700/05	1015/05	12.25	279	177	L, 2I
29	12–13 Aug	2330/12	0330/13	0830/13	1430/13	15.0	356	235	R, F, 4K
30	13–14 Aug	2230/13	0700/14	1100/14	1330/14	15.0	243	105	T, W, L, R, 3I
31	15 Aug	0430	0830	1100	1500	11.5	193	115	L
32	26–27 Aug	2230/26	0400/27	0730/27	1100/27	12.5	385	197	W, R, F
33	29–30 Aug	2130/29	0330/30	0600/30	0930/30	12.0	169	74	T, H, W, L, R, F
34	30–31 Aug	2100/30	0200/31	0645/31	0900/31	12.0	212	92	H, W
35	31–01 Sep	2000/31	2300/31	0230/01	0530/01	9.5	166	94	W
36	02 Sep	0300/02	0545/02	0815/02	1145/02	8.75	199	145	W
37	05 Sep	0545/05	1015/05	1345/05	1715/05	11.5	340	217	W, L
Average values		2135	0302	0658	1145	14.2	281	181	

* Significant weather reports are taken from the NOAA publication *Storm Data* and are abbreviated as T = Tornado(es); H = Large Hail; W = High Wind; L = Lightning Damage; R = Heavy Rain; F = Flash Flooding, Street Flooding; *n*K = (Number of People) Killed; *n*I = (Number of People) Injured.

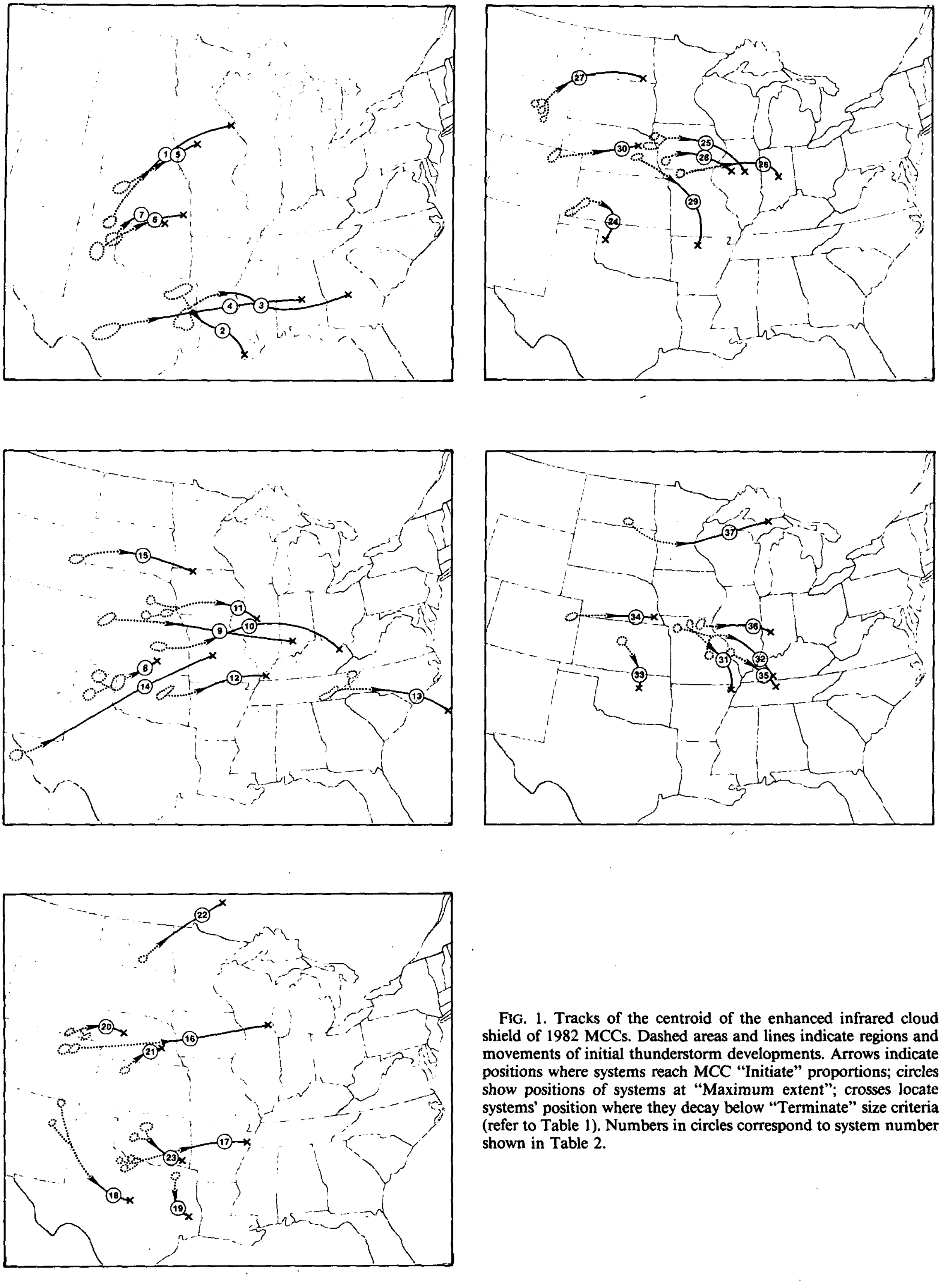

FIG. 1. Tracks of the centroid of the enhanced infrared cloud shield of 1982 MCCs. Dashed areas and lines indicate regions and movements of initial thunderstorm developments. Arrows indicate positions where systems reach MCC "Initiate" proportions; circles show positions of systems at "Maximum extent"; crosses locate systems' position where they decay below "Terminate" size criteria (refer to Table 1). Numbers in circles correspond to system number shown in Table 2.

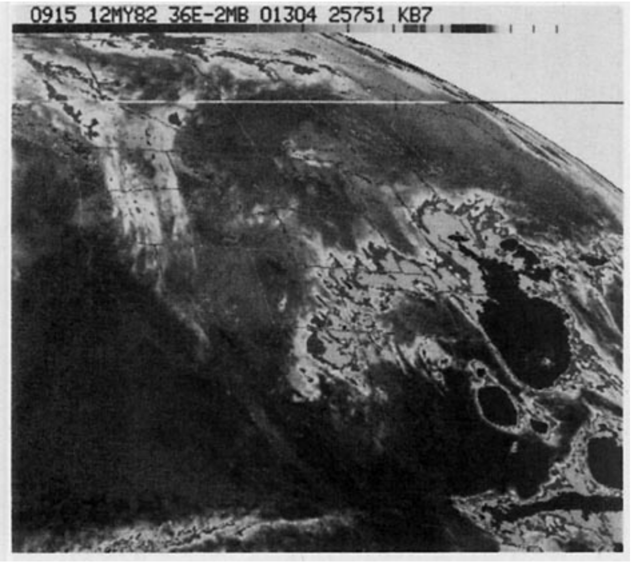

FIG. 2. Enhanced infrared satellite image for 0915 GMT 12 May 1982.

Nine MCCs occurred during a 10-day period between 7 and 16 June. At least one MCC occurred on every day during the period except for the 12th and 13th. Figs. 3a–c show a rapid succession of three MCCs developing in and moving through roughly the same region. The first of the series, case 9 on 7 June, was described as one of the most violent and widespread thunderstorm systems in recent memory to hit northeast Kansas and northern Missouri. Fig. 3a shows the system about one hour after the most intense storms passed through the Kansas City area. The fast-moving system caused extensive damage in eastern Kansas, Missouri and Iowa with 40 m s^{-1} gusts, very large hail and at least one tornado. This storm was succeeded by two more systems (Figs. 3b, 3c) that followed similar paths (Fig. 1b). These MCCs occurred within a large-scale 500 mb pattern common to many MCCs. This pattern is characterized by a quasi-stationary long wave trough over the west with a broad ridge positioned over the central United States. The MCCs developed on the north side of the ridge in a nearly westerly flow regime. Fig. 4 shows two more MCCs occurring almost simultaneously, at the extreme east and west edges of the region of the United States that is typically affected by this type of mesosystem. The northern portion of the massive convective cluster over eastern New Mexico and west Texas was intensifying while the mature MCC over the Carolinas was beginning to decay at the time of this image. With minor variations, the behavior of these two systems is consistent with the pattern described above. The series of MCCs finally ended when the pattern changed after 16 June and the ridge was replaced by an extensive trough that covered most of the US.

The most dramatic example of a flood-producing MCC for the year was the system which moved through Missouri on the night of 12–13 August. Torrential rains caused widespread flooding from the Kansas City area into west central Missouri, with the highest amounts falling in downtown Kansas City. Official rainfall totals ran as high as 224 mm at Independence to 320 mm at Raytown. Unofficial reports of higher amounts were received. Fig. 5 shows the satellite per-

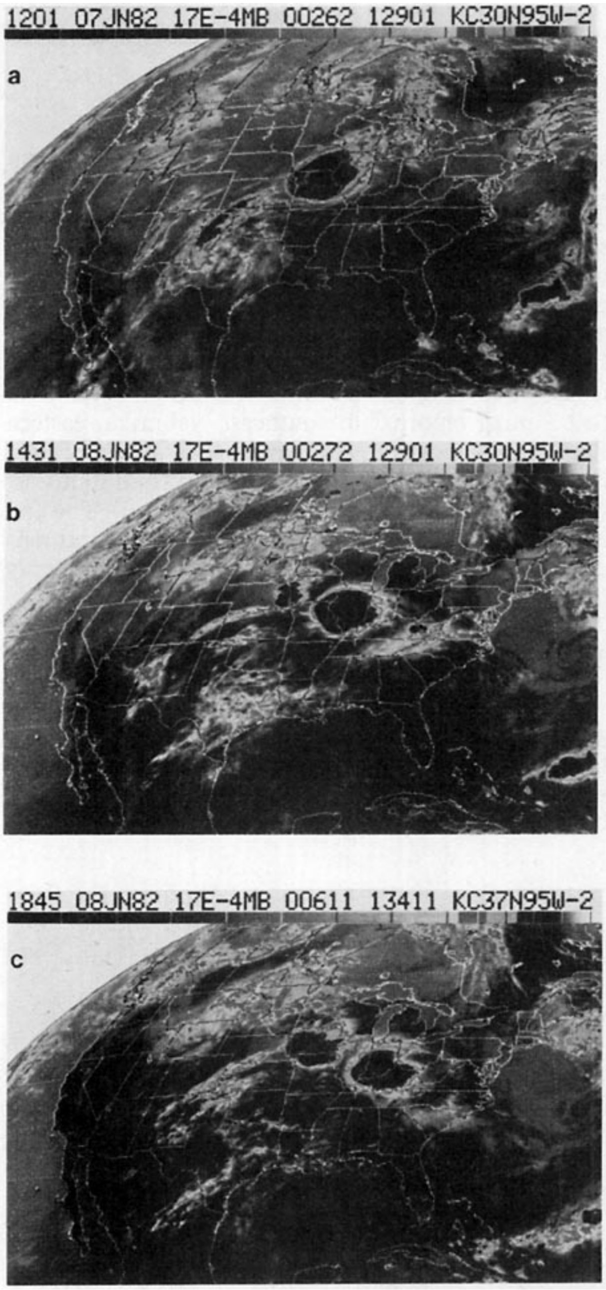

FIG. 3. As in Fig. 2, but for (a) 1201 GMT 7 June 1982, (b) 1431 GMT 8 June 1982, and (c) 1845 GMT 8 June 1982.

FIG. 4. As in Fig. 2, but for 0115 GMT 11 June 1982.

spective of the system with the coldest thunderstorm tops over west central Missouri including Kansas City. The NMC radar summary chart reproduced in Fig. 6 shows a large area of VIP level 1 or greater reflectivities with the strongest echoes in northeast Kansas and west central Missouri at chart time, (0135 CST). An isohyet analysis of the 24-h rainfall totals ending at 1200 GMT 13 August is shown in Fig. 7. This precipitation pattern is fairly typical of MCC events with significant rainfall (⩾2.5 mm) reported in southeast Nebraska, eastern Kansas and most of Missouri. A long swath of very heavy rain (⩾100 mm) affected the area from southeast Nebraska through extreme western Missouri. The end result of this storm system was four deaths and tens of millions of dollars worth of property damage, mostly in Jackson County, Missouri.

3. Concluding remarks

Although 37 convective mesosystems met the stringent, satellite-based criteria for MCCs during 1982, there were numerous other significant mesoscale convective episodes which did not. Due to the inherent limitations of this type of satellite overview, one can not conclude that all 37 cases displayed exactly the same characteristics and internal structure or that they were spawned within similar synoptic situations. Nevertheless, the consistent satellite appearance implies that similar mesoscale processes were likely occurring (at least within the upper troposphere) within each system. This summary is intended to bring significant convective events to the attention of researchers who may be interested in them for a variety of reasons.

FIG. 5. As in Fig. 2, but for 0830 GMT 13 August 1982.

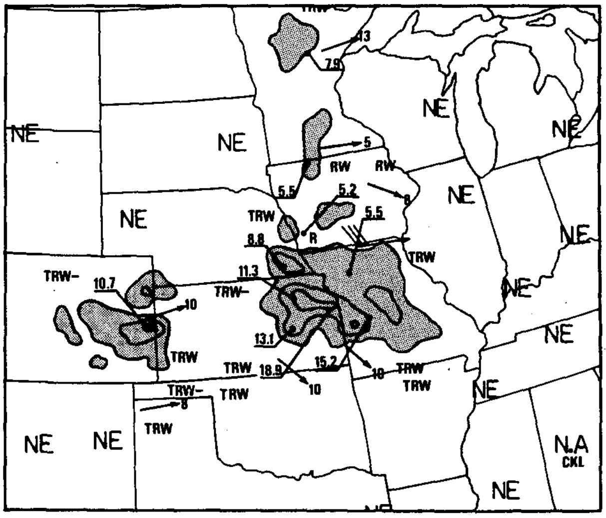

FIG. 6. Radar summary chart for 0735 GMT 13 August 1982. Shading indicates echo areas. Contours at echo intensities 1, 3, and 5; echo heights are in km; cell movement given at end of arrows in m s^{-1}; system movement given by pennant with full barb = 5 m s^{-1}.

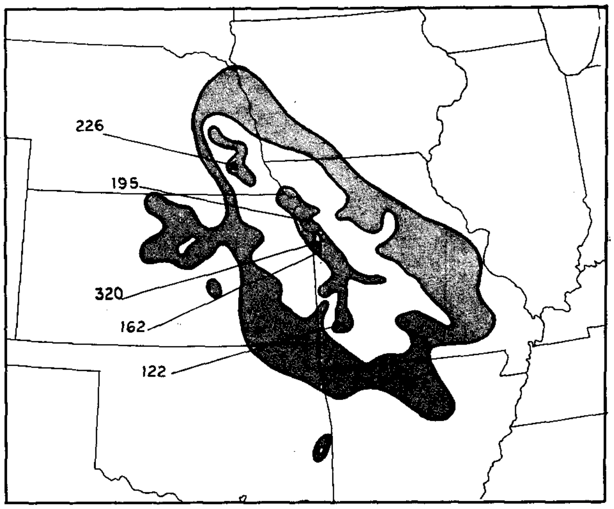

FIG. 7. Isohyet analysis for 24-h precipitation ending 1200 GMT 13 August 1982. Rainfall is in millimeters with first contour delineating (shaded) area which received amounts ⩾ 2.5 mm; second contour (no shading) shows area of ⩾25 mm; third contoured (shaded) area received ⩾100 mm; fourth contoured (unshaded) area received ⩾200 mm. Locations of selected accumulation reports are indicated by lines.

Research under way at the Environmental Research Laboratories is designed to address important questions concerning MCCs, such as:

- What are the large-scale and sub-synoptic settings conducive to MCC development?
- What and where are the interactions between the various scales of motion in the formation of the initial convection through the evolution of the MCC?
- What are the precipitation characteristics, i.e., convective versus stratiform, at different stages of MCC development?

Results of this research should ultimately help to improve the understanding and predictability of these significant weather events.

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