Contract Report 2005-03

The Pre-Christmas 2004 Snowstorm Disaster in the Ohio River Valley

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Prepared for
Midwestern Regional Climate Center

April 2005

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A Division of the Illinois Department of Natural Resources

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Abstract

The worst winter storm on record in southern Illinois occurred on December 22-23, 2004, and then moved eastward with severe impacts for Indiana, Kentucky, and Ohio. Snowfall amounts from the storm that lasted 30 hours at many locations reached 29 inches, and more than 6 inches fell over a 137,600-square-mile area. Snowfall totals set new records across southern Illinois, the southern half of Indiana, and western Ohio. This prolonged, enormous storm system also produced a major ice storm along its southern edge in Kentucky and Ohio. This record event produced a myriad of impacts totaling $900 million in losses and costs.

All aspects of transportation were affected, and the impacts were extreme because the storm occurred at a time of extensive pre-holiday travel. Traffic was paralyzed on numerous interstate highways, and thousands of persons were stranded for 6-36 hours in the bitter cold. Hundreds of airline flights were cancelled or delayed, and trains were halted at several locations. Thousands of vehicular accidents led to numerous injuries, and 17 persons died as a result of the storm. Insured property losses totaled $230 million, ranking the storm as the 32nd most damaging among the nation's 156 catastrophic winter storms since records began in 1949. Airline losses were extremely high, $260 million, and costs to remove snow and ice from highways and streets totaled $133 million.

Unusual atmospheric conditions created this unique winter storm. An arctic cold front interacted with a warm, moist air mass along the Ohio River valley, producing the first phase of winter precipitation. A few hours later, a low-pressure center from east Texas moved to the northeast just south of the Ohio River valley, causing the second phase of the storm. Extremely cold arctic air covered the storm area for four days, creating record low temperatures throughout the region that limited recovery efforts.

Acknowledgments

This study was performed as part of the climate event monitoring program of the Midwestern Regional Climate Center (MRCC), and as part of the climate impacts program of the Illinois State Water Survey (ISWS). The MRCC is supported by funds from the National Oceanic and Atmospheric Administration (NOAA) and by the ISWS. The views expressed herein are those of the authors and do necessarily reflect the views of NOAA.

The authors appreciate the help of several ISWS and MRCC staff members. Steve Hilberg provided data on the emergency declarations in the states affected. Jon Burroughs provided necessary snowfall data in a timely fashion. Cyndee Riggin accessed hundreds of news files for the impact analysis. The reviews of Ken Kunkel and Mike Palecki are also much appreciated. Eva Kingston edited the manuscript, and Linda Hascall did the layout of the report.

Cartographer Lenny Walther, Northern Illinois University, prepared certain illustrations; weather maps were obtained from the NOAA National Center for Environmental Prediction. Curtis Caldwell, Public Assistance Program, Illinois Emergency Management Agency, provided valuable data. The Property Claims Service provided data on storm losses, as did several state agencies and power companies in the storm area.

Contents

Introduction

A major snowstorm occurred along the Ohio River valley on December 22-23, 2004, with severe impacts over large parts of Illinois, Indiana, Kentucky, and Ohio. Southern portions of the large snowstorm area had freezing rain that created ice layers 1-2 inches thick in several locales in Kentucky and Ohio. Heavier snow amounts of 6-29 inches broke all-time 1- and 2-day records over a wide area. Four days of extremely low temperatures followed the lengthy storm, resulting in record low values on December 24-25. The snowstorm, as defined by the area with snowfalls of 6 inches or more, was 160 miles wide and 860 miles long (137,600 square miles, an area larger than Illinois and Indiana combined). Unusual storm features were its immense size (Figure 1) and its location in an area in which heavy snows seldom occur.

More than 20 inches of snow fell over an area 310 miles long (Evansville, Indiana, to near Dayton, Ohio) and 30 miles wide (Figure 1). Snowfall totals at many locations set new 1- and 2-day records. From west to east, these values included records in Illinois for Carbondale (12 inches), McLeansboro (14 inches), and Carmi (18 inches). Some of the many locations with new records in Indiana were Evansville (22.3 inches), Bloomington (18 inches), Salem (20 inches), Seymour (29 inches), North Vernon (26 inches), Greensburg (24.5 inches), and Connersville (20

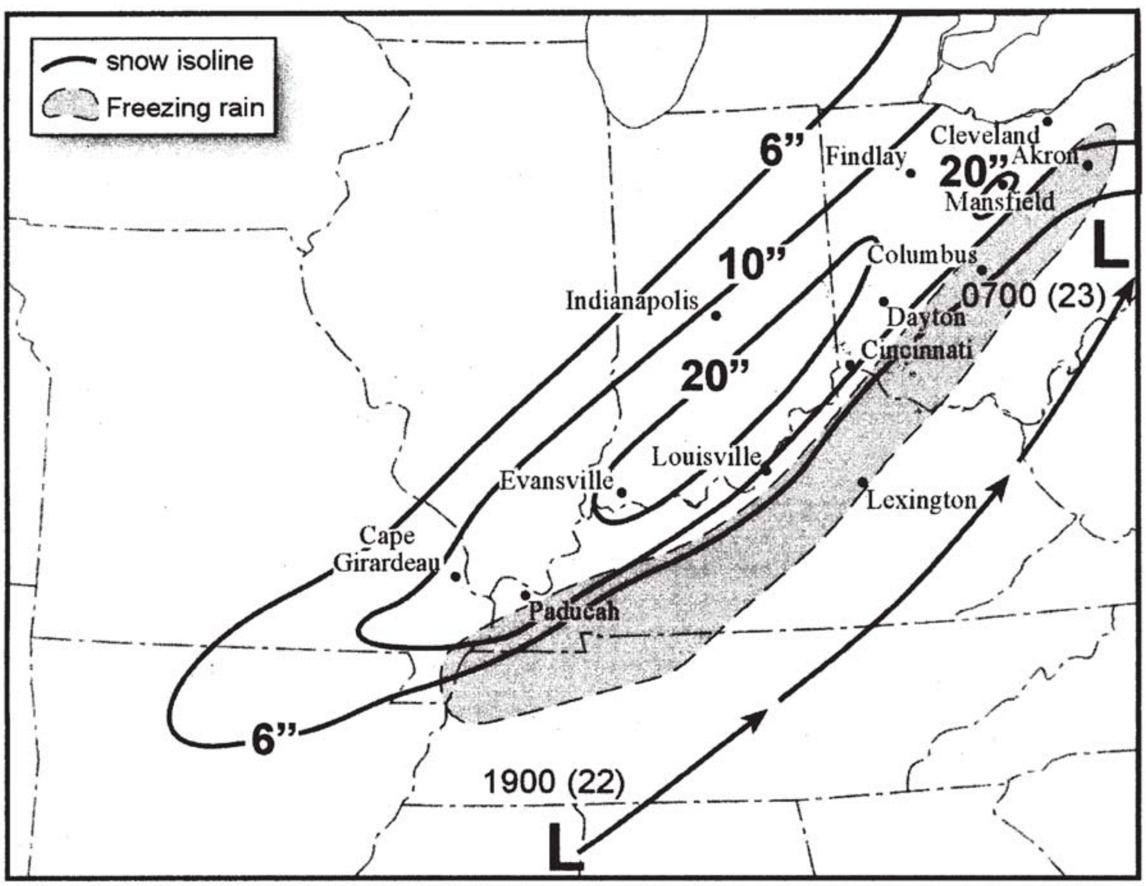

Figure 1. Pattern of total storm snowfall (inches), ice storm area, and position of the Gulf low pressure center (L) related to December 22-23, 2004 storm. Times (CST) and December dates are shown for the low center.

inches). Record snowfalls also occurred at Paducah, Kentucky (14 inches), and in Ohio at Dayton (16 inches), Greenfield (24 inches), and Mansfield (23 inches).

This record-setting snowstorm caused 17 deaths and enormous damages and losses. Interstates and state highways became impassable, paralyzing traffic and resulting in major problems for regional transportation. Part of the problem was that this major storm occurred in an area not accustomed to such extreme winter storm conditions. Insured property losses amounted to $230 million (Property Claims Service, 2005). This storm qualifies as one of the nation's winter storm catastrophes, defined as events causing insured losses in excess of $25 million, since 1948 when insurance records began (Changnon, 2005). The amount of insured loss was nearly double the national average for a catastrophic winter snowstorm, and the 32nd highest loss among the nation's 167 catastrophic winter storms. Total losses and costs of this record-setting snowstorm were $900 million, the largest loss ever in this four-state (Illinois, Indiana, Kentucky, and Ohio) region. That large loss, coupled with the time of storm occurrence (just before Christmas when record travel was in progress) were other unusual aspects of this record weather event.

Storm Dimensions

The storm came in two phases. At many locales that received snow totals of 6 inches or more, the first phase lasted 4-10 hours, producing less than half the storm's total snow. This was followed by a period of sleet and freezing rain, lasting 3-6 hours, before phase two of the snowstorm began. That phase lasted 6-12 hours at most locations. For example, Evansville, Indiana had 9 inches of snow by 1800 Central Standard Time (CST) on December 22, a total of 19.3 inches by midnight, and 3 more inches by 0600 CST on December 23, a total of 22.3 inches.

The developing storm system began on December 21 in central Arkansas and southwestern Missouri. It then moved northeastward into southern Illinois and western Kentucky during the night of December 21-22 (Figure 2). Freezing rain occurred along a west-southwest to east-northeast path from north-central Arkansas through southeastern Missouri, across Kentucky, portions of northern Tennessee, and into Ohio (Figure 1). The result was a major ice storm in parts of Kentucky and Ohio.

Snow in and north of the freezing rain area began at 1500 CST on December 21 in central Arkansas. The developing snowstorm moved east-northeast during the night and reached southern Illinois by 0000 CST on December 22. Advancing snowfall crossed southern Illinois and moved northeast, reaching south-central Indiana by 0300 CST on December 22. The front edge of the storm moved further eastward, reaching Dayton, Ohio, by 0600 CST, Cleveland by 0900 CST, and Toledo by 1800 CST. Cleveland had a storm sequence of snow, sleet, freezing rain, and then snow again.

The massive snowstorm ended in southern Illinois by 0300 CST on December 23 (Figure 2), and by 0600 CST across south-central Indiana where it had begun 30 hours before. The storm continued to move to the northeast until it ended by 1500 CST in central Ohio and by 1800 CST at Cleveland, 33 hours after it began there.

Temperatures were much below average for four days after the storm. Table 1 presents daily high and low temperatures at three locations along the storm's track: Louisville, Kentucky; Indianapolis, Indiana; and Mansfield, Ohio. These data reveal that temperatures remained below freezing until December 28, four days after the storm ended, another factor making post-storm recovery very difficult and slow. Many sites set new record low temperatures on Christmas Day, including Evansville, Indiana (-11^{o}F), Cleveland, Ohio (-17^{o}F), and Paducah, Kentucky (-8^{o}F).

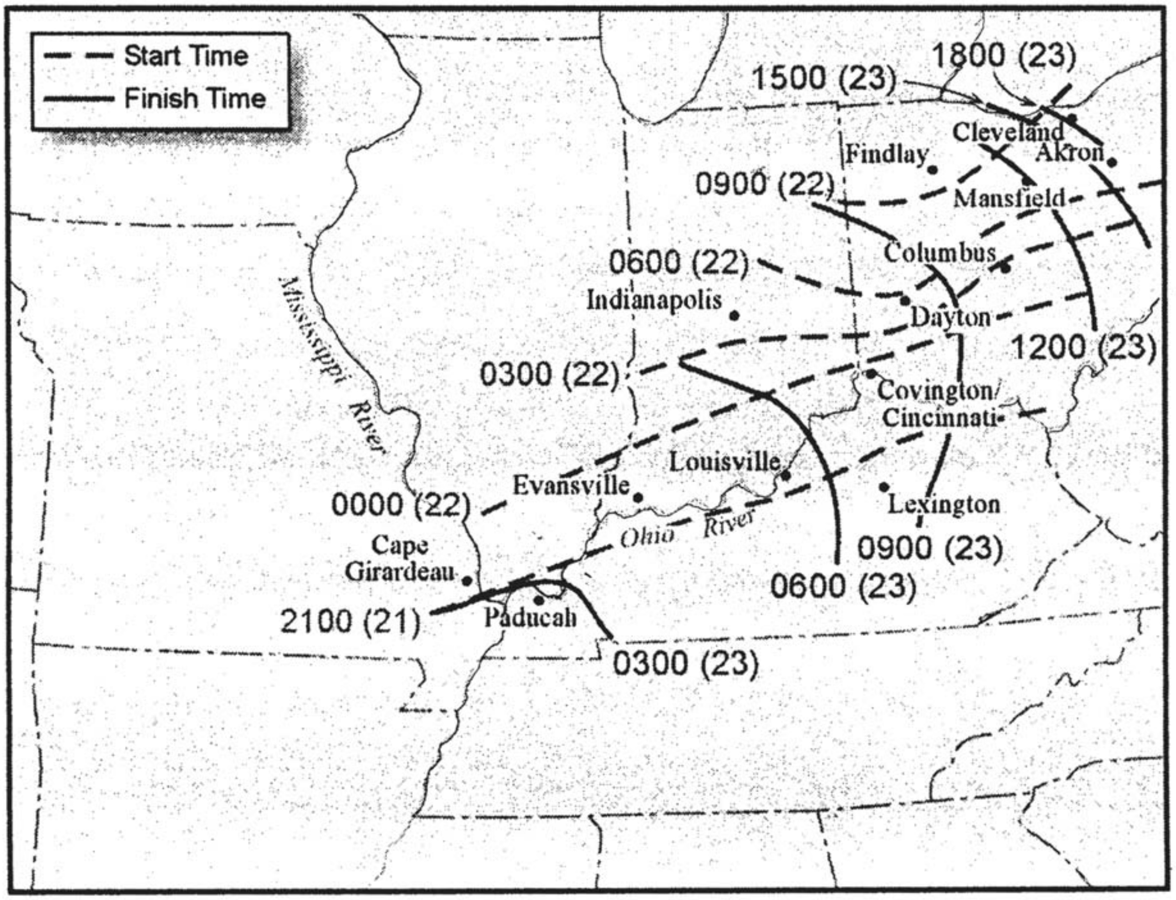

Figure 2. Lines depicting beginning and ending of December 22-23, 2004 snowstorm. Times are CST and dates are in parentheses.

Table 1. Daily Maximum and Minimum Temperatures (^{o}F)

	Louisville, KY		*Indianapolis, IN*		*Mansfield, OH*	
December	*High*	*Low*	*High*	*Low*	*High*	*Low*
24	19	4	16	-5	11	-8
25	27	2	20	-3	17	-15
26	30	16	25	12	20	14
27	30	10	22	4	18	6
28	46	16	41	17	38	16

Synoptic Conditions Associated with the Snowstorm

Conditions at 0600 CST on December 21

A surface low-pressure center (997 millibars or mb) over Lake Superior was the primary synoptic-scale weather system in the United States on the morning of December 21 (Figure 3). Associated with this surface system was a fast-moving cold front that had pushed southward into northeastern Kansas. Further north, surface air temperatures across much of North Dakota were below freezing.

The primary area of precipitation was located in the Great Lakes in association with an extra-tropical cyclone. As shown in Figure 3, a weak and diffuse low-pressure area (1008 mb) was situated in central Texas along a surface frontal boundary extending from Arkansas to southwestern Texas, but little cloudiness and no precipitation occurred along this boundary.

During the day, the cold front quickly moved southward and eastward passing through southeastern Missouri in early afternoon. By midnight, the front extended from near Cincinnati, Ohio, to northeastern Arkansas, where it joined the southern frontal boundary west of the Mississippi River. Midwestern first-order stations reported wind shifts to the north-northwest, falling

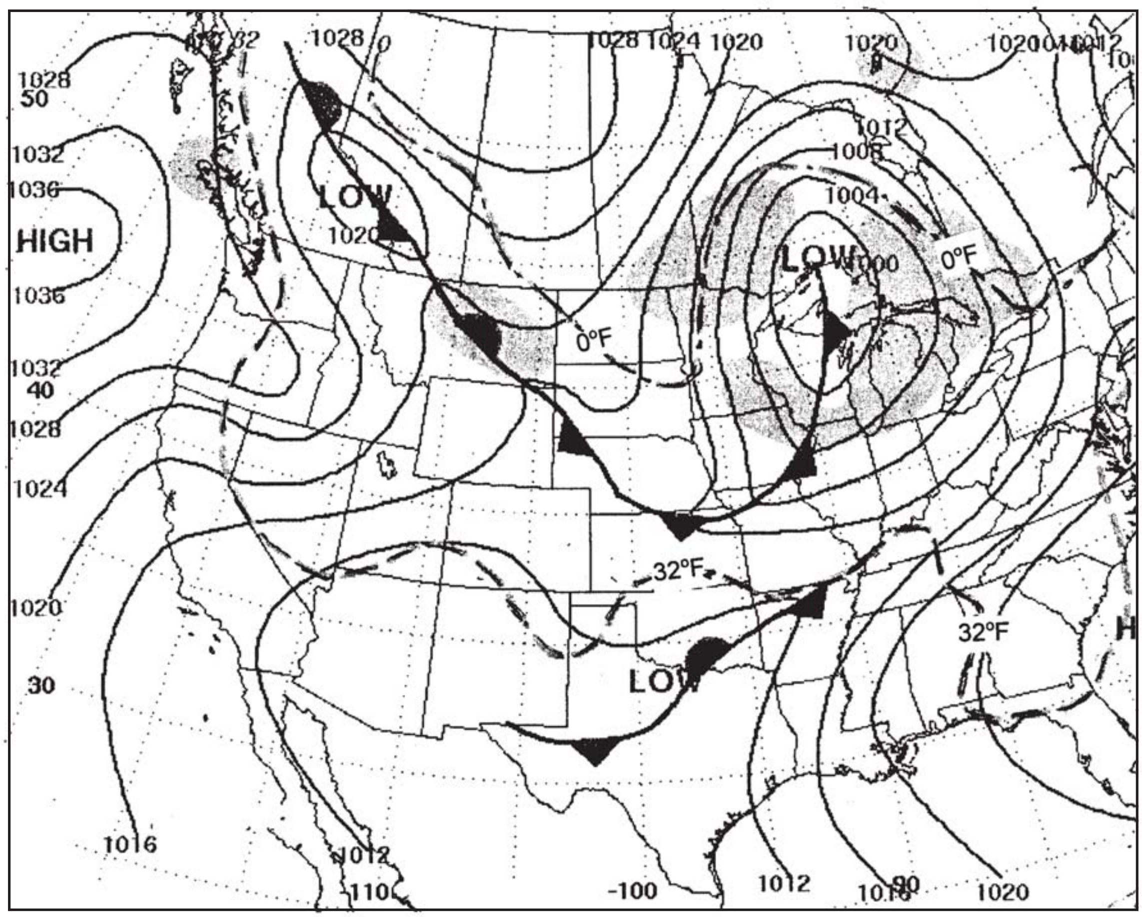

Figure 3. Surface weather map for 0600 CST on December 21, 2004
(National Center for Environmental Prediction, NOAA).

temperatures, and slight pressure increases after the front. As this front continued to advance southward, warm, moist air advancing northward from the Gulf of Mexico was lifted above the colder surface air, which triggered the start of precipitation in the Ohio River valley. Precipitation initially fell as rain between 1800 CST and midnight (Figure 2) in locations across Kentucky, southeastern Missouri, and southern Indiana. Evaporative cooling associated with rain falling into the dry arctic air mass north of the cold front quickly cooled surface temperatures from the 40s into the lower 30s. Precipitation changed from rain to a mix of ice, sleet, drizzle, and snow by 0600 CST (December 22) at Cape Girardeau, Missouri; Evansville, Indiana; Louisville, Kentucky; and Cincinnati, Ohio. North of this region, precipitation started later (between midnight and 0600 CST) and generally fell as snow at most locations including Indianapolis, Indiana, and Dayton, Ohio.

Upper air conditions were similar to those at the surface. The most important weather feature at 850 mb (December 21) was an area of lowest heights (<1250 meters or m) just north of Lake Superior. A trough extended from just south of the 850-mb low through Missouri to northern Texas. The height pattern east of the trough allowed mid-level moisture to begin moving northward from the Gulf of Mexico into parts of Kentucky. This moisture advection provided the fuel for the mixed precipitation that began in the Ohio River valley after 1800 CST.

A broad trough bounded by the Rockies on the west was located in the central United States at the 500-mb level. The 5400-m level was situated from central Wyoming generally eastward toward Detroit, Michigan, before turning north toward eastern Canada. The strong height gradient along the western side of the trough indicated that it would continue to "dig" southward into the Midwest.

Conditions at 0600 CST on December 22

The Great Lakes surface low became occluded, weakened (now with a minimum surface pressure of 1010 mb), and was located north of Lake Huron (Figure 4). An occluded front was located from the center of the low pressure area to Pittsburgh, Pennsylvania, with a cold front then running southwestward through Lexington, Kentucky; Memphis, Tennessee; and Shreveport, Louisiana, to a weak (1007 mb), but developing, surface low center in southern Texas. Cold air was pouring into the Midwest behind the frontal boundary and ahead of a 1043-mb surface high in northern Alberta that brought freezing temperatures to southern Illinois by 0600 CST (Figure 4). There was a mix of precipitation in the Ohio River valley, and along and north of the cold front from central Arkansas to central Ohio (Figure 4) by 0600 CST.

The surface low in southern Texas (referred to as a Gulf low) began to deepen and move slowly northeastward along the cold front to northeastern Mississippi by 1900 CST (Figure 2). This surface pattern, combined with strong warm air advection at 850 mb west of the Appalachians (Figure 5), established an uninterrupted flow of warm, moist air northward from the Gulf. This enhanced the widespread precipitation that already had begun in the Ohio River valley. Precipitation mainly as snow was occurring northward to Lake Erie by 1200 CST. Surface air pressures in the Ohio River valley (north of the cold front) began to fall by noon on December 22, signaling the approach of the Gulf low. A pressure minimum (29.69 mb) occurred around 1900 CST at Cape Girardeau, Missouri, as the Gulf low (located in northeastern Mississippi) moved northeastward into eastern Kentucky. Weather stations east and north of Cape Girardeau

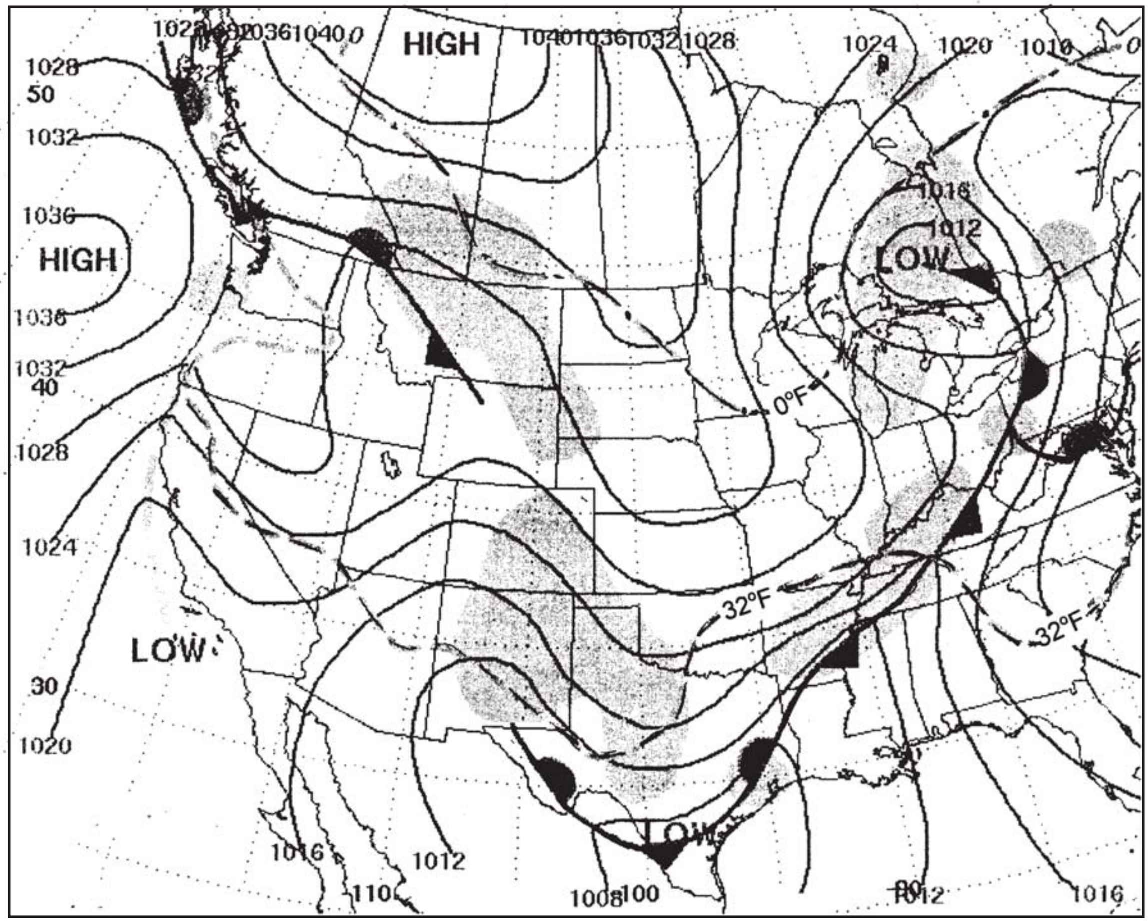

Figure 4. Surface weather map for 0600 CST on December 22, 2004
(National Center for Environmental Prediction, NOAA).

also experienced a pressure minimum between 2100 CST on December 22 and 0800 CST on the December 23.

Most locations north of the Ohio River had snow falling by 0600 CST on December 22, and that changed from snow to a mix of freezing rain and sleet for several hours at many locations as warm air advection ahead of the approaching Gulf low established a >32°F layer of air above the surface arctic air mass. For example, conditions at Louisville (Table 2) changed from snow to sleet around noon on December 22 and continued to have a mix of freezing precipitation until 0200 CST on December 23. Interestingly, these changes in precipitation type occurred while surface air temperatures remained in the low to mid-20s. A narrow area from Missouri (Cape Girardeau) to Kentucky (Paducah and northeastward through Louisville) and Ohio (Cincinnati, Columbus, and Cleveland) experienced this change from snow to a mix of freezing rain and/or sleet, and then back to snow before the storm exited the region (Table 2). Areas just north of this region, such as Dayton, Ohio, experienced many hours of moderate to heavy snowfall. A radar image at 1245 CST on December 22 showed a wide area of precipitation from Montreal southwestward into Texas.

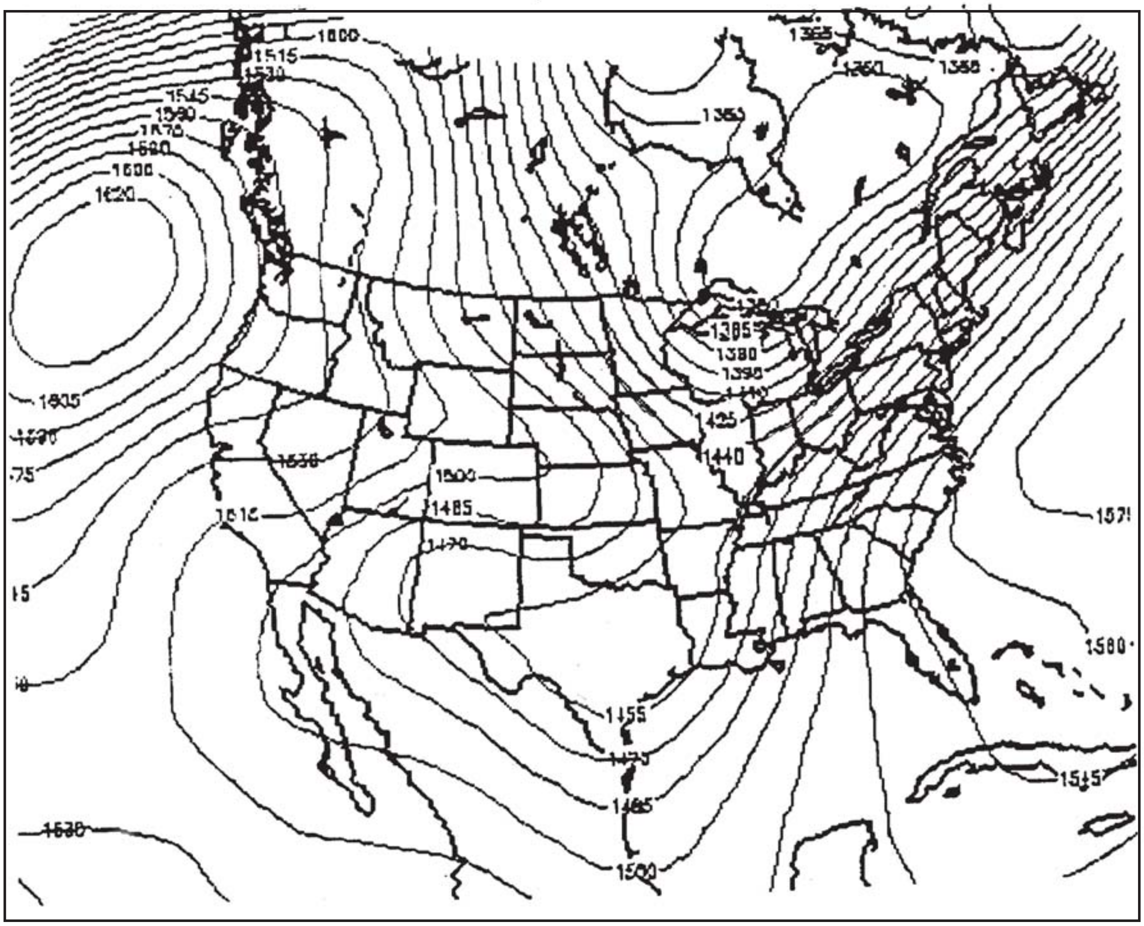

Figure 5. Pressure pattern (850-mb level) at 0600 CST, December 22, 2004
(National Center for Environmental Prediction, NOAA).

The 850-mb analysis (Figure 5) at 0600 CST showed that the low over the Great Lakes had weakened as central heights increased nearly 80 m from those on the previous day. However, a more distinct high-amplitude trough existed from the upper Great Lakes through eastern Missouri into central Texas. This narrow north-south trough was characterized by a strong height gradient that enhanced the unimpeded advection of warm, moist air directly from the Gulf, moving west of the Appalachians, and towards the eastern Great Lakes.

The 500-mb level trough extended from central Canada southwestward into New Mexico. East of the trough, the slowly developing surface Gulf low moved northeastward parallel to the upper-level height gradient that extended from Texas into western New England.

Conditions at 0600 CST on December 23

The Gulf low was located in southwestern Ohio (Figure 1) with a trailing cold front aligned north-to-south towards Florida, and a warm front was positioned northeast from the low center into upstate New York (Figure 6). The surface low-pressure center had deepened slightly in 24 hours and was near 1000 mb, a weak extra-tropical cyclone for this time of the year. However,

Table 2. Surface Hourly Temperatures (°F/CST) and Weather Types for Cape Girardeau, Missouri (CGI), Louisville, Kentucky (SDF), Cincinnati, Ohio/Covington, Kentucky (CVG), Dayton, Ohio (DAY), and Akron, Ohio (CAK)

	Temperature (°F) and Weather Types				
Date/Time	*CGI*	*SDF*	*CVG*	*DAY*	*CAK*
21/2200	38-RA	47-RABR	43	37	37
21/2300	34-SNBR	46-RABR	41	33	37
22/0000	32-SNBR	45-RABR	42-RABR	32	36
22/0100	30-SNBR	44-RABR	41-RABR	32	36
22/0200	28-SNBR	43-RABR	36-RABR	31	35-BR
22/0300	27-FZFG	37-RABR	33-RABR	31	36
22/0400	25-BR	35-RA	32-FZRABR	29	36-BR
22/0500	25-FZFG	34-RABR	31-FZDLBR	28	35-RABR
22/0600	24-BR	32-FZRABR	31-FZDLBR	26-SN	34-BR
22/0700	23-SNFZFG	31-FZRABR	28-SNBR	24-SNBR	34
22/0800	22-SNBR	30-SNFZBR	28-SNBR	23-SNBR	34
22/0900	21-SNBR	28-SNBR	27-SNBR	23-SNFZFG	33-SNBR
22/1000	21-FZRA	27-SNBR	26-SNBR	23-SNFZFG	32-SNBR
22/1100	21	27-SNFZFG	27-SNBR	22-SNFZFG	30-SNBR
22/1200	21-FZRA	26-SNBR	26-SNFZFG	21-SNFZFG	30-BR
22/1300	21-FZRA	26-SNBR	25-SNFZFG	21-SNFZFG	30
22/1400	21-FZRA	26-PL	24-SNFZFG	20-SNFZFG	30-SNBR
22/1500	21-FZRA	26-FZRAPL	24-SNBR	20-SN	29-SNBR
22/1600	21	24-PLBR	24-SN	20-SN	28-SNFZFG
22/1700	19-SN	23-FZRAPL	23SNFZFG	20-SN	28-SNFZFG
22/1800	18-FZFG	23-FZRAPL	22-PLSNBR	19-SN	27-SNFZFG
22/1900	17-BR	23-FZRAPL	22-SNBR	19-SN	27-SNFZFG
22/2000	16-BR	24-PLBR	22-PLSNBR	19-SN	27-SNFZFG
22/2100	15-FZFG	23-PLBR	23-PLSNBR	20-SN	28-SN
22/2200	15-BR	21-PLBR	22-PLSNBR	20-SN	28-SNBR
22/2300	15-SNBR	22-PLBR	22-SNBR	20-SN	29-SN
23/0000	15-SNBR	22-PLBR	22-PLSN	20-SN	30-SNBR
23/0100	14-SNBR	23-PLBR	22-PLSN	20-SN	30-SNBR
23/0200	14-SN	22-SNPLBR	24-PLSNBR	19-SN	31-FZRABR
23/0300	14-FZRA	22-SNBR	22-SNPL	19-SNPL	31-FZRABR
23/0400	14-FZRA	21-SNBR	21-PLSNBR	17-SNPL	32-FZRABR
23/0500	14-FZRA	21-SN	19-SNBLSN	17-SN	32-FZRABR

Table 2. Concluded

Date/Time	*CGI*	*SDF*	*CVG*	*DAY*	*CAK*
	Temperature (°F) and Weather Types				
23/0600	12	21	18-SNBLSN	16-SN	32-FZRABR
23/0700	10	21	18-SNBLSN	17-BLSN	32-FZRABR
23/0800	10	21	19	17-BLSN	32-FZRABR
23/0900	11	20	19	17-BLSN	32-FZRABR
23/1000	13	19-SN	18-SN	17-BLSN	28-SNBR
23/1100	14	18	19	18-BLSN	28-SN
23/1200	16	20	19	19-BLSN	28-SN
23/1300	17	19	20	19-BLSN	25-SN
23/1400	18	21	21	20-BLSN	24-SNBR
23/1500	18	22	21	20-BLSN	25-SNBR
23/1600	17	22	20	19-BLSN	22-SN
23/1700	14	22	19	16-BLSN	21

Notes: SN=snow, BLSN=blowing snow, FZ=freezing, RA=rain, FG=fog, BR=mist, PL=ice pellets, DL=drizzle, FZRA=freezing rain.

this low combined with a 1041-mb arctic high centered over northwestern North Dakota to create a strong pressure gradient and near blizzard conditions in parts of eastern Indiana and western Ohio. Precipitation associated with the Gulf low was widespread throughout the eastern United States with rainfall occurring in the warm sector ahead of the system from Florida to Maine, and snowfall from northern Kentucky to the eastern Great Lakes. Arctic air was approaching the Gulf of Mexico, as shown by the 32°F isotherm in Figure 6. Winter precipitation in the Ohio River valley slowly tapered off, ending in western Kentucky by 0600 CST and by 1200 CST in all areas except northeastern Ohio (Figure 2) as the surface low continued to move northeastward into southern Canada.

The 850-mb analysis continued to show a trough from eastern Canada southward into the Ohio River valley and towards Louisiana. A south-to-north flow on the east side of the trough continued transporting copious amounts of water vapor into eastern Canada primarily along and east of the Appalachians. This flow continued to feed the large area of precipitation associated with the extra-tropical cyclone. The 500-mb trough had become even more pronounced. Its location and amplitude allowed for significant meridional transport of arctic air southward east of the Rockies and warm air northward from the Gulf into northeastern Canada.

Conditions at 0600 CST on December 24

Since 0600 CST on December 23, the Gulf low had continued to deepen (994 mb), while rapidly moving northeastward into eastern Canada. The cold front was located off the Atlantic

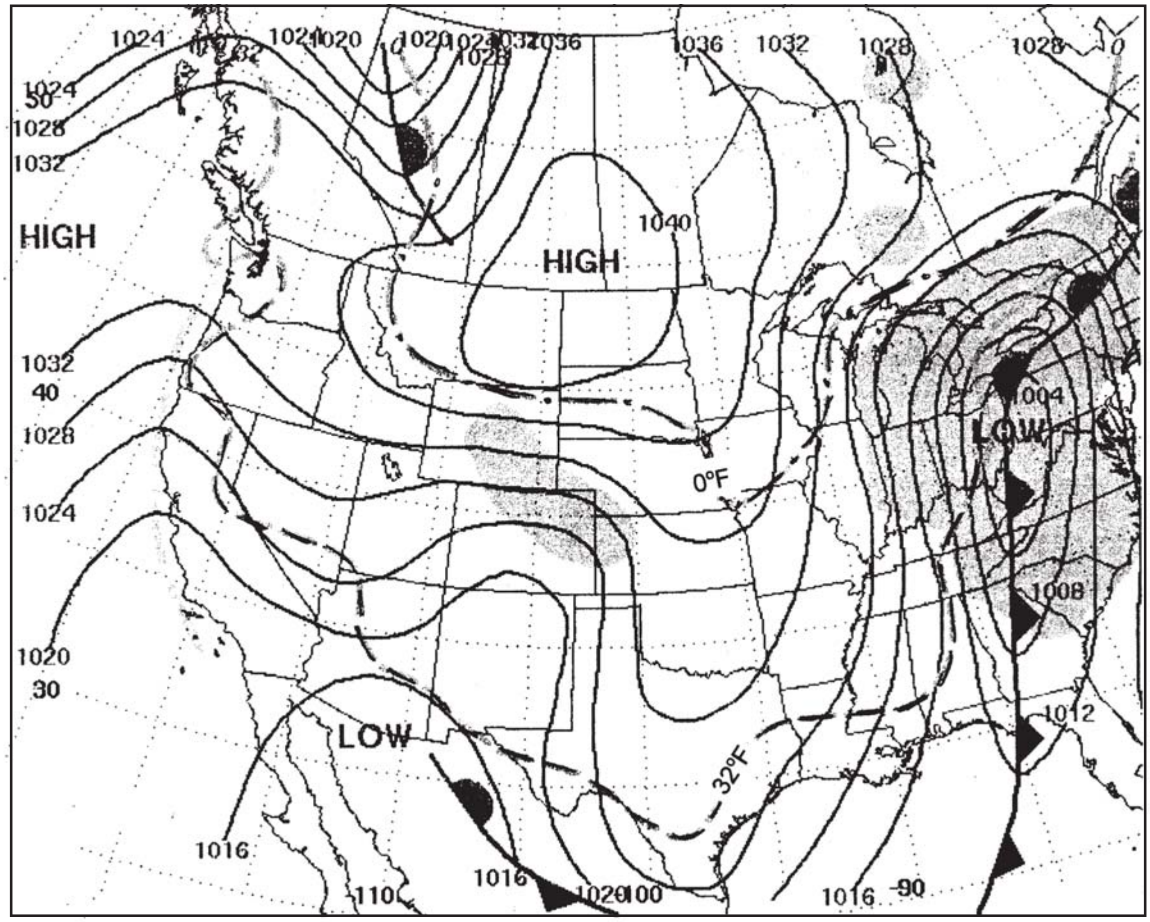

Figure 6. Surface weather map for 0600 CST on December 23, 2004
(National Center for Environmental Prediction, NOAA).

Coast, and no precipitation was reported except along the front in southern Florida. A 1034-mb high moved into the central Great Plains, bringing 0°F minimum temperatures into parts of the Ohio River valley. Morning temperatures were below freezing in Mobile, Alabama; New Orleans, Louisiana; and Houston, Texas. Interestingly, after Christmas a major snowstorm developed in this cold air along the Gulf and produced record snowfall in many areas of coastal Texas. Ohio River valley residents who were trying to dig out of a record snowstorm were greeted by very cold temperatures that persisted for four days after the snowstorm.

Synoptic Weather Assessment

This storm was unusual in a number of ways. A strong arctic front spread cold air over a broad area, and development and slow northeastward movement of the Gulf low created long periods of “overrunning” winter precipitation at many locations along the Ohio River valley. At the surface, the Gulf low strengthened, and its track remained west of the Appalachians. In most cases when New England or the Mid-Atlantic states receive heavy snowfall, a Gulf low (similar to the one with this storm) moves northeastward from the Gulf of Mexico but to the Appalachians in eastern Tennessee or Kentucky, and a secondary low develops along the Atlantic Coast (Brandes and Spar, 1971). In these situations, the 850-mb flow is much more southwest-northeast oriented over the Appalachians, with a broad trough located over the Mississippi River valley. However, in the December 2004 storm, a high-amplitude, but narrow, 850-mb trough over the Mississippi River valley produced a northerly flow of moisture along and generally west of Appalachians. Those conditions created the unusual pre-Christmas winter storm for people living or traveling through the Ohio River valley. The arctic blast after the storm had further impacts on those who were without power or were still trying to dig out from the storm's snow and ice.

Review of Storm Precipitation

Several factors contributed to this unusual winter precipitation event in the Ohio River valley. These factors included the long duration of precipitation, widely varying precipitation types, low temperatures during precipitation, and precipitation amount and intensity. All first-order stations along and south of a line from Cape Girardeau, Missouri, to Cleveland, Ohio, reported 30 or more hours of precipitation (Figure 2), more than double the duration identified for High Plains and Southwest Flow heavy snow types by Beckman (1987) in his study of heavy snowstorms. Nearly all stations in the Ohio River valley affected by this event also experienced all possible forms of winter precipitation, from rain to a mix of sleet, freezing rain and drizzle, and then snow, often switching back and forth between types. After the arctic air moved in, freezing rain, sleet, or snow generally occurred from southeastern Missouri to central Ohio at temperatures that ranged from the lower to upper 20s, reducing the potential for melting any frozen precipitation. Many stations reported several hours of moderate to heavy snowfall that greatly reduced visibility and hindered travel. Snowfall amounts exceeded 10 inches from southeastern Missouri to the eastern Great Lakes, with amounts topping 20 inches in a region from southern Indiana into western Ohio (Figure 1).

Precipitation that occurred at most stations initially was related to the overrunning of moist Gulf air over the arctic air behind the cold front, while more significant amounts of precipitation were associated with the approach and passage of the Gulf low. For some locations along the northern and western edge of the storm, such as Indianapolis, two distinct precipitation events occurred. A 3-hour period of snow was associated with the initial overrunning process, followed by a 10-hour break in precipitation before a second 13-hour period of snowfall in association with the Gulf low (Table 2). Stations farther south and east of Indianapolis generally experienced nonstop winter precipitation that often shifted back and forth from snow to freezing rain, creating conditions that made driving in the rolling hills of southern Illinois, Indiana, Ohio, and Kentucky nearly impossible. Dayton, Ohio (Table 2) experienced nonstop snowfall throughout the event as the Gulf low tracked far to the south. Ohio stations closer to the low, such as Akron (Table 2) and Cleveland, reported more than 12 hours of snow, followed by 4 or more hours of sleet and freezing rain before returning to snow for several hours. Stations further south and/or east (such as Columbus and Cincinnati, Ohio; Louisville, Kentucky; and Cape Girardeau, Missouri) had precipitation that changed from rain to freezing rain to snow and back to freezing rain or sleet before ending with snow (Table 2). Lexington, Kentucky, and stations from northern Tennessee into southern Ohio, reported long periods of rain followed by many hours of freezing rain before the precipitation ended as snow.

Impacts

This massive winter storm caused many diverse and costly impacts. Most losses and costs resulted from impacts to 1) surface and air transportation, which were delayed or halted, 2) power and telephone systems, 3) humans (bodily harm and anxiety), 4) property, 5) businesses, and 6) snow removal.

Transportation

Storm effects on all forms of surface and air transportation included major damages, losses, added costs, and injuries or major inconveniences for travelers. Transportation-related impacts were the most frequent and created more damages (loss) than in any other sector. Vehicles and trains were slowed or stopped in many locales. Most regional airports also were closed, and hundreds of flights were cancelled or delayed.

Vehicular traffic was the prime target of the storm, and travel problems resulted from four factors. The storm occurred just 2-3 days before Christmas when large numbers of people were traveling or attempting to finish shopping. The American Automobile Association's travel experts labeled the 2004 Christmas season as having the greatest volume of travelers of any past holiday season: 62 million travelers and 51 million of them by auto. Roads and highways were loaded with vehicles. Delivery services, such as FedEx and UPS, also were in the midst of handling massive amounts of Christmas-related shipping.

A second factor was that most of the storm area occurred over rolling topography and hills, making travel on slick roads dangerous and very difficult. Drivers often lost control of their vehicles, slid on or off roads on slick slopes, and blocked traffic.

A third factor was that the storm occurred in areas where major snow and ice storms are not common. Consequently, local, urban, county, and state snow-removal facilities were not adequate to deal with the massive storm producing 6-29 inches of snow or 1-2 inches of ice over 30 hours. The National Weather Service (NWS) correctly issued storm forecasts on December 21 calling for an impending winter storm, well in advance. Although local road officials readied their facilities, preparations and facilities were inadequate for this massive storm. Additionally, many accidents occurred because local residents were not accustomed to driving during winter storm conditions.

A fourth factor was that temperatures fell well below freezing after the storm, and extremely cold conditions lasted for four days, making snow and ice removal extremely difficult. Travel also continued to be dangerous for many days after the storm.

Hundreds of vehicles became stalled along regional interstates, creating major problems. Interstates oriented north-south and east-west were blocked because of the storm's southwest-northeast orientation (Figure 1) and by jack-knifed semi-trailer trucks on slick slopes. Many vehicles sent to remove blocked vehicles either could not reach them or became stuck themselves.

Interstates in many states were blocked for periods ranging from hours up to several days:

- Indiana: I-64 (closed 3 days), I-65 (closed 10 hours), I-74 (closed 20 hours), and I-94 (closed on December 22 and not open until Christmas Eve)
- Ohio: I-70 and I-74 (closed 18 hours), I-747 (closed several hours), and I-71 (closed 14 hours)
- Kentucky: I-71, I-75, I-24, and I-65 (closed by ice for 12 hours)

- Illinois: I-64 (blocked 3 days), and I-57 (intermittent lane closures)
- Missouri: I-55 (closed 8.5 hours)
- Arkansas: I-40 (closed 6 hours)

A section of I-64 in southwestern Indiana had hundreds of stranded travelers along a 25-mile section for more than 24 hours. The Indiana National Guard, the prime relief force sent to help, used helicopters and Humvees to rescue stranded travelers and to take them to local hotels, churches, and rest shelters. Those same travelers then had to be taken back to their vehicles 2-3 days later. This interstate was not totally cleared until December 28.

Hundreds of thousands of auto accidents caused many injuries and deaths. The Kentucky Department of Transportation reported that the ditches along the highways in the Louisville area were filled with vehicles on December 23. Accidents also were widespread across southeastern Missouri and the northern half of Arkansas. Thousands of auto accidents occurred in Indiana on December 22-23, and thousands of others in Kentucky on December 22-24. There were 300 auto accidents in one 6-hour period in Akron, Ohio. Police in Nashville, Tennessee, reported 122 auto accidents in one 45-minute period. Power outages in Ohio and elsewhere caused stoplights to fail, leading to many accidents at intersections. Many larger Ohio communities, such as Cleveland and Cincinnati, banned parking on city streets and towed many autos. Many urban streets were closed in Cleveland, Louisville, and Evansville for two days or more. Most city streets in the main storm area were not cleared of snow until December 29.

Railroads in the storm area experienced major train delays. The heavy snow in railyards in Evansville and Cincinnati caused many freight trains to be halted for 3-24 hours. The CSX Railroad's major railyard in Evansville, which normally handles 35-40 trains a day, could only handle 4 trains on December 23. The CSX held its trains elsewhere until December 24-25. Switch and signal problems required major maintenance with employees working overtime (*CTC Board*, 2005). Snow removal equipment from northerly sites was brought in to remove the heavier (>6 inches) snow on the tracks in southern Indiana and western Ohio. Amtrak trains operating through Arkansas were delayed by 4-6 hours. Record cold temperatures on December 24-25 caused numerous broken rails.

Flight delays or cancellations included ones reported at Evansville, Louisville, Cincinnati, Dayton, Indianapolis, Little Rock, Columbus, and Cleveland. The worst problems occurred at Cincinnati, a major hub of Delta Airlines, which cancelled more than 200 flights on December 22-23. Trucks bringing de-icer for aircraft at that airport became trapped and stalled for a day on interstates north of the city. The huge impact of the storm on Delta Airlines resulted in major financial losses. The airline's Fourth Quarter 2004 losses were $2.2 billion, and storm-related losses were a contributing factor (*Chicago Tribune,* January 21, 2005).

Flight problems in the storm region also caused flight delays and cancellations at Midwestern airports such as Chicago O'Hare, major eastern airports, and southern airports, including Orlando, Florida, and Atlanta, Georgia. At the busy Orlando airport, 40 percent of all flights on December 23 were delayed an hour or more. Thousands of travelers were stranded at storm-area airports and had to stay overnight, adding to storm costs. Based on company reports, information from the Federal Aviation Agency, and news reports (*Chicago Tribune,* January 21, 2005), losses due to airline cancellations and delays amounted to $270 million.

Property Losses

More than 100,000 auto and truck accidents occurred, representing the top property losses caused by the storm. Heavy snowfall caused collapse of roofs on buildings and homes. For example, the collapse of a warehouse roof in Cleveland cost $500,000. In Louisville where the snow totaled 9 inches and sleet fell for 11 more hours, roofs collapsed at two schools, an office building, a warehouse, and two retail businesses. Damages to these buildings' contents represented losses of $1.7 million, and estimated repair costs were $1.3 million. Every city and town in the storm area with 10 inches or more snow experienced various forms of roof damages. The storm and ensuing low temperatures also led to heating problems resulting in house and trailer fires attributed to the storm.

The insurance industry reported storm-related insured property losses of $230 million (Property Claims Service, 2005). Past studies (Changnon and Hewings, 2001) have revealed that insured property losses in major storms represent 90 percent of all property losses (the remaining 10 percent is not insured). When that relationship is applied to insured losses from this storm, total property losses amount to $255 million.

Human Harm and Suffering

The storm resulted in 17 deaths, 11 by auto accidents, 5 after heart attacks from overexertion while shoveling snow, and 1 electrocution. That total included deaths in Indiana (5), Ohio (4), Kentucky (2), and Arkansas (6).

The storm created thousands of injuries largely due to auto accidents but also from falls on slick surfaces. Exceptionally low temperatures on December 23-28 also led to many cases of hypothermia and frostbite. Anxiety affected many of those stranded on highways and in airports. Frustrations were high over inability to complete Christmas shopping or to reach destinations on time. There were numerous complaints about the inability of local road crews to clear city streets.

Power/Telephone Outages

The snowstorm and associated ice storm to the immediate south created extensive power outages due to the weight of the snow and/or ice on lines. Much of the ice storm area in Kentucky and Ohio occurred in areas with numerous trees and forests, and the weight of the snow and ice caused many tree branches to snap and fall, also breaking power/telephone lines. The most extensive outages occurred in Kentucky and Ohio where ice layers were 1-2 inches thick.

Power outages were widespread across parts of Ohio on December 22-23, including those lasting more than 24 hours at 48,000 homes and businesses in and east of Cincinnati. The local power company sent 300 repairmen to restore power. Extensive power outages in the Cleveland-Akron area affected 300,000 customers, many for 2-3 days. Power outages in areas around Columbus affected 330,000 customers, many of those without power until December 25. Ohio had a total of 678,000 outages from the massive storm. For those who had no power until December 25, restored power was a welcome Christmas present.

There were 33,000 Louisville area homes without power for a 2-day period that ended on Christmas Eve, as well as 135,000 other customers in eight other Kentucky counties. Isolated communities in southern Indiana reported power outages lasting 12-36 hours. Clarksville and other northern Tennessee communities lost power at 23,000 homes on December 22-23. More than 11,000 Arkansas residents lost power for 2-3 days, a result of the high winds and icing. Repairs crews imported from Louisiana helped restore power.

The costs to restore power were excessive for local and regional power companies. Many had to contract with outside firms in nonstorm areas for crews to help restore power lines and broken equipment.

Telephone lines also were downed by the weight of ice and by falling tree branches. Repair crews from many states worked to repair these lines. Consequently, excessive cell phone usage occurred in some areas, and at times overwhelming systems. Costs for line and pole restoration exceeded $48 million, based on reports from power companies and news accounts.

Business Losses

Many retail businesses reported lost sales, some by as much as 80 percent of expected sales. Retail losses in larger communities with populations of 100,000 or more averaged $50,000-$100,000. December 23-28 total losses in retail sales in the 4-state area were an estimated $63 million, based on measured losses in comparable storms (Adams, et al., 2004). Other unmeasured losses affected major package carriers, such as FedEx and UPS, who had major problems with long-haul trucks (stalled, slowed, or unable to deliver to specified destinations) and greatly delayed air shipments. These and other losses created severe losses of local, state, and federal tax revenues, $45 million based on calculations derived from a recent economic study of winter storms (Adams et al., 2004).

Income Losses

The widespread storm and extreme difficulties of moving vehicles on streets and highways kept many employees of retail stores and area manufacturing plants from their jobs for up to 4 days. This resulted in major loss of income in Illinois Indiana, Kentucky, and Ohio for December 22-28: an estimated $40 million, based on calculations presented in a prior study of storm losses (Adams, et al., 2004).

Costs of Snow/Ice Removal

The magnitude of storm damages led the governor of Indiana to declare a state of emergency for 50 counties, qualifying them for state and federal aid. Governors of Kentucky, Illinois, and Ohio also declared a state of emergency for many counties (30 in Kentucky, 16 in southern Illinois, and 23 in Ohio).

For areas declared emergencies and with snow totals near or above records, the federal government, through the Federal Emergency Management Agency provided funds for 75 percent of local/state costs of snow removal on December 22-23. Federal payments in Illinois totaled $1.1 million of the $13 million total in federal relief and assistance payments for snow removal to communities and counties in the 4-state area.

Costs of snow removal were excessive. One Ohio County reported costs of $398,000 to remove snow and ice, with the cost of salt representing $200,000 of that amount. Cincinnati spent $510,000 on salt. The Ohio Department of Transportation had all 136 trucks out 12-18 hours a day for 5 consecutive days. Reported total costs for snow removal and supplies in the 4-state area were $108 million. Missouri and Arkansas also had extensive added costs, an estimated

$25 million based on past storm studies (Changnon et al., 1980), bringing the storm total to $133 million.

Environmental Damages

Trees and landscaping were badly damaged throughout the storm area. Some trees were blown down by high winds (Le Comte, 2005). No costs for landscape replacement have been determined, but measured losses in similar Midwestern winter storms caused $10-$15 million in environmental damages (Changnon et al., 1980).

Costs for Stranded Travelers

The major blockages of several interstates left stranded hundreds of people in their vehicles. State police and county vehicles were often inadequate for their rescue. In fact, many recovery vehicles also became stuck in deep snows. The Red Cross contributed vehicles and aid. In Indiana, the National Guard helped extract the stranded from their vehicles on interstates. These efforts cost an estimated $2 million.

Homeless shelters and churches near blocked highways from Little Rock, Arkansas, to Cleveland, Ohio, were at capacity during the storm and sometimes for 2-3 days afterwards. Many hotels near blocked highways also were filled to capacity, and some even allowed people to reside in their lobbies. One group estimated costs at $750,000 for stranded travelers. Of course, that figure does not begin to measure the human suffering and anxiety associated with being stranded in autos overnight, particularly while on holiday-related travel.

Post-storm Repairs/Problems

Estimates to repair to roads and highway, including the many potholes resulting from the storm and ensuing temperature fluctuations, were $15 million, using past storm assessments (Changnon et al., 1980). There was much concern over potential damages to vehicles resulting from massive salt applications, as well as concern over soil and stream pollution, but no related costs have been assessed.

Snowmelt amounting to 1-2 inches of water into area soils and streams was followed by heavy rains of 4-6 inches along the Ohio River valley on January 1-10, 2005. This led to record floods on the Ohio River and many tributary streams.

Total Losses/Costs

Measures of losses and costs were summed and are listed (Table 3). Most of these amounts are either directly or indirectly related to travel and transportation systems.

Table 3. Losses/costs from the December 22-23, 2004 Winter Storm

Insured property	$230,000,000
Uninsured property	25,000,000
Railroads	7,000,000
Airlines	270,000,000
Power/telephone repairs	48,500,000
Business losses	63,000,000
Tax losses	45,000,000
Income Losses	40,000,000
Snow/Ice removal	133,000,000
Environmental damages	15,000,000
Costs for stranded travelers	2,750,000
Post-storm repairs	15,000,000
Total	**$894,250,000**

Summary and Conclusions

Although good NWS pre-storm forecasts of the onset of the December 2004 winter storm allowed local and state highway agencies to prepare, the record-setting conditions overwhelmed most existing facilities. Massive surface transportation problems ensued.

Five factors made this storm unusual:

- Its huge size.
- Its occurrence in an area seldom experiencing massive snowstorms.
- Excessive losses/costs total.
- Unusual atmospheric conditions that created the storm.
- Timing just before the holiday season with a record-setting volume of travelers/shoppers.

An important lesson learned from this study concerns interstate travel when there is extensive snow and/or ice. Accidents occur, often blocking passage and stranding of other vehicles because interstates have few exits. Travelers should be made alert to this possibility.

References

Adams, R.M., Houston, L.L., and R. Weiher. 2004. *The Value of Snow and Snow Information Services*. National Oceanic and Atmospheric Administration, Washington, DC, pp. 23-24.

Beckman, S.K. 1987. Use of Enhanced IR/Visible Satellite Imagery to Determine Heavy Snow Areas. *Monthly Weather Review* **115**: 2060-2087.

Brandes, E. A., and J. Spar. 1971. A Search for Necessary Conditions for Heavy Snow on the East Coast. *Journal of Applied Meteorology* **11**: 397-409.

Changnon, S.A. 2005. *Developing Data Sets for Assessing Long-term Fluctuations in Snowstorms in the U.S.* Changnon Climatologist, Mahomet, IL.

Changnon, S.A., Changnon, D., and P. Stone. 1980. *Illinois Third Consecutive Severe Winter: 1978-1979.* Report of Investigation 94, Illinois State Water Survey, Champaign.

Changnon, S.A., and J. Hewings. 2001. Losses from Weather Extremes in the United States. *Natural Hazards Review* **2**: 113-123.

Chicago Tribune. January 21, 2005. $2.21 Billion Loss a Record for Delta. p.B.2

CTC Board. March 2005: Winter Storm Woes. p.10.

Le Comte, D. 2005. Wet and Windy. *Weatherwise* **58:** 31-38.

Property Claims Service. 2005. *December 2004 Storm Losses.* Alton, NJ.Figure 6. Surface weather map for 0600 CST on December 23, 2004 (National Center for Environmental Prediction, NOAA).

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