

A COMPARISON OF TWO MAJOR SNOWSTORMS THAT AFFECTED THE SOUTHERN GREAT LAKES REGION

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Abstract

The southern Great Lakes region typically receives significant snowfall each winter, especially in areas subject to lake-effect snow. Even though residents expect heavy snow each winter, some winter storms can paralyze the region. This paper compares two winter storms (25-27 January 1978 and 2-4 January 1999) that significantly affected the region. Near-record amounts of snow fell during each event and combined with high winds, made travel impossible in many areas. The source region for both surface cyclones was the southern Great Plains. Southerly wind flow ahead of each system advected copious moisture into the region, setting the stage for heavy snowfall. Strong upper-level dynamics also aided in the strengthening of each system. Specifically, enhanced secondary circulations induced by stronger jet stream dynamics resulted in increased vertical ascent in the 1978 storm. Enhanced upper-level dynamics, more easterly path of the surface low, and deeper low-level circulation of the 1978 storm caused it to affect the southern Great Lakes region more severely than the 1999 storm. This paper will discuss the evolution of each system.

1. Introduction

Winters are typically snowy across the southern Great Lakes region. Seasonal snowfall totals range from approximately 25 inches over central Indiana and Ohio to nearly 100 inches in the lake-effect snowbelts near Lake Michigan and Lake Erie. Occasionally, intense storm systems move through the region and produce significant single-storm total amounts of precipitation.

A powerful winter storm system that moved through the region during the first few days of January 1999 resembled an earlier system that paralyzed the region during late January 1978. Both systems were similar in that they formed in the southern Great Plains and moved north through the Ohio Valley. Rapid deepening of both

low-pressure areas and plentiful low-level moisture combined to produce heavy snow and high winds, resulting in blizzard and near-blizzard conditions across much of the region during each event.

The purpose of this paper is to compare the dynamics of the two events. It is hoped that any similarities found may help in the forecasting of major snowstorms across this region in the future.

2. Methodology

Data for the January 1978 snowstorm was derived from a variety of sources. The NOAA publication *Daily Weather Maps* for the period from 16 January through 5 February 1978 provided an excellent overview of the event (U. S. Dept. of Commerce 1978a, 1978b, and 1978c.). The NOAA/NWS National Centers for Environmental Prediction (NCEP) Grid Point Data Set: Version III was used to look at the event in more detail (University of Washington and NCAR 1996). Data for the 1999 snowstorm were downloaded from servers at NCEP and the NWS Central Region office, and archived at the Northern Indiana NWS Forecast Office (NWSFO) for post analyses.

3. The January 1978 Event

The winter of 1977-1978 was the second consecutive severe winter experienced over the eastern half of the United States. An amplified ridge-trough pattern allowed for strong northwesterly flow over the eastern and central U.S. (Harnack 1980). During January 1978, temperatures across the southern Great Lakes averaged 6 to 10 °F below normal (Wagner 1978b). Lake Erie and most of Georgian Bay were ice-covered by mid-January 1978 (Assel et al. 1979). Snowcover during December 1977 was near normal across the U.S. The month of January 1978, however, turned out to be one of the snowiest on record across the mid-Atlantic States and eastern Great Lakes

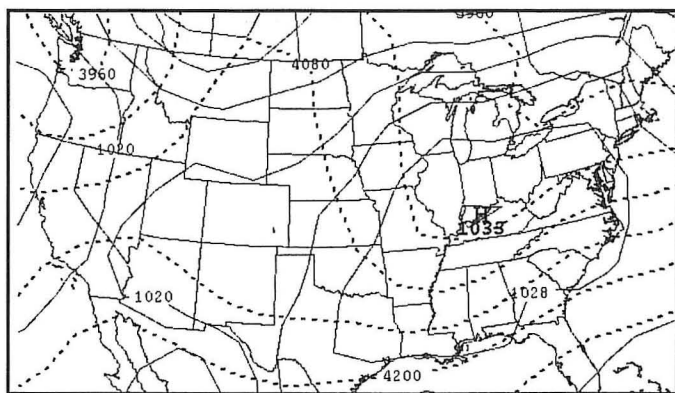


Fig. 1. Surface pressure analysis (hPa; solid lines) and 850-500 hPa geopotential thickness analysis (m, dashed lines) for 1200 UTC 22 January 1978 (derived from NCEP Grid Point Data Set, Version III (University of Washington and NCAR 1996)).

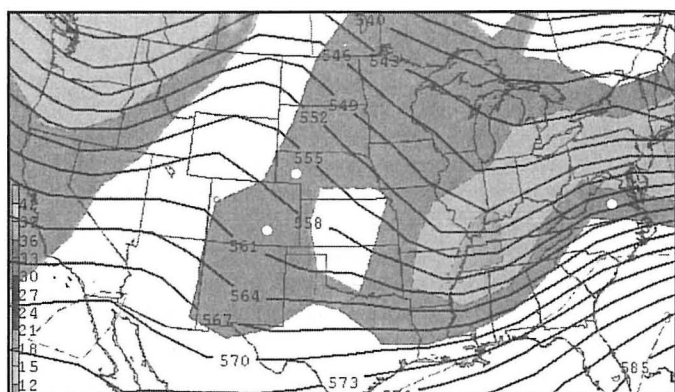


Fig. 2. 500 hPa height analysis (dm; solid lines) and absolute vorticity analysis (s^{-1} ; shaded) for 1200 UTC 22 January 1978 (derived from NCEP Grid Point Data Set, Version III (University of Washington and NCAR 1996)).

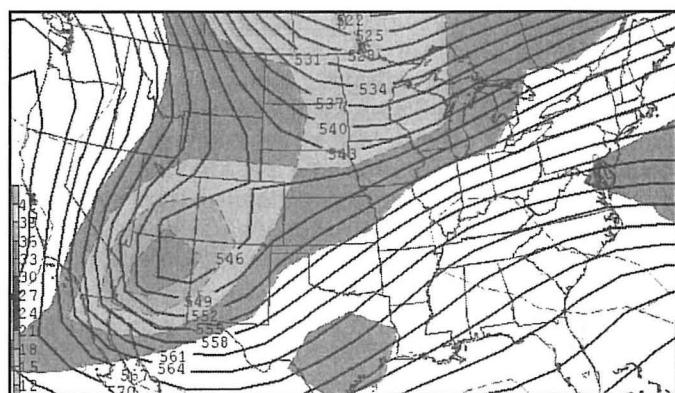


Fig. 3. Same as in Fig. 2, except for 1200 UTC 24 January 1978.

regions. Average snowcover for the month of January typically does not extend much farther south than a line extending from northern Missouri to northern Pennsylvania. This area of snowcover includes the northern third of Illinois, Indiana, and Ohio. During January 1978, average snowcover for the month extended as far south as northern Arkansas and Tennessee (Weisnet and Matson 1979).

Like many winter storms that affect the Great Lakes region, this system originated as a low-pressure area over

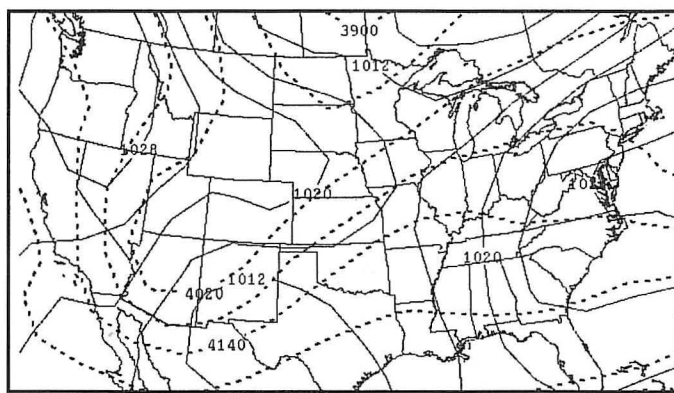


Fig. 4. Same as in Fig. 1, except for 1200 UTC 24 January 1978.

the southern Plains. Early in the week, surface high pressure dominated the eastern third of the nation (U. S. Dept. of Commerce 1978a). At 1200 UTC 22 January 1978, a 1033 hPa surface high-pressure center was located over the lower Ohio valley (Fig. 1). The corresponding ridge at 500 hPa was located over the northern High Plains (Fig. 2). The ridge moved east in response to a developing system to the west. The ridge weakened and moved to the western Great Lakes by 1200 UTC on 23 January 1978. This "retreating eastern ridge" is a common pattern in the formation of major Midwestern winter storms (Weber 1978).

The 500 hPa trough over the intermountain west deepened during the next twenty-four hours. This baroclinic system induced an upper-level low to form over northern Utah (U. S. Dept. of Commerce 1978b). Twenty-four hours later, at 1200 UTC 24 January 1978, the 500 hPa low had moved southeast over the four-corners area to northern Arizona (Fig. 3). By this time, a 1008 hPa surface low-pressure area had formed over southwestern Texas and warm moist southerly flow was moving northward into the lower Mississippi Valley (Fig. 4).

Upper-level dynamics contributed to the extraordinary strengthening of the surface system during the next 48 hours. This was observed in the intensification of the snowstorm on 25-27 January 1978. It is well known that jet stream dynamics can have a major impact on surface systems; specifically, dynamics resulting from speed gradients in the jet stream (referred to as "jet streaks"). Uccellini and Kocin (1987) asserted that "there is growing recognition that jet streak-induced circulations play a role in cyclogenesis." These circulations, called "transverse circulations," in the vicinity of a jet streak, can induce the upward vertical motion necessary to cause surface lows to deepen. They also act to transport relatively greater values of potential vorticity (the absolute vorticity ($\zeta + f$) multiplied by the static stability ($\partial\theta/\partial p$) from the stratosphere down to lower layers in the troposphere.

The transverse circulation at the entrance region of a jet streak is a direct circulation in which air from lower levels in the atmosphere, on the warm side of the jet, rises beneath the right rear quadrant of the jet streak (looking downstream). At the tropopause, this air then moves toward the jet core. The transverse circulation in the exit region of a jet streak is an indirect circulation. In this area, air on the cold side of the jet stream rises beneath

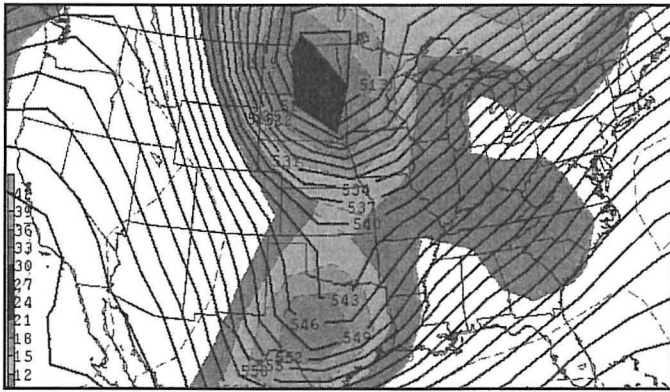
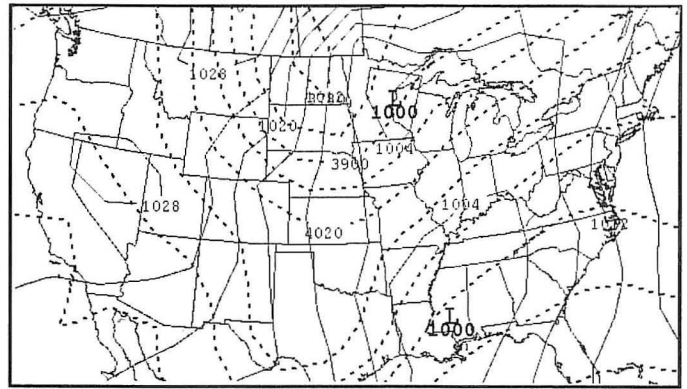


Fig. 5. Same as in Fig. 2, except for 1200 UTC 25 January 1978.

the left front quadrant and then moves toward the jet core. As is well known in ageostrophic theory, the right entrance and left exit regions of jet streaks are areas of upper-level divergence. Therefore, if a transverse circulation associated with the entrance or exit region of a jet streak is located above a surface low-pressure system, the upward motion induced by the area of upper divergence can cause surface low-pressure systems to intensify (sometimes rapidly). This process resulted in the rapid intensification of the surface low by 26 January 1978.

At 1200 UTC 25 January 1978, a deep upper-level trough stretched from Manitoba to southern Texas (Fig. 5). At 250 hPa a 160-kt jet streak had developed to the east of the trough axis. At 500 hPa a vorticity maximum was located over the Dakotas with a second weaker one over central Texas. The surface low had deepened to 1000 hPa and had moved into central Mississippi (Fig. 6). The left exit region of the 250 hPa jet streak was located directly above the surface low at this time. With the strong divergence at 250 hPa the surface low deepened 15 hPa during the next 12 hours.

By 1200 UTC 26 January 1978 the two 500 hPa vorticity maxima had merged and were now over western Pennsylvania. The left front quadrant of the 250 hPa jet streak was now located just to the southeast of both the 500 hPa vorticity maximum and the surface low, which were now over the upper Ohio valley. The close proximity of this strong jet streak contributed to the rapid strengthening of the 500 hPa and surface features. During this time explosive cyclogenesis was occurring as the surface low moved from central Mississippi to Lake Erie. Between 1200 UTC 25 January 1978 and 1200 UTC 26 January 1978 the surface low deepened 38 hPa (23 hPa in the second twelve hours alone). Even more remarkable was the drop in surface pressure measured over southeastern Ontario as the low approached. Between 1200 UTC 25 January 1978 and 1200 UTC 26 January 1978 the surface pressure over southeastern Ontario dropped almost 40 hPa (Fig. 7). The drop in surface pressure for the final 12 hours of this 24-hour period was 30 hPa (Fig. 8). As the low passed Cleveland, Ohio the surface pressure dropped to 958 hPa (28.28 inches), the lowest reading reported in the U.S. during the event (Wagner 1978b). The surface low continued to strengthen and had deepened to 955.3 hPa (28.21 inches) as it passed Sarnia, Ontario, Canada (Ludlum 1978).



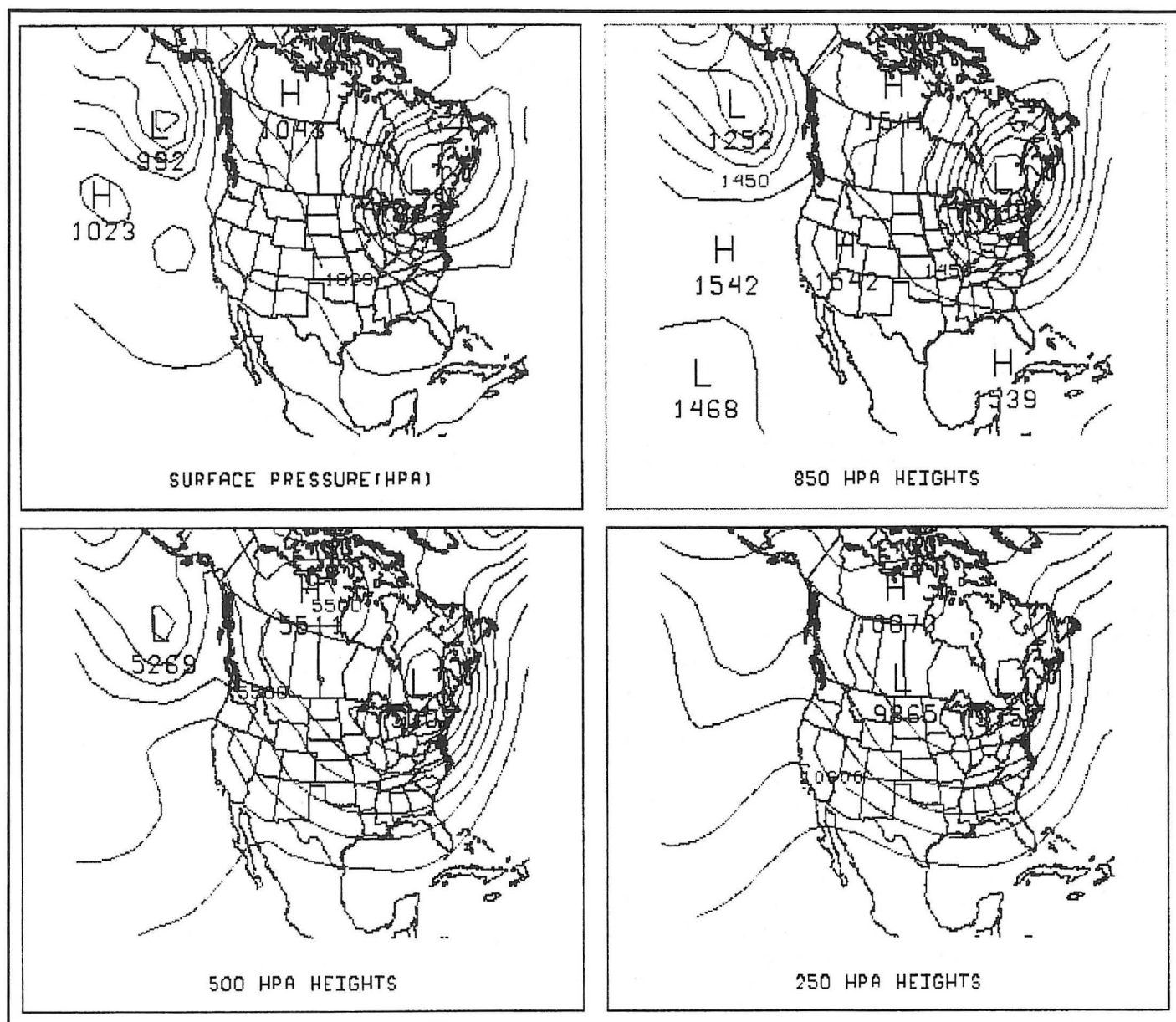


Fig. 9. Four panel chart (surface, 850 hPa, 500 hPa, and 250 hPa) illustrating the vertical stacking of the intense low-pressure system at 1200 UTC 27 January 1978. Surface pressure analysis in hpa; upper-level height contours in meters. (Derived from the NCEP Grid Point Data Set, Version III (University of Washington and NCAR 1996).

Evidence for the rapid deepening of the surface low during this event can also be seen in the folding of the tropopause in the vicinity of the jet streak. Tropopause folds are formed as a result of extrusions of stratospheric air downward into the troposphere. These folds develop "along the axis of confluence between direct and indirect circulation cells beneath the core of the jets" (Danielsen 1968). In the thermally direct circulation (south of the jet axis), warm air rises, cools as it rises, and moves north and then sinks in the vicinity of the jet core. In the thermally indirect cell (north of the tropopause fold) cold air rises, travels south along the tropopause, and then sinks and warms beneath the jet core.

Stratospheric air can intrude into the troposphere in the region between the direct and indirect vertical circulations in the jet core. Numerous studies have shown that

the movement of stratospheric air and its constituents (such as can be measured by potential vorticity (PV), and concentrations of radioactive particles, and ozone) can be traced from upper levels of the atmosphere (at approximately 200 to 300 hPa) downward into regions normally associated with the troposphere at 500 hPa or lower (Reed 1955; Staley 1960; Reiter 1975; and Shapiro 1980). As measured on isentropic surfaces, the isentropic potential vorticity (IPV) has been shown to be a dynamically significant tracer of synoptic scale evolution (Hoskins et al. 1985). Turbulent mixing in the lower troposphere can then carry this stratospheric air (with its large values of potential vorticity) even closer to the surface (Reiter 1975).

Tropospheric values of potential vorticity are typically on the order of 1 Potential Vorticity Unit (PVU). Potential

vorticity values in the stratosphere are typically an order of magnitude greater. The tropopause is often defined as the surface with a value of 1.5 PVUs. Thus, PVU values greater than 1.5 PVUs are indicative of stratospheric air.

Hakim et al. (1995) observed that by 1200 UTC 26 January 1978 a vertical circulation had developed in which the tropopause had lowered to 800 hPa. Stratospheric values of vorticity had thus been brought close to the surface low-pressure system. This coincided with the period of greatest deepening of the surface low. These relatively higher values of potential vorticity helped to strengthen the circulation in the surface low.

The extraordinary pressure gradient surrounding the surface low caused wind speeds to approach hurricane force. Wind gusts in northern Ohio were in excess of 100 mph (U. S. Dept. of Commerce 1978d). The upper trough had become negatively tilted by the morning of 26 January 1978. In a study of twenty snowstorms that affected the northeastern coast of the United States, Kocin and Uccellini (1990) found that negatively-tilted upper troughs may be a prerequisite for heavy snow. A possible area for future study could investigate this for snowstorms across the Great Lakes region.

Surface winds continued to increase and the movement of the surface low slowed. As suggested by Hakim et al., non-conservative effects (such as ageostrophic circulations) may have been responsible for the decreased eastward progression (Hakim et al. 1995). By 1200 UTC 27 January 1978, the surface low and upper components were becoming vertically-stacked (Fig. 9). By this time the surface low began to fill, the surface pressure had increased to approximately 984 hPa, and surface wind speeds had also dropped off considerably. By 1200 UTC 28 January 1978 the 988 hPa surface low had moved to eastern Quebec (Fig. 10).

Snowfall totals from this event were impressive (Fig. 11). From 25 January 1978 through 28 January 1978 South Bend received a record 27.1 inches of snow. During the same four-day period Indianapolis received 15.6 inches of snow. During this blizzard "24-hour snowfall totals of a foot or more were observed at Dayton, Ohio; Grand Rapids, Michigan and Houghton Lake, Michigan." (Wagner 1978a). Total snowfall from the event equaled 15 to 30 inches across much of northern Indiana and southwestern Lower Michigan west of the surface low's track. Snowfall totals of 10 to 15 inches were reported in northwestern Ohio, and also close to the Lake Michigan coast in northeastern Illinois and southeastern Wisconsin. Chicago's Midway Airport received 12.4 inches of snow during the three-day period 25-27 January 1978. During this same period Cleveland, Ohio (almost exactly in the path of the surface low) received 7.5 inches.

The high winds combined with the snow to produce blizzard conditions. Chicago's O'Hare International Airport was forced to close for only the third time in its history (*Chicago Tribune* 1978a). And, in the publication *Storm Data*, the blizzard was called the worst of the century in Ohio (U. S. Dept. of Commerce 1978d). During the snowstorm across Indiana, Illinois, and Wisconsin sustained winds were measured at 25 to 35 mph with gusts over 50 mph. Similar wind speeds occurred across southeastern Ohio. The highest wind speeds were experienced

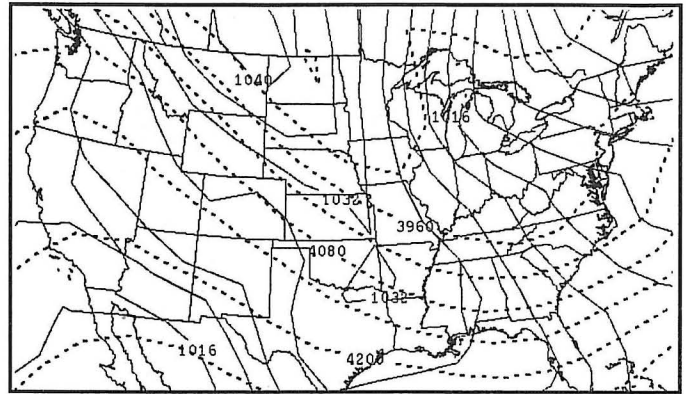


Fig. 10. Same as in Fig. 1, except for 1200 UTC 28 January 1978.

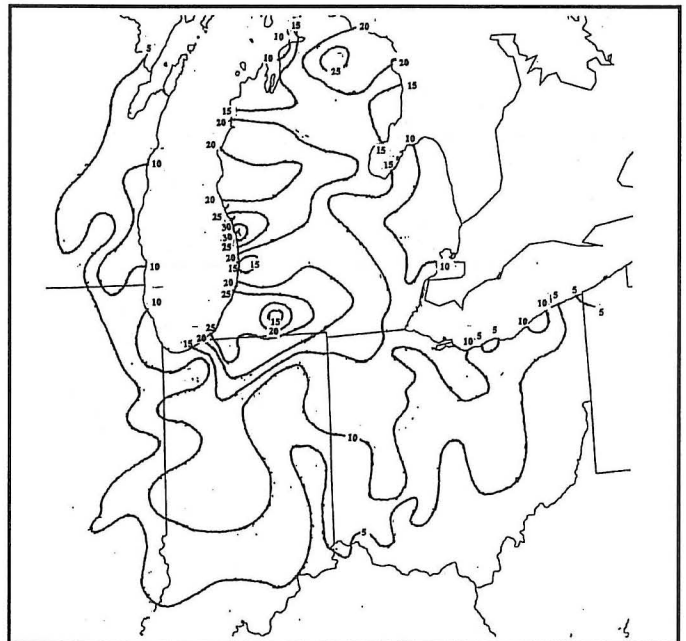


Fig. 11. Total snowfall (in inches) for the three-day period 25-27 January 1978.

close to the surface low's track. As reported in *Storm Data*, sustained winds in western and central Ohio and southern Lower Michigan were 50 to 70 mph with gusts in excess of 100 mph on 26 January 1978. Snow drifts over ten feet high made highways impassable, and wind chill readings of -40 to -50 °F made travel extremely dangerous.

4. The January 1999 Event

Winter-type precipitation did not affect the southern Great Lakes region greatly during the last three months of 1998. For example, during October and November, no measurable snow was reported at Detroit and Lansing, Michigan; Indianapolis, Fort Wayne, and South Bend, Indiana; and Columbus, Ohio. Most other locations across the southern Great Lakes region reported less than 0.5 inches of snow during October and November 1998. December was also warmer and drier than normal throughout the region. December 1998 was the third

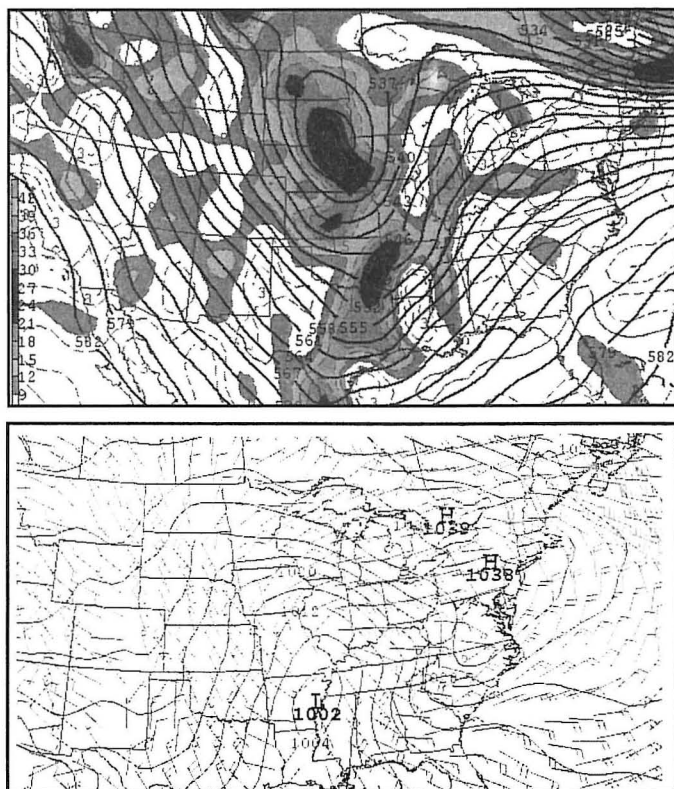


Fig. 13. Top panel is 500 hPa heights (dm; solid lines) and absolute vorticity (s^{-1} ; shaded) for 1200 UTC 2 January 1999. The data depicted is from the NCEP Eta model. The bottom panel is the surface pressure analysis (hPa) and 1000 hPa winds (in standard notation) valid at the same time.

By 0000 UTC 2 January 1999, a 1002 hPa low-pressure area had developed over north central Texas, setting the stage for one of the largest snowstorms in the southern Great Lakes region since 1978. By 1200 UTC 2 January 1999, a 500 hPa vorticity maximum located over South Dakota and a second one over Oklahoma began to show signs of phasing with each other. At the same time, the 1002 hPa surface low began moving to the east and was located over the lower Mississippi valley (Fig. 13). Surface high pressure over the northeastern U.S. measured 1038 hPa, creating a strong pressure gradient over the upper Ohio valley, and increasing wind speeds across the region to 25 to 35 mph. Infrared satellite imagery indicated cooling cloud tops over the southern Great Lakes region. At this time a 180-kt jet streak at 250 hPa was located over New England. The jet maximum extended back to the west with the 120 kt right entrance region over the western Great Lakes. Between 1200 UTC 2 January 1999 and 1200 UTC 3 January 1999 the 500 hPa vorticity maximum intensified, but the jet dynamics only seemed to affect the midlevels of the troposphere. The surface low only deepened by seven hPa during this same 24-hour period.

As in the January 1978 storm, the 1200 UTC 2 January 1999 cross-sectional analysis indicated the dynamic tropopause lowered, resulting in a stratospheric intrusion and enhanced vertical motion (Fig. 14). In this figure the ageostrophic response to the

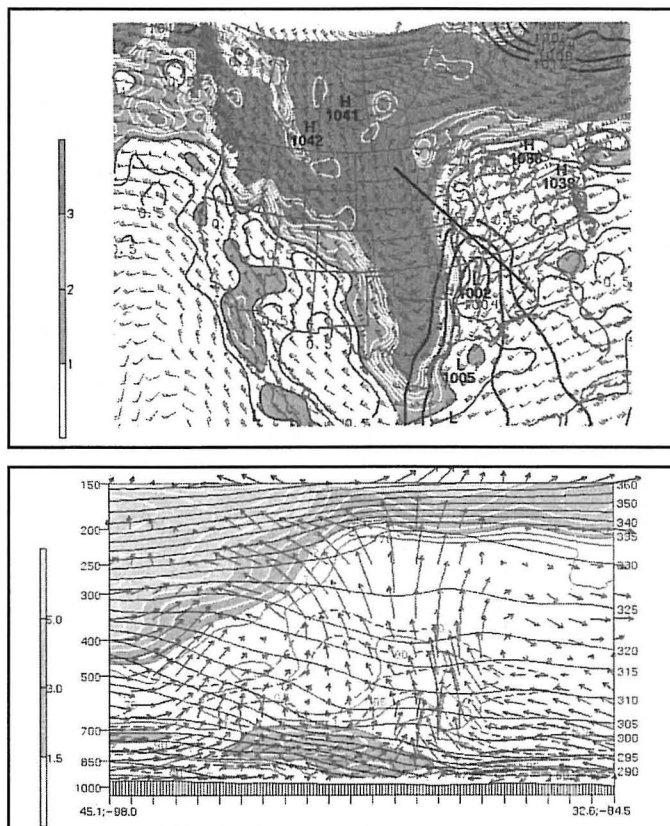


Fig. 14. Cross section line (top panel) and resulting analysis (bottom panel) of potential vorticity (shaded), ageostrophic winds (arrows), potential temperature (solid lines), and relative humidity (dashed lines) for 1200 UTC 2 January 1999. Dynamic tropopause is located along the lower edge of shaded region between 500 hPa and 200 hPa.

strong dynamic forcing is seen just south of the high potential vorticity air. High values of IPV have been brought to lower levels in the atmosphere. Also evident in Fig. 14 is the location of the highest relative humidity which was coincident with the most favored region of lift, resulting in the highest snowfall totals during this event.

The surface cyclone pressure dropped only 1 hPa during the 12 hours from 1200 UTC 2 January 1999 to 0000 UTC 3 January 1999 as it moved into west central Indiana. Herein lies a major difference between the two systems; the surface feature in 1999 contributed less to the resultant impact in both wind and precipitation totals. The upper-level dynamics, however, were quite similar to the 1978 event. It is believed that low-level advective processes and cyclogenesis played a larger role in the 1978 event leading to the higher snowfall totals and longer duration of greater wind speeds. A more concise comparison is discussed in section 7.

In response to the strong upper-level dynamics, the central pressure in the surface low dropped six hPa over the next twelve hours. By 1200 UTC 3 January 1999 the surface pressure had dropped to 995 hPa as the low passed over northern lower Michigan. By this time the system had occluded and was moving slowly into Ontario (Fig. 15).

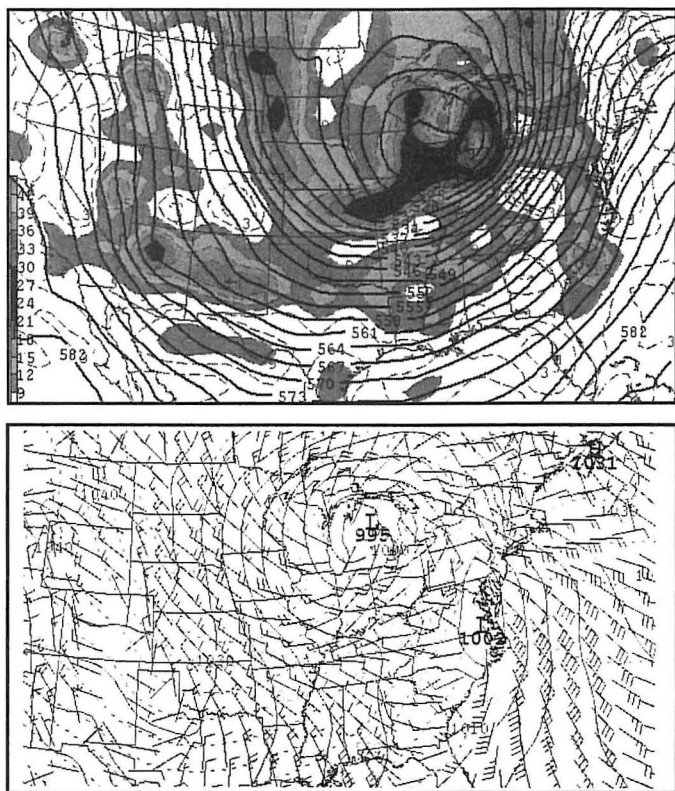


Fig. 15. Same as in Fig. 13, except for 1200 UTC 3 January 1999.

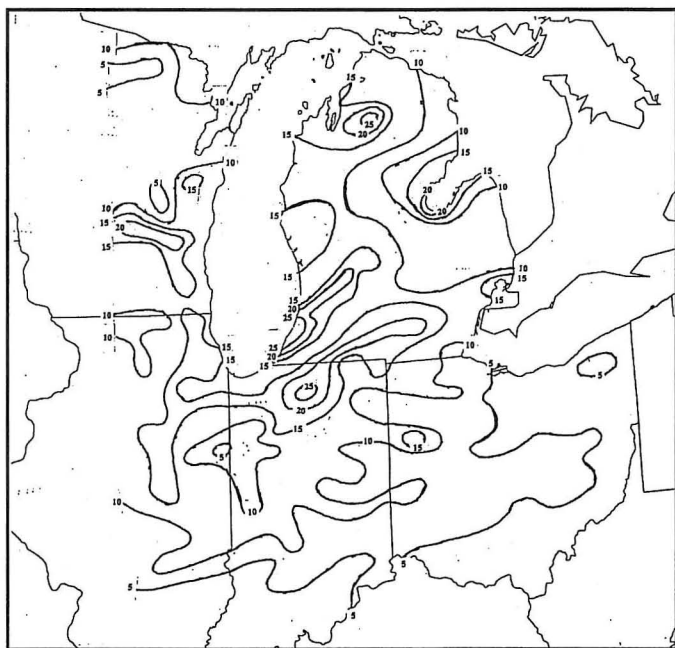


Fig. 16. Total snowfall (in inches) for the three-day period 2-4 January 1999.

5. Effects of the January 1978 Event

The heavy snowfall and strong winds associated with the January 1978 storm, paralyzed the region. Extreme winter conditions were noted across Lower Michigan where Interstate Highway 75 was closed from Saginaw County north to the Mackinac Bridge. Interstate

Highway 96 was closed "west of Brighton all the way across the state to the Lake Michigan shore." (*Lansing State Journal* 1978). Many major interstate highways were closed by drifting snow, including the Indiana Toll Road (U.S. Interstate Highway 80/90) across northern Indiana, the Ohio Turnpike (U.S. 80/90) west of Lorain, and Interstate Highway 70 from western Indiana to Columbus, Ohio (*Chicago Tribune* 1978b). Major airports were also closed as a result of the storm. Chicago's O'Hare International, as mentioned previously, was closed for only the third time in its history. The airports at Detroit, Indianapolis, and Columbus were also closed, along with numerous smaller airports.

As a result of this storm, many locations set snowfall records. Over 20 inches of snow fell across northern Indiana and southwestern Lower Michigan. Over 15 inches fell across portions of north central Indiana and northwestern Ohio and much of Lower Michigan (see Fig. 11). Lake-effect snow added to the synoptic totals in areas east of Lake Michigan after the surface low moved north. Muskegon, Michigan received 21.7 inches of snowfall on 26 January, setting a new 24-hour snowfall record. Some of the largest snowfall totals reported across the southern Great Lakes region for the three-day period 25-27 January 1978 were:

Muskegon, MI	30.0 in.	Goshen, IN	22.2 in.
Eau Claire, MI	29.5 in.	Kalamazoo, MI	22.0 in.
Coldwater, MI	28.0 in.	Montague, MI	22.0 in.
La Porte, IN	28.0 in.	Lagrange, IN	20.8 in.
Wellston, MI	24.5 in.	Greenville, MI	20.3 in.
South Bend, IN	24.0 in.	Gladwin, MI	19.5 in.
Saginaw, MI	23.9 in.	Jackson, MI	19.4 in.
Battle Creek, MI	23.5 in.	Lansing, MI	19.3 in.
Plymouth, IN	23.0 in.	Grand Rapids, MI	19.2 in.
Baldwin, MI	22.8 in.	Adrian, MI	18.0 in.

Surface low pressure records were also set across the region. Cleveland reported a surface pressure of 957.6 hPa (28.28 inches) as the low passed over Lake Erie. A record low pressure reading of 959.7 hPa (28.34 inches) was set at both Detroit, Michigan and Erie, Pennsylvania. Surface pressure dropped to a record low of 964.8 hPa (28.49 inches) at Pittsburgh, Pennsylvania and Toledo, Ohio (Assel et al. 1979).

The incredibly intense system caused hurricane force winds near the center of the surface low. Cleveland, Ohio reported wind gusts of 82 mph, while Erie, Pennsylvania reported gusts of 77 mph. The duration of the high-amplitude wind resulted in additional problems as blizzard conditions were experienced for 36 to 48 hours across much of the southern Great Lakes. The strong, sustained winds knocked down power lines across the region. More than 150,000 people were without power during much of the storm in Ohio (*New York Times* 1978). A similar number of people were without power across southeastern Michigan. Especially hard hit was the area from Monroe County, north through Detroit, to the Michigan thumb region (*Detroit Free Press* 1978).

Snow drifts 10- to 20-feet deep blocked roads from northwestern Indiana to north central Ohio. Drifts as high as 20 feet blocked U.S. Highway 30 in northwestern

Ohio (*Chicago Tribune* 1978b). On the Ohio Turnpike south of Sandusky "snow had drifted higher than some overpasses" (*Cleveland Plain Dealer* 1978b). Drifts were so high along rural roads in northeastern Indiana southeast of Fort Wayne that only the power lines were visible (*Fort Wayne Journal-Gazette* 1978a). After the snowstorm it was estimated that 60 percent of Ohio's roads were impassable due to drifting snow, stranded vehicles and downed trees (*Cleveland Plain Dealer* 1978a). Roads could not be opened due to the strong winds as roads drifted shut shortly after they were cleared. It took over two weeks for road crews to clear side streets in cities and rural county roads across the region.

The blizzard claimed the lives of eighty-five people across the southern Great Lakes region. Thirty-four people died in Ohio, twenty in Illinois, sixteen in Michigan, and fifteen in Indiana. Agricultural losses were extensive. It was estimated that farmers in Ohio alone suffered almost \$50 million in damage (*Fort Wayne Journal-Gazette* 1978b).

6. Effects of the January 1999 Event

Many roads across the region were closed due to the snowfall. However, major highways were not closed for more than twenty-four hours as in the 1978 event. Interstate Highway 65 in northwestern Indiana was closed for a short time due to the heavy snowfall. Secondary roads, however, were closed for much of the event. Detroit Metropolitan Airport closed due to the heavy snowfall. Other major airports were able to stay open, although there were numerous flight delays and cancellations (*Detroit News* 1999).

Some areas of southwest lower Michigan reported snow depths of nearly three feet after the storm, but these locations were generally in the lake-effect regions. Most locations across northeast Illinois, northwest Indiana, and southwest Michigan reported snowfall totals of 15 to 25 inches (Fig 16). Totals were less east of the track of the surface low. Ten to 15 inches of snowfall was reported from north central Illinois to southeastern lower Michigan. Five to ten inches of snow was reported in northeastern Indiana and northwestern Ohio (U. S. Dept. of Commerce 1999). Interestingly, Chicago received 18.6 inches of snow on 2 January, which was the largest single-day snowfall total in the city's history (*Chicago Tribune* 1999). A total of 19.6 inches of snowfall was reported at O'Hare for the period 2-4 January 1999. The great January 1967 snowstorm, however, remained its largest total snowfall from a single event when 23.0 inches of snow fell on 26-27 January 1967. Some of the largest snowfall totals recorded across the southern Great Lakes region for the three-day period 2-4 January 1999:

South Haven, MI	28.0 in.	Essexville, MI	21.0 in.
Eau Claire, MI	27.0 in.	Lowell, MI	21.0 in.
Plymouth, IN	26.8 in.	Tecumseh, MI	20.0 in.
Benton Harbor, MI	25.0 in.	West Bend, WI	20.0 in.
Bloomington, MI	24.0 in.	Chicago (O'Hare), IL	19.6 in.
Dowagiac, MI	24.0 in.	Chicago (Midway), IL	18.9 in.
Dalton, WI	23.0 in.	South Bend, IN	18.8 in.
Lakeville, IN	22.0 in.	Muskegon, MI	18.3 in.

Grand Rapids, MI	21.7 in.	Greenville, MI	18.2 in.
Coldwater, MI	21.0 in.	Angola, IN	18.1 in.

Wind speeds were generally in the 25 to 35 mph range throughout the event, although gusts of over 50 mph occurred. For example, the highest wind speed reported at Chicago (west of the track of the surface low) was 63 mph at Meigs Field. The highest wind speed reported at O'Hare was 47 mph. The strong winds caused blowing and drifting snow, which closed many roads across the region.

Power outages occurred during the storm but they tended to be repaired fairly quickly and affected fewer people. For example, a power outage in the St. Joseph/Benton Harbor, Michigan area affected 5000 people. In another outage, 1700 people lost power in Detroit.

7. Comparison of Events

Both the 1978 snowstorm and the 1999 snowstorm affected the southern Great Lakes region in significant ways. However, the 1978 storm had a much greater effect on the region. One reason may be because the 1999 snowstorm was so well forecasted. The 1978 snowstorm had been forecasted a couple of days in advance. Forecasters in late December 1998, however, had access to much higher-resolution models and satellite imagery than were available in 1978. As a result, the public knew almost a week ahead of time that a major snowstorm was possible during the first few days of January 1999. The upper-level dynamics of the two systems were similar. But, lower-level processes, such as moisture and cold air advection, and rapid surface cyclogenesis, in the 1978 storm induced a much stronger surface low and relatively stronger winds, heavier snow, and very cold air; resulting in a much greater impact on the region. When comparing the two events, some similarities and some differences were noted.

a. Similarities between the two events

<i>Path of surface low</i>	Each low formed over the southern Great Plains and moved north through the Ohio valley and the Great Lakes.
<i>500 hPa negative tilt</i>	Both systems showed a negative tilt trough from 850 to 300 hPa. The 1978 storm, however, showed a slightly more pronounced negative tilt in the upper-level height contours.
<i>Potential Vorticity Analyses</i>	Both systems exhibited lowering of the dynamic tropopause, stratospheric intrusions, and enhanced upward vertical motion as a result of ageostrophic response to the dynamic forcing.
<i>Relatively heavy snowfall</i>	Both systems generated widespread heavy snowfall.

b. Differences between the two events

<i>Path of surface low</i>	<p>Although the path was similar in both events, the 1999 system tracked slightly farther west than the 1978 system.</p> <p>1978 – through Ohio, SE Ontario into Quebec</p> <p>1999 – through Indiana, lower Michigan, into Ontario</p>
<i>Strength of system</i>	<p>During the 1978 event the surface low pressure dropped to less than 960 hPa.</p> <p>During the 1999 event the surface low pressure did not drop below 990 hPa.</p>
<i>Wind speed</i>	<p>During the 1978 event sustained wind speeds reached 50 to 70 mph (with gusts in excess of 100 mph).</p> <p>During the 1999 event sustained wind speeds reached 30 to 40 mph (with gusts to 60 mph).</p>
<i>Societal effects</i>	<p>More widespread power outages occurred during the 1978 event.</p> <p>Many major highways were closed for days in 1978.</p> <p>Numerous major airports were closed in 1978.</p> <p>It took more than two weeks for some areas to dig out after the 1978 storm.</p>

8. Summary

Both the 1978 and the 1999 snowstorms will long be remembered by those who experienced them. Even in a region in which heavy snow is common during the winter, these two snowstorms stand out as remarkable. Winter events of this magnitude do not occur very often but studying events such as these can be quite beneficial. Forecasters can look for things such as negatively-tilted troughs, dynamic forcing and atmospheric response mechanisms, systems phasing, rapid intensification, and moisture advection ahead of the cold front when predicting the formation and movement of these systems. Increasing our understanding of these weather systems can only benefit the potential users of our forecasts, advisories, and warnings.

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