The Great Arctic Outbreak and East Coast Blizzard of February 1899

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(Manuscript received 23 September 1988, in final form 4 November 1988)

ABSTRACT

An unprecedented period of extreme cold accompanied by an intense East Coast blizzard during February 1899 is documented through an examination of detailed surface weather charts constructed from original data. The surface weather analyses depict the passage of several anticyclones of Canadian or polar origin that propagated southward, spreading progressively colder temperatures throughout the central, eastern, and southern United States. This series of cold outbreaks culminated in the southward plunge of one final, massive anticyclone that yielded the coldest temperatures on record for much of the south-central and southeastern United States. The final cold wave was associated with the development of a cyclone that left measurable snow over most of the Gulf Coast and Florida and then produced severe blizzard conditions along much of the East Coast.

To place this period in historical perspective, minimum temperatures recorded during February 1899 are compared with minimum temperatures measured during more recent cold air outbreaks. Snowfall records set during February 1899 that have never been exceeded are also documented. Examples of extreme weather events such as this enable forecasters and students to gain practical experience by visualizing the meteorological patterns these events are associated with, by acquiring a historical perspective when assessing other events, and by gaining an appreciation of the limits of severity that atmospheric phenomena can attain.

1. Introduction

In February 1899, a two-week period of exceptionally cold weather culminated in what weather historian David Ludlum (1970) describes as "the greatest Arctic outbreak in history." Temperatures fell to 0°F (−18°C) along the beaches of the Gulf Coast and ice flowed from the mouth of the Mississippi River into the Gulf of Mexico. All-time record minimum temperatures were established in 12 states spanning the central and southern Plains, the Ohio Valley, the southeastern United States, and the District of Columbia.

The cold weather was associated with a series of surface anticyclones of Canadian or polar origin that affected the northwestern United States early in the month and then shifted to the central and eastern United States by the second week of February. The period of extreme cold climaxed in one final massive anticyclone that propagated southward from central Canada to the Gulf Coast. Other cold waves have yielded lower temperatures but none have produced as many widespread low temperature records as were observed during the first half of February 1899.

The cold weather was associated with a series of snowstorms across the eastern United States. This succession of storms left behind a deepening blanket of snow which served to intensify the effects of the cold. As the final and most significant cold air mass spread over the central and eastern United States, a cyclone developed along the leading edge of the cold pool and evolved into one of the most intense blizzards ever to affect the Gulf and East Coasts. Near-blizzard conditions occurred in such unlikely sites as New Orleans, Louisiana; Mobile, Alabama; and Pensacola, Florida. More than a foot of snow (30 cm) fell in a swath from the Carolinas to Maine, accompanied by high winds and temperatures close to 0°F (−18°C).

The purpose of this study is to shed light on this little-known series of events and the meteorological context in which it evolved, through an examination of detailed surface weather charts constructed from original data. Examples of extreme weather events such as described here can enable forecasters and students to gain practical experience by 1) visualizing the me-

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teorological patterns these events are associated with, 2) acquiring a historical perspective when assessing other events or similar situations encountered in real-time, and 3) gaining an appreciation of the limits of severity that atmospheric phenomena can attain. Additional goals of this paper are to demonstrate the utility and limitations of the application of historical weather data, and to speculate on some of the physical and dynamical processes that may have been operating during this sequence of events.

2. Data sources

One hundred, sixty-two main Weather Bureau stations existed nationwide in February 1899, taking measurements of a complete set of surface meteorological parameters, including temperature, dewpoint temperature, pressure, wind direction and speed, and precipitation form and intensity (light versus heavy). Observations were taken twice daily, at 0800 eastern standard (or 75th meridian) time (1300 UTC) and at 2000 EST (0100 UTC). The data were recorded on tabular monthly forms, available from the National Climatic Data Center (NCDC) in Asheville, NC. Daily maximum and minimum temperatures, precipitation and snowfall were also tabulated. Original surface weather charts which were plotted daily by the U.S. Department of Agriculture at 0800 EST were used here to verify the surface observations obtained from NCDC, as well as to supply Canadian and missing United States observations.[1]

Ship weather reports were obtained in tabular form from NCDC, but many of these reports appear to be inconsistent and unreliable. Additional marine observations were taken from the Northern Hemispheric Synoptic Weather Map series, also available from NCDC. These charts show a fairly extensive coverage of ship weather data over the western Atlantic Ocean and Gulf of Mexico at 0800 EST that could not be reproduced from the tabular reports on file at NCDC. Other data used for this study include measurements taken by voluntary observers, who numbered 2385 across the nation in February 1899. These reports included daily minimum and maximum temperatures, precipitation, and snowfall, allowing the construction of detailed minimum temperature and snowfall charts.

The combination of data obtained from these sources was used to construct surface analyses that depict the evolution of an intriguing weather episode. Sea level pressure analyses were drawn by hand. Any obvious biases in the sea level pressure measurements at local stations were evaluated by examining successive analyses, making comparisons with surrounding observation sites, and then corrected.

[1] The Department of Agriculture charts were made available to the public each day and are the forerunner of today's "Daily Weather Map, Weekly Series," published by the Climate Analysis Center, National Oceanographic and Atmospheric Administration (NOAA), Department of Commerce. These charts included station reports, isobars, isotherms, precipitation, state weather forecasts, and observed river stages.

3. Weather conditions in early February 1899

During the first week of February, very cold conditions gripped the western third of the United States. Temperatures fell as low as 33°F (1 °C) at Los Angeles, California, 9°F (−13°C) at Portland, Oregon, −9°F (−23°C) at Boise, Idaho, and 12°F (−11°C) at Seattle, Washington on the third and fourth. Meanwhile, much of the Middle Atlantic, South Atlantic and Gulf states were experiencing unseasonably mild conditions. Temperatures soared to 63°F (17°C) at Richmond, Virginia, and 72°F (22°C) at Raleigh, North Carolina on the fourth, and to 81°F (27°C) at Savannah, Georgia on the fifth. The leading edge of the cold air advanced southeastward during the first few days of the month, then became nearly stationary from the Texas coast to the Carolinas by 4 February.

By Sunday morning, 5 February, the first in a series of three low pressure centers formed along the stationary frontal boundary over northwestern South Carolina. Rain fell over the Carolinas and southern Virginia while snow was occurring from northern Virginia to southern New York. Accumulations of 6 inches (15 cm) were common across portions of northern Virginia, Maryland, and Pennsylvania by evening. Later in the day, this storm system intensified gradually as it headed rapidly east-northeastward off the North Carolina coast, spreading generally light snows throughout southern New England. Cold temperatures now covered much of the nation east of the Rocky Mountains, with readings above freezing confined to the Gulf Coast and the southeastern United States.

On the following morning, 6 February, the old frontal boundary remained nearly stationary across the southern United States. The pronounced surface temperature gradient near the front, indicative of the baroclinicity necessary to generate widespread precipitation, was illustrated by 60°F (15°C) readings in eastern Georgia and South Carolina in contrast with 30°F (near 0°C) temperatures across North Carolina. A new low pressure center developed over Alabama and Georgia, with a new region of snowfall spreading over the Middle Atlantic states. This second low pressure area later propagated east-northeastward over the Atlantic Ocean with little intensification, producing another light to moderate snowfall from the Virginias through southern New England. Rain and snow also extended westward across a large portion of the Gulf Coast states. Meanwhile, generally fair and cold conditions covered much of the central and northern United States in association with a 1040 hPa high pressure center over Wyoming and Idaho.

On Tuesday morning, 7 February, we begin a sequence of daily surface weather analyses (Fig. 1a). The last of three storm systems in this series was developing

in southern Georgia, with a central sea level pressure of 1004 hPa. During the day, this storm center propagated northeastward along the Atlantic coast. Snow redeveloped over the Middle Atlantic states, where two separate periods of snowfall had already occurred during the previous 2 days. Precipitation ended across the Gulf Coast states, following several days of inclement weather with temperatures (degrees Fahrenheit) mostly in the 60s and 70s (15° to 25°C). Temperatures now fell dramatically as cold air rushed southward and eastward toward the eastern Gulf and South Atlantic coasts. By nightfall, freezing temperatures had penetrated as far south as southern Texas, New Orleans, and Pensacola. Meanwhile, very cold air over the Plains states would soon spread south and eastward, leaving much of the central and eastern United States with record or near-record low temperatures during the next several days.

The East Coast storm continued northeastward and intensified overnight. By Wednesday morning, 8 February (Fig. 1b), the low pressure center was located off the New Jersey coast, with a central sea level pressure of approximately 988 hPa. Moderate to heavy snows were occurring over much of the northeastern United States, where 6–10 in. (15–25 cm) new accumulations were common across the more heavily populated coastal sections, including New York City and Boston, Massachusetts. Greater than 10 in. (25 cm) fell in sections of interior New York and New England, where Binghamton, New York measured 10.7 inches (27 cm) and Northfield, Vermont recorded 15.0 in. (38 cm). By storm's end, the total snow depth from this and the previous two systems reached 14 inches (35 cm) at Washington, D.C.

Behind the storm, colder air began to pour in across the entire eastern half of the nation. A high pressure center located over southern Texas was associated with subfreezing temperatures across the entire Gulf Coast region through the Florida Panhandle. A second anticyclone could be seen north of North Dakota, associated with extremely cold temperatures, strong winds, and clear skies. Early morning temperatures fell to values of −30°F (−35°C) to −40°F (−40°C) in the Dakotas and Minnesota, with subzero temperatures (less than −18°C) as far south as Kansas, Missouri, and the Ohio Valley. By evening, the storm had moved beyond the Maine coast and temperatures dropped rapidly across much of the snow-covered northeastern United States.

The final East Coast storm of this series was no longer affecting the United States by Thursday morning, 9 February (Fig. 1c), but was followed by a blustery westerly flow of bitterly cold air. Much of the eastern two-thirds of the United States was gripped by temperatures well below seasonal normals, with daily averages across the Plains states and the Ohio Valley as much as 35°–45°F (20°–25°C) below normal. Temperatures of <0°F (≤ −18°C) were reported from

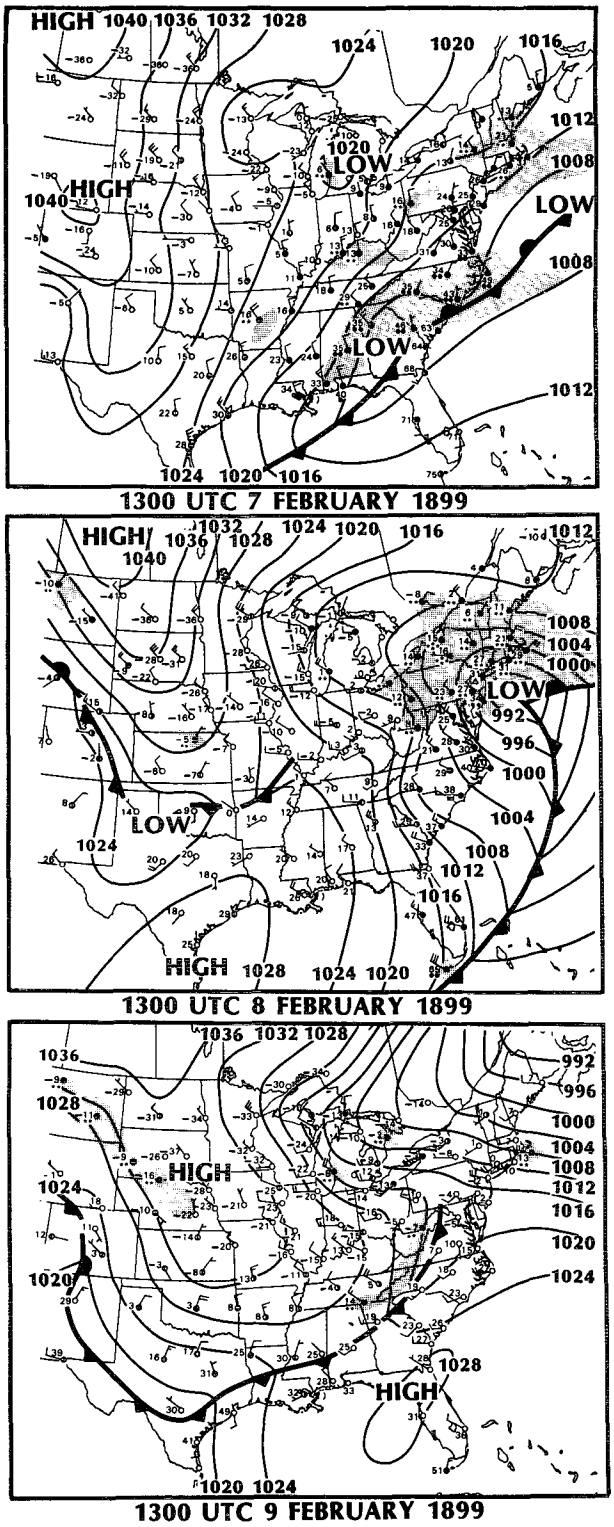


FIG. 1. Sea level pressure (hPa) and surface frontal analyses at (a) 1300 UTC 7 February 1899, (b) 1300 UTC 8 February 1899, and (c) 1300 UTC 9 February 1899. Station plots depict cloud cover, temperature (°F), precipitation type and intensity, and wind velocity. Precipitation areas are shaded. Isobars were analyzed using observed sea level pressures (not plotted).

nearly half the nation, generally north of a line from Oklahoma to Virginia. Readings of ≤ −10°F (−23°C) were widespread in the Ohio Valley. Temperatures of ≤ −20°F (−28°C) were evident from Illinois and central Missouri northward, including −21°F (−29°C) at Chicago, Illinois and −22°F (−30°C) at Milwaukee, Wisconsin. Temperatures of −30°F (−35°C) to −40°F (−40°C) or lower covered much of the Dakotas, Minnesota, and parts of Wisconsin. All-time record low temperatures were established at Cincinnati, Ohio, with −17°F (−27°C) (that record was broken in 1977) and at Sioux Falls, South Dakota at −42°F (−41°C).

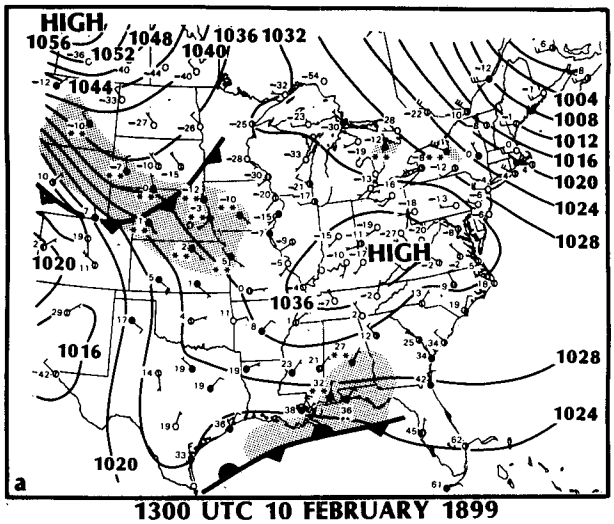
A cold front separated this very cold air mass from the previous cold air outbreak that had settled over the Southeast and Gulf coasts. Minimum temperatures (degrees Fahrenheit) in Florida generally ranged between the 20s and 30s (−4°–4°C). This air modified somewhat, allowing afternoon temperatures (degrees Fahrenheit) to recover to the 50s and 60s (10° to 20°C) along the Texas coast. However, the cold front spanning the southeastern United States continued to drift to the south and east, and by nightfall had crossed all sections but Florida. At the same time, yet another new cold air mass, marked by rapidly rising sea level pressures, was observed near the Canadian border north of North Dakota and Montana. In the days to follow, this air mass would accompany the final and most spectacular combination of winter weather elements of this period.

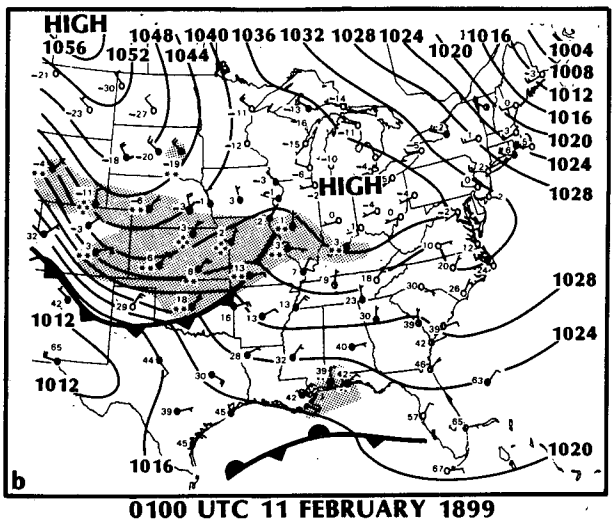
4. The main event: 10–14 February 1899

Detailed 12-h surface weather analyses are shown in Figs. 2 through 4 to highlight the period 10–14 February. This period exhibited some of the most severe winter weather conditions ever to descend upon the eastern two-thirds of the United States. The analyses begin at 0800 EST 10 February 1899.

a. Friday, 10 February 1899

On Friday morning, the central and eastern United States were already under the influence of a widespread, record-breaking cold air mass (Fig. 2a). A strong northwesterly flow of bitterly cold air remained across New England to the northeast of a 1038 hPa anticyclone over the Ohio Valley. Temperatures of −21°F (−29°C) at Milwaukee, Wisconsin, −27°F (−33°C) at Parkersburg, West Virginia (an all-time record low), −8°F (−22°C) at Washington, D.C., and −7°F (−21°C) at Nashville, Tennessee, illustrate the severe and widespread nature of the cold weather conditions. Low temperatures also extended into the southern United States. The only region to escape the chill was southern Florida, where temperatures were above 60°F (15°C). Light snow and rain were observed across the Gulf Coast states north of a front which had become stationary in the Gulf of Mexico. Snow accumulations





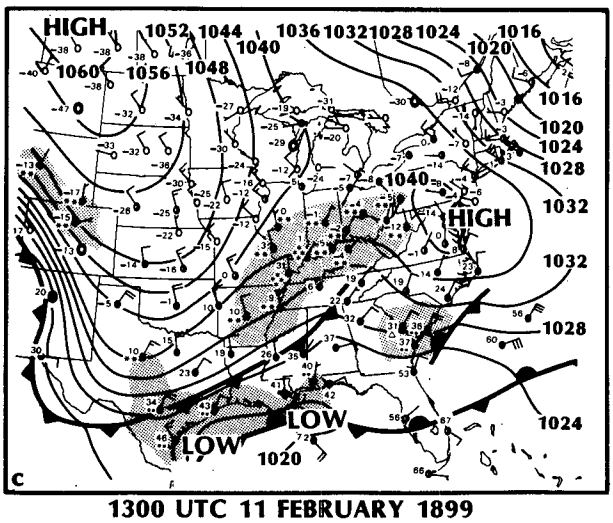


FIG. 2. Sea level pressure (hPa) and surface frontal analyses at (a) 1300 UTC 10 February 1899, (b) 0100 UTC 11 February 1899, and (c) 1300 UTC 11 February 1899. See Fig. 1 caption for details.

of an inch or two (2.5–5 cm) occurred over portions of Louisiana, Mississippi and Alabama.

A weak trough of low pressure extended through Nebraska, South Dakota, and Minnesota, marking the leading edge of the newest mass of cold air. This trough/front was accompanied by a widespread area of primarily light snows. Little temperature contrast was observed in the immediate vicinity of the front, with temperatures no higher than approximately 0°F (−18°C) on either side of the boundary. At the heart of the Arctic air, sea level pressures exceeding 1055 hPa were found north of Montana. Surface air temperatures at this time ranged from −25° to −35°F (−32 to −37°C) across North Dakota to below −40°F (−40°C) north of the United States–Canadian border.

In the following days, the anticyclone north of Montana propagated southward into the United States, with an unprecedented surge of bitterly cold air that would break many all-time low temperature records from the Plains states to the Gulf Coast and the southeastern United States. This cold air outbreak would also be associated with the development of a fierce snowstorm along the Gulf and East Coasts.

By the evening of 10 February (Fig. 2b), the inverted trough/front that represents the leading edge of the major cold outbreak had sagged southward to a position extending from northern Texas to Illinois. A large area of snow had developed immediately to the rear of the inverted trough. Moderate to heavy snow was recorded at Cheyenne, Wyoming, where the temperature was −11°F (−23°C), and over eastern Kansas and western Missouri, where temperatures were slightly above 0°F (−18°C). North of this snow area, temperatures fell during the day across Nebraska, the Dakotas, Wyoming, and Montana, as gusty northwest winds drew exceptionally cold air southward into the central United States. The anticyclone in west-central Canada now had a central sea level pressure exceeding 1060 hPa. With temperatures of −20° to −30°F (−28° to −34°C) and winds of 20 kt (10 m s^{-1}) or greater, wind-chill temperatures across the Northern Plains states were in the −70° to −100°F (−57° to −73°C) range.[2]

Even in advance of this outbreak, much of the eastern United States remained locked in the deep freeze, with a 1038 hPa anticyclone still located over the Ohio Valley. Evening temperatures across the Ohio Valley and northeastern United States were uniformly within a few degrees of 0°F (−18°C) as an extensive snow cover thwarted the sun's moderating influence, then contributed to rapid radiational heat loss in many areas after nightfall.

b. Saturday, 11 February 1899

By 1300 UTC Saturday (Fig. 2c), the high pressure cell from the Ohio Valley had drifted over the Middle Atlantic states with a central pressure now in excess of 1040 hPa. The combination of clear skies, light winds, and a deep snow cover produced the coldest morning ever known in the Washington, D.C. area. The official low temperature reached −15°F (−26°C) and surrounding rural locations reported temperatures as low as −25°F (−32°C). While minimum temperatures across the other major urban centers along the northeastern coast of the United States were not as low as those reported in and around Washington (perhaps due to the strong winds that minimized radiational heat loss), numerous daily temperature records were established, with readings generally below 0°F (−18°C).

The inverted trough that delineated the leading edge of the next Canadian anticyclone continued to progress southward and eastward overnight, extending from southern Texas east-northeastward into the Tennessee and Ohio valleys at 1300 UTC. To the rear of the inverted trough/cold front, pressures continued to rise rapidly in the central United States as cold air from the Canadian anticyclone spilled further southward and eastward. Medicine Hat, Alberta reported a sea level pressure of 1063.6 hPa. Temperatures of −30°F (−34°C) were common across the Dakotas and Minnesota and −20°F (−29°C) readings prevailed across much of the Central Plains. Low temperature reports in many of the Northern Plains states were above their all-time minimum readings because radiational effects were offset by the presence of strong winds. Despite less than ideal conditions for radiational cooling, Rapid City, South Dakota and Wichita, Kansas both recorded their all-time minimum temperatures on this morning (see Table 1). The effect of radiational cooling under light wind and cloud-free conditions can be seen at Miles City, Montana, where the temperature at 1300 UTC had fallen to −47°F (−44°C). Although strong winds prevented the establishment of new absolute minima across much of the Northern Plains, they served to advect this air mass rapidly southward with little modification from the February sun. By the following morning, many residents of the south-central United States would experience colder temperatures than had ever been witnessed there before.

The area of snow that occurred the previous night in Kansas and Missouri had shifted eastward and was still located to the north and west of the inverted trough axis. Moderate to heavy snow fell across southeastern Missouri into southern Indiana, Illinois, and Kentucky, where as much as 6 in. (15 cm) accumulated. As the trough crossed the Tennessee and Ohio Valleys, a separate inverted trough and probable coastal front formed offshore of the Southeast United States coast. In association with this coastal front, some light rain and ice pellets developed across Georgia and South Carolina. It is speculated that whatever upper-level trough/jet system was associated with the inverted surface trough crossing the Tennessee and Ohio Valleys was

[2] Wind chill temperatures were derived from a chart appearing in Driscoll (1987).

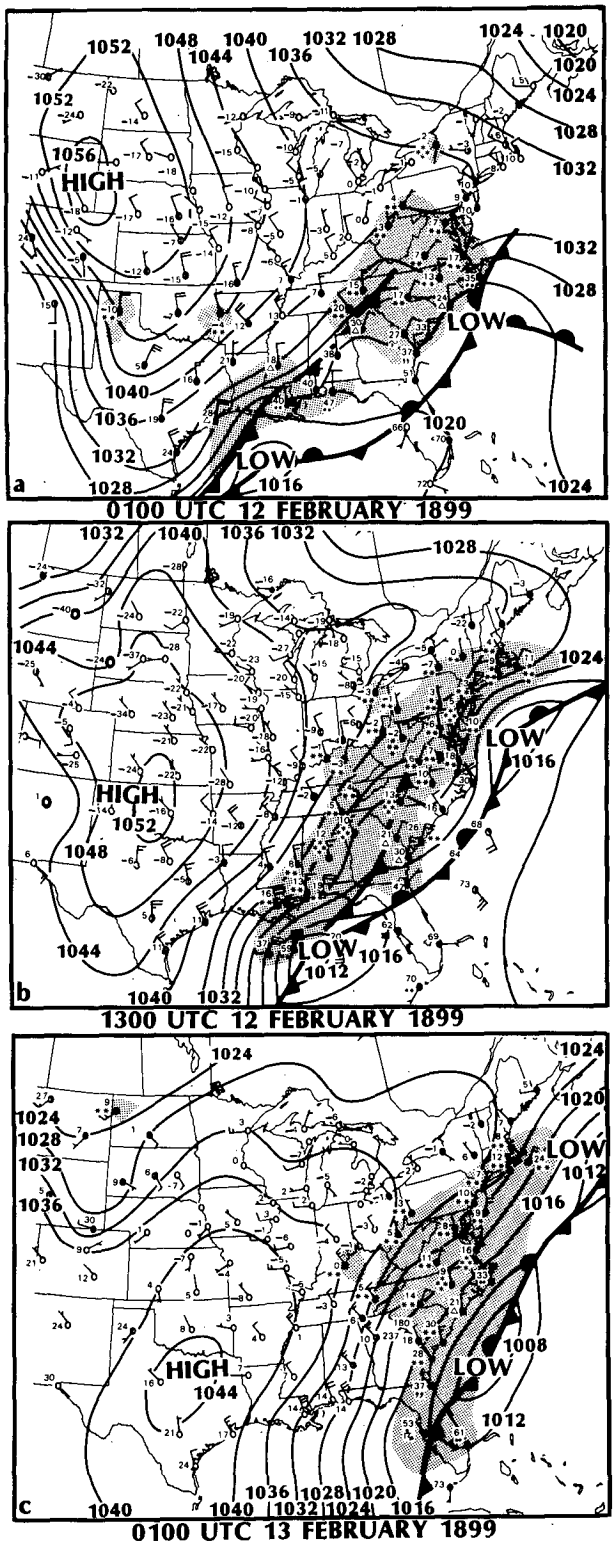


FIG. 3. Sea level pressure (hPa) and surface frontal analyses at (a) 0100 UTC 12 February 1899, (b) 1300 UTC 12 February 1899, and (c) 0100 UTC 13 February 1899. See Fig. 1 caption for details.

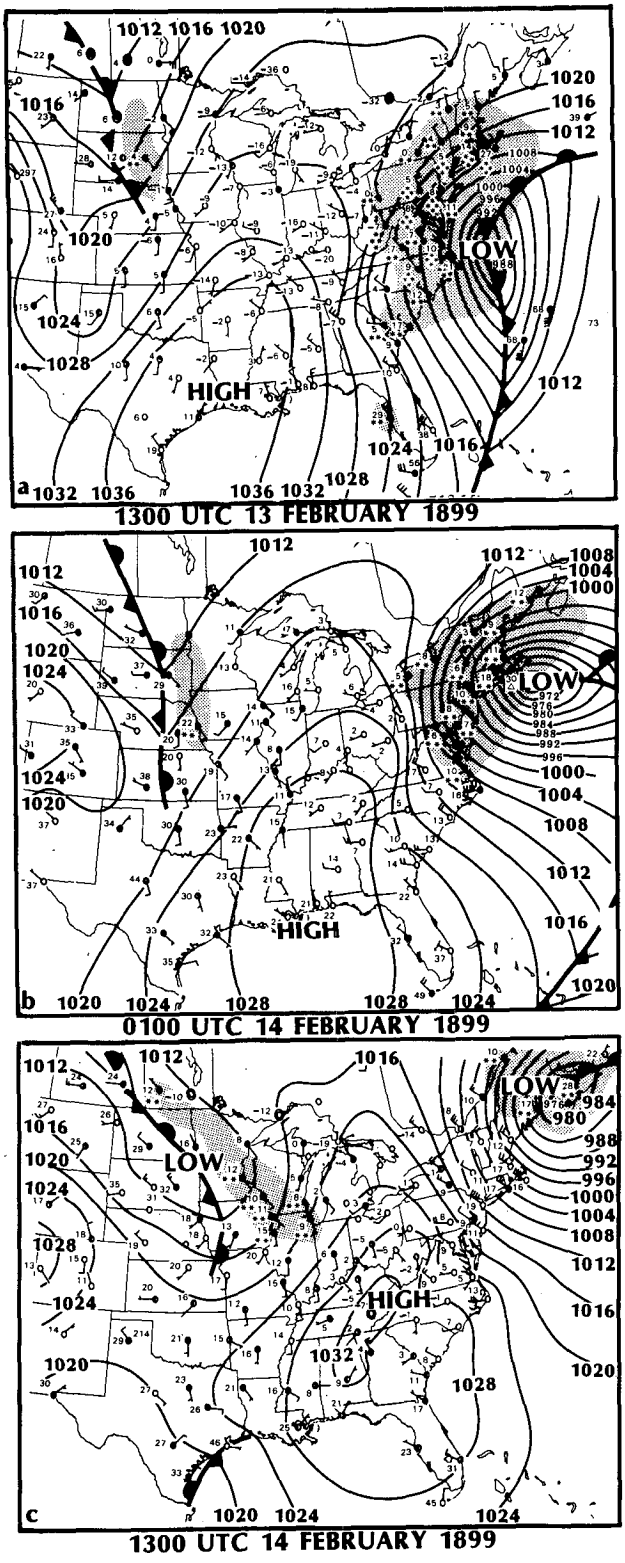


FIG. 4. Sea level pressure (hPa) and surface frontal analyses at (a) 1300 UTC 13 February 1899, (b) 0100 UTC 14 February 1899, and (c) 1300 UTC 14 February 1899. See Fig. 1 caption for details.

TABLE 1. Minimum temperatures in degrees Fahrenheit and degrees Celsius. An asterisk represents the current state record. (Ludlum 1982).

Location	°F	°C	Location	°F	°C
9 February 1899			*13 February 1899*		
Cincinnati, Ohio	−17	−27	Atlanta, Ga.	−9	−23
Sioux Falls, S. Dak.	−42	−41	Rome, Ga.	−7	−22
			Savannah, Ga.	8	−13
10 February 1899			Athens, Ga.	−3	−19
			Vicksburg, Miss.	−1	−18
Pittsburgh, Pa.	−20	−29	Shreveport, La.	−5	−21
Columbus, Ohio	−20	−29	New Orleans, La	7	−14
Parkersburg, W. Va.	−27	−33	Baton Rouge, La.	2	−17
Milligan, Ohio*	−39	−39	Minden, La.*	−16	−27
Monterey, Va.	−29	−34	Brownsville, Tex.	12	−11
			Tallahassee, Fla.*	−2	−19
11 February 1899			Jacksonville, Fla.	10	−12
			Pensacola, Fla.	7	−14
Rapid City, S. Dak.	−34	−37	Mobile, Ala.	−1	−18
Washington, D.C.*	−15	−26	Montgomery, Ala.	−5	−21
Wichita, Kans.	−22	−30	Lexington, Ky.	−20	−29
Muskegon, Mich.	−30	−34	Meridian, Miss.	−6	−21
			Dayton, Ohio	−28	−33
12 February 1899					
			14 February 1899		
Little Rock, Ark.	−12	−24			
North Platte, Nebr.	−35	−37	Columbia, S.C.	−2	−19
Camp Clarke, Nebr.*	−47	−44	Raleigh, N.C.	−2	−19
Scottsbluff, Nebr.	−45	−43	Charleston, S.C.	7	−14
Dodge City, Kans.	−26	−32	Augusta, Ga.	3	−16
Topeka, Kans.	−25	−32	Wilmington, N.C.	5	−15
Oklahoma City, Okla.	−17	−27	Grand Rapids, Mich.	−24	−31
Galveston, Tex.	8	−13			
Fort Worth, Tex.	−8	−22			
Amarillo, Tex.	−16	−27			
Corpus Christi, Tex.	11	−12			
Fort Smith, Ark.	−15	−26			
Kansas City, Mo.	−22	−30			
Columbia, Mo.	−26	−32			
Springfield, Mo.	−29	−34			

also influencing the development of the coastal front off Georgia and the Carolinas. The coastal front may also have been developing in combination with cold air damming east of the Appalachian Mountains, as evidenced by the distinct inverted sea level pressure ridge from Virginia to Georgia, and the establishment of a zone of intense temperature contrast between the cold air over the coastal plain and the ocean-modified air over the Gulf Stream and beyond. Note that two ship reports indicate temperatures (degrees Fahrenheit) in the 50s to near 60° (12° to 16°C) east of the South Carolina–Georgia coast, while temperatures (degrees Fahrenheit) across the Carolinas and Georgia range from the teens to the 30s (−10° to 3°C). In addition to these features, a new region of low pressure had formed in the western Gulf of Mexico along the preexisting stationary front. This weak low pressure area was associated with some light rain along the Texas and Louisiana coasts.

By Saturday evening, 0100 UTC 12 February (Fig. 3a), the massive surface anticyclone was located over the United States, with a 1058 hPa center over Wyoming. The cold front at the edge of the Arctic outbreak had passed off the Texas coast and was followed by strong northerly winds and rapidly plummeting temperatures. Subzero readings (less than −18°C) had progressed as far south as north-central Texas and northwestern Arkansas.

The area of snowfall that was located over the Ohio Valley at dawn had now reached the Atlantic coast. The remnants of the earlier inverted trough were now located over the Appalachian Mountains, with the coastal front remaining east of the Carolinas coast. Further evidence for the existence of the coastal front was demonstrated by the precipitation and temperature reports at Cape Hatteras, North Carolina. Snow fell for much of the day and accumulated 3 to 4 in. (7.5 to 10 cm) before changing to rain by 2300 UTC, as temperatures began to rise rapidly above freezing and winds veered from a northeasterly to southeasterly direction. Later that evening, temperatures continued upward to 52°F (11°C), indicating that the coastal

front actually passed briefly to the west of Cape Hatteras before receding oceanward. A weak low pressure center formed along the Carolina coastal front, possibly in response to the upper-level trough/jet system associated with the inverted trough crossing the Ohio Valley, as it approached the East Coast. Generally light snowfall occurred this evening across the Middle Atlantic states, as temperatures in Virginia and Maryland remained below 10°F (−15°C). Further to the south, a mixture of snow, sleet, and freezing rain was reported from the Carolinas to Georgia.

A separate region of low pressure remained in the western Gulf of Mexico with light rain, ice pellets, and snow reported from Texas to northwestern Florida. While temperatures along coastal Louisiana, Mississippi, Alabama, Georgia, and Florida remained above freezing at this time, the leading edge of the intense Arctic outbreak would cross the region overnight, bringing one of the few tastes of severe winter weather this region would ever experience.

c. Sunday, 12 February 1899

On Sunday morning, 12 February (Fig. 3b), numerous all-time record low temperatures were established across the central and southern Plains states as the Canadian anticyclone continued to drop southward. The surface high pressure center was located in Oklahoma at 1300 UTC, with a central sea level pressure exceeding 1052 hPa. This morning represents the coldest on record for large portions of Kansas, Missouri, Arkansas, Oklahoma, and Texas. Some of these records include North Platte, Nebraska, −35°F (−37°C), Kansas City, Missouri, −22°F (−30°C), Springfield, Missouri, −29°F (−34°C), Oklahoma City, Oklahoma, −17°F (−28°C), Amarillo, Texas, −16°F (−27°C), Little Rock, Arkansas, −12°F (−24°C), Shreveport, Louisiana, −5°F (−21°C), Galveston, Texas, 8°F (−13°C), and Corpus Christi, Texas, 11°F (−12°C), as shown in Table 1. In Texas, the combination of clear skies, strong northerly winds and record-cold temperatures created perhaps the most severe version of the "Texas blue norther" ever experienced. Along the southern Texas coast, a region normally dominated by a semitropical climate, temperatures near 10°F (−12°C) and winds of 20 to 40 kt (10 to 20 m s^{-1}) brought wind chill temperatures of −25° to −40°F (−32° to −40°C), possibly the coldest day every known there.

Meanwhile, the leading edge of the cold air mass had crossed much of the central Gulf Coast overnight followed by increasing wind speeds, rapidly dropping temperatures, and rain changing to snow. By morning, snow, blowing snow, and temperatures (degrees Fahrenheit) in the teens (−7° to −12°C) greeted residents of New Orleans, and Mobile, Alabama. Even Pensacola saw as much as 2–3 in. (5–7.5 cm) of snow, which was blown and drifted by strong northerly winds. With the exception of the palm trees, these cities probably resembled Alaska more than the Gulf Coast.

Heavy snowfall extended from central Alabama and northern Georgia into the western carolinas. The eastern edge of the cold outbreak advanced toward the East Coast and became increasingly difficult to define, as uniformly cold temperatures covered much of the southeastern United States north of the Florida peninsula. The area of snow was located to the north of a low pressure system that had begun moving eastward across the Gulf of Mexico. This low center separated warm, moist air in the eastern Gulf (note the 70°F (21°C) temperature reading to the east of the low center) from the frigid conditions that were surging southward across the western Gulf. This low pressure center, or a succession of newly redeveloping centers propagating to the east-northeast, would produce a major blizzard along the East Coast during the following 24–48 h.

It is not difficult to envision the factors which may have contributed to such an intense storm. Extremely cold conditions were already established along the East Coast, the record-setting cold outbreak was marching eastward toward the coast, and warm moist air was located over the Atlantic Ocean, as exemplified by the two observations east of South Carolina and Georgia showing southerly winds and temperatures of 68°F (20°C) and 73°F (22°C). If there ever was a case with the likelihood of enhanced low-level temperature gradients—a condition that can promote cyclogenesis—this was it!

Snowfall was not confined solely to the Gulf Coast and southeastern states, as a widespread swath of snow extended from Louisiana northeastward to central New England. Analysis indicated a separate, relatively weak storm system that had developed the previous day along the Carolina coastal front off the Middle Atlantic coast, with a central sea level pressure estimated at about 1014 hPa. This storm system was associated with significant snowfall from Virginia to southern New England. New accumulations of 4 to 8 in. (10 to 20 cm) were common across this region, which had already received considerable amounts of snow from storms earlier in the week. Temperatures between 0° and 10°F (−18° and −12°C) compounded the rigorous winter weather conditions that were experienced in these areas.

By the evening of 12 February (Fig. 3c), the large surface high pressure area was weakening as it continued to drift southward, with a central pressure now at approximately 1046 hPa. The core of the coldest air was located over Missouri and Illinois, where temperatures of about −5°F (−20°C) were prevalent. While many residents of the central and southern Plains states and the western Gulf Coast had endured their coldest weather the previous night, it was now turn for the Tennessee Valley and southeastern United States to experience their share of the bitter cold conditions.

Snows had ended along the Gulf Coast, but the stiff

north wind did not abate, and daytime temperatures (degrees Fahrenheit) held primarily in the teens (−7° to −12°C). The low pressure center that was located over the central Gulf of Mexico in the morning moved east-northeastward during the day and appeared to redevelop farther northeastward along the preexisting front east of Florida. The remnants of the Gulf storm center can be seen in the cyclonically curved isobars over and to the west of Florida. Evidence for the redevelopment of a storm center further to the north is given in the observation that precipitation ended rapidly to the north of the initial low pressure center over the Gulf. This suggests that perhaps an upper-level "forcing" mechanism (i.e., a cyclonic vorticity maximum) associated with the Gulf storm system was diminishing while a separate, more important forcing mechanism (i.e., a separate vorticity center further to the north) was becoming more dominant, allowing cyclogenesis to proceed further to the north along the intense baroclinic zone immediately off the South Atlantic coast.

While snow was ending across Alabama and Georgia, where as much as 6 to 8 in. (15 to 20 cm) had fallen, it continued to snow from eastern Georgia northeastward along the immediate coastline of the southeastern United States into the Middle Atlantic states and southern New England. At this time, the heaviest snow was falling in a band from western South Carolina into central North Carolina and southeastern Virginia. The low pressure center previously off the Middle Atlantic coast had moved east-northeastward, now positioned well east of the New England coast. However, light snow continued to fall across the Middle Atlantic states and southern New England.

d. Monday, 13 February 1899

Overnight, the developing cyclone off the Southeast coast began to intensify explosively, and by morning was located east of the North Carolina coast (Fig. 4a). The central sea level pressure of the storm was estimated to have fallen by more than 20 hPa in the previous 12 h to 984 hPa by 1300 UTC Monday. Snowfall rates increased significantly overnight from the Carolinas northward into southern New England as northeasterly winds increased along the coast. By morning, severe blizzard conditions,[3] characterized by visibilities near zero in falling snow, gale-force winds, and temperatures below 10°F (−12°C) were occurring over a wide region from South Carolina to New England.

By sunrise, the storm had already left new snowfall amounts exceeding 10 in. (25 cm) over portions of South and North Carolina (Fig. 5). Across northern Florida, rain changed to snow before ending during the night, leaving the heaviest accumulation on record [1.9 in. (5 cm)] at Jacksonville. Measurable snow fell as far south as Lakeland and Tampa, where the 0.1 inch (0.25 cm) accumulation was the first measurable snowfall reported in the city's history [0.2 in. (0.5 cm) fell in January 1977]. Fort Myers recorded a trace, the southernmost penetration of snowfall on record in Florida until January 1977. Three inches (7.5 cm) fell at Lake City and 3.5 in. (8.8 cm) accumulated at Haywood; these were the greatest Florida amounts reported. Note that Tampa was getting light snow at 1300 UTC Monday (Fig. 4a), possibly as a result of cold air passing over the Gulf of Mexico, picking up moisture, and producing a form of "Gulf-effect" snowfall. A recent bitter cold outbreak in January 1985 produced a similar phenomenon in Sarasota, Florida.

As the cold front associated with the storm passed east of Florida overnight, cold air swept across the southeastern United States yielding the coldest morning on record, although several of these marks were approached and even exceeded in portions of Tennessee, Georgia, Florida, and the Carolinas during the January outbreak of 1985. All-time low temperature records were established at many stations, including −9°F (−23°C) at Atlanta, Georgia, 7°F (−14°C) at New Orleans, −5°F (−21°C) at Montgomery, −1°F (−18°C) at Mobile, and −2°F (−19°C) at Tallahassee, Florida; this is the coldest temperature ever recorded in Florida. Other minimum temperatures are given in Table 1. The anticyclone was now located along the Gulf Coast, where it continued to weaken as its maximum central pressure decreased to 1039 hPa. Despite the diminished intensity of the anticyclone, the effects of high winds and low temperatures were being felt well into Mexico, and across the western Caribbean, especially in Cuba.

During the day, the cyclone continued to deepen rapidly as it tracked northeastward. By 0100 UTC (Fig. 4b), it was just southeast of Nantucket, Massachusetts, with a central sea level pressure estimated at 966 hPa. Blizzard conditions raged along the Middle Atlantic and New England coasts all day. By evening, 20 in. (50 cm) of new snow had piled up in Washington, D.C. and Baltimore, Maryland, with greater than 30 in. (75 cm) of snow on the ground. As shown in Fig. 5, the heaviest snow appeared to have fallen from central North Carolina northeastward through Virginia, Maryland, and southern New Jersey, where ≥20 in. (50 cm) were widespread. The heaviest amounts were found across Maryland and southern New Jersey, where Cape May, New Jersey measured 34 in. (86 cm). This, combined with snowfalls earlier in the month, left 30–40 in. (75–100 cm) or more on the ground following this storm. By evening, the heaviest snows were falling across New England, while the snow began to mix with or change to ice pellets across extreme southeastern Massachusetts, close to the storm center.

Meanwhile, the southern high pressure center weakened further, with maximum pressures of about 1032

[3] See definition in the *Glossary of Meteorology* (1959).

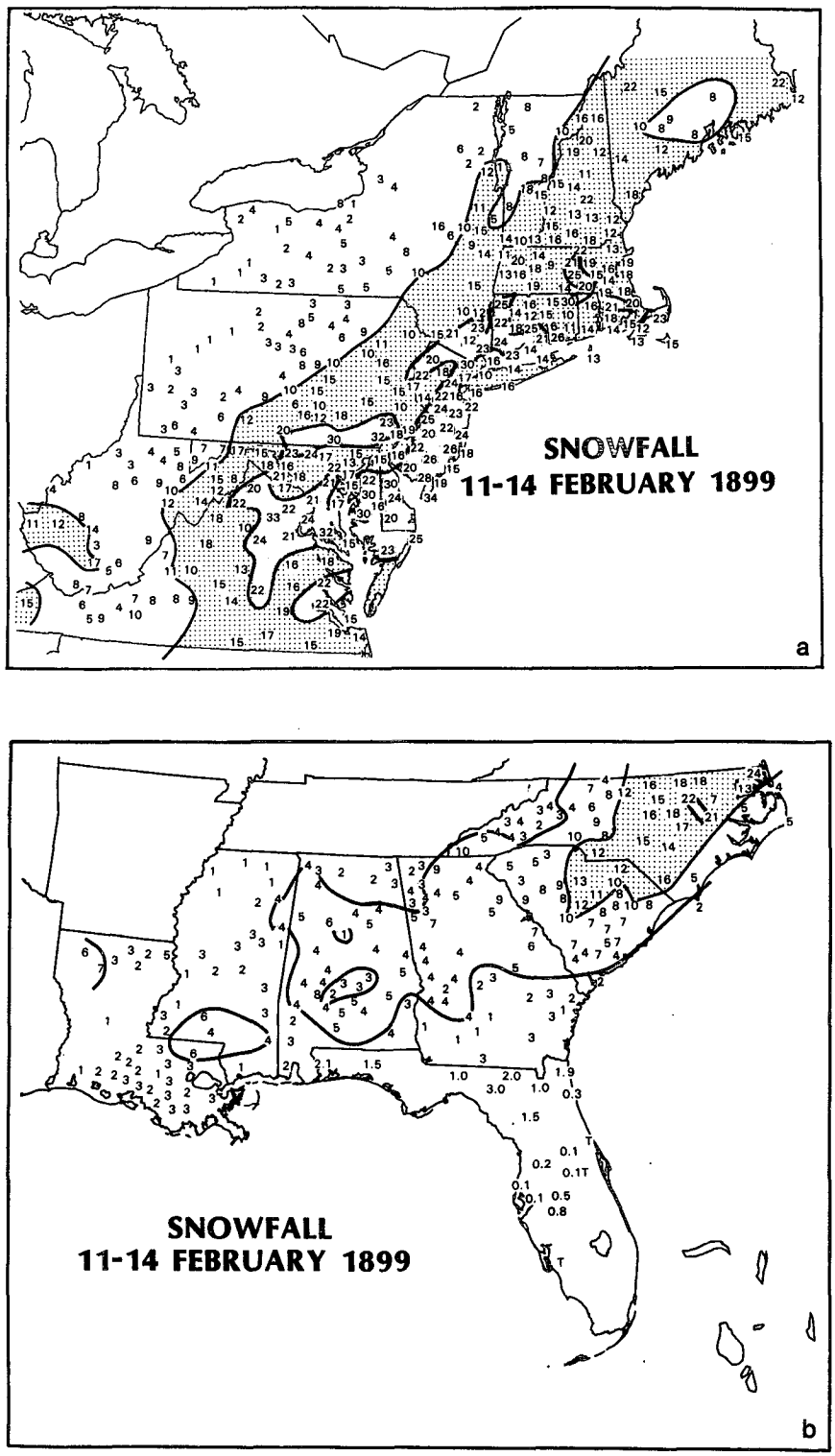


FIG. 5. Total storm snowfall in inches for the period 11–14 February 1899 over (a) the northeastern United States, and (b) the southeastern United States. Dotted shading represents amounts exceeding 10 in. (25 cm) and grey shading represents amounts exceeding 20 in. (51 cm). In (b), thin solid line depicts the 4 in. (10 cm) contour.

hPa. The bright February sun at low latitudes was now beginning to modify the air mass, but even so, temperatures across Georgia and South Carolina struggled to surpass 10°F (−12°C) during the afternoon. When the sun set, temperatures again fell quickly as the snow-covered surfaces lost heat easily.

e. Tuesday, 14 February 1899

Overnight, the storm center raced northeastward to Nova Scotia and by Tuesday morning snows ended across New England, except eastern Maine. Total snowfalls of 10 to 20 in. (25 to 50 cm; see Fig. 5) were common across much of eastern Pennsylvania, New Jersey, southeastern New York, and New England. Accumulations of greater than 20 in. (50 cm) were observed across most of New Jersey and sections of southeastern New York and southern New England. Over the highly industrialized Northeast urban corridor, 16.0 in. (41 cm) fell at Boston, 15.5 in. (39 cm) at New York City, 18.9 in. (48 cm) at Philadelphia, Pennsylvania, 21.4 in. (54 cm) at Baltimore, and 21.0 in. (53 cm) at Washington, D.C. (34 in. or 86 cm total depth on the ground).

Temperatures (degrees Fahrenheit) actually rose overnight across much of the northeastern United States, reaching the teens (−7° to −12°C) from New York to Maine, with clearing skies and strong winds. Farther to the south, the surface anticyclone had begun to move northeastward and ceased weakening, as maximum sea level pressures were now approximately 1034 hPa. Temperatures over the southeastern United States were not as cold as the previous night but clear skies, snow cover, and light winds resulted in subzero readings (degrees Fahrenheit; ≤ −18°C) in portions of the Ohio Valley and Middle Atlantic states. Single digit (degrees Fahrenheit) readings (less than −12°C) prevailed through South Carolina, Georgia, and Alabama, while subfreezing temperatures extended well into southern Florida. Only Key West escaped the freeze, with a 44°F (7°C) reading.

The anticyclone continued drifting to the north and east and was located off the East Coast by Wesnesday, 15 February. For the week following this period, temperatures over the eastern half of the United States recovered to and then exceeded seasonal normals. By 19–22 February, temperatures across the Plains, Ohio Valley, and eastern United States reached levels of 10°F to 35°F (5°C to 20°C) *above* normal, with temperatures climbing to 67°F (19°C) at Wichita, Kansas, 60°F (16°C) at Columbus, Ohio, 71°F (22°C) at Nashville, and 61°F (16°C) at Washington, D.C. These readings were 76° to 89°F (42° to 49°C) higher than at the peak of the cold wave. While observers in Washington D.C. measured a snow depth of nearly 3 ft (90 cm) on the morning of 15 February, the warming that followed reduced this impressive blanket to a mere trace by 22 February, only a week later. In effect, the massive anticyclone and blizzard represented the winter's dramatic last gasp.

5. Discussion

Daily mean temperature anomalies for four selected locations during the first three weeks of February 1899 (Fig. 6) illustrate the duration, geographical variability,

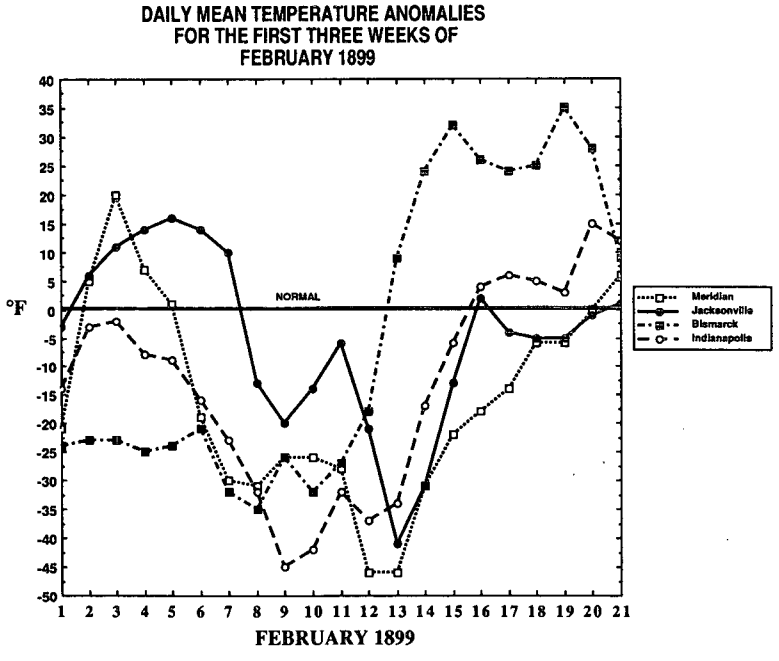


FIG. 6. Daily mean temperature anomalies at Meridian, Jacksonville, Bismarck, and Indianapolis, for the first three weeks of February 1899.

and intensity of the cold outbreak. Persistent extreme cold characterized the first two weeks of February in the north-central United States, as represented by the temperature anomalies at Bismarck, North Dakota, averaging more than 20°F (11°C) below normal. A reversal of temperature followed this period, with readings rising to levels more than 30°F (17°C) above normal. Across the Ohio Valley, as represented by Indianapolis, Indiana, progressively colder temperatures characterized the first two weeks of the month, with anomalies reaching −45°F (25°C) by 9 February. The final Arctic outbreak on 11–14 February yielded temperatures that were not as extreme as on 9–10 February, but were still 35°–40°F (19°–22°C) below normal. The cold wave broke on 15–16 February, when temperatures rose above normal.

The shift of the cold air from west to east and north to south is observed by comparing the temperature anomalies of Bismarck and Indianapolis with Meridian, Mississippi and Jacksonville. While Bismarck reported temperature departures of −20°F (−11°C) by the first of the month, similar levels were not achieved at Indianapolis and Meridian until 6–7 February, and not until 9 February at Jacksonville, where temperatures recovered temporarily before plunging again on 12–13 February. For both Meridian and Jacksonville, lowest temperatures were realized by 13 February, with anomalies of −46°F (−25°C) and −41°F (−23°C), respectively. During the third week of February, temperatures at these southern locations recovered to near-seasonal levels, in contrast to the recovery to much-above seasonal levels over the northern United States.

To place the cold period in some historical perspective, minimum temperatures recorded during February 1899 (Fig. 7) are compared with minimum temperatures registered during two similar severe cold weather episodes of the past decade in the central, southern, and eastern United States (Fig. 8). The more recent episodes include the cold waves of 1) 8–12 January 1982, and 15–18 January 1982, two notable outbreaks that established numerous low temperature records across the central and eastern United States; and 2) 19–22 January 1985, a cold spell that established several new all-time minimum temperature records in portions of the same regions affected by the siege of February 1899. The 1985 cold spell is also notable because it resulted in the cancellation of the outdoor festivities for Ronald Reagan's second Presidential Inauguration in Washington, D.C.

In general, the period 6–14 February 1899 yielded lower temperatures over a larger area than either of the two cold outbreaks illustrated in Fig. 8, or any of the other extreme cold periods of the past dozen years, including January 1977, February 1979, and December 1983 (not shown). Increased urbanization probably does not account for the lesser severity of the more recent cold waves relative to the 1899 outbreak. Each of the three temperature analyses compared here was

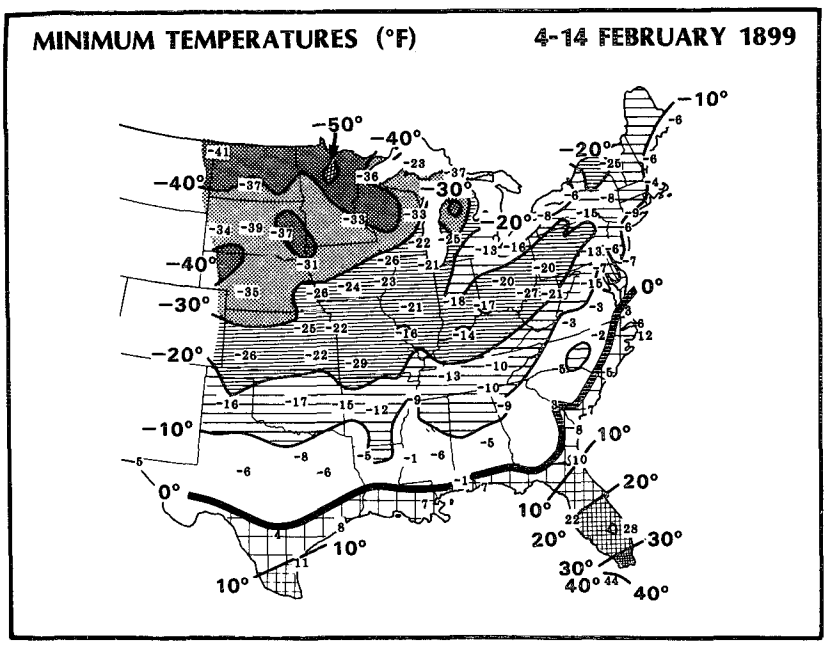


FIG. 7. Minimum temperatures (°F) observed during the period 4–14 February 1899 over the central, eastern, and southern United States. Analyses were generated from measurements at main Weather Bureau stations and from reports of voluntary and cooperative observers. Isotherms are drawn at 10°F (5.6°C) intervals and reflect reports from approximately 1500 cooperative observers. Temperatures at the main Weather Bureau stations are plotted.

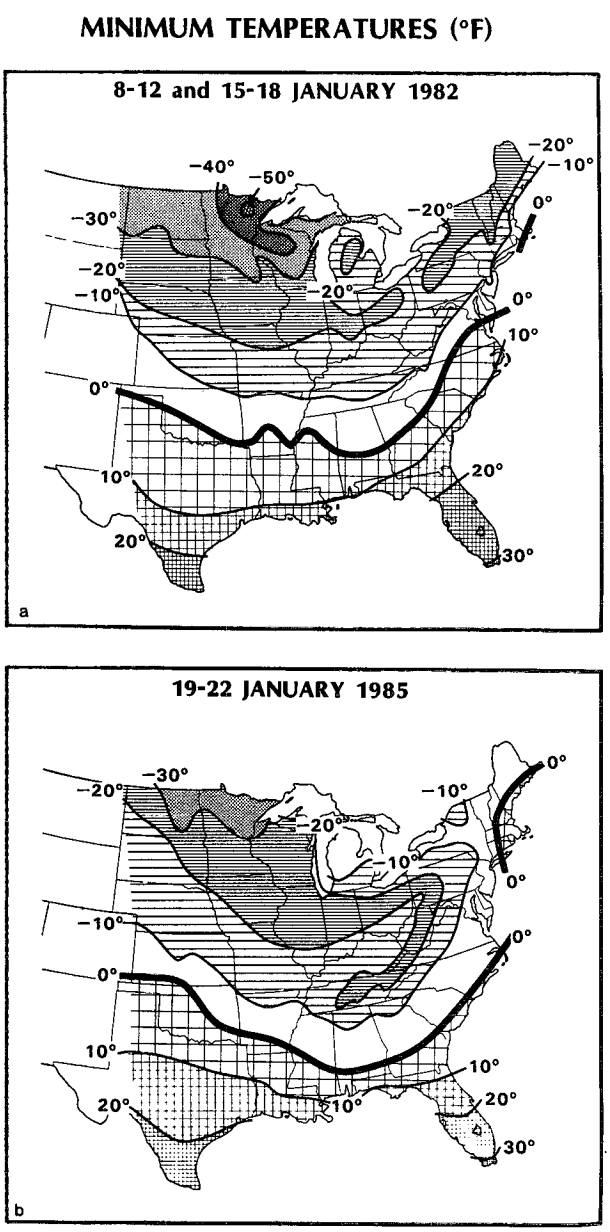


FIG. 8. Minimum temperatures (°F) observed during the periods (a) 8–12 and 15–18 January 1982, and (b) 19–22 January 1985, over the central, eastern and southern United States. Analyses were generated from temperature reports tabulated in *Climatological Data.* Isotherms are drawn at 10°F (5.6°C) intervals.

derived from more than a thousand measurements so as to include many rural locations for every case. Also, many of the record low temperatures established in February 1899 were accompanied by strong winds, producing greater uniformity between rural and urban temperatures due to mixing.

During the cold waves of 1982 and 1985, subzero temperatures (degrees Fahrenheit; $\leq -18°C$) penetrated deep into the southern United States (Fig. 8). However, the areal extent of these cold temperatures was not as widespread as in February 1899 (Fig. 7), when subzero readings covered a region north of a line extending from south-central Texas to the Gulf Coast and into southern Georgia and northern Florida. A comparison of the −10°F (−23.3°C), 0°F (−17.8°C), 10°F (−12.2°C), and 20°F (−6.7°C) isotherms in Figs. 7 and 8 also shows that February 1899 registered lower temperatures nearly everywhere east of the Rocky Mountains, except over New England, eastern Tennessee, and along scattered portions of the Southeast coast. In addition, none of these more recent cold waves were associated with a major storm development over the continental United States.

The 1899 blizzard established some historic snowfall records that have never been exceeded. The single storm snowfall record for New Jersey was set at Cape May, where 34 in. (86 cm) were measured. Total snow depths following the storm (which include accumulations from previous storms) were the greatest on record in some of the major Northeast urban centers, with 34.2 in. (86 cm) in Washington, D.C., 30.0 in. (76 cm) in Baltimore, and 26.0 inches (66 cm) in Philadelphia. While the storm did not establish any single storm or 24-hour snowfall marks in any of the major Northeast cities, it produced the second greatest snowfall of the past hundred years at Washington, D.C. (21.0 in., 53 cm) and the fourth greatest total at both Baltimore (21.4 in., 54 cm) and Philadelphia (18.9 in., 48 cm). February 1899 also remains the snowiest month on record for these three cities. Farther to the south, Jacksonville measured its greatest snowfall, 1.9 in. (5 cm), while Tampa received its first measurable snow on record with 0.1 in. (0.3 cm).

While other storms have also produced very heavy snow accumulations along the length of the Northeast urban corridor between Virginia and Maine (Kocin and Uccellini 1988), few have produced such large accumulations, in combination with temperatures of 10°F (−12°C) or lower to result in severe blizzard conditions. Also, the elements have rarely combined to bring a major snowfall to both the Atlantic *and* Gulf Coasts from the same storm system.[4]

Weather forecasts and warnings made during the course of this record-setting severe weather outbreak were remarkably accurate and well received, according to a summary published in the February edition of Monthly Weather Review (Garriott 1899). The report noted that "ample and timely warning of the advance of the cold wave was given to all interests. . . .", and ". . . warnings prompted protective measures, whereby crops, livestock, and perishable goods and merchandise to the value of hundreds of thousands of dollars were saved." According to the *Times Union*

[4] An examination of other major East Coast snowstorms during the past 100 years (Weiss and Wagner 1987) has not uncovered any storms that attained the widespread severity of the blizzard of 1899.

newspaper (Garriott 1899) in Albany, NY: "It is seldom that the Weather Bureau fails in predicting a big storm, and it had been more than successful this year." The Boston Herald (Garriott 1899) stated that "The Weather Bureau is entitled to distinguished consideration for its services. . . . It foretold the widespread disturbance with remarkable accuracy. . . ." This starkly contrasts the weather forecasts issued 11 yr earlier, prior to the infamous March 1888 "Blizzard of '88," which gave no hint of the impending storm (Kocin 1983).

In conclusion, the February 1899 outbreak was unique in its capacity to chill and bury a large section of the nation. Therefore, whenever very cold and snowy conditions return to the United States and reports begin to circulate that the present weather is "the worst," "coldest," or "snowiest," forecasters and weather observers can always refer to February 1899 as a benchmark with which to compare similar events.

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