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AN OVERVIEW OF THE JUNE 7, 1984 IOWA TORNADO OUTBREAK

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U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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ABSTRACT. On June 7, 1984, Iowa experienced the greatest outbreak of tornadoes in a single day in its recorded history. Twenty-six tornadoes were documented including the longest track tornado of the year. It was estimated that 100 to 150 farms received moderate to severe damage, plus untold damage to town dwellings and buildings. An estimate of 75 to 200 million dollars in damage was done by tornadoes, severe thunderstorms, and flash floods along with four deaths and 93 injuries.

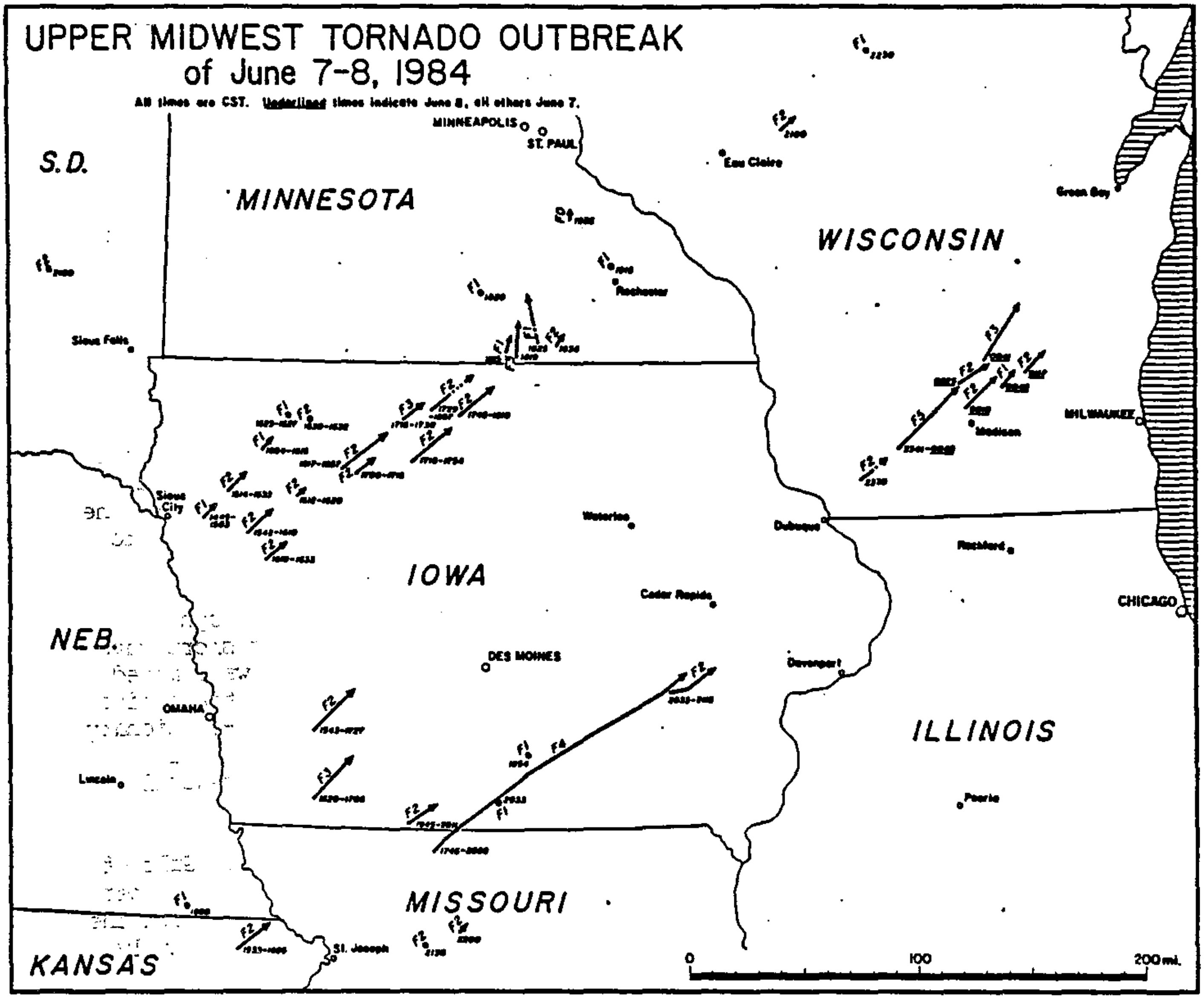
Most sections of the state were affected by severe thunderstorms except for the northeast quarter. The severe thunderstorms initially developed at the intersection of a low level jet and warm boundary that extended across northeast Nebraska arcing into western Iowa. Regeneration of several lines of thunderstorms occurred along rain-cooled outflow boundaries in the northwest. The development of thunderstorms in the southwest occurred in a convergent zone ahead of the dryline. Redevelopment occurred later along the cold front. Tornadoes were occurring in both northwest and southwest quadrants simultaneously.

A significant feature of this event was the intensification of the upper flow during the day with a doubling of the 200 mb divergence. This, coupled with a strong, near steady-state low level wind field gave very strong vertical wind shear.

I. INTRODUCTION

On June 7, 1984, Iowa experienced the greatest outbreak of tornadoes in a single day in its recorded weather history (Dowd, 1986). Twenty-one tornadoes were documented including the longest track tornado of the year in the United States, 127 miles (Ferguson et al., 1985). This outbreak outclassed the previous Iowa record of 14 on April 30, 1967. The outbreak also helped set a new monthly record of 61 tornadoes.

The Iowa outbreak was part of a larger number of tornadoes that formed in the upper Midwest (Fig. 1). During an 11 hour period from mid-afternoon to late evening, 42 tornadoes occurred; of which 50% tracked through Iowa (Storm Data, 1984). The tornado breakdown by F-scale in Iowa was: five F1; 13 F2; two F3; and one F4.



---Data supplied by NWSFOs at Des Moines, Iowa; Topeka, Kansas; Minneapolis, Minnesota; St. Charles, Missouri; Omaha, Nebraska; Sioux Falls, South Dakota; and Milwaukee, Wisconsin. Mapped by the University of Chicago.

Figure 1. June 7 tornado outbreak map.

The F4 tornado had the longest track, 127 miles from near Eagleville, Missouri to about 25 miles southwest of Iowa City in east central Iowa. Near total destruction occurred along the entire path of the storm. The small towns of Wright and Delta in south central Iowa were nearly decimated. Two deaths occurred near Delta when the occupants of a car were tossed out of their vehicle as the tornado hurled it more than 300 yards from the road (Ferguson et al., 1985).

It was estimated that 100 to 150 farms, plus an untold number of town dwellings and buildings, received moderate to severe damage during the outbreak. An estimate of 75 to 200 million dollars in damage occurred from tornadoes, severe thunderstorms and flash flooding along with four deaths and 93 injuries (Storm Data, 1984).

II. LARGE SCALE SETTING

Since June 4, the western and central U.S. had been under broad west to southwest flow aloft as a large Gulf of Alaska low ejected negatively tilted short waves. The short waves would travel east through the Rockies and up the west side of a long wave ridge which was anchored from the southeast U.S. to the Great Lakes area (Figs. 2, 3, and 4).

At the surface, a cold front oscillated from the Dakotas through Nebraska into Kansas. This front would move east with each strong short wave, and then reestablished itself over the western High Plains as the wave moved up the eastern ridge. The farthest east the front traveled during the period was from north central Minnesota, extreme northwest Iowa to a quasi-stationary lee-side low in the western Kansas/Nebraska area. Each eastward frontal movement ellicited tornado or severe thunderstorm watches over the central and/or upper Midwest (Hales and Crowther, 1984).

Plentiful moisture was available at low levels due to the open Gulf of Mexico and persistent East Coast ridge. Large parts of the central and upper Midwest were wet due to repeated showers and thunderstorms associated with the eastward frontal oscillation. Significant evapotranspiration occurred daily with highs mainly in the 80's.

III. BROAD SCALE FEATURES

At 7:00 am CDT, June 7, a broad southwest flow was over Iowa. Several short waves were moving in the flow at 500 mb (Fig. 5). On-station objective vorticity analysis (Anderson and Spry, 1983) of 1200 GMT 500 mb data showed a string of relative vorticity maxima with centers over southeast South Dakota, eastern Colorado, southern Utah and western Nevada.

Using the same objective programs, divergence was calculated at 200 mb (Fig. 6). Strong divergence stretched from the Kansas/Nebraska border across Iowa into Wisconsin. Wind maxima of 80 to 100 knots were upstream with a 9 decameter height fall at Grand Junction, Colorado.

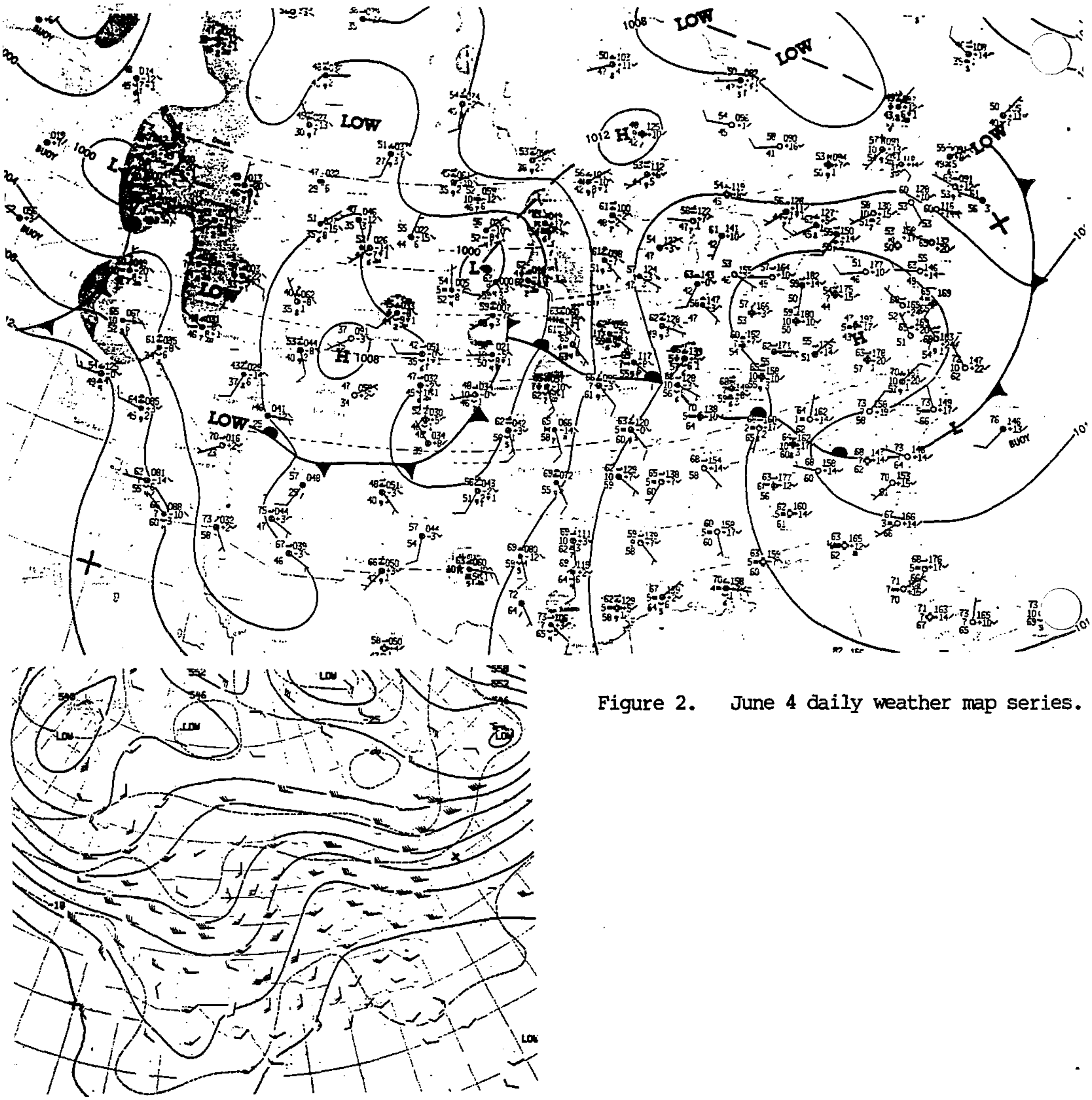
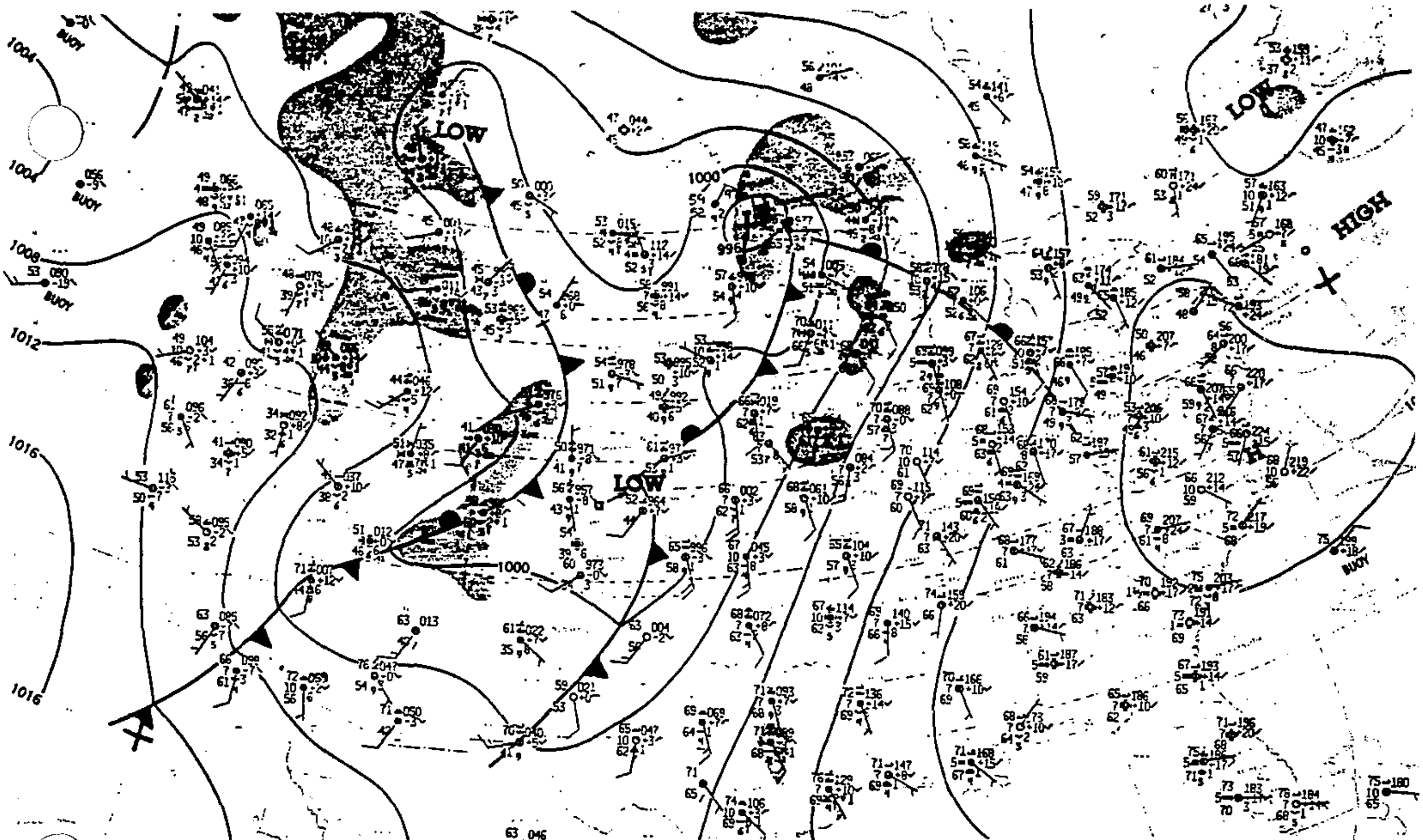


Figure 2. June 4 daily weather map series.



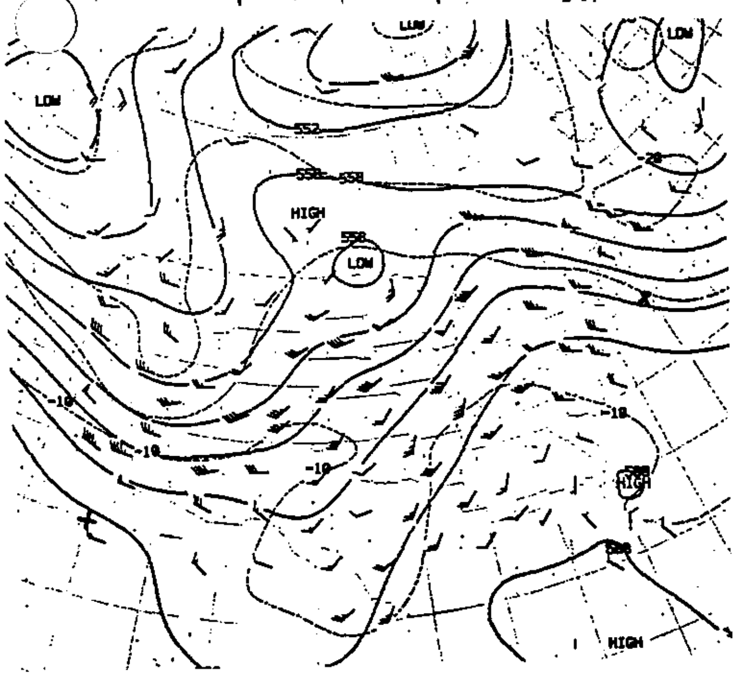
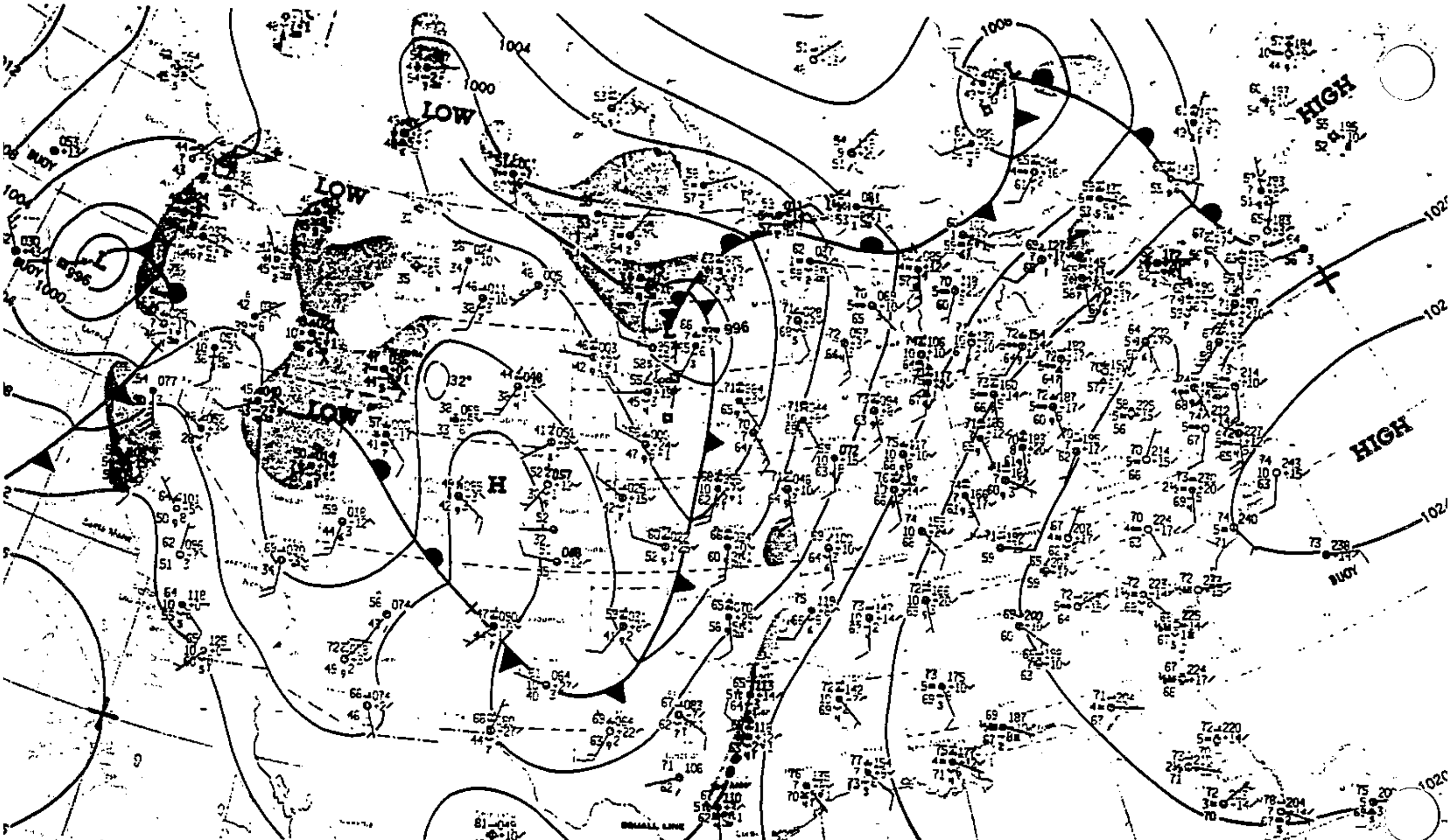


Figure 3. June 5 daily weather map series.



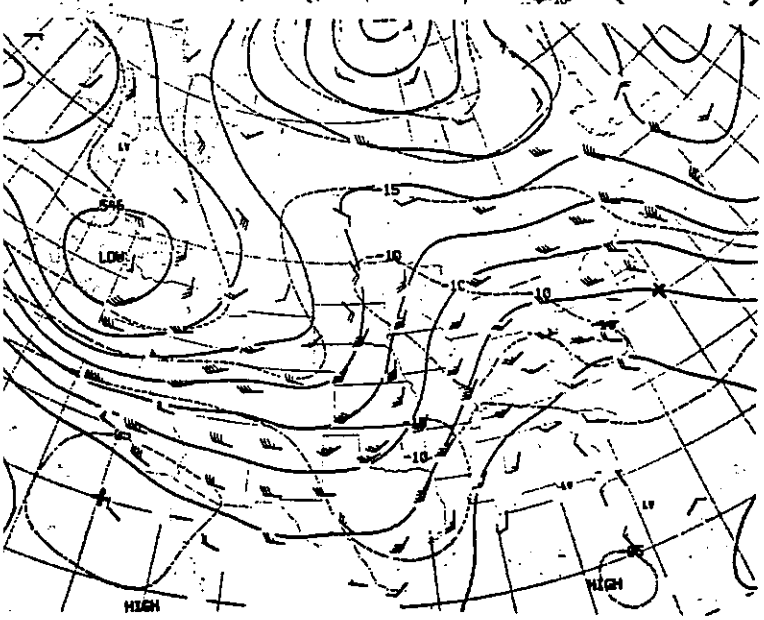


Figure 4. June 6 daily weather map series.

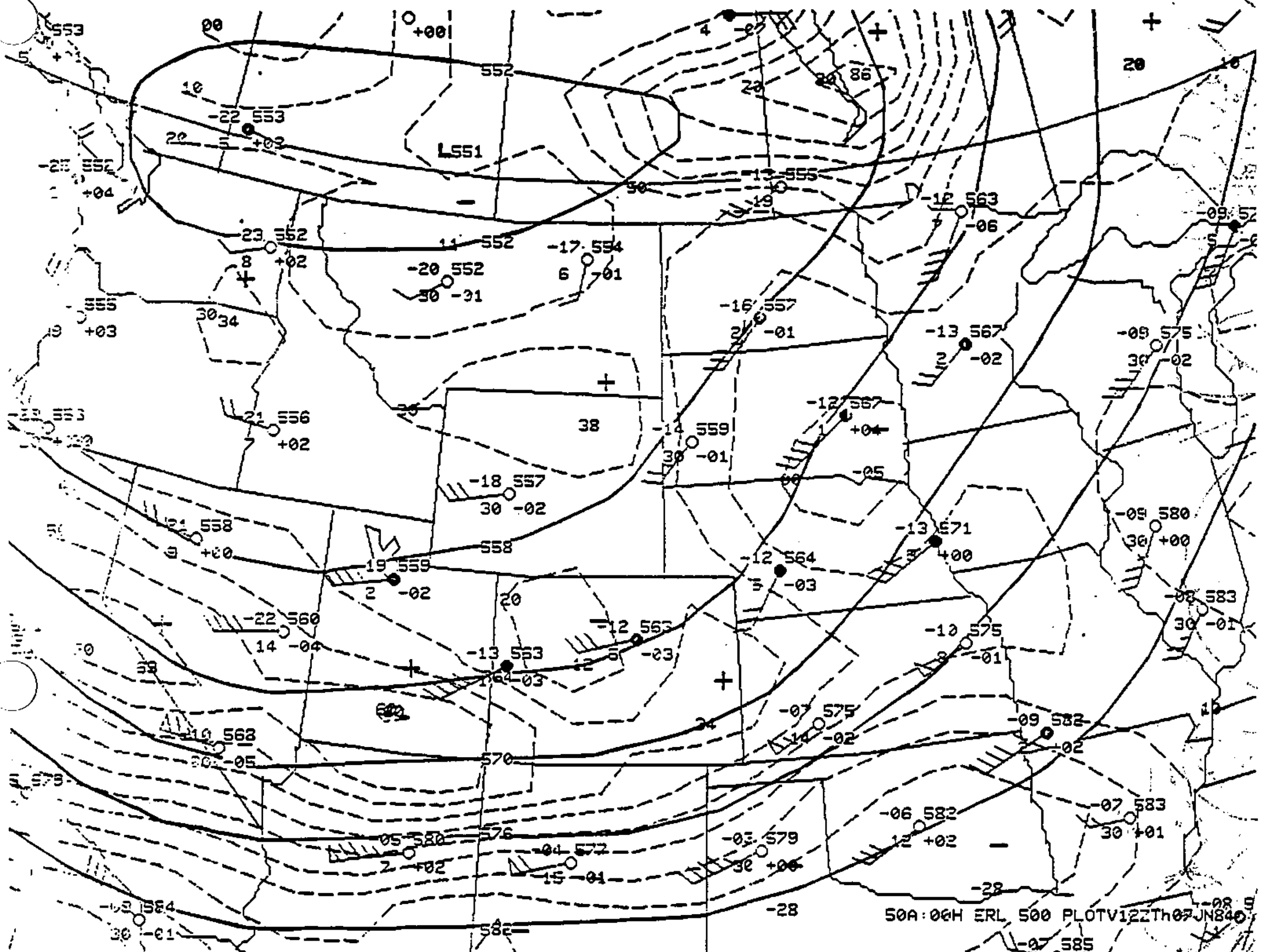


Figure 5. June 7, 1200 GMT initial 500 mb data, height and vorticity fields - heights in decameters, vorticity in 1E-6/sec/sec.

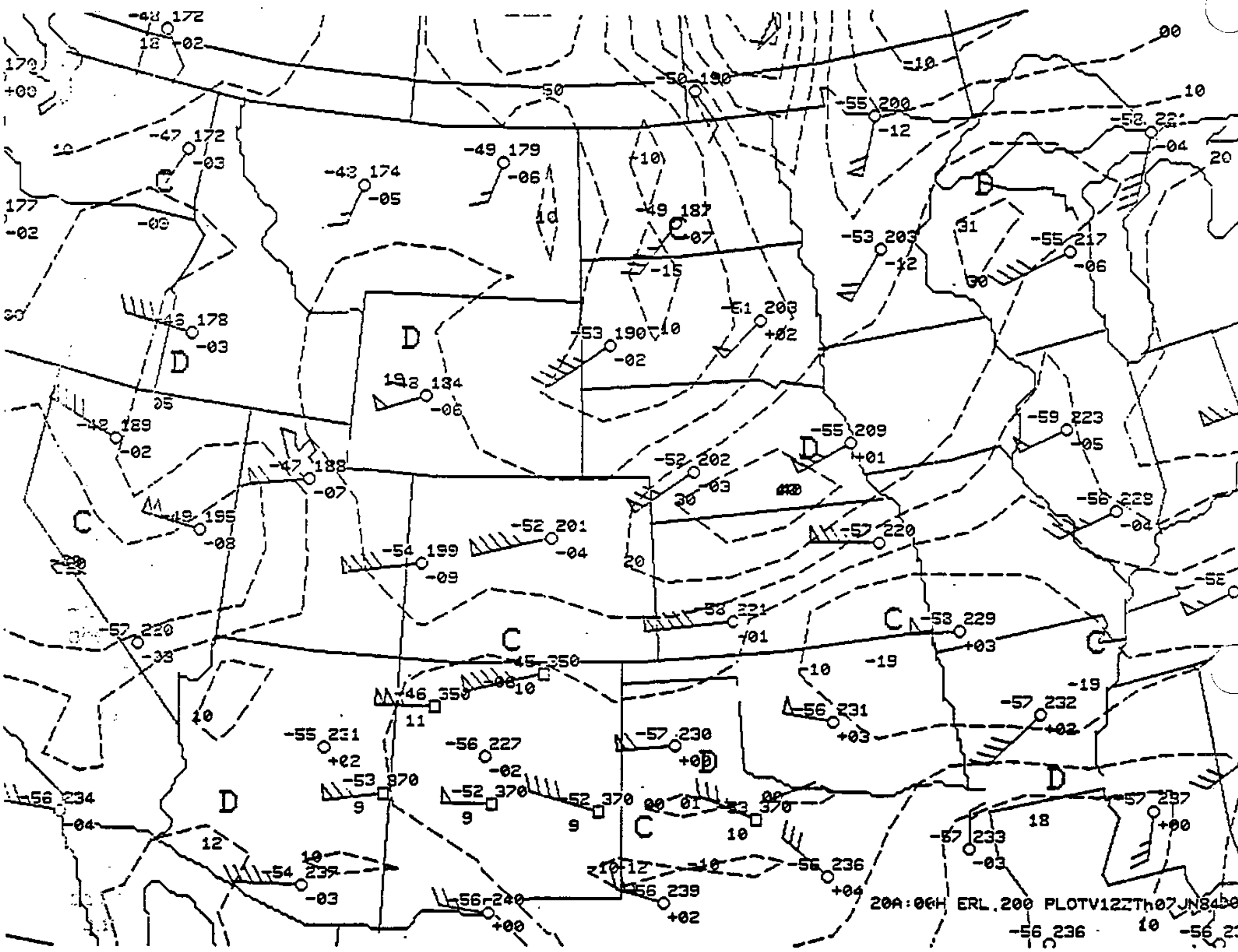


Figure 6. June 7, 1200 GMT initial 200 mb data and divergence field - divergence in 1E-6/sec/sec.

At lower levels, a strong 700 mb low was positioned over south central Canada with a broad trough south along the Rockies (Fig. 7). Warm and relatively drier air was being advected northeast toward the Great Lakes from the High Plains of Texas, Kansas and Oklahoma. The 850 mb level showed similar broad scale features (Fig. 8). However, the trough was much sharper with a broad 40 to 50 knot wind flow from the Texas Panhandle across Oklahoma into eastern Kansas and western Missouri. Warmer air was being advected northeast into Iowa. Dew point analysis of the 850 mb level showed a large pool of moisture across Wisconsin, Iowa and into Nebraska.

A plot of the 1200 GMT Topeka (TOP) rawinsonde showed a classic Type I severe weather sounding, moist in the lower levels and dry above the inversion with a gradual increase in moisture through the mid-levels (Miller, 1972) (Fig. 9). Further inspection of the lower wind field showed a 55 knot wind maximum just below the inversion, near the 850 mb level. Looking at the Omaha (OMA) 1200 GMT rawinsonde (Fig. 10), the low level inversion was practically non-existent with a weaker low level wind field. An impressive early morning -7 lifted index was computed.

On the surface at 1500 GMT, a trough and weak cold front extended from western North Dakota into central Nebraska and western Kansas (Fig. 11). Two low centers were along the boundary, one in central South Dakota near Pierre (PIR) and the other in central Nebraska near North Platte (LBF). A quasi-stationary front extended into northern Minnesota from the South Dakota low. The beginnings of a dryline were evident in southwest Kansas. Moderate southerly flow was beginning to take hold in southeast Kansas with sustained speeds of 20 to 30 knots. Temperatures in the warm air were in the lower 70's to lower 80's with dew points in the middle 60's to 70's. Skies were mostly cloudy from convective debris and a few showers and thunderstorms. The precipitation was mainly east of a Minneapolis-Kansas City line.

IV. NMC/NSSFC GUIDANCE

The 1200 GMT LFM package moved the vorticity maximum from eastern Colorado to near Norfolk, Nebraska (OFK) and strengthened it to 16 units by 0000 GMT (Fig. 12). The closed 500 mb low in southeast Alberta moved eastward to southwest Saskatchewan. The East Coast ridge "weakened" in advance of the strengthening short wave.

On the surface, the LFM showed the Nebraska low rotating to near Sioux City, Iowa (SUX) and deepening some as the Canadian surface low remained anchored (Fig. 13).[1] A cold front arced from the SUX low southwest into central Kansas. The 12-hour lifted index prog indicated a -4 over a concentrated area from extreme northeast Kansas through southwest into north central Iowa and into northwest Wisconsin (Fig. 13).

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[1] The initialized LFM at 1200 GMT positioned the Nebraska low in northeast Kansas.

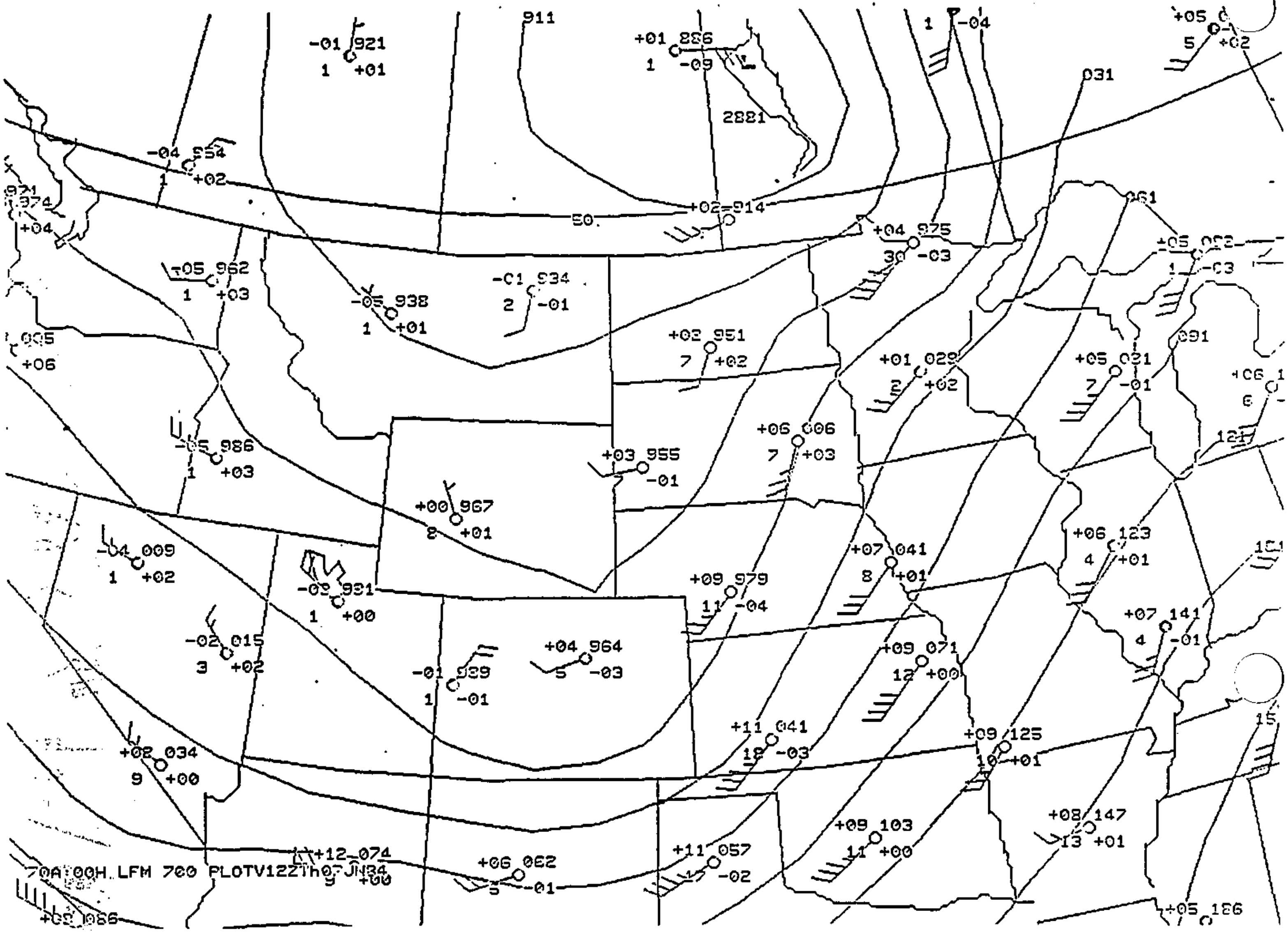

Figure 7. June 7, 1200 GMT initial 700 mb data and height field - heights in decameters.

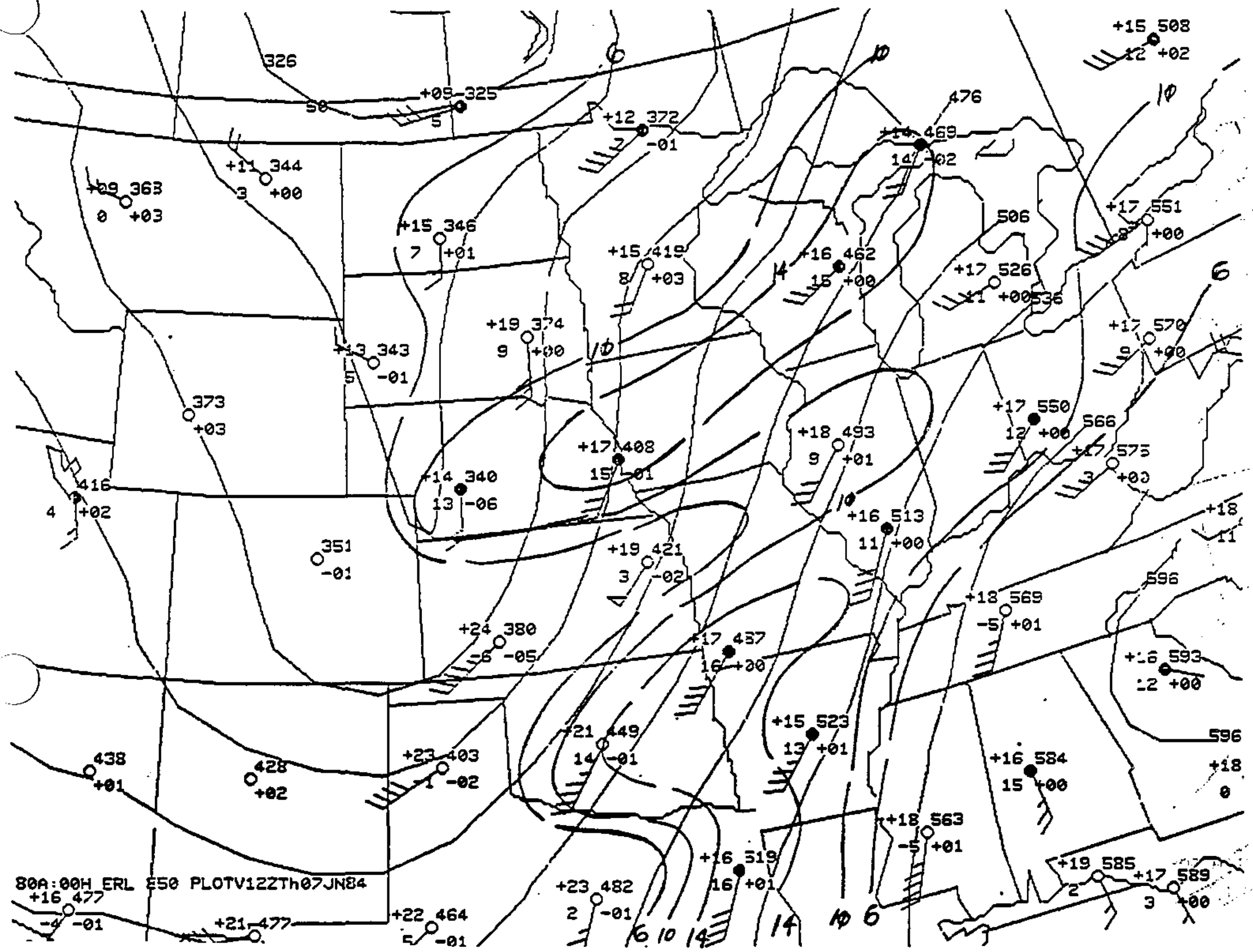

Figure 8. June 7, 1200 GMT initial 850 mb data, height and dew point fields - heights in decameters, temperatures in degrees Centigrade.

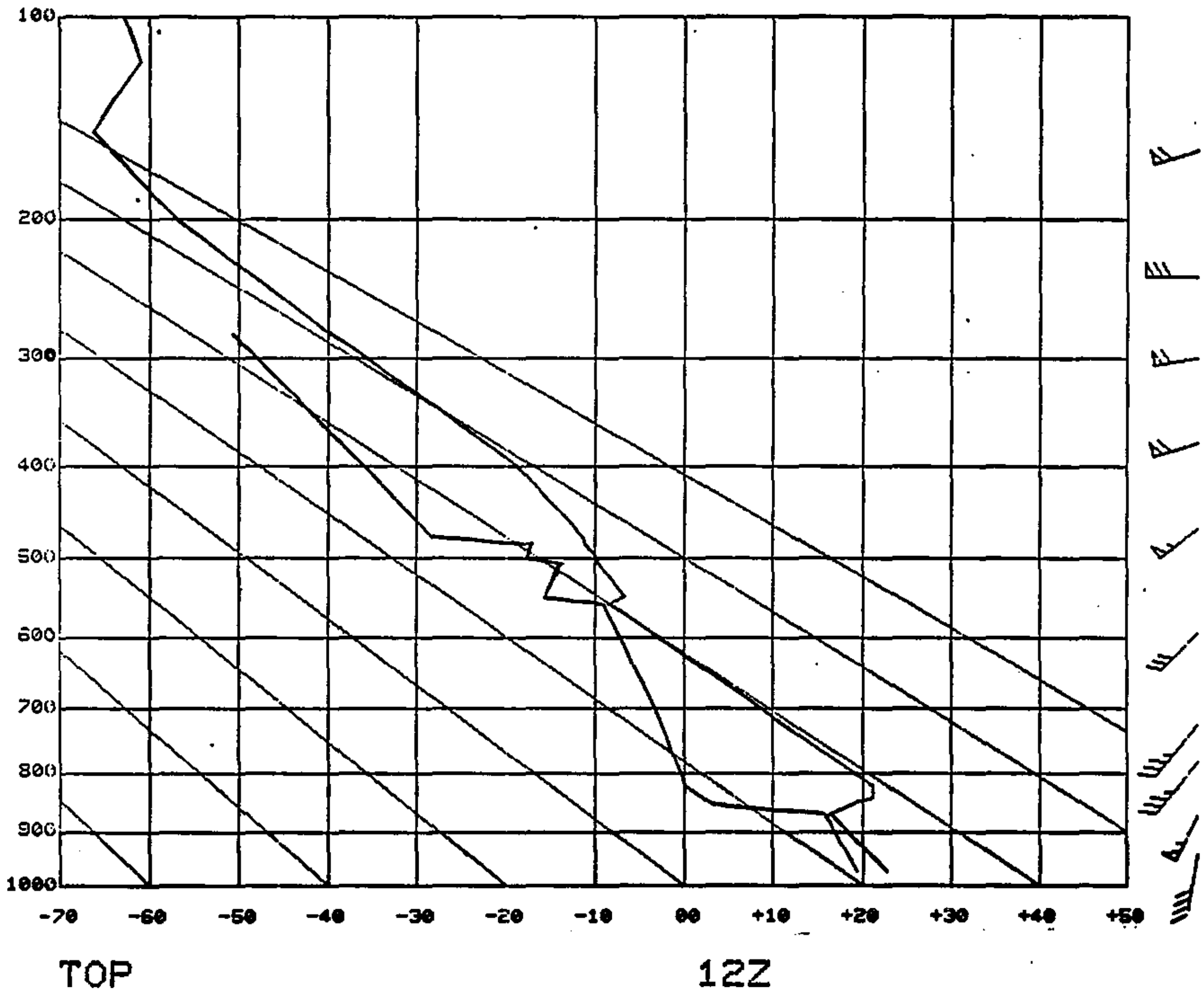

Figure 9. June 7, 1200 GMT Topeka radiosonde sounding.

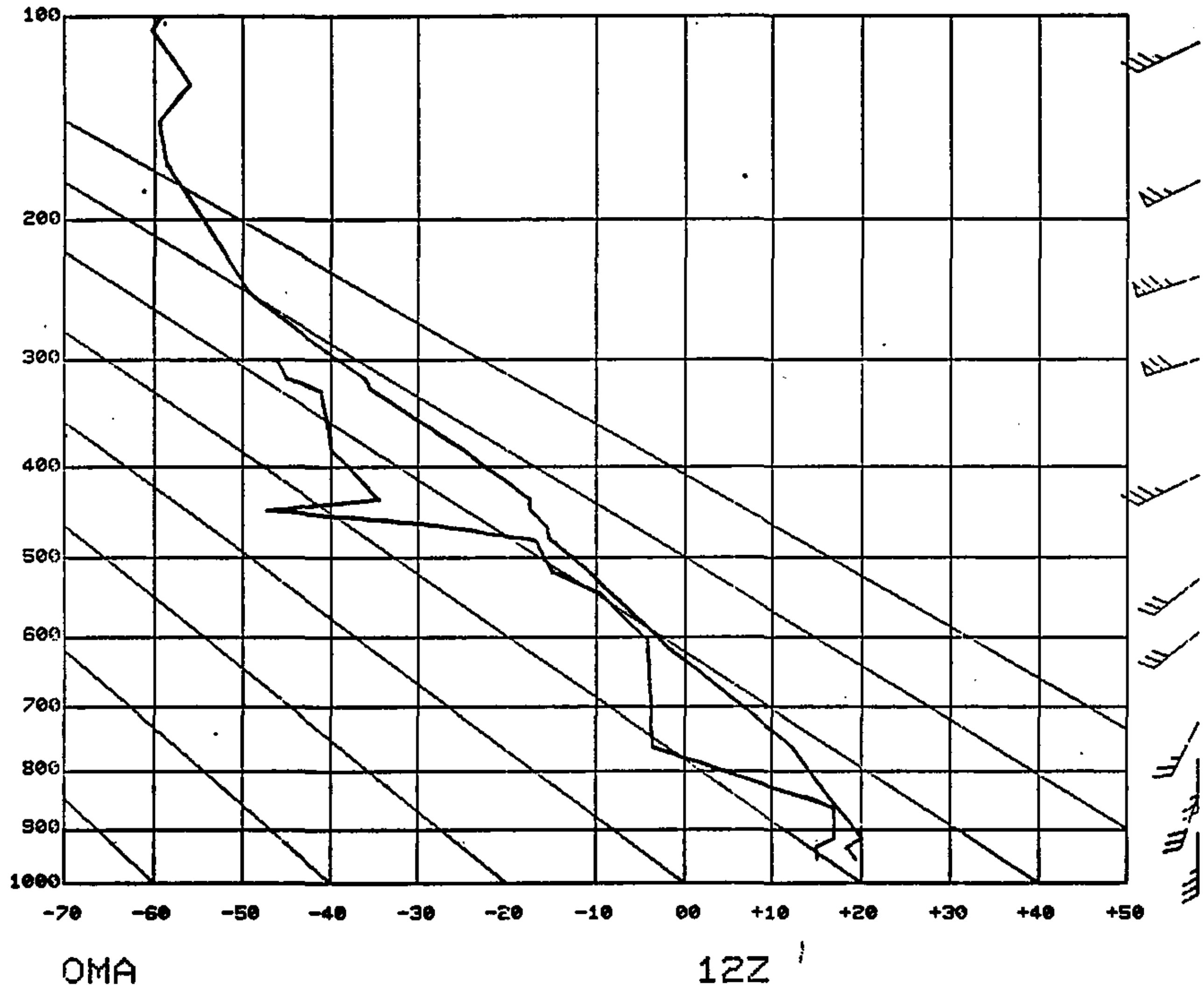

Figure 10. June 7, 1200 GMT Omaha radiosonde sounding.

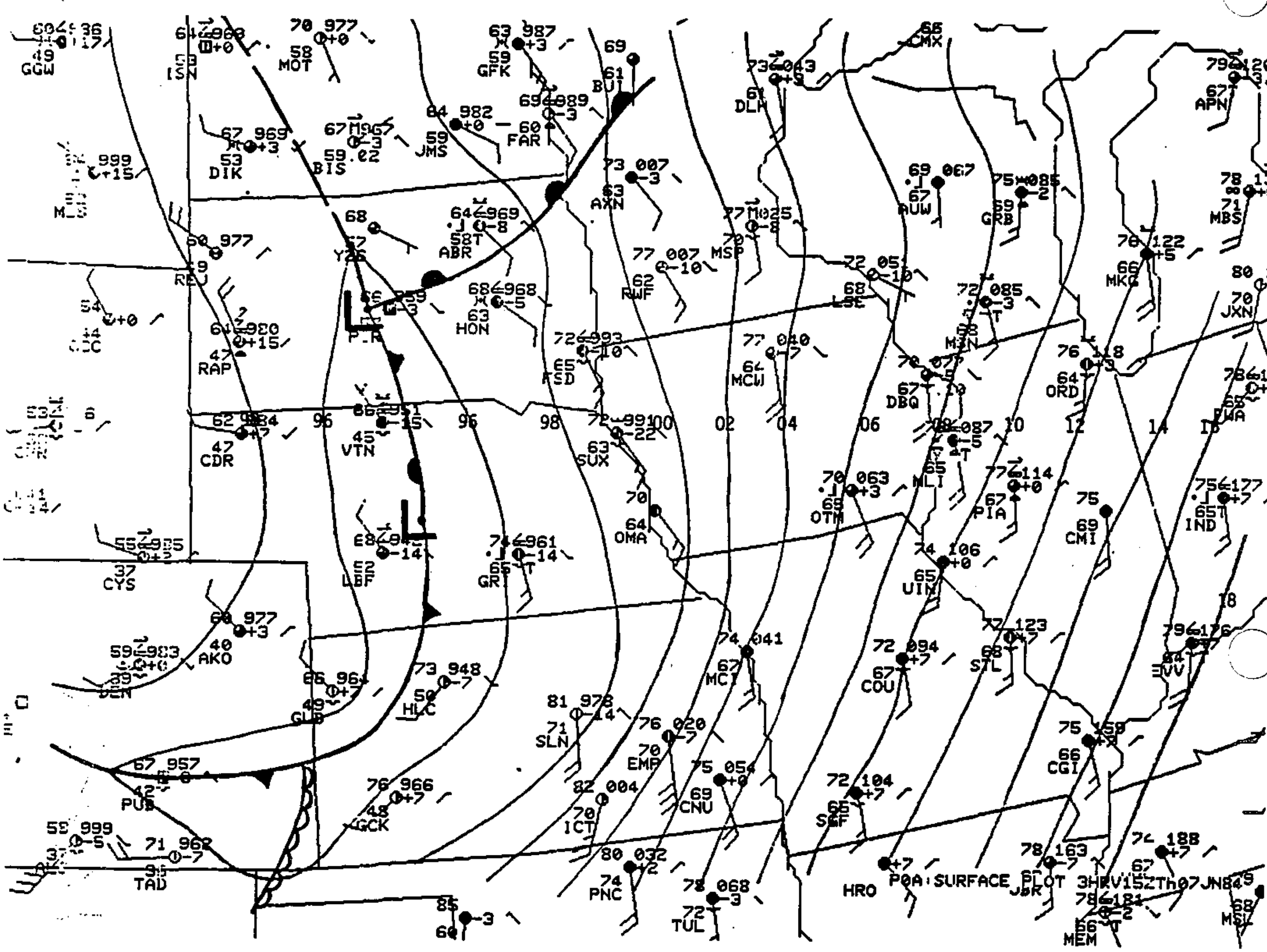

Figure 11. June 7, 1500 GMT sea level pressure analysis (2 mb).

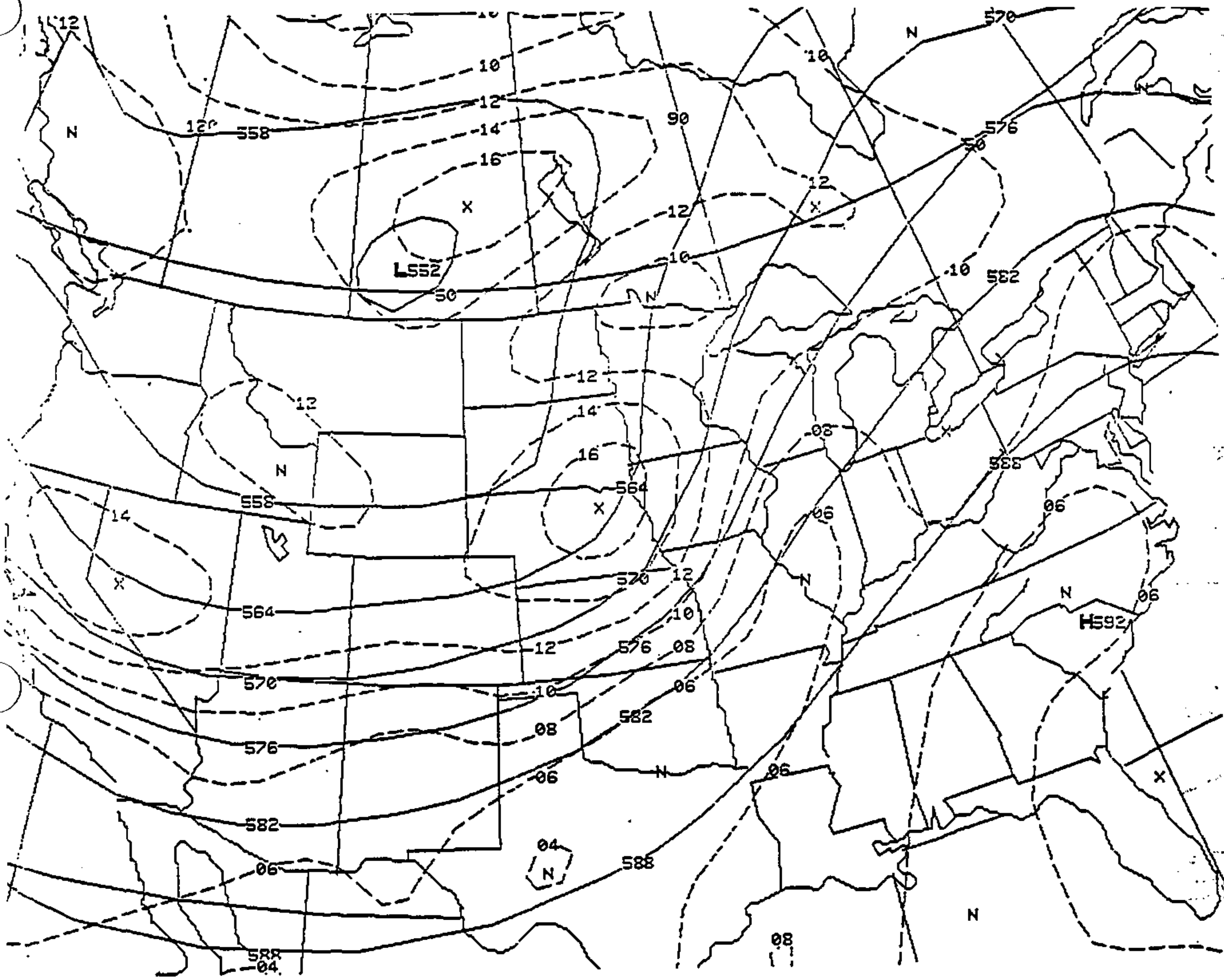

Figure 12. June 7, 1200 GMT LFM 12-hour 500 mb height and vorticity forecast - heights in decameters, vorticity in 1E-6/sec/sec.

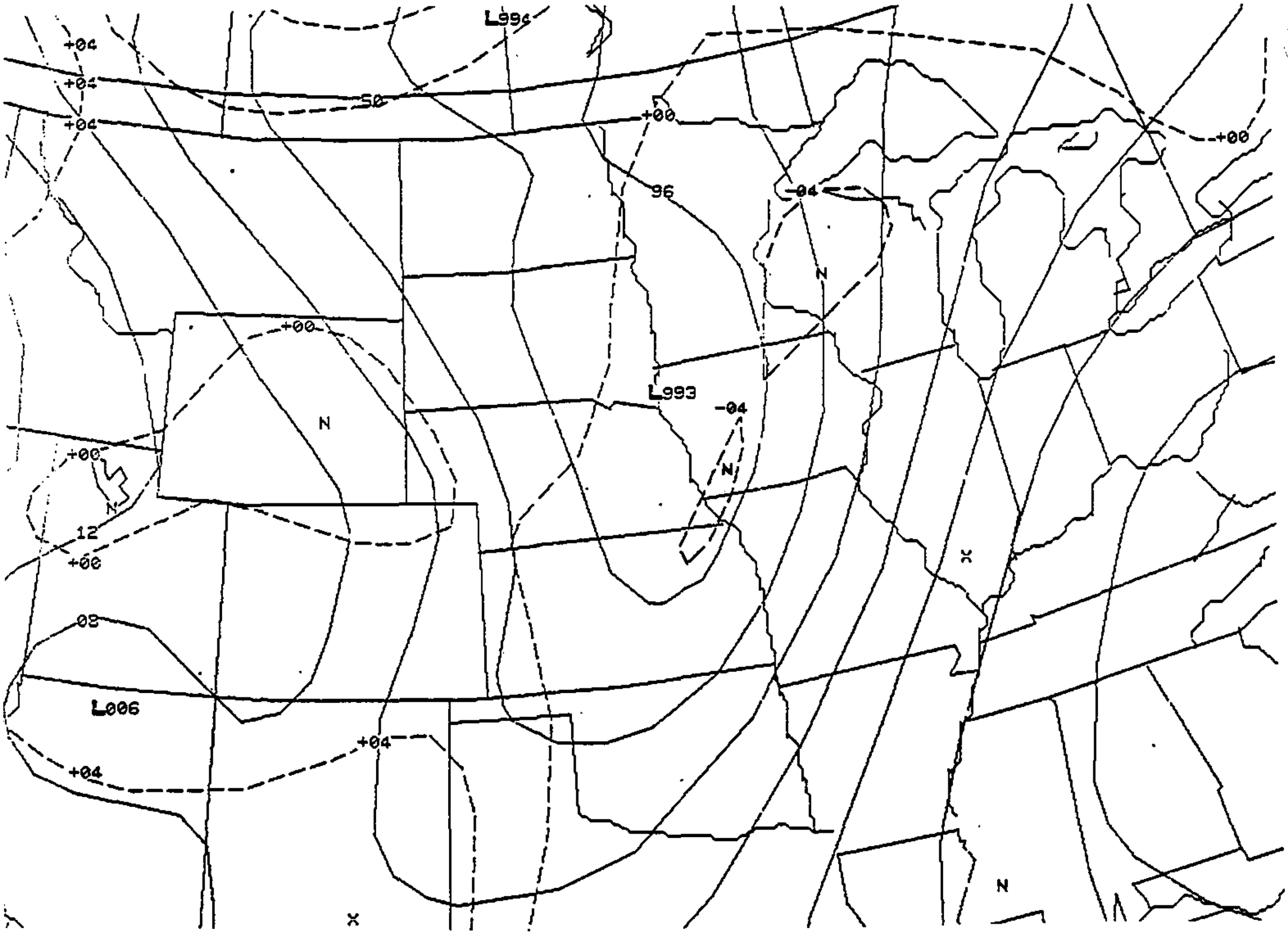

Figure 13. June 7, 1200 GMT LFM 12-hour surface and lifted index forecast.

The NSSFC 0700 GMT convective outlook predicted a moderate risk of severe weather for a large part of Iowa and adjacent areas (Fig. 14). The outlook specifically mentioned a "more active severe weather day than the past few days". Severe thunderstorms were anticipated to develop in strong low level convergence across northern Iowa/southern Minnesota. Also, severe thunderstorms were expected to form ahead of the surface trough in eastern Nebraska/eastern South Dakota by late afternoon. The 1500 GMT updated outlook expanded the moderate risk area a little further to the east, with severe weather expected by late afternoon through the Central Plains spreading into the Upper Mississippi Valley during the evening.

V. SEQUENCE OF EVENTS

The GOES 1600 GMT visible image (Fig. 15) shows considerable cloud cover over Iowa, Missouri, eastern Kansas and eastern halves of Nebraska and South Dakota. Cumulus streets visible in the eastern thirds of Kansas and Oklahoma depict a deeper moisture field, compared to the nearly cloud free environment over the remainder of the two states.

By 1800 GMT, surface features have changed considerably. Dew points in the 70's that were in extreme southeast Kansas at 1500 GMT have moved into southeast Nebraska (Fig. 16). Sustained southerly winds of 35 knots are occurring at Emporia, Kansas (EMP). The lows near LBF and PIR have moved eastward a little maintaining their central pressure. The dryline is quite evident from southern Nebraska across Kansas. Frontogenesis is occurring as a warm boundary takes shape across eastern Nebraska. This boundary divides very warm, moist air from slightly cooler and less humid air to its north. Strong winds are also noted in the warm air south of the boundary. Surface pressure falls of 3 mb are observed near OMA.

The GOES 1800 GMT visible image (Fig. 17) shows convection ahead of the old quasi-stationary front across eastern South Dakota nearing west central Minnesota. Cumulus streets are clearly evident over the eastern half of Oklahoma and Kansas and are becoming visible over southern Missouri, southwest Iowa and southeast Nebraska. A subtle thinning of high and middle level cloudiness has occurred.

By 1900 GMT, sustained winds of 30 knots with gusts to 42 have moved into extreme southeast Nebraska at Falls City (FNB) (Fig. 18). Similar wind velocities now extend from southern Kansas into southeast Nebraska and westward to the strengthening dryline in central Kansas. Dew points near 70 have advected farther north to near Columbus, Nebraska (OLU) and extreme southwest Iowa. A significant increase in local convergence ahead of the strengthening warm boundary is indicated by the east wind at SUX. The dew point gradient intensifies across the dryline with the differential nearing 20°F in some areas.

By 2000 GMT, the atmosphere is beginning to get its act together as verified by the GOES visible image (Fig. 19). Convection explodes from near OFK to SUX, <u>at the intersection of the low level jet and warm boundary</u>.

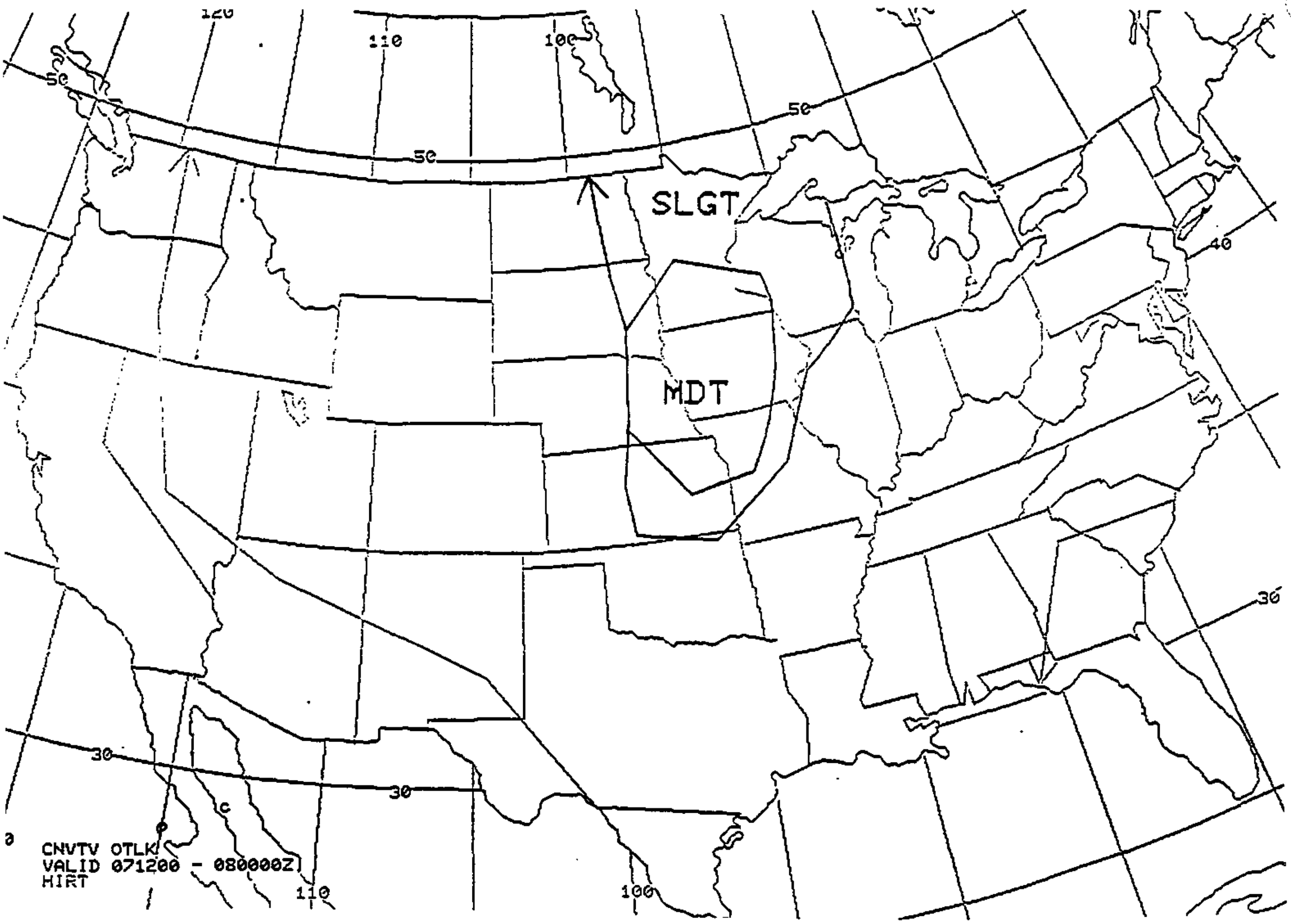

Figure 14. NSSFC convective outlook valid June 7, 1200 GMT to June 8, 0000 GMT.

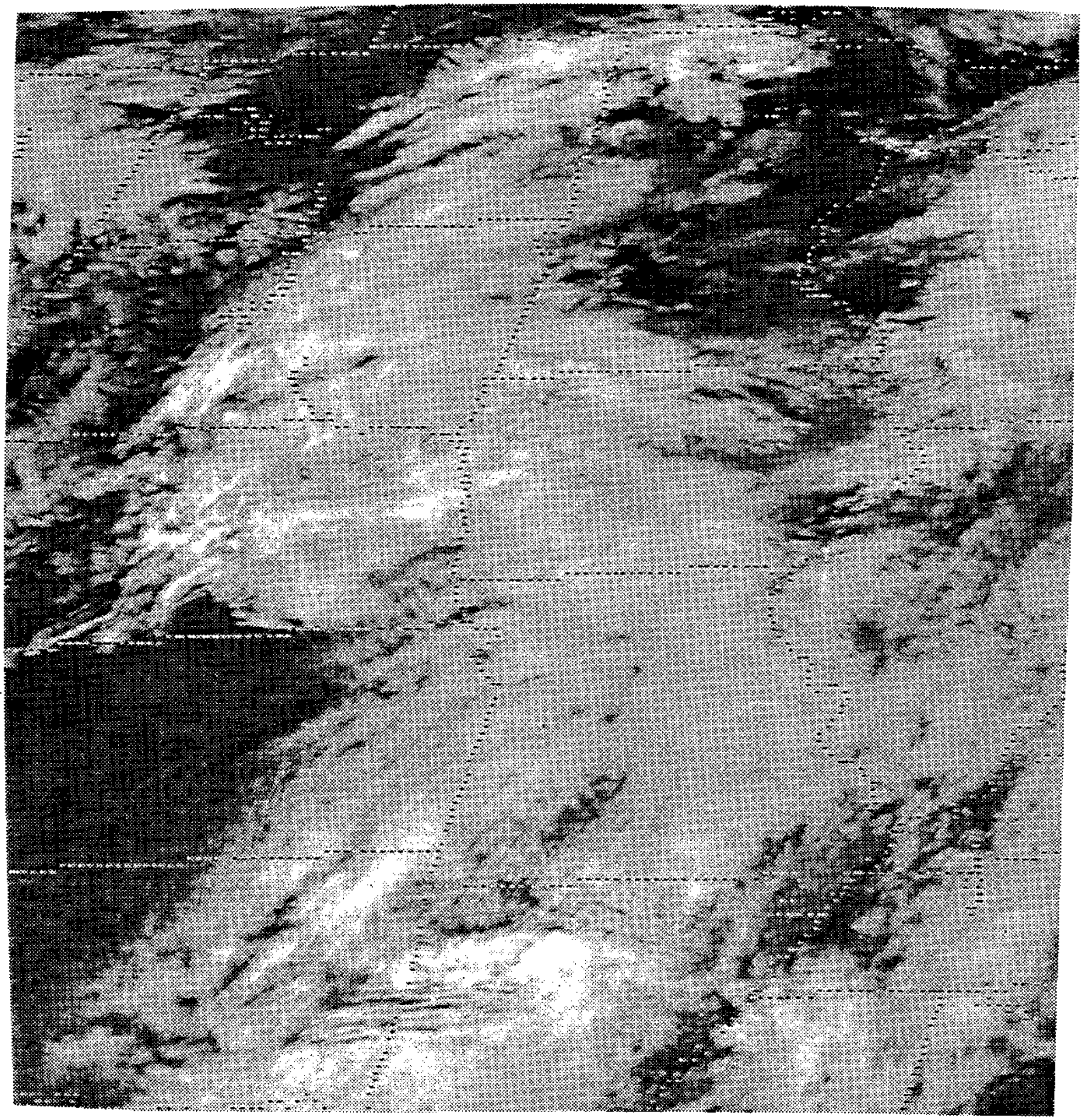

Figure 15. GOES June 7, 1601 GMT visible satellite image.

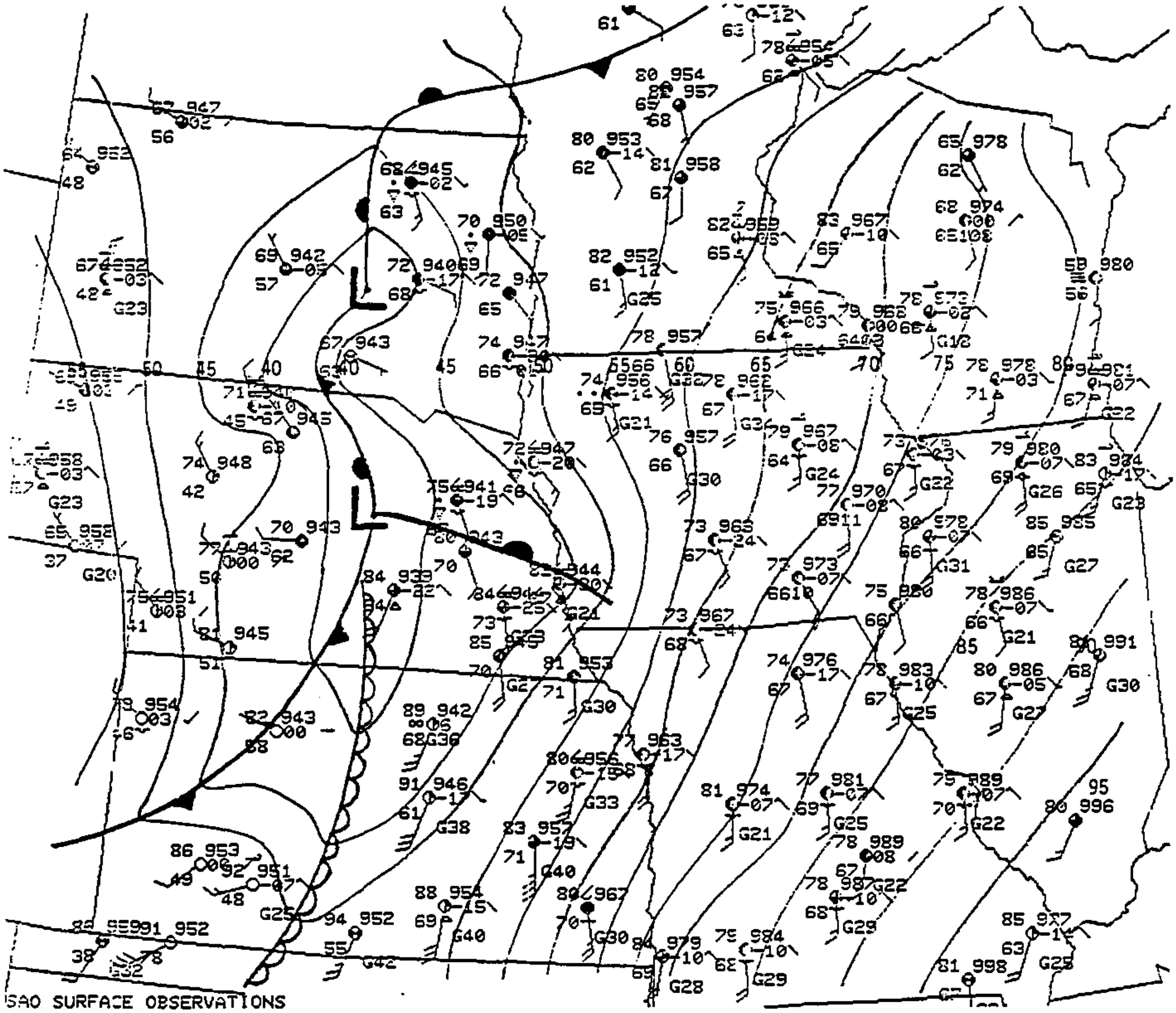

Figure 16. June 7, 1800 GMT sea-level pressure analysis (.05 in. Hg).

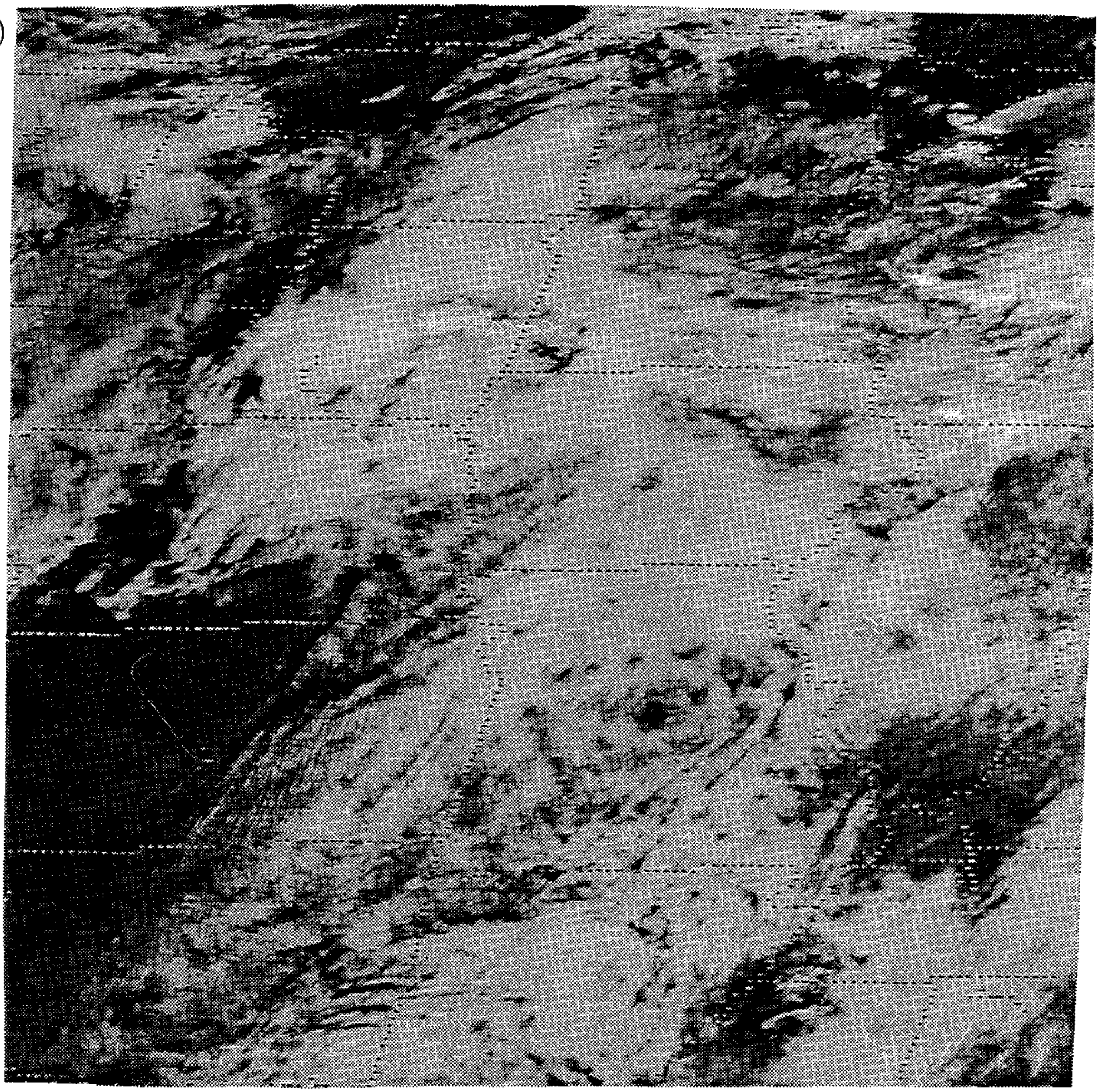

Figure 17. GOES June 7, 1801 GMT visible satellite image.

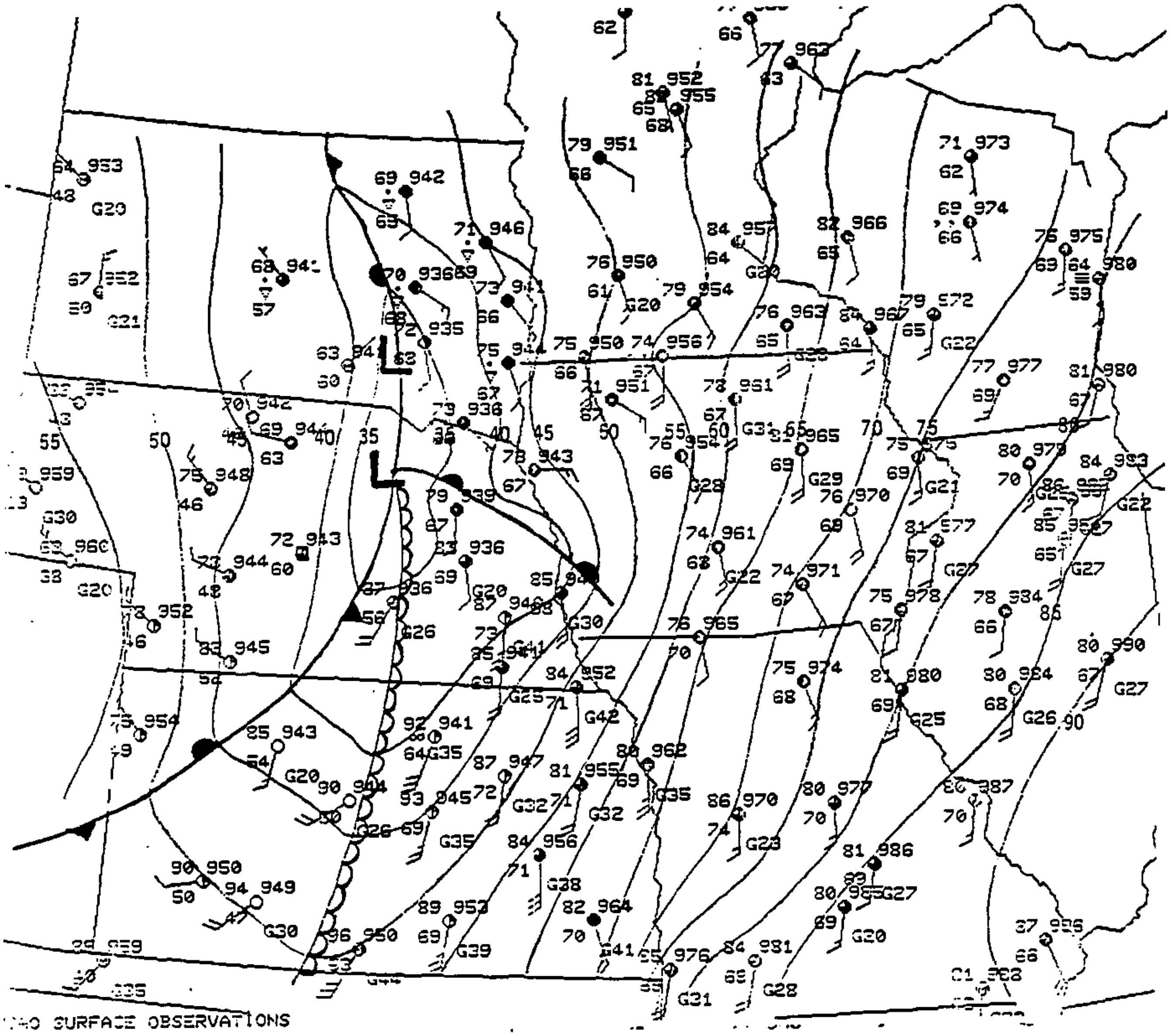

Figure 18. June 7, 1900 GMT sea-level pressure analysis (.05 in. Hg).

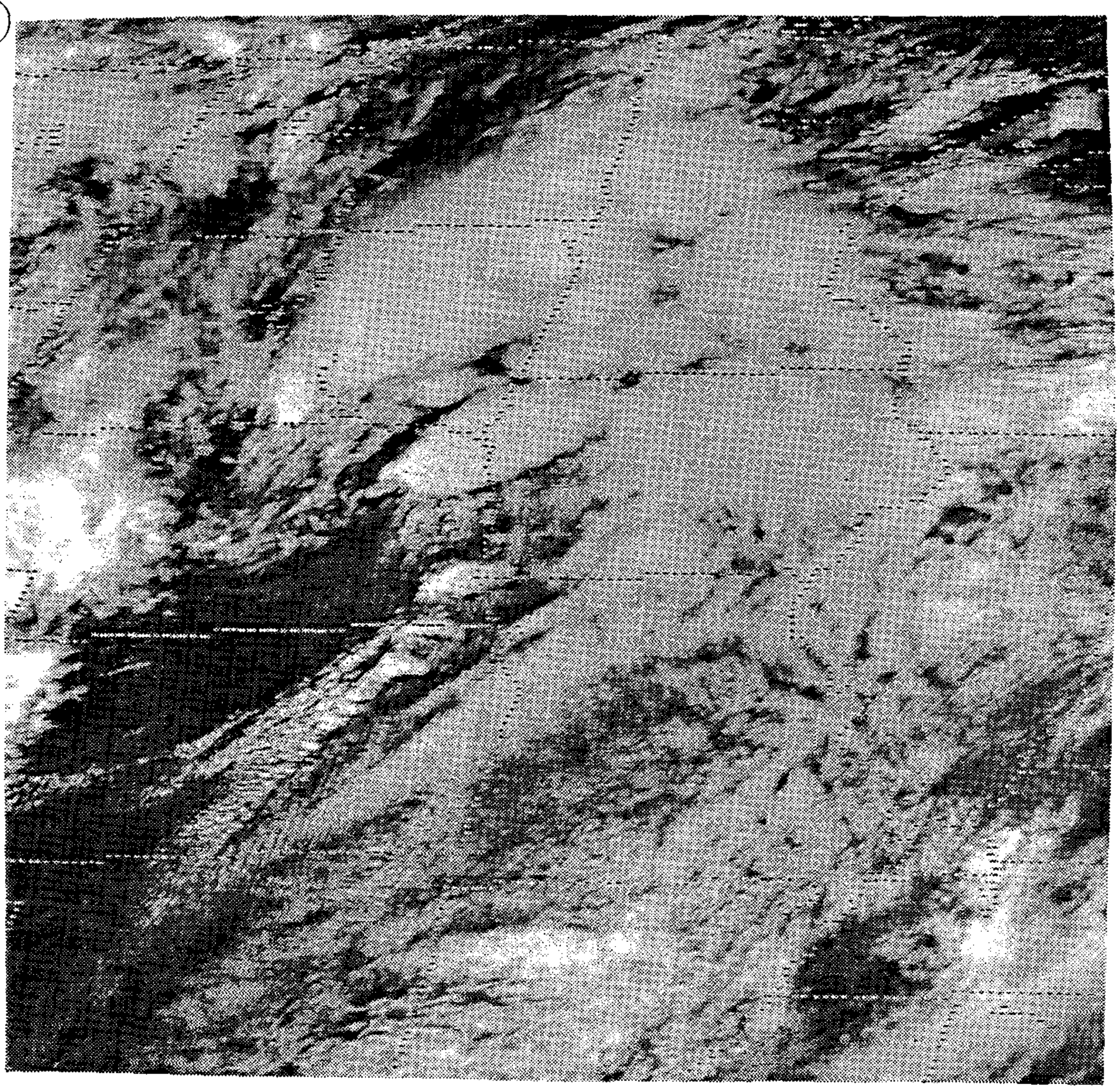

Figure 19. GOES June 7, 2000 GMT visible satellite image.

Thunderstorms are in progress at SUX and OFK. SUX reports a pressure decrease, during the past hour, of double that of any other nearby station. The image also confirms the location of the dryline across eastern Nebraska into central Kansas as convection begins in earnest in the convergence zone ahead of this feature.

By 2030 GMT, cold tops near SUX are nearing -65°C as thunderstorms grow farther south along the dryline (Fig. 20). An unimpeded flow of moisture into the OFK/SUX storms ahead of the dryline in Kansas is visible. Near this time, large hail and torrential rains bombarded the Sioux City area. Des Moines radar senses new development in southeast Nebraska and northwest of Topeka (Fig. 21). The storm near Manhattan, Kansas will eventually evolve into the longest track tornado of the year!

By 2045 GMT, the first tornado occurs in Woodbury County outside of Moville (17 E SUX) (Figs. 1 and 21). The F1 Moville tornado does considerable damage to four farmsteads along its seven mile path ending at 2103 GMT. For the next seven hours, severe weather would erupt across the Hawkeye state at a record rate!

The 2100 GMT surface plot (Fig. 22) shows the location of the low pressure systems north of OFK with the dryline extending south into central Kansas. The warm boundary is readily apparent from the low into western Iowa. Thunderstorms erupting near SUX along the boundary feed off 17 g/kg moist air as supplied by 40 knot south gusts at OMA. A surface pressure fall of 6 mb occurs at SUX.

The GOES 2100 GMT visible image shows the rapidly growing thunderstorm complex in northwest Iowa and the exploding thunderstorms near OMA towards TOP (Fig. 23). Very close inspection of the image hints at an overshooting top just east of SUX. This is likely associated with the Moville tornado.

Between 2114 to 2133 GMT, a stronger F2 tornado from the same cell that produced the Moville storm occurs in Cherokee County. The tornado tracks ten miles northeast through 15 farmsteads (Figs. 1 and 21).

The GOES 2130 GMT image reveals the coldest tops in northwest Iowa are moving rapidly northeast (Fig. 24) with an enhanced-V signature (McCann, 1981). Thunderstorms ahead of the dryline have moved into southwest Iowa. The storm previously north of TOP shows a possible enhanced-V in extreme northeast Kansas.

As the initial outbreak of thunderstorms moves across Cherokee County, new development appears just south of SUX (Fig. 21). This second cell initiation generates another F2 tornado across northern Ida County (east of Moville) from 2142-2210 GMT (Figs. 1 and 21). The 16 mile long track damages farms and the grain elevator plus homes in Holstein (35 E. SUX). From 2204 to 2215 GMT a short-lived tornado (again from the Moville cell) damages seven farms across O'Brien County in northwest Iowa. Many trees are destroyed as well as a 100 year old barn (Figs 1 and 21).

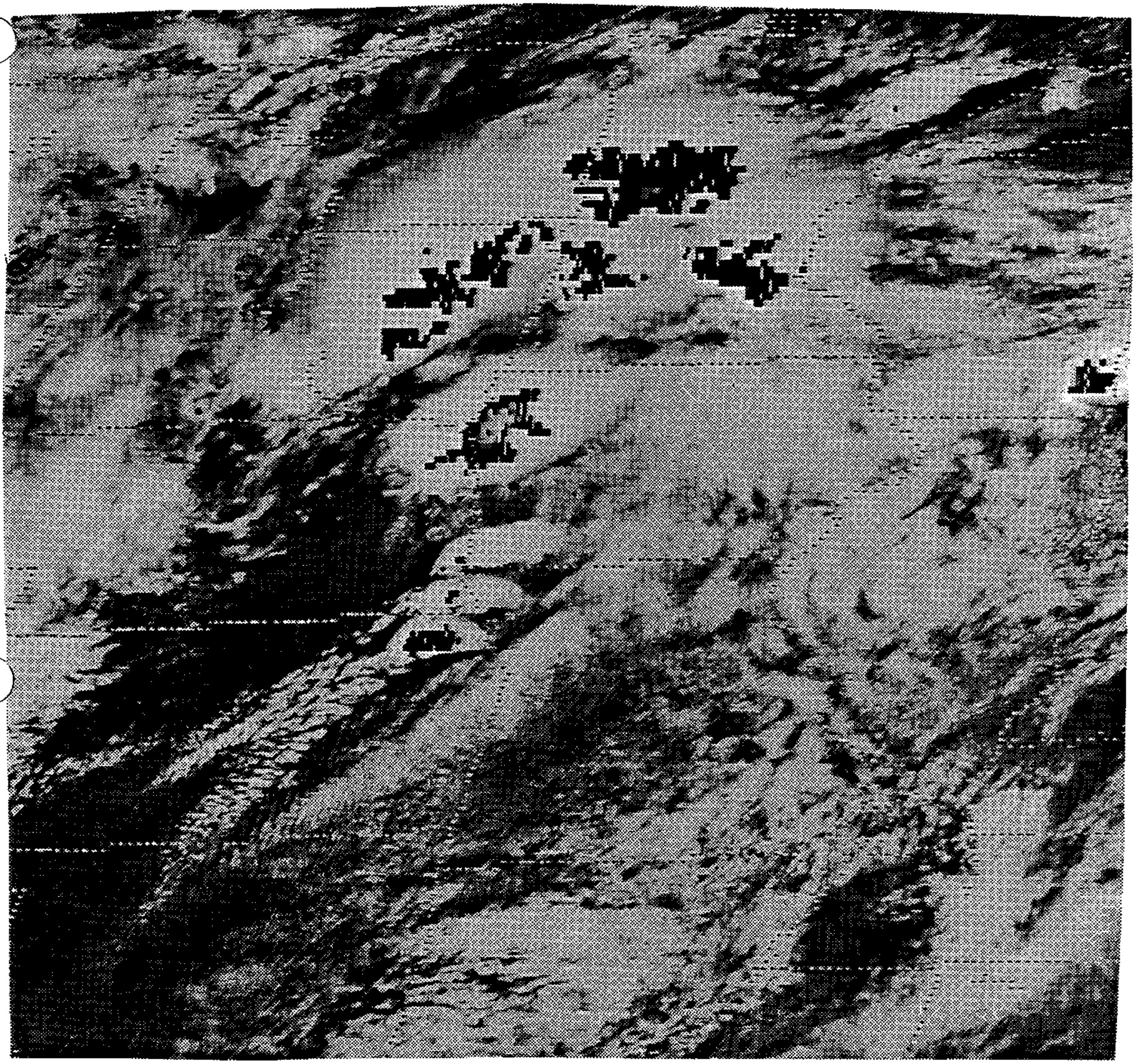

Figure 20. GOES June 7, 2030 GMT enhanced visible satellite image.

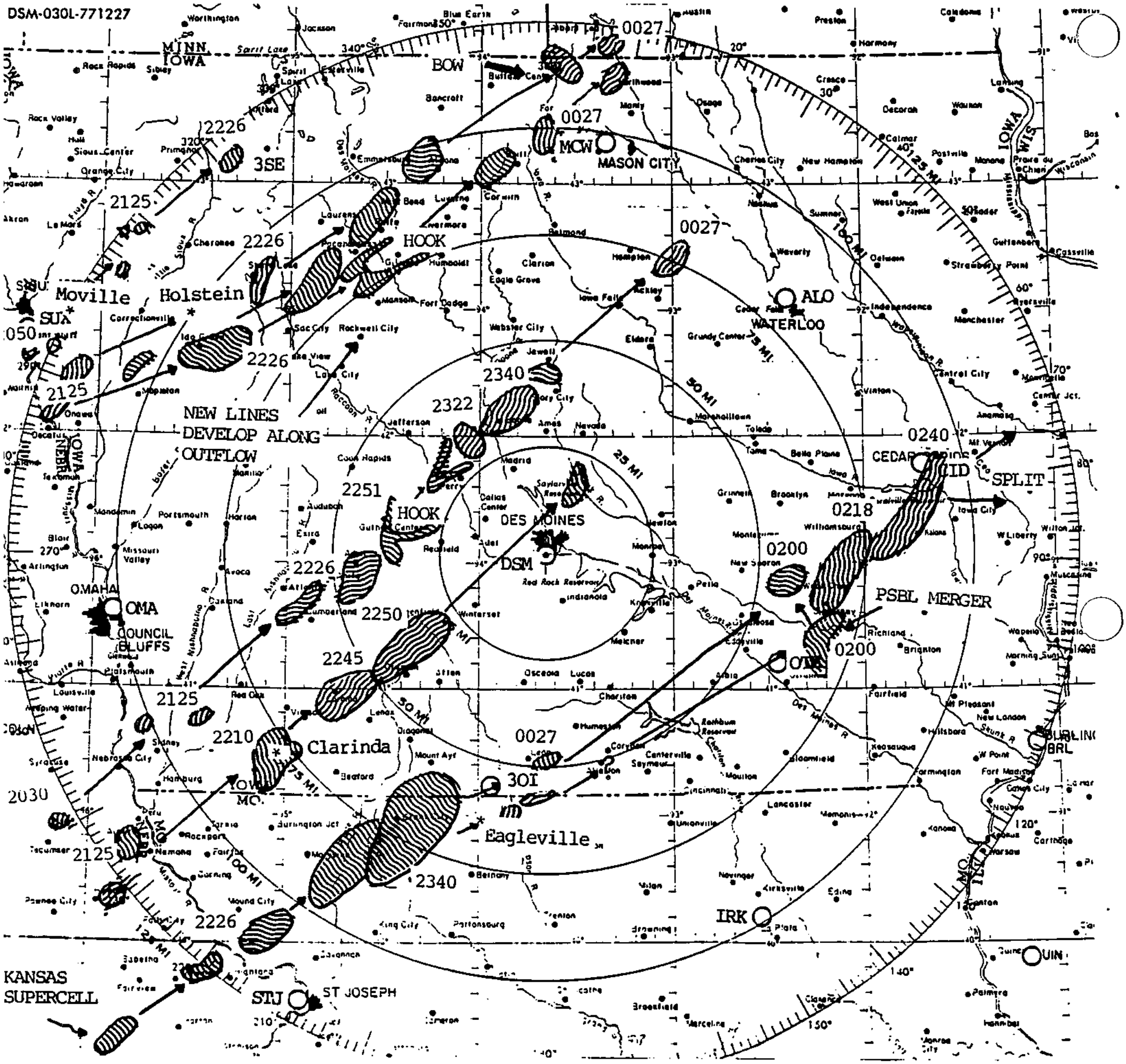

Figure 21. Radar overlay composite starting June 7, 2030 GMT.

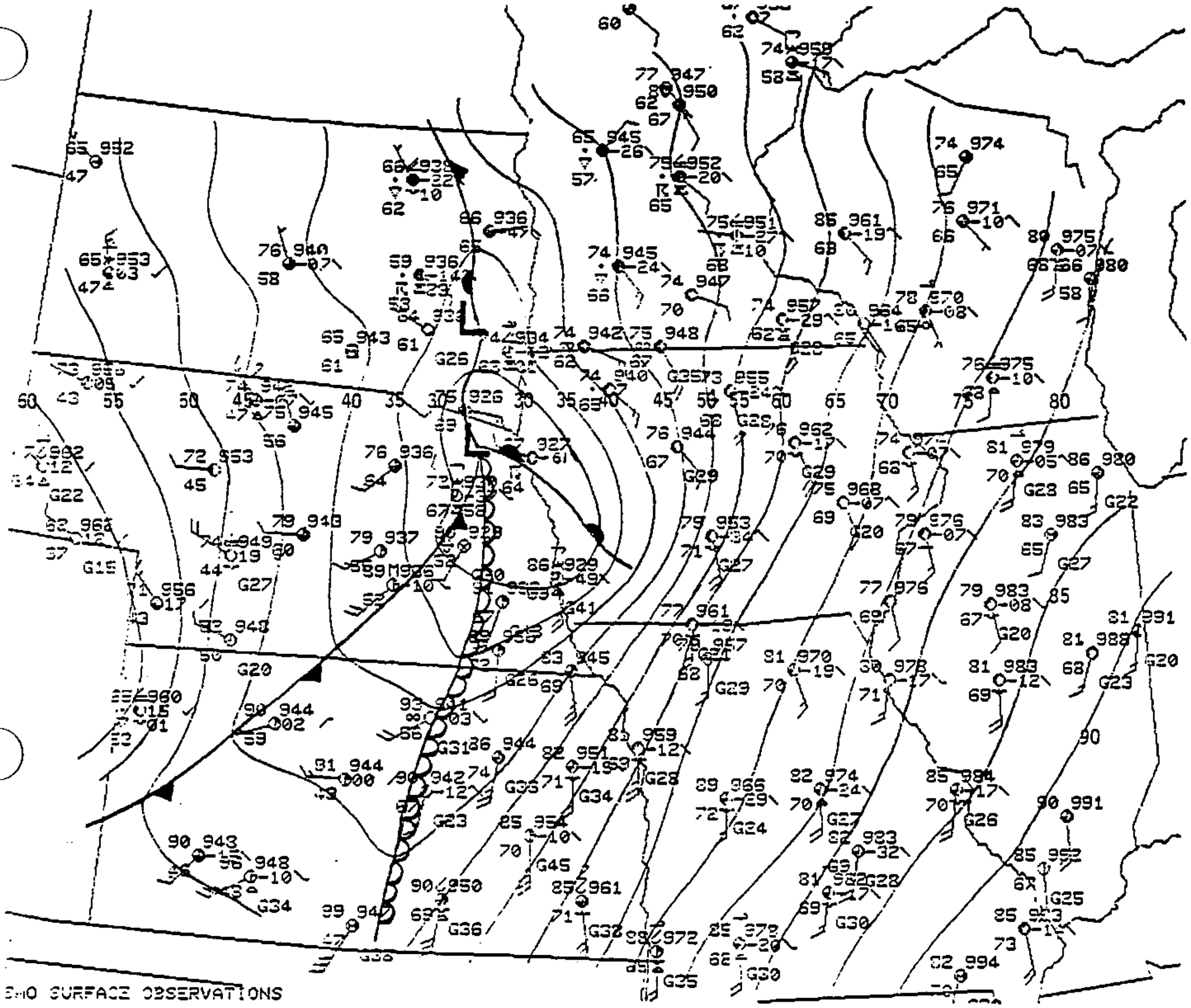

Figure 22. June 7, 2100 GMT sea-level pressure analysis (.05 in. Hg).

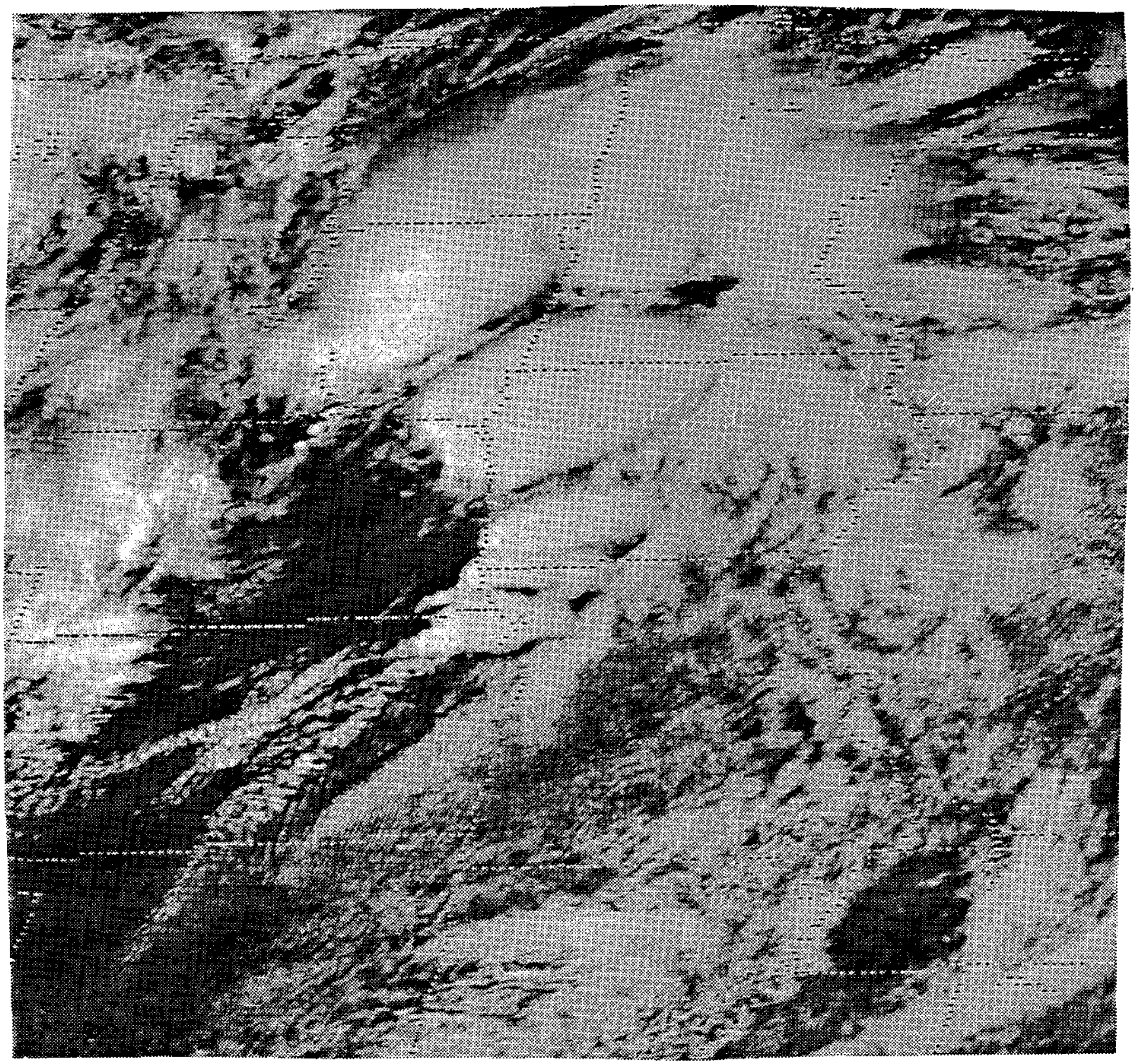

Figure 23. GOES June 7, 2100 GMT visible satellite image.

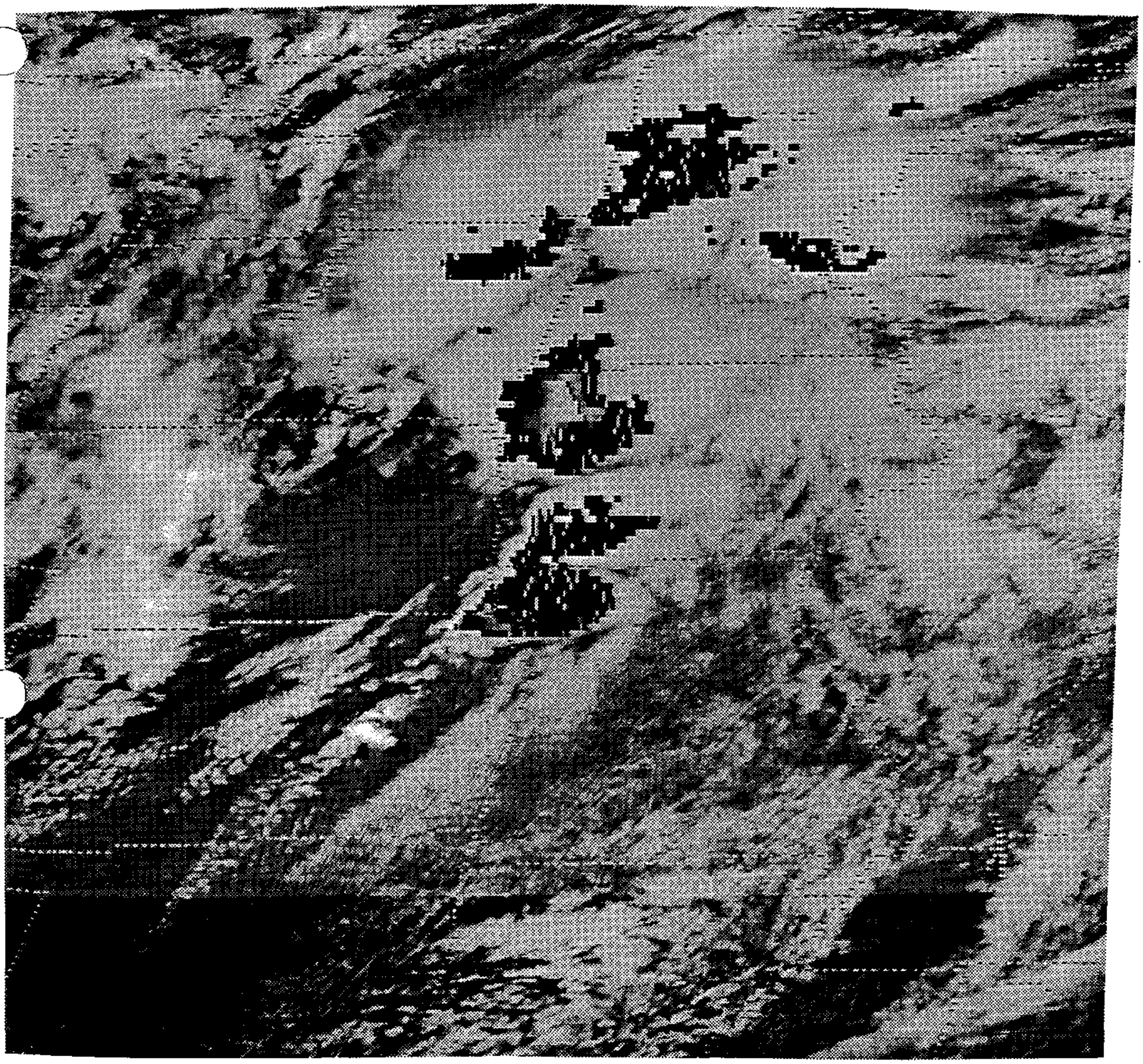

Figure 24. GOES June 7, 2130 GMT enhanced visible satellite image.

As the tornadoes capture attention in northwest Iowa, the dryline thunderstorms in southwest Iowa become violent. Southwest winds gusting to 44 knots at LNK and a south southeast wind gusting to 28 knots at OMA are reported at 2200 GMT and aid convergence along the dryline. From 2143 to 2227 GMT, an F2 tornado crosses 26 miles of Cass County (36 E OMA) (Figs. 1 and 21). At least 29 farms are hit and a fertilizer plant are destroyed. The damage estimate is 1.6 million dollars.

Meanwhile, back to the north, another cell develops just south of SUX around 2130 GMT moves across eastern Ida County spawning an F2 tornado from 2210 to 2233 GMT (Figs. 1 and 21). The tornado strikes the town of Arthur (55 SE SUX) hurling grain bins about and damaging the town's only restaurant, the "Hard Times Cafe". The Holstein cell remains active from 2212 to 2233 GMT and from 2217 to 2257 GMT, two more F2 tornadoes strike northwest Iowa, affecting Buena Vista, Pochahontas and Palo Alto counties respectively. Eyewitnesses view multiple vortices, possibly as many as four in the Pochahontas and Palo Alto tornado.

Shifting back to southwest Iowa, that section's second tornado is underway at 2220 GMT. Five tornadoes are now occurring over Iowa, three in the northwest and two in the southwest. The second southwest tornado touches down in northern Clarinda in Page County (55 SE OMA). This is the afternoon's first F3 tornado. It moves northeast across Taylor and Adams counties past Corning (60 ESE OMA) ending at 2306 GMT.

At 2223 GMT an F1 tornado visits the vicinity of Everly (10 W 3SE) in Clay County of northwest Iowa lasting until 2227 GMT. From 2230 to 2232 GMT, a brief F2 tornado damages five houses in Spencer (3SE). These are still from the Moville cell. At 2230 GMT, four tornadoes are underway.

The 2230 GMT GOES image (Fig. 25) shows the northwest Iowa convection has warmed a little since 2130 GMT. A slight bow-shaped enhanced area east of the original cluster is new. The enhanced-V signature previously in northeast Kansas at 2130 GMT has become a little more apparent in northwest Missouri. Convection continues to grow in southwest Iowa, as more thunderstorms develop along the dryline/cold front from OMA southwest to northern Kansas. Convergent cumulus streets indicate the fuel source for the southwest Iowa and northwest Missouri storms.

At 2300 GMT, the action shifts back to the northwest remaining there for the next hour as an F2 tornado does major damage to three farms near Havelock (35 SE 3SE) in Pochahontas County (Figs. 1 and 21). The tornado touches down at 2300 GMT covering its eight mile path by 2315 GMT. No sooner than the Havelock tornado ends, then another F2 ravages Humboldt, Kossuth, and Hancock counties from 2315 to 2354 GMT (Figs. 1 and 21). At least 40 farms are struck along its 21 mile path with 800,000 dollars damage in Humboldt County alone.

At 2315 GMT, the second F3 tornado of the outbreak begins its nine mile path in Kossuth County striking the town of Burt (50 E 3SE) (Fig. 1). Burt

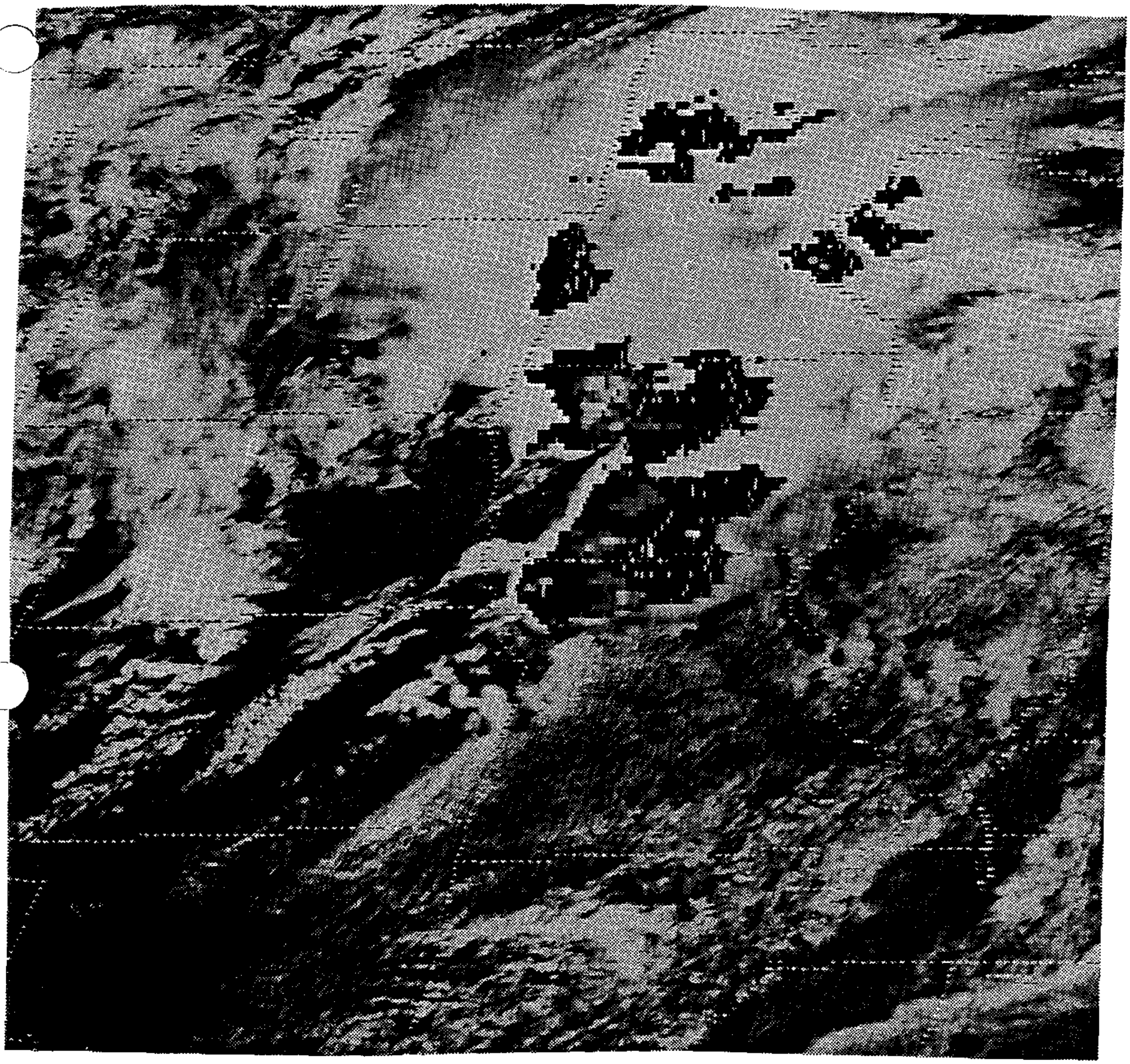

Figure 25. GOES June 7, 2230 GMT enhanced visible satellite image.

becomes the hardest hit of any town in northern Iowa with significant damage to the church, school, and 25 homes. Several mobile homes are destroyed, including the mayor's.

The 2330 GMT GOES image (Fig. 26) indicates the continued slow warming of convective cluster tops in northwest Iowa. Small CB's are becoming apparent on the southwest edge of the cluster developing back toward the OMA area. The enhanced-V signature in northwest Missouri at 2230 GMT has moved to near 3OI. Thunderstorms along the dryline/cold front in extreme southeast Nebraska, southwest Iowa, and northeast Kansas have intensified dramatically.

Two more tornadoes affect northern Iowa from 2329 to 0007 GMT. An F2 tornado rolls 21 miles through Kossuth and Winnebago counties injuring one person (Figs. 1 and 21). The tornado touches down southwest of Titonka (55 E 3SE) damaging the school and several homes. One more F2 from 2345 to 0018 GMT travels 18 miles across Hancock and Winnebago counties (Figs. 1 and 21). The tornado forms southwest of Crystal Lake (30 WNW MCW) damaging a large grain elevator and high school in the town. Significant damage extends northeast into Winnebago County.

Surface features have changed considerably by 0000 GMT (Fig. 27). The low that was near OFK at 2100 GMT is now near SUX as the South Dakota low has lifted northward. The warm boundary and dryline lose definition and the cold front extends southwest into central Kansas. South winds gusting to 35 knots fuel thunderstorms with 65 to 70 degree dew point air. Surface pressure falls of 4 mb are present near MCW while 2 to 3 mb rises are occurring in eastern Nebraska.

The GOES 0000 GMT image (Fig. 28) depicts numerous overshooting tops throughout the western two-thirds of Iowa into northeast Kansas. New thunderstorms are developing in southwest Iowa (55 SE of OMA) in the same area of Page County where the Clarinda tornado occurred 1 1/2 hours earlier (Fig. 29). Also, thunderstorms are reforming rapidly along the outflow in west central Iowa from Crawford County northeast to the north of Fort Dodge (FOD). The storm with the overshooting top that was previously in northwest Missouri nears 3OI.

At 2345 GMT, the beginning of the most powerful and destructive tornado of the outbreak occurs near Eagleville, Missouri (15 S 3OI). This F4 tornado enters Iowa near Nine Eagles State Park in Decatur County (7 S 3OI). Near complete destruction occurs along its 117 mile path from south central into east central Iowa (Figs. 1, 21, and 29). The towns of Wright (30 NW OTM) in Mahaska County and Delta (25 N OTM) in Keokuk County are devastated. Damage estimates run 3.4 million dollars in Mahaska and 25 million in Keokuk. Fifty homes are destroyed, 150 have major damage and about 600 farm-related buildings are leveled. Many more buildings and untold numbers of equipment and farm machinery are damaged. Two people die while 63 others sustain injuries. The tornado lasts a little over three hours.

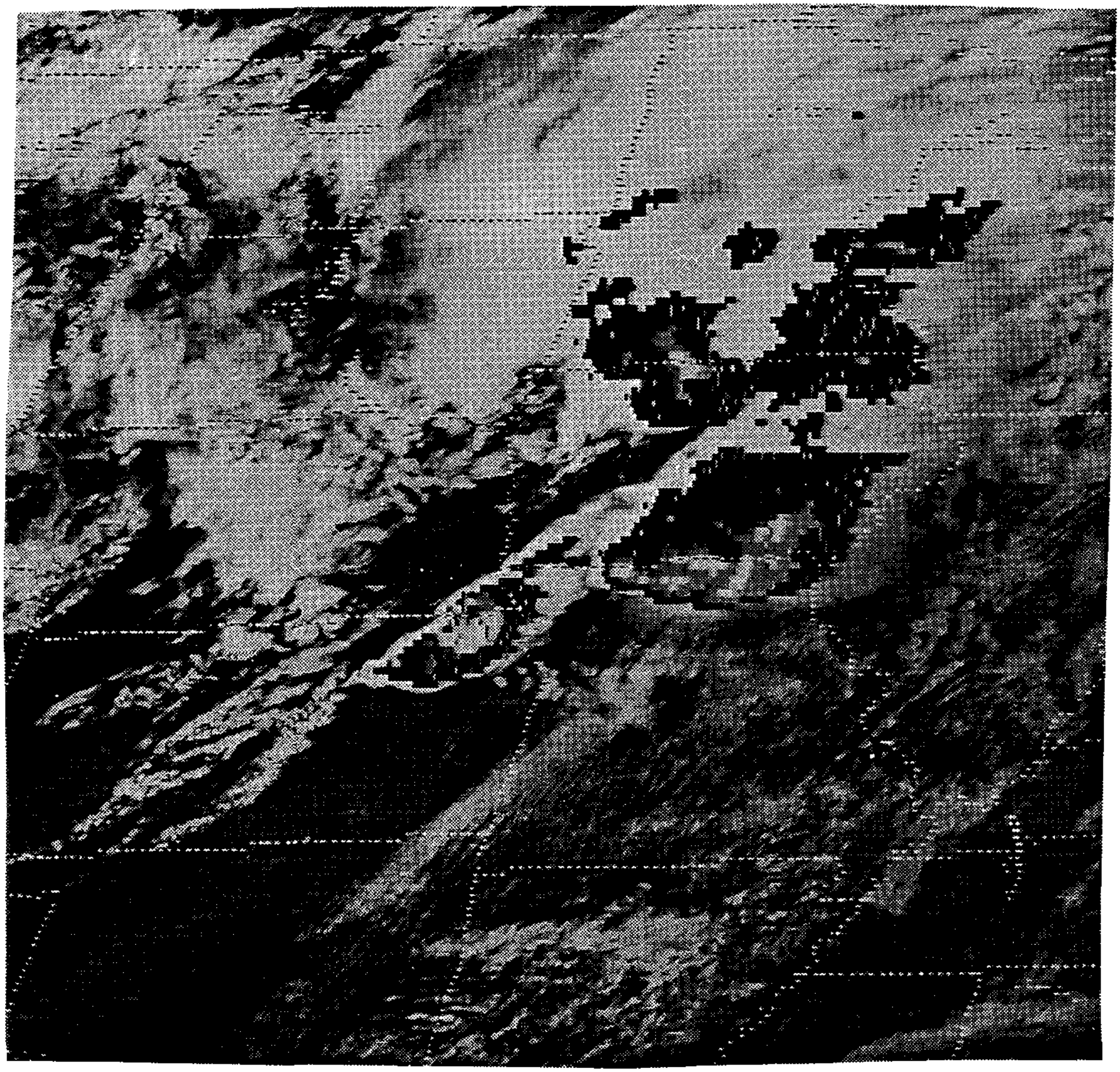

Figure 26. GOES June 7, 2330 GMT enhanced visible satellite image.

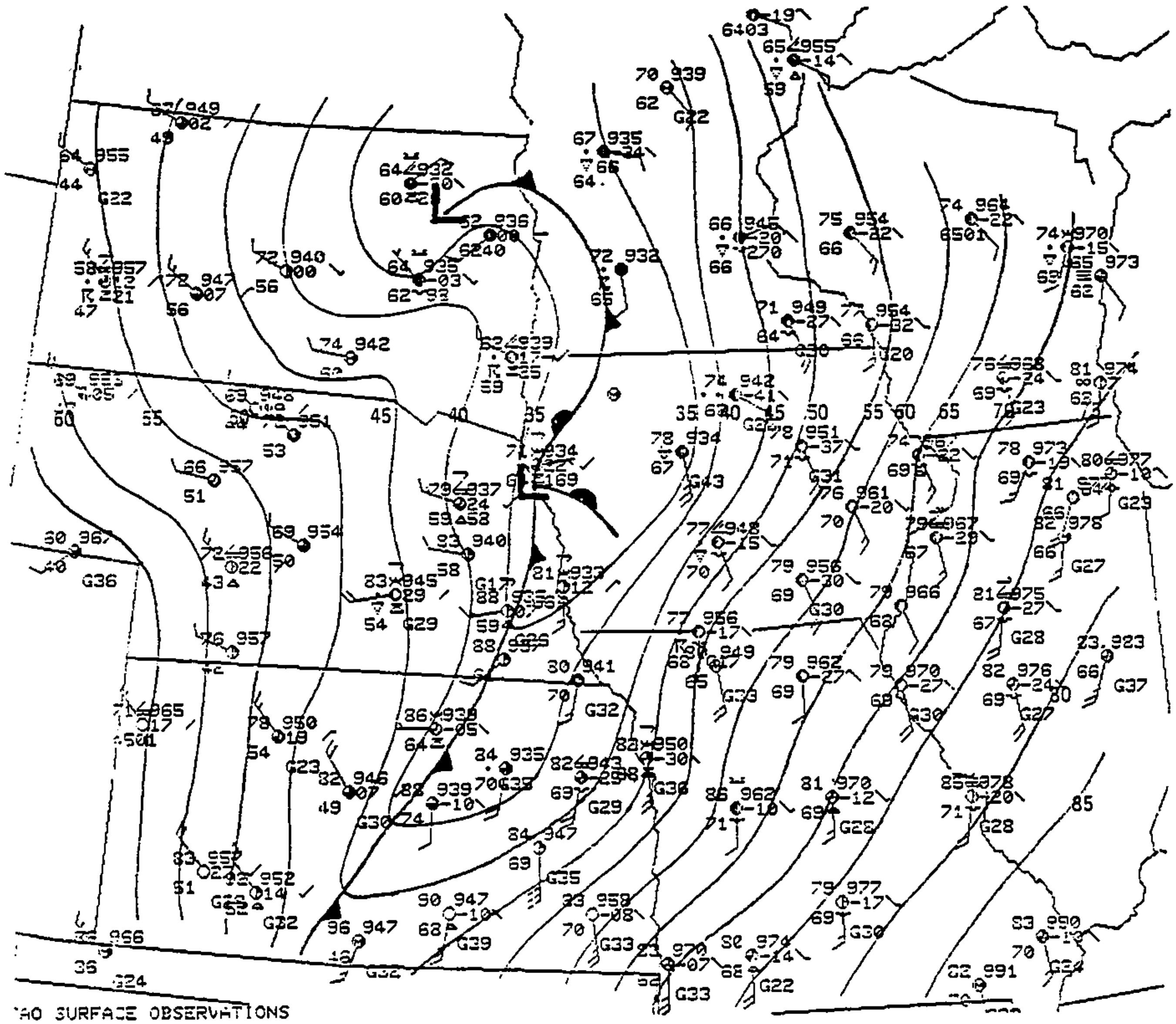

Figure 27. June 8, 0000 GMT sea-level pressure analysis (.05 in. Hg).

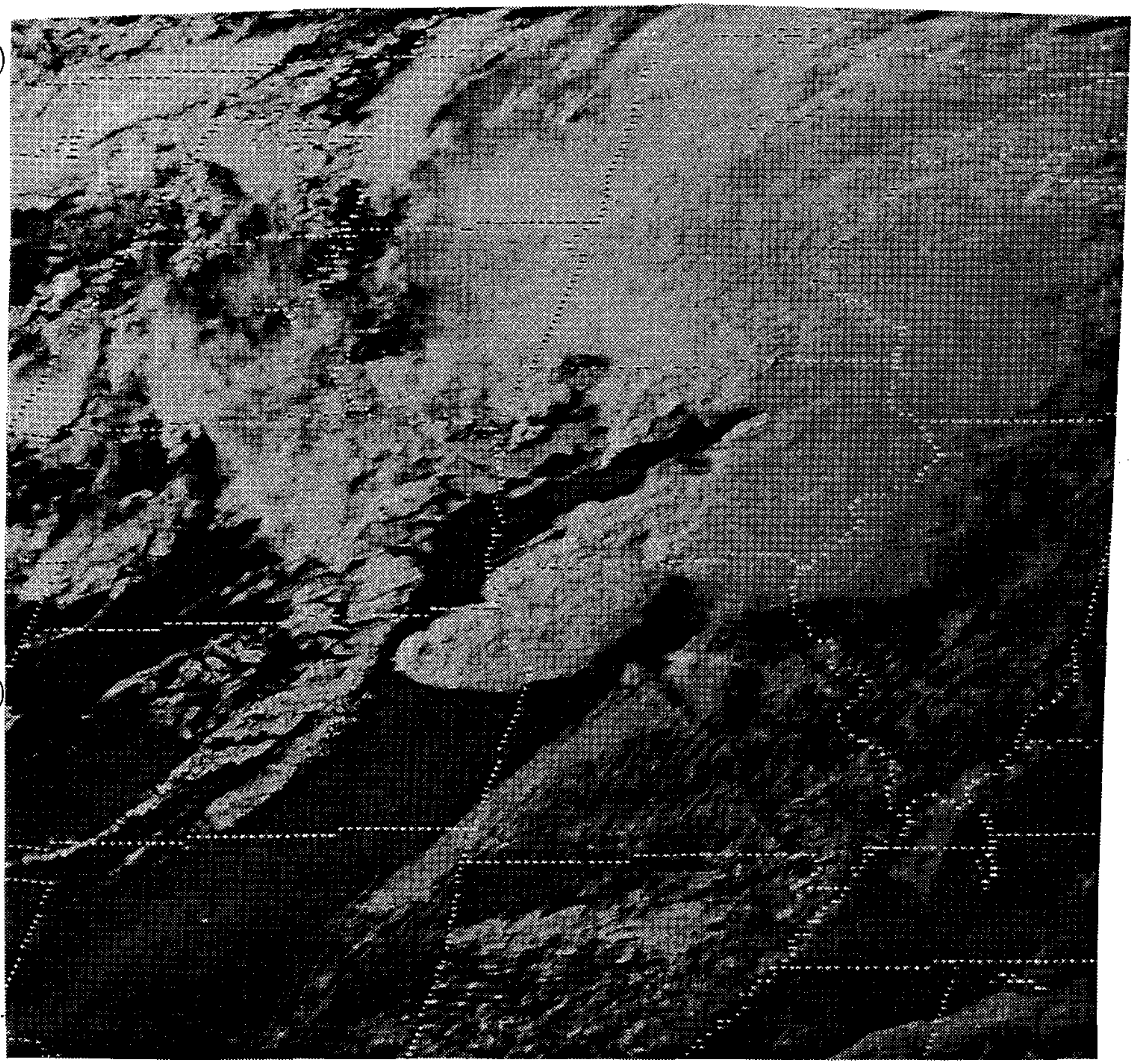

Figure 28. GOES June 8, 0000 GMT visible satellite image.

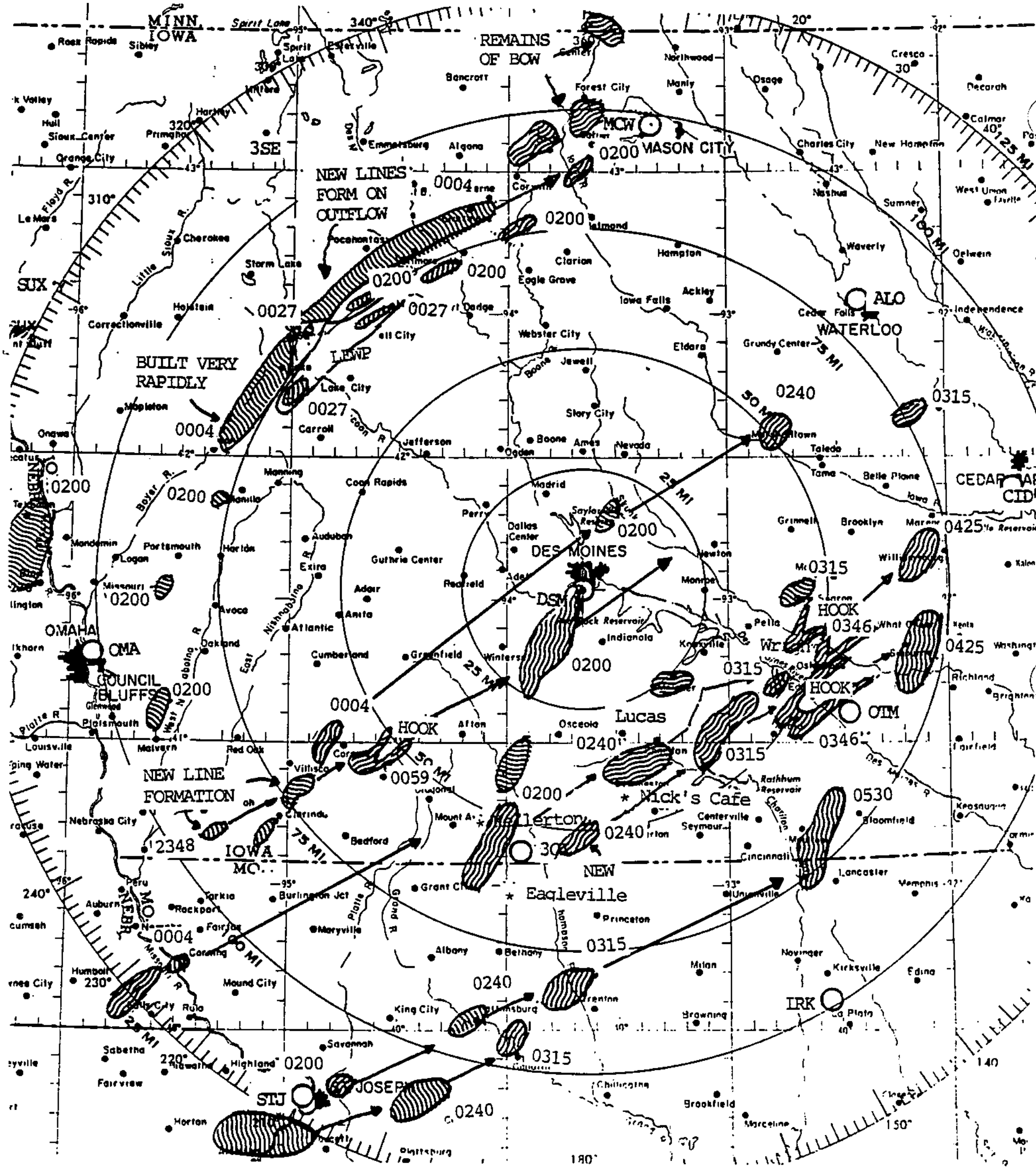

Figure 29. Radar overlay composite starting June 7, 2348 GMT.

Iowa was not to escape a few more tornadoes. At 0054 GMT an F1 touchdown is viewed between Chariton and Lucas (40 S DSM) by a sheriff's deputy causing tree damage (Fig. 1). At 0145 GMT an F2 tornado causes the third tornado-related death at Kellerton (10 NW 3OI) in Ringgold County (Fig. 1). A mobile home resident is killed while seeking better shelter. Six homes are destroyed in Kellerton, 12 with major damage.

The GOES 0130 GMT image (Fig. 30) shows cool tops in south central Iowa. Cool tops in eastern Iowa are associated with the Wright/Delta tornado. From 0233 to 0313 GMT another F2 tornado moves through northern Keokuk, Washington and Johnson counties (Fig. 1). This tornado apparently split off from the powerful Wright/Delta storm veering east across Keokuk then northeast into Washington and Johnson. Damage is confined to rural areas.

The last tornado of the day occurs at 0233 GMT, striking "Nick's Cafe" at the junction of Highways 2 and 65 (20 ENE 3OI) in Wayne County. The F1 half mile path length tornado arrives about two hours after the deadly Wright/Delta tornado passed, felling any remains that are still standing.

The surface chart at 0300 GMT (Fig. 31) shows the primary low in Minnesota with the cold front through western Iowa into Kansas. Possible remains of the dryline are depicted as a trough from near FOD into northeast Missouri. Surface pressure falls of 4 to 5 mb are observed in east central Minnesota and west central Wisconsin. Rises of 3 to 4 mb remain in eastern Nebraska.

VI. DISCUSSION

The overriding question that comes to mind is "Why did Iowa have so many tornadoes?" An indication lies in comparing the 1200 and 0000 GMT upper wind fields. By 0000 GMT a much stronger wind field was in place than at 1200 GMT, especially at the middle and upper levels. A broad 50-55 knot jet was observed at TOP and OMA, an increase of 20 knots (Fig. 32). At 500 mb, the wind increased from 45 knots to 75 knots at OMA (Fig. 33). The most impressive upper feature to change was 200 mb divergence. The peak divergent area in southeast Nebraska at 1200 GMT had moved to north central Iowa by 0000 GMT, more than doubling in value (Fig. 34). The 0000 GMT 200 mb chart showed a 40 knot wind increase at TOP and a 60 knot increase at Green Bay (GRB), positioning Iowa in the left front quadrant of the TOP jet streak.

Weisman and Klemp (1982) demonstrated that strong wind shear is a significant factor in the development of severe thunderstorms. It appears from this overview that the broad synoptic situation "set up" the initial ingredients for convection (potential instability with significant buoyancy, moisture supply, and wind field) while mesoscale features (warm boundary, local convergence and gust fronts) acted as focusing mechanisms. It also appears that a combination of mesoscale and synoptic features acted in harmony to trigger the convection; initially at the intersection of the warm boundary and low level jet near OFK. Increasing shear aloft and instability was occurring as the thunderstorms moved east in the prevailing flow. Mesoscale outflow then acted as focusing and trigger mechanism for thunderstorm

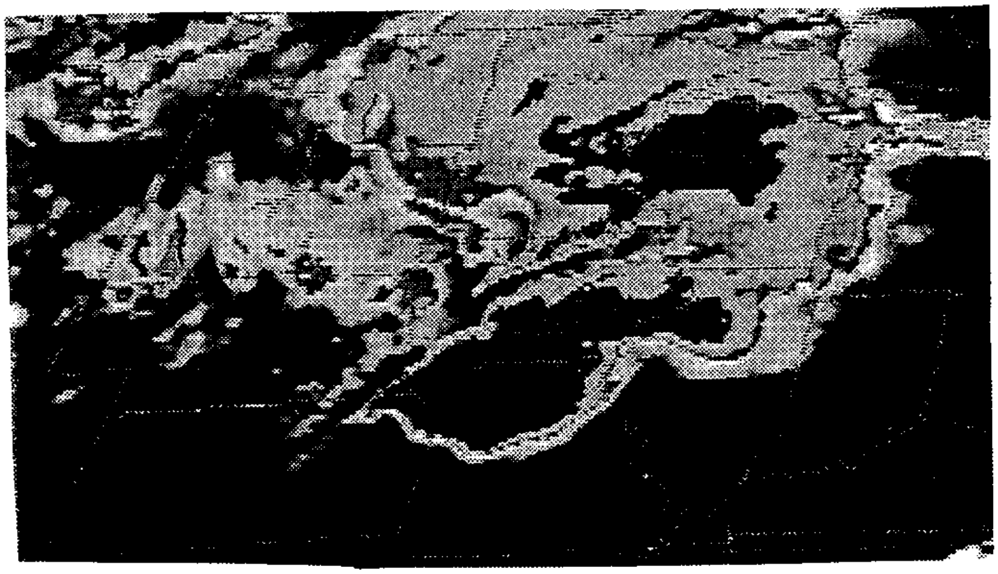

Figure 30. GOES June 8, 0130 GMT enhanced infrared satellite image.

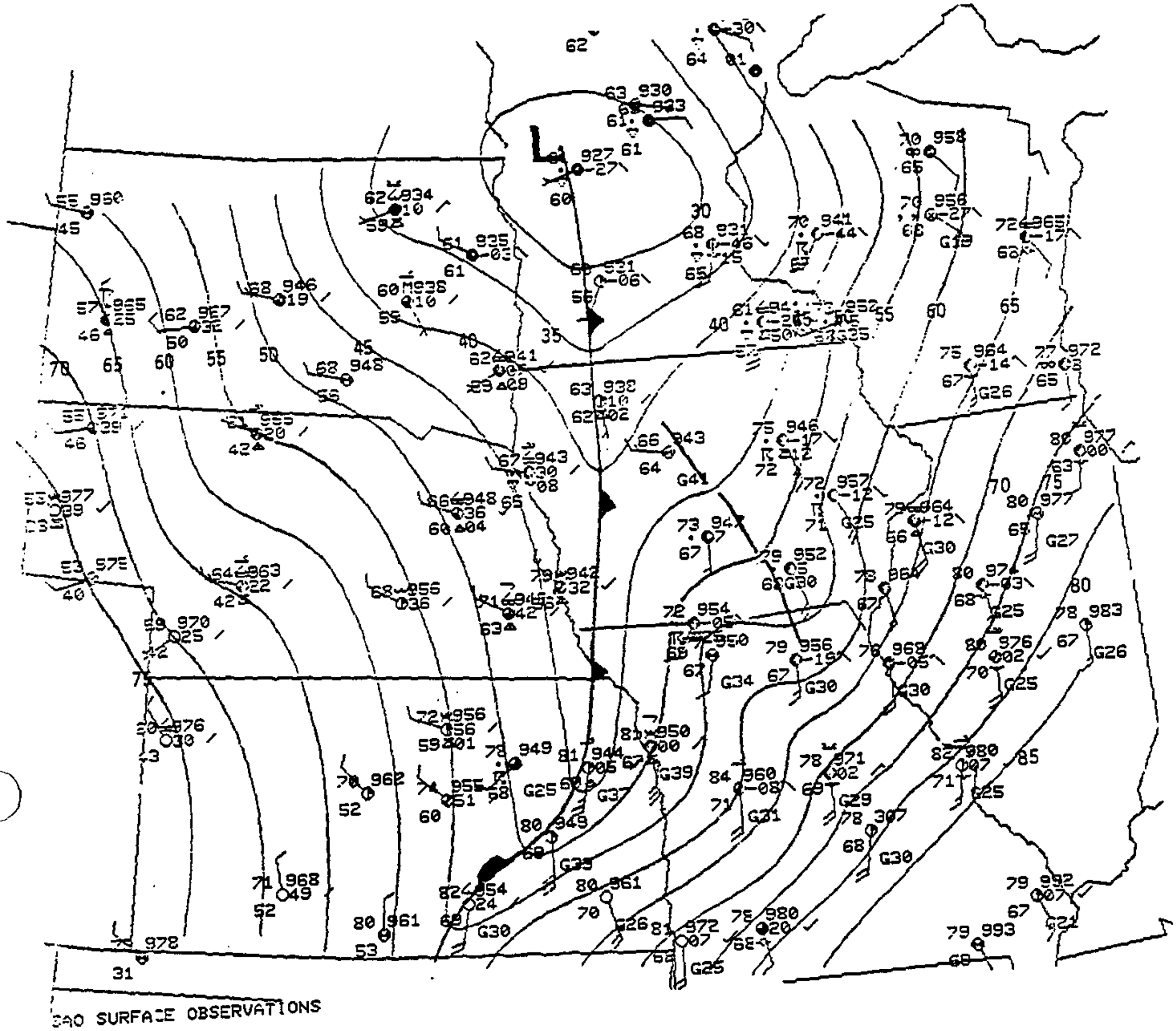

Figure 31. June 8, 0300 GMT sea-level pressure analysis (.05 in. Hg).

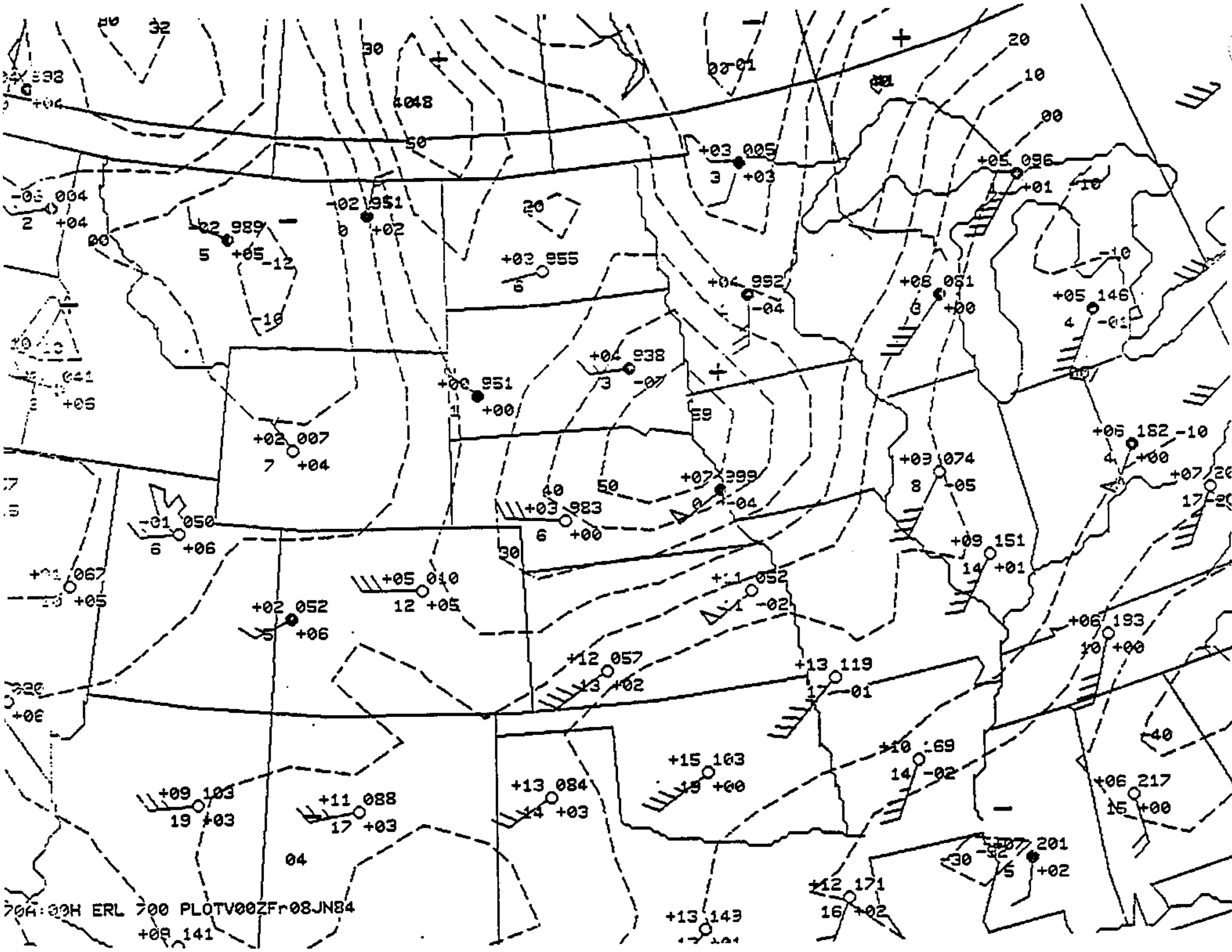

Figure 32. June 8, 0000 GMT initial 700 mb data and vorticity field - vorticity in 1E-6/sec/sec.

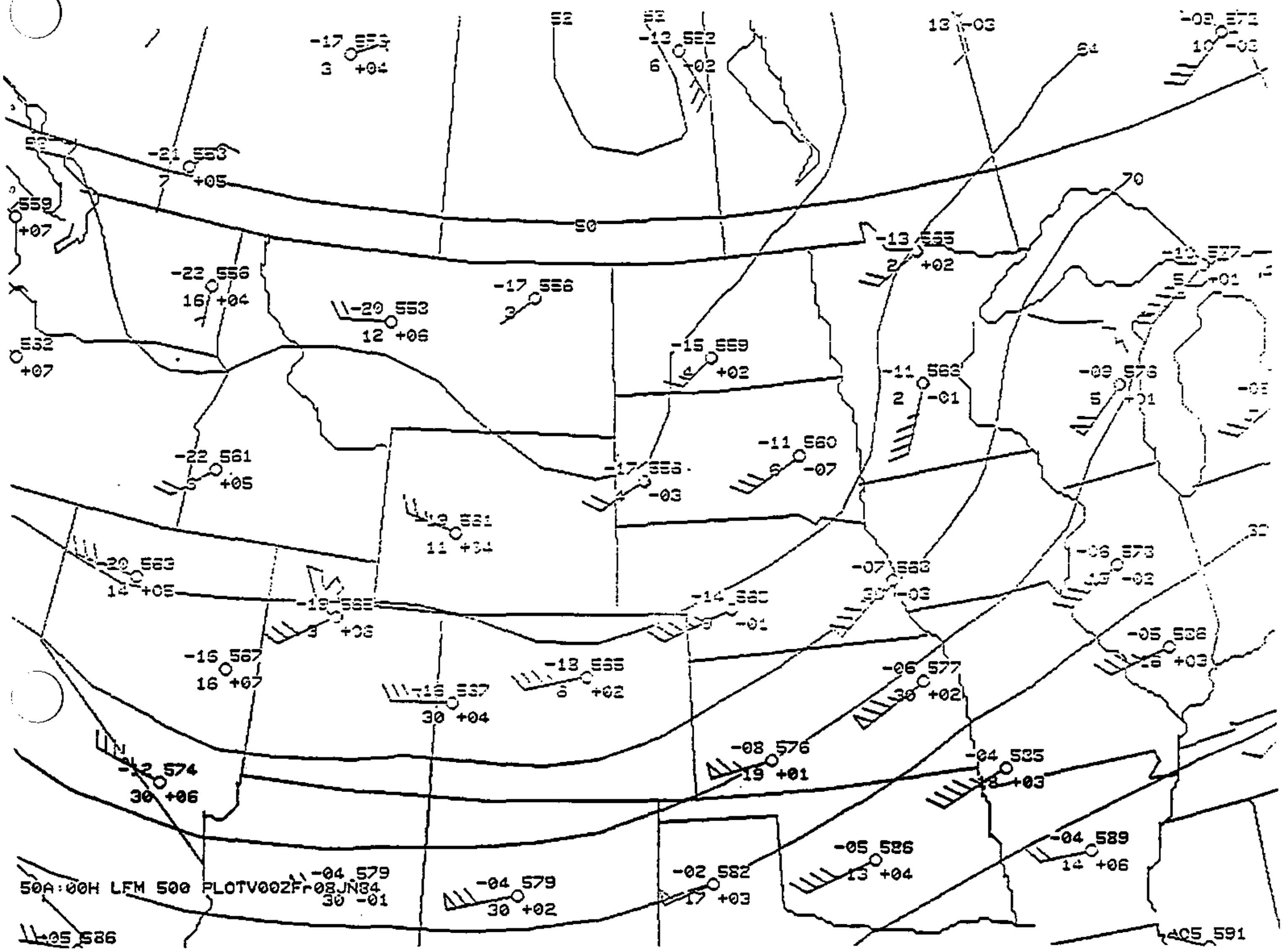

Figure 33. June 8, 0000 GMT initial 500 mb data and height field - heights in decameters.

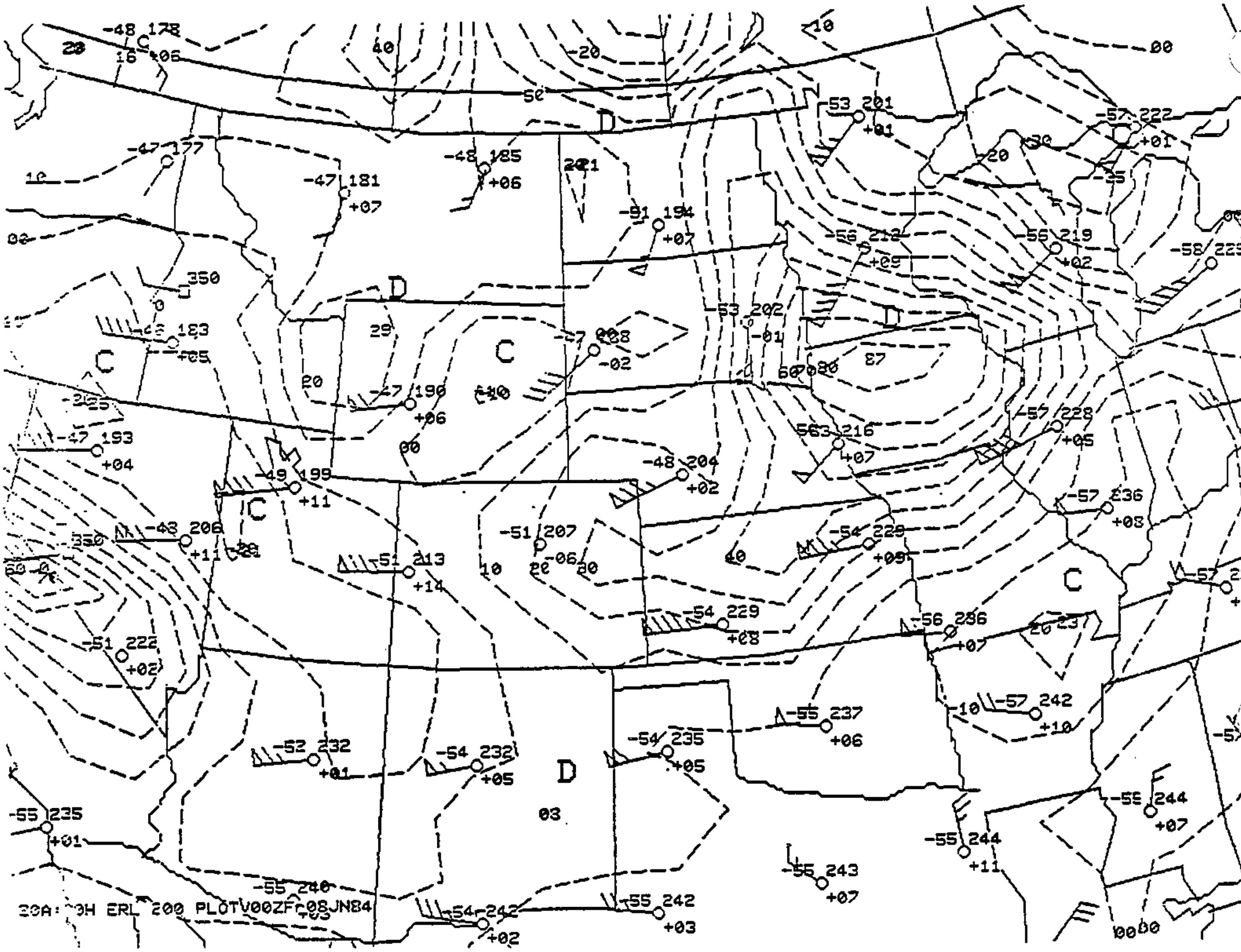

Figure 34. June 8, 0000 GMT initial 200 mb data and divergence field - divergence in 1E-6/sec/sec.

regeneration in northwest Iowa. The thunderstorms in southwest Iowa initially fired in the convergent zone ahead of the dryline, and were acted upon by the strongly-sheared wind field aloft. Other thunderstorms later redeveloped in the same area as a cold front passed. The significant synoptic feature of the outbreak was the unusually strong, near steady-state lower wind field coupled with the doubling of divergence aloft during a short period of time. This led to dramatically increasing wind shear.

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VIII. REFERENCES

Anderson, J. L. and Spry, A. J. 1983: Mesoscale objective analysis. NOAA Western Region Computer Programs and Problems NWS WRCP No. 33. Western Region Headquarters, Salt Lake City, UT, 32 pp.

Dowd, B., 1986: Personal communication, National Weather Service Forecast Office, Des Moines, Iowa.

Hales, J. E., and Crowther, H. G., 1985: Severe thunderstorm cases of 1984. NOAA Technical Memorandum NWS NSSFC-7, National Severe Storms Forecast Center, Kansas City, MO, 41-44.

McCann, D. W., 1981: The enhanced-V, a satellite observable severe storm signature. NOAA Technical Memorandum NWS NSSFC-4, National Severe Storms Forecast Center, Kansas City, MO, 31 pp.

Miller, R. C., 1972: Notes on analysis and severe storm forecasting procedures of the Air Force Global Weather Central. Technical Report 200 (Rev.), Air Weather Service, Scott AFB, IL.

U. S. Department of Commerce, 1984: Storm Data, 26 (6).

Weisman, M. L., and Klemp, J. B., 1982: The dependence of numerically simulated convective storms on vertical wind shear and buoyancy. Mon. Wea. Rev., 110, 504-520.

NWS CR 49 A Preliminary Transport Wind and Mixing Height Climatology, St. Louis, Missouri. Donald E. Wuerch, Albert J. Courtois, Carl Ewald, Gary Ernst, June 1972 (COM 72-10859).

NWS CR 50 An Objective Forecast Technique for Colorado Downslope Winds. Wayne E. Sangster, December 1972 (COM 73-10280).

NWS CR 51 Effect on Temperature and Precipitation of Observation Site Change at Columbia, Missouri. Warren M. Wisner, March 1973 (COM 73-10734).

NWS CR 52 Cold Air Funnel Clouds. Jack R. Cooley and Marshall E. Soderberg, September 1973, (COM 73-11753/AS).

NWS CR 53 The Frequency of Potentially Unfavorable Temperature Conditions in St. Louis, Missouri. Warren M. Wisner, October 1973.

NWS CR 54 Objective Probabilities of Severe Thunderstorms Using Predictors from FOUS and Observed Surface Data. Clarence A. David, May 1974 (COM 74-11258/AS).

NWS CR 55 Detecting and Predicting Severe Thunderstorms Using Radar and Sferics. John V. Graff and Duane C. O'Malley, June 1974 (COM 74-11335/AS).

NWS CR 56 The Prediction of Daily Drying Rates. Jerry D. Hill, November 1974 (COM 74-11806/AS).

NWS CR 57 Summer Radar Echo Distribution Around Limon, Colorado. Thomas D. Karr and Ronald L. Wooten, November 1974 (COM 75-10076/AS).

NWS CR 58 Guidelines for Flash Flood and Small Tributary Flood Prediction. Lawrence A. Hughes and Lawrence L. Longsdorf, October 1975 (PB247569/AS)

NWS CR 58 (Revised) March 1978 (PB281461/AS)

NWS CR 59 Hourly Cumulative Totals of Rainfall - Black Hills Flash Flood June 9-10, 1972. Don K. Halligan and Lawrence L. Longsdorf, April 1976 (PB256087).

NWS CR 60 Meteorological Effects on the Drift of Chemical Sprays. Jerry D. Hill, July 1976 (PB259593).

NWS CR 61 An Updated Objective Forecast Technique for Colorado Downslope Winds. Wayne E. Sangster, March 1977 (PB266966/AS).

NWS CR 62 Design Weather Conditions for Prescribed Burning. Ronald E. Haug, April 1977 (PB268034).

NWS CR 63 A Program of Chart Analysis (With Some Diagnostic and Forecast Implications). Lawrence A. Hughes, December 1977 (PB279866/AS).

NWS CR 64 Warm Season Nocturnal Quantitative Precipitation Forecasting for Eastern Kansas Using the Surface Geostrophic Wind Chart. Wayne E. Sangster, April 1979 (PB295982/AS).

NWS CR 65 The Utilization of Long Term Temperature Data in the Description of Forecast Temperatures. Arno Perlow, November 1981 (PB82 163064).

NWS CR 66 The Effect of Diurnal Heating on the Movement of Cold Fronts Through Eastern Colorado. James L. Wiesmueller, August 1982 (PB83 118463).

NWS CR 67 An Explanation of the Standard Hydrologic Exchange Format (SHEF) and Its Implementation in the Central Region. Geoffrey M. Bonnin and Robert S. Cox, April 1983 (PB83 193623).

NWS CR 68 The Posting of SHEF Data to the RFC Gateway Database. Geoffrey M. Bonnin, April 1983 (PB83 222554).

NWS CR 69 Some Basic Elements of Thunderstorm Forecasting. Richard P. McNulty, May 1983 (PB83 222604).

NWS CR 70 Automatic Distribution of AFOS Products Created at the NOAA Central Computer Facility via Hamlet (RJE) Punch Stream. Billy G. Olsen and Dale G. Lillie, November 1983 (PB84 122605).

NWS CR 71 An Investigation of Summertime Convection Over the Upper Current River Valley of Southeast Missouri. Bartlett C. Hagemeyer, July 1984 (PB84 222389).

NWS CR 72 The Standard SHEF Decoder Version 1.1. Geoffrey M. Bonnin, August 1984 (PB85 106508).

NWS CR 73 The Blizzard of February 4-5, 1984 Over the Eastern Dakotas and Western Minnesota. Michael Weiland, October 1984 (PB85 120087).

NWS CR 74 On the Observation and Modeling of the Slope Winds of the Upper Current River Valley of Southeast Missouri and Their Relationship to Air-Mass Thunderstorm Formation. Bartlett C. Hagemeyer, June 1985 (PB85 226926/AS).

NWS CR 75 Complete Guide to Canadian Products in AFOS. Craig Sanders, July 1985 (PB85 228153/AS).

NWS CR 76 The Reliability of the Bow Echo as an Important Severe Weather Signature. Ron W. Przybylinski and William J. Gery, September 1985 (PB86 102340).

NWS CR 77 Observation of Bow Echoes with the Marseilles Radar System. John E. Wright, Jr., September 1985 (PB86 102340).

NWS CR 78 Statistical Analysis of SHEF Coding Errors. Robert S. Cox, Jr., January 1986 (PB86 145141).

NWS CR 79 On the Midwestern Diurnal Convergence Zone on the West Side of the Warm Season Bermuda High. Bartlett C. Hagemeyer, March 1986 (PB86 171378).

NWS CR 80 Some Characteristics of Northeast Kansas Severe Weather 1963-1984. Larry W. Schultz, March 1986 (PB86 173952/AS).

NWS CR 81 The Severe Thunderstorm Outbreak of July 6, 1983 in Southeast Idaho, Western Wyoming and Southwest Montana. Gary L. Cox, April 1986 (PB86 184322/AS).

NWS CR 82 Some Proposals for Modifying the Probability of Precipitation Program of the National Weather Service. Wayne E. Sangster and Michael D. Manker, July 1986 (PB86 226636/AS).

NWS CR 83 Deformation Zones and Heavy Precipitation. Henry Steigerwaldt, August 1986 (PB86 229085/AS).