Major Winter Weather Events during the 2011-2012 Cold Season

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1. Introduction

Winter storms cause millions of dollars in damage and disrupt countless lives across the United States every year. They directly cause an average of 24 deaths in the U.S. each year (2002-2011 average), with an additional 27 deaths each year caused by cold temperatures (NWS 2012). Winter storms produce a variety of precipitation including snow, sleet, and freezing rain, often with high winds and extreme cold in addition to the precipitation. Some parts of the U.S. are more prepared than others, and thus the impact of winter storms varies widely by region. Winter storm activity varies widely from year to year, in connection with large-scale atmospheric phenomena such as the North Atlantic Oscillation (NAO), Arctic Oscillation (AO), and El Nino-Southern Oscillation (ENSO).

Because winter storms cover spatial scales much larger than that of an individual NWS office, WPC is positioned well to provide guidance on these storms. One role of the WPC is to provide winter storm specific forecasts for the U.S. These include quantitative precipitation forecasts (QPF), low-tracks, and probabilistic heavy precipitation (rain, snow, freezing rain) forecasts.

The WPC issues Storm Summary products for high-impact winter weather events that affect multiple NWS county warning areas, affect commerce and transportation, and are likely to attract media attention. Storm summaries contain information on the current location and intensity of a storm system, a summary of rain and snowfall accumulations, and a short term forecast for the storm system. The purpose of this article is to provide an overview of the 2011-2012 cold season and the season’s most notable winter weather events for which the WPC issued storm summaries. For the purposes of this article, the cold season is defined as September 15 - May 15. These dates align with the dates that the Winter Weather Desk at the NOAA/NWS Weather Prediction Center (WPC) is active.

Section two of the article describes the data used for the images in the article. Section three of the article provides an overview of the large scale patterns that affected North America during the cold season. Climatological anomalies are examined, with the goal being to show that the 2011-2012 cold season deviated substantially from climatological averages. Section four of the article discusses the individual details of the most significant winter storms of the cold season. Finally, conclusions are given in section five.

2. Datasets

NCEP Reanalysis data (Kalnay et al. 1996) were used to create the seasonal and monthly anomaly graphics shown in section three. Snowfall analyses shown are interpolated snow analyses from the National Operational Hydrologic Remote Sensing Center (NOHRSC). The NOHRSC analyses are created using observed snowfall data received in SHEF (Standard Hydrometeorological Exchange Format) over AWIPS II (Advanced Weather Interactive Processing System II) (NOHRSC 2005). The data are then interpolated temporally using preprocessed RADAR (Radio Detection and Ranging) data (Stage II) as well as spatially using a weighting function (NOHRSC 2005). Snowfall data are not interpolated above 1640 feet in elevation in the eastern U.S. and above 5741 feet in the western U.S. In northern Idaho, Washington, and Oregon snowfall data are not interpolated above 2625 feet. For further details on the data assimilation and interpolation schemes used in the NOHRSC snowfall analyses the reader is referred to NOHRSC 2005.

3. Seasonal Overview

The cold season of 2011-2012 was quite unique, with significant climatological anomalies across the majority of the contiguous U.S. (CONUS). Additionally, the cold season was ‘book-ended’ by the two most notable winter storms of the season for the Eastern U.S., in October and April. From 15 September, 2011 to 15 May, 2012, the WPC issued Storm Summaries for seven notable winter storms across the CONUS. Table 1 provides an overview of these events, the dates they occurred, the impacts, and any deaths or injuries directly attributed to the events. For most of the cold season, the majority of the contiguous U.S. received anomalously low snowfall, along with anomalously warm temperatures. Several climatological factors may have contributed to the anomalous season, including a La Niña in the Pacific, as well as a strongly positive North Atlantic Oscillation (NAO)/Arctic Oscillation (AO).

Average climatological anomalies for the cold season (Fig. 1) show substantial deviations from climatological averages. 250 hPa wind speed anomalies (Fig. 1a) show a pattern in which the upper-level jet stream was displaced to the north of its typical location. Positive 250 hPa wind speed anomalies were observed across the Pacific Northwest and across most of Canada, while negative anomalies were observed across the majority of the CONUS. 500 hPa geopotential height anomalies for the same time period (Fig. 1b) show an anomalous upper-level ridge centered across the Great Lakes. A blocking pattern was dominant in the North Pacific during the season, with an anomalous 500 hPa low centered over Alaska and an anomalous high centered over the northern Pacific Ocean, between Alaska and Hawaii. Seasonal temperature anomalies at 1000 hPa for October through April (Fig. 1c) were positive across the majority of the CONUS. The positive anomalies were maximized across the north central U.S., where positive temperature anomalies of greater than 4 degrees C were noted at 1000 hPa. Finally, sea-level pressure anomalies (Fig. 1d) show negative anomalies across Alaska and into most of Canada, as well as the north central U.S. into the Great Lakes. These areas of negative sea-level pressure anomalies are likely areas with a larger than average number of surface lows tracking across them. Conversely, the positive sea-level pressure anomalies shown across portions of the U.S. West Coast, as well as off the East Coast, indicate below average surface low activity. As was shown by the 250 hPa wind speed anomalies, the sea-level pressure anomalies also depict a dominant seasonal pattern in which storm tracks were largely shifted north of climatological mean locations. Additionally, cyclone activity along the U.S. east coast was substantially below average. Surface low tracks for the season (Fig. 2) were largely focused across the central U.S., with only two major episodes of cyclogenesis along the U.S. East Coast.

The NAO and the AO (Barnston and Livezey, 1987; Thompson and Wallace, 1998) remained in the positive phase for most of the cold season (Fig. 3), as indicated by an anomalous low at 500 hPa across Greenland in the seasonal anomalies (Fig. 1b), with an anomalously strong Azores high. The abnormally warm temperatures resulted in below average snow depth across much of the nation. An image showing the snow depth departure from normal on 31 January, 2012 (Fig. 4) shows that the majority of the CONUS was experiencing below average snow depth, even during the climatologically coldest month of the year. Seasonal outgoing longwave radiation (OLR) anomalies (Fig. 5) indicate above average OLR across a substantial portion of the nation, which corresponds to below average precipitation (Liebmann et al. 1989). Seasonal correlations using data back to 1949 (Fig. 6) demonstrate that above average temperatures and below average 700 hPa relative humidity (and subsequent precipitation) across much of the contiguous U.S. are both consistent with a strongly positive NAO/AO.

4. Individual Event Summaries

a. Early-Season Mid-Atlantic and Northeast Winter Storm (29-30 October, 2011)

1) Meteorological Overview

An October Nor'easter struck portions of the Mid-Atlantic and Northeast U.S. on 29-30 October, 2011. A surface low developed off the coast of the Carolinas on 29 October as a strong upper-level shortwave trough moved through the Ohio River Valley. The surface low rapidly deepened and moved up the coast as the upper trough approached the East Coast and became negatively tilted.

Precipitation began falling across the Mid-Atlantic states during the early morning hours of 29 October in association with warm air advection east and north of the developing low. Initially, the precipitation fell as snow only at the higher elevations, well-inland. As the surface low moved northward up the coast, winds at the surface backed from northeasterly to northwesterly across much of the Mid-Atlantic region, allowing colder air to advect southeastward. This cold air advection changed the precipitation from rain to snow in the foothills of Virginia, Maryland, and Pennsylvania. Cooling of the atmospheric thermal profile as a result of melting in the bands of heavier precipitation (Kain et al. 2000) likely accelerated the changeover to snow across the Mid-Atlantic region. Farther north, precipitation began across New England by midday on 29 October. Cold air was already in place across interior New England, therefore precipitation began as snow for all but the coastal areas.

Early in the event, a coastal front extended from the Virginia coast northward to Cape Cod. This boundary weakened and was no longer analyzed in the WPC surface analysis by 21 UTC on 29 October. A surface analysis from 00 UTC on 30 October (Fig. 7a) shows the surface low centered off the coast of New Jersey, with a pressure of 993 hPa. Isentropic ascent, as moisture from lower latitudes streamed northward and crossed this coastal front may have enhanced precipitation in some areas. As the intensifying surface low passed east of New England, wind gusts of more than 50 mph were recorded along the coast. The highest wind gust of 69 mph was measured at Nantucket, MA. By 12 UTC on 30 October (not shown) the surface low had deepened to 977 hPa south of Nova Scotia. The surface low reached its peak intensity of 976 hPa at 15 UTC on 30 October just east of the southern tip of Nova Scotia.

Total snowfall exceeded a food in areas from northeastern Pennsylvania to southern Maine, with some areas of Massachusetts and New Hampshire receiving more than 30 inches of snow (Fig. 7b). The heaviest snow was associated with intense 850-700 hPa warm frontogenesis, north of the surface low. Several snowfall records were broken across the region, including in Central Park, NY, where the 2.9" accumulation was an all-time snowfall record for the month of October.

2) Impacts

Because trees in many areas of the Mid-Atlantic and Northeast had not yet lost all their leaves, many trees were downed, resulting in downed power lines and loss of power for more than 3 million residents. Some locations were without power more than a week after the storm ended. The storm resulted in one direct fatality due to a fallen tree (NWS Storm Data). Additionally, air travel was severely disrupted with several planes stranded on the tarmac at the Hartford airport for an extended period of time. Total reported damage from the storm amounted to $18.8 million from a combination of heavy snow, high wind, and coastal flooding (NWS Storm Data).

b. Eastern U.S. Heavy Rain and Snow (28-29 November, 2011)

1) Meteorological Overview

A slow-moving low pressure system brought a rare November snowfall to the central Mississippi River valley. Prior to the event on 26 November, a north-south oriented cold front and a high amplitude upper-level trough moved eastward across the Mississippi River valley. Upper-level flow was aligned nearly parallel to the lower levels, therefore the eastward progression of the frontal boundary was rather slow. A ridge of high pressure at the surface and aloft across the southeastern states, hindered the progress of the front. The front was associated with a wide swath of rain from the onset. As time progressed, energy became more consolidated near the base of the upper-level trough as cyclogenesis commenced in the evening of 27 November over the southeastern U.S. The cyclone quickly became occluded as the upper-level cut-off low deepened, while moving generally northward into the Tennessee River valley by 00 UTC on 29 November (Fig. 8a). By early on 29 November, the core of the cold air associated with the upper-level low began changing the rain to snow in the central Mississippi River valley on the back side of the surface cyclone. After the snow ended the morning of 29 November, a few inches of snow had accumulated in parts of northeastern Arkansas and southeastern Missouri (Fig. 8b), with the highest amount of 8 inches reported at Paragould, Arkansas. After delivering a rare snowfall in the central Mississippi River valley, the storm continued north into the Ohio River valley on 29 November.

As the occluded cyclone continued moving northward, cold air advection from the northwest during the afternoon of 29 November caused the rain across Lower Michigan and northern Indiana to change to snow. In addition, a mesoscale band of snow organized on the west side of the cyclone during the night, bringing a brief period of heavy snow across the central portion of Lower Michigan where over 6 inches of snow were reported (Fig. 8a). The highest amount was 9.0 inches in Lansing, MI.

2) Impacts

There were no known casualties and injuries directly related to the storm. Total reported damage for the storm amounted to $25 thousand from flooding in Arkansas and Kentucky (NWS Storm Data).

c. Southern Rockies to Central Plains Winter Storm (19-20 December, 2011)

1) Meteorological Overview

A classic cut-off low drifted eastward across the southwestern U.S. then moved northeastward toward the southern plains on 19-20 December, 2011. This upper low was associated with a significant snowstorm accompanied by blizzard conditions in parts of the south central and southwestern U.S. As the system moved northeastward, it encountered milder temperatures, and became more of a rain producer from Kansas into the Mississippi River valley and the Midwest.

Heavy snow was accompanied by strong winds which created blizzard conditions in some locations. Clayton, NM, in the northeast corner of the state, reported 17.7 inches on 19-20 December. Lamar, CO received 19.0 inches of snow on 20 December and set a new record as the highest one-day snowfall total for any day in December. Total snowfall (Fig. 9) shows widespread areas of greater than 12 inches. Additionally, snow drifts of 2 to 4 feet were reported. On the eastern fringes of the heavy snow swath, a mixture of rain, sleet, and snow occurred in portions of central and south central Kansas creating some slick and slushy spots on roads. The slow-moving low pressure system also produced rainfall amounts of generally 1.5 to 2.5 inches across much of south central and southeastern Kansas.

Surface analyses superimposed on satellite images on 19 December show the distinct comma-shaped swirl of clouds associated with the developing storm, as an area of surface low pressure consolidated over the panhandle of northern Texas to the south of a sprawling area of high pressure moving eastward from the northern Rockies toward the northern plains states (Fig. 10).

2) Impacts

For southeastern Colorado, northeastern New Mexico and western Kansas, this was a debilitating snowstorm with high winds, low visibility and blowing snow, stranding motorists at the start of the long holiday travel season. The primary impact of the storm was to transportation. Total reported damage from the storm was $53 thousand in New Mexico, from heavy snow and blizzard conditions (NWS Storm Data). No known direct fatalities or injuries were attributed to this storm.

d. Western U.S. Winter Storm (14-20 January, 2012)

1) Meteorological Overview

The period from 14-20 January was marked by numerous upper-level disturbances along with an Arctic air outbreak over the northwestern U.S, which peaked with historic snowstorms and ice storms over Washington State. The period began with a shortwave trough embedded within the fast onshore flow to the south of an upper low moving toward British Columbia. The shortwave moved southeastward through the Pacific Northwest and helped to usher one of the coldest air masses of the season into the region, in addition to producing snow showers across western Washington and Oregon. Heavy snows were reported in the Olympic and Cascade Mountains, as well as some lighter snows in the lower lying regions surrounding the Seattle-Tacoma metropolitan region. A surface analysis from 00 UTC on 15 January (Fig. 11a) shows the cold air mass advecting into the region.

The upper-level low and trough continued to move inland from 12 UTC on 15 January to 12 UTC on 16 January, with the leading edge of the associated low level cold air plunging southeastward through the central Great Basin and Rocky Mountains. Precipitation across the Pacific Northwest tapered off the morning of 16 January, with scattered light precipitation advancing through the northern Rockies. Heavy snows returned to the region including the Washington and Oregon coastal ranges and the western slopes of the Cascades by the evening of 16 January as another shortwave trough approached the coast. This shortwave along with a strong upper-level jet pushed across the Pacific Northwest from 17-18 January, accompanied by a plume of subtropical moisture. This moisture overrunning the preexisting cold air left in place by the previous system resulted in heavy to near record snow amounts across portions of western Washington. 11 inches of snow at the Olympia, WA airport and nearly 7 inches at the Seattle-Tacoma International Airport on 18 January were the third and sixth highest, respectively, on record. Up to 2 feet of snow occurred in the Oregon Coastal Range. Heavy snows of near-record to record values were also reported further to the east across the Blue Mountains in eastern Oregon and the Sawtooth and Bitterroot Ranges into the northern Rockies.

As this system continued to the east from 12 UTC on 18 January to 12 UTC on 19 January the low level cold air over western Washington was reinforced by continued precipitation and northerly flow at the surface. This set the stage for a historic freezing rain event over western Washington, with a first ever ice storm warning for the region. Ice accumulations of 0.5 to 0.75 inch were reported in the Seattle-Tacoma metropolitan region, with an inch or more reported in areas further to the south and east. Heavy snows falling along the Cascades spread to the south into northern California and along the Rockies into the Tetons and northern Wasatch Mountains. Arctic high pressure at the surface settled south through the northern Plains with the Arctic front banking up against the eastern slopes of the northern Rockies (Fig. 11b). High winds were recorded across and east of the mountains with gusts of up to 100 mph reported.

These systems impacted much of the northwestern U.S. with a combination of heavy snow, rain, and ice. Snows from these storms (Fig. 12) covered areas from the Pacific Northwest to the northern Plains. By 12 UTC on 20 January, 2 to 5 feet of snow had been reported across the Cascades with the heaviest amounts centered near the Mount Hood region. Over the northern Rockies, widespread accumulations of 1 to 3 feet of snow were recorded, with the heaviest amounts falling along the Sawtooth Range where 3 to 6 foot amounts were common and totals as high as 70 inches were reported. Widespread rains of 3 to 6 inches with local amounts of 9 inches were observed along the Northern California coast. Rainfall amounts as high as 15 inches were reported along the Oregon coast. Freezing rain accumulations of 0.25 to 1 inch were reported across the

Columbia River Gorge east of Portland, with similar amounts observed across the Seattle-Tacoma metropolitan area.

2) Impacts

Over 300 flights at SeaTac Airport were cancelled, costing the airline industry millions of dollars. Total reported damage from this event amounted to $24.5 million. Three deaths and four injuries were directly attributed to the storm. Two of the deaths occurred in Oregon when a car was swept into a swollen creek. One death and one injury occurred in Washington, both the result of fallen trees under the weight of heavy ice. Three injuries were also documented in Nevada as a result of trees blown down from high winds associated with the storm system (NWS Storm Data).

e. Central U.S. Winter Storm (3-4 February, 2012)

1) Meteorological Overview

On 3-4 February 2012, a strong upper-level disturbance in the subtropical jet stream resulted in a major winter storm over the central Front Range of the Rocky Mountains and adjacent High Plains. Surface analyses at the height of the event on the evening of the 3 February were indicative of a classic upslope snow event with strong easterly winds on the north side of a strong surface low positioned over Oklahoma (Fig. 13b). An inverted trough from the low over the central Plains acted as another forcing mechanism for the snow that fell over Kansas and especially south central Nebraska. At 500 hPa, a closed low was evident over eastern Colorado and the western parts of Kansas and Nebraska, aiding in mid-level frontogenesis and ascent. A ridge of Canadian high pressure over the northern Rockies and northern Plains reinforced the cold air advection.

Farther to the east over the Middle Mississippi River Valley, temperatures were considerably warmer and rain was observed.

The greatest snowfall amounts (Fig. 13a) were concentrated in an area extending from near Laramie, Wyoming to the Colorado foothills, and also east of Denver. There were a few isolated reports of snow in the 3 to 4 feet range in the Colorado foothills from this event, including 48 inches at Black Hawk, 46 inches at Pinecliffe, 37.7 inches at Jamestown, and 36 inches at Evergreen. Over the state of Nebraska, a band of lighter but still significant snowfall fell from North Platte eastward to near Omaha, with a localized enhanced area of snow just to the north of North Platte. Winds gusted up to 40 mph over the open plains of eastern Colorado and Nebraska.

2) Impacts

This snowstorm had significant impacts on transportation in the affected areas. Interstate 70 was closed from Denver to the Kansas state line as heavy snow and strong winds prevented snow removal crews from keeping the road adequately clear of snow. About 600 flights were canceled in Denver as a result of the heavy snow in that region. In Nebraska, the Interstate 80 corridor was most affected. The wet and compact nature of the snow was enough to break large limbs and these frequently fell onto power lines, causing over 15,000 people to lose power. There were no deaths or injuries directly attributed to this storm. Total reported damage from this storm amounted to $693 thousand, however this was primarily from flooding associated with the storm system that occurred across the Southern Plains/Lower Mississippi River Valley, and not from the winter storm (NWS Storm Data).

f. Upper Midwest to New England Winter Storm (28 February - 1 March, 2012)

1) Meteorological Overview

A significant winter storm impacted the north central to northeastern U.S. from 28 February to 1 March, 2012, producing heavy snow and blizzard conditions along with minor to locally moderate accumulations of sleet and freezing rain. The winter storm ended up being one of the most significant storms of the 2011 to 2012 winter season for the north central U.S. and occurred toward the end of what had been a very quiet winter season for the region up to that point. In fact, much of the region was experiencing a moderate to severe drought at the time, but the storm managed to put a dent in the precipitation deficit. Central Minnesota into northern Wisconsin were hit hardest in the Upper Midwest with snowfall totals topping out at 20 inches (both at Clam Lake, WI and Hinckley, MN). The Northeast also experienced a significant snowstorm with storm total snowfall around a foot in many locations from central New York into central New England (Figure 14a). The warmer side of this storm system was responsible for hundreds of severe weather reports, stretching from the central Plains into the central Appalachians.

Synoptically, the storm developed as a strong mid to upper level trough entered the western U.S. on 28 February. At the surface, several disorganized areas of low pressure consolidated into a single low pressure center during the evening of 28 February. Snow began to overspread the Upper Midwest from late on 28 February into 29 February. The upper-level trough translated eastward, acquiring a negative tilt at 00 UTC on 29 February, and closed off a mid-level center by 12 UTC on 29 February over the central High Plains. The surface low subsequently continued to deepen on 29 February as it tracked into Minnesota, reaching a peak intensity of 986 hPa that morning (Figure 14b), while generating winds of 50 to 60 mph from portions of the Central Plains into the Upper Mississippi River Valley. At the same time to the east, light to moderate snow developed out ahead of a warm front into portions of the Northeast, with snowfall intensity tapering off overnight. By the morning of 1 March, moderate snow began to develop again as the main surface low from the Upper Midwest approached, and a secondary low off developed off of the New England coast. 250 hPa winds on the downwind side of the upper trough were in the 100 to 150 kt range, which helped to enhance vertical motion within the left exit region of the strong upper jet and a region of upper level diffluence, both directly over the regions which experienced the heaviest snow. The upper trough had weakened by the time it reached the Northeast on 1 March, partially explaining why the impacts on the Northeast were less intense than observed over the Upper Midwest.

2) Impacts

The winter weather impacts from this storm were greatest across the Upper Midwest with blizzard conditions causing widespread power outages and road closures, along with the closure of numerous schools and businesses. State officials closed Interstates 29 and 90 at one point during the storm due to the hazardous travel conditions. State troopers reported hundreds of accidents on state highways. As less snow fell across the Northeast, the impacts on school and business closures were reduced, but there were many accidents attributed to blowing snow and icy roads. One fatality was directly attributed to this event; a person in Minnesota died as a result of exposure to extreme cold. A number of indirect injuries and fatalities also occurred due to traffic accidents during the storm. Total reported damage from the event amounted to $741 thousand from the winter storm and associated high winds (NWS Storm Data).

g. Late-Season Mid-Atlantic and Northeast Winter Storm (22-25 April, 2012)

1) Meteorological Overview

Several key ingredients came together to create a favorable setup for this late-season coastal storm. Shortwave energy moved into the Ohio and Tennessee valleys Saturday night (00-12 UTC 22 April), while a shortwave in the subtropical jet moved eastward through the northern Gulf of Mexico. A cutoff upper-level low formed over the Ohio and Tennessee valleys, and the southern stream energy slowly weakened while lifting east northeastward. These two systems, combined with divergence aloft from the right entrance region of an upper jet and a sharp baroclinic zone set up along the Eastern Seaboard, allowed a surface low to rapidly strengthen while tracking up the Carolina coast by 12 UTC on 22 April (Fig. 15a). As the low deepened and tracked northward just off the Mid-Atlantic coast on 22 April, an expansive area of precipitation developed from North Carolina to Maine. Strong warm air advection and northerly moisture flux ahead of the storm fueled bands of moderate to heavy rain along the coast.

The storm continued to track due north up the eastern seaboard Sunday night, and by 12 UTC on 23 April, a 986 hPa surface low was analyzed near New York City (Fig. 15b). While the deep surface low along the coast brought gusty winds and drenching rains to the coastal regions, the amplifying shortwave energy that closed off a low over the Ohio River valley led to a secondary area of heavy precipitation farther inland (Fig. 16). The highest amounts were observed within the comma head that set up across northeastern Pennsylvania and central New York. Northeasterly flow behind the storm advected enough cold air to support snow in the higher elevations of the central Appalachians Monday morning (12 UTC 23 April). The relatively high April sun angle caused many locations to change back over to rain by Monday afternoon, however. The surface low along the coast took a northwestward turn and started to slowly weaken while tracking inland over New York State on 23 April. By 00 UTC on 24 April, the storm had moved well into Quebec, and the strong winds and heavy precipitation over the Northeast and Mid-Atlantic states had diminished. Coastal regions from North Carolina to Maine reported widespread rainfall totals in excess of one inch from the event, and isolated reports approaching five inches were observed across New England. New Boston, New Hampshire exceeded five inches of rain, with 5.74 inches reported. Farther inland, the late-season storm blanketed much of the central Appalachians with over four inches of snow. A few sites over Western New York and Central Pennsylvania received over a foot of snow, and one location, Laurel Summit, PA, measured 23.7 inches of snowfall.

2) Impacts

Travel was difficult throughout heavily populated cities along the I-95 corridor. Travel conditions were particularly hazardous near the New England coast, where steady rains combined with wind gusts of 40-50 mph. Thousands of power outages were reported due to heavy wet snow falling on leafy tree branches. No reported deaths or injuries were directly attributed to the storm. Total reported damage from the event amounted to $206 thousand, primarily from snow and strong winds (NWS Storm Data).

5. Conclusion

The 2011-2012 cold season featured an unusually low number of significant winter precipitation events. Seven notable precipitation events were discussed in this summary. The most significant winter weather events ‘book-ended’ the season, in October and April. The events discussed in this summary directly caused a total of 5 fatalities with 4 additional injuries. A total of $45 million in damage was attributed to these events. Climatologically, the overwhelming majority of the CONUS experienced well above average temperatures, with below average precipitation, for much of the season. A La Niña in the Pacific as well as a positive phase of the NAO/AO for most of the season may have contributed to the development and persistence of this pattern across the U.S. Below average precipitation across much of the nation during the cold season would set the stage for drought that would persist into the warm season across much of the contiguous U.S.

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Table:

Date	Event	Impacts	Deaths/Injuries	Damage
29-30 October, 2011	Early-Season Mid-Atlantic and Northeast Winter Storm	Heavy Snow, High Wind	1/0	$18.8 M
28-29 November, 2011	Eastern U.S. Heavy Rain and Snow	Flooding	0/0	$25 K
19-20 December, 2011	Southern Rockies to Central Plains Winter Storm	Heavy Snow, Blizzard	0/0	$53 K
18-20 January, 2012	Western U.S. Winter Storm	Winter Storm, Ice Storm, High Winds, Landslide, Flooding	3/4	$24.5 M
3-4 February, 2012	Central U.S. Winter Storm	Winter Storm, Flooding	0/0	$693 K
29 February - 2 March, 2012	Upper Midwest to New England Winter Storm	Winter Storm, Blizzard, High Winds, Cold/Wind Chill	1/0	$741 K
23-24 April, 2012	Late-Season Mid-Atlantic and Northeast Winter Storm	Winter Storm, Lake-Effect Snow, Strong Wind	0/0	$206 K

Table 1: Impacts, deaths/injuries, and damage amount (dollars) for the 2011-2012 Cold Season listed by event (NWS Storm Data).

Figures:

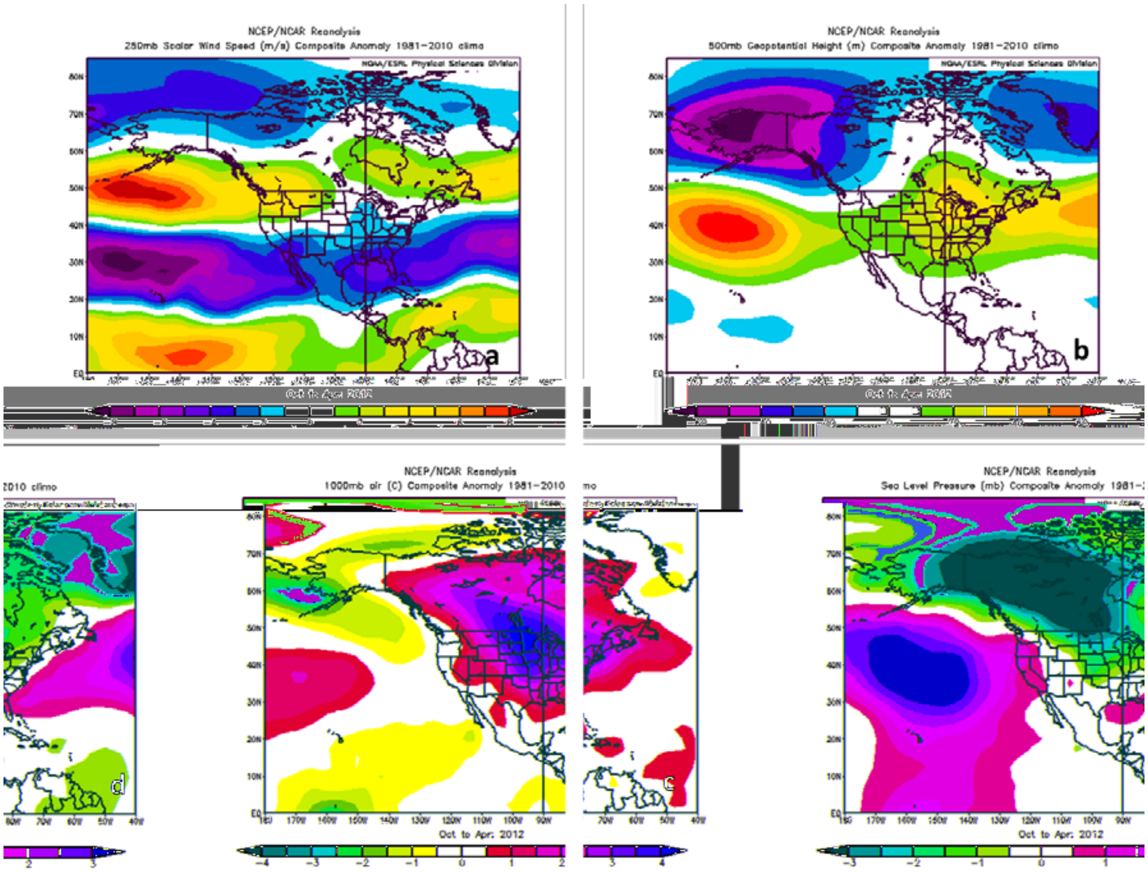


Figure 1: 250 hPa wind speed anomalies (a), 500 hPa geopotential height anomalies (b), 1000 hPa air temperature anomalies (c), and sea-level pressure anomalies (d), averaged from October 2011 to April 2012 (NCEP Reanalysis).

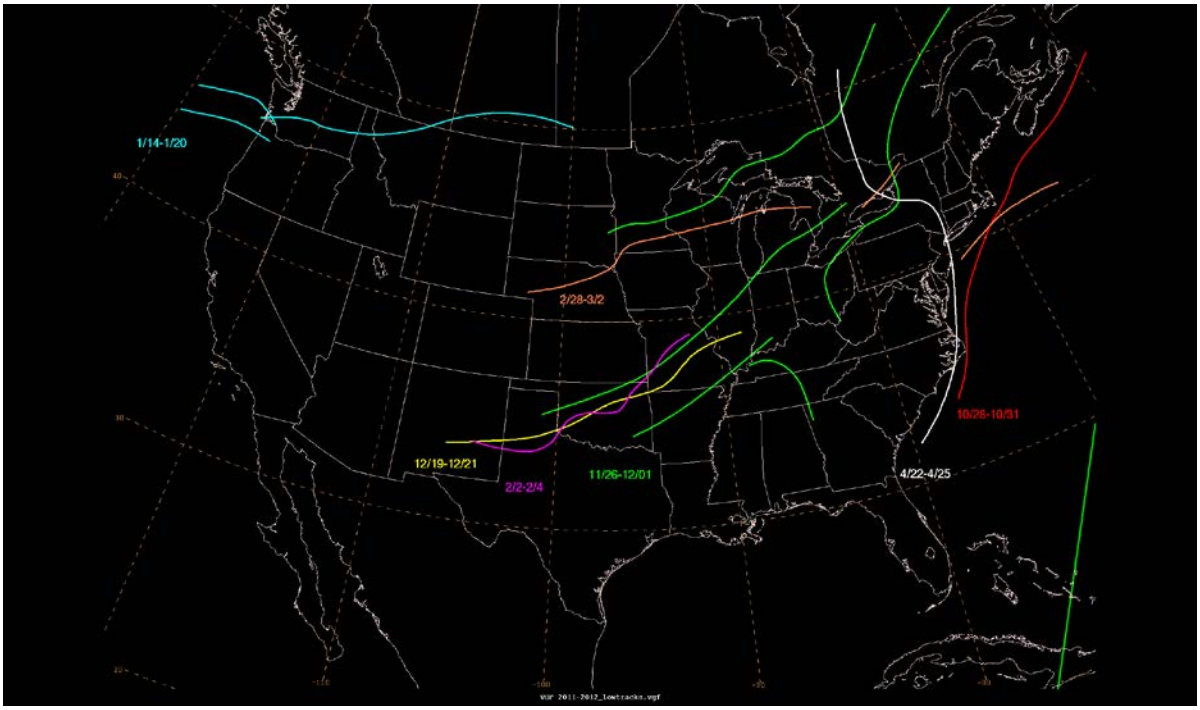


Figure 2: Surface low tracks for all events discussed in this article. Note that some events consisted of multiple surface lows.

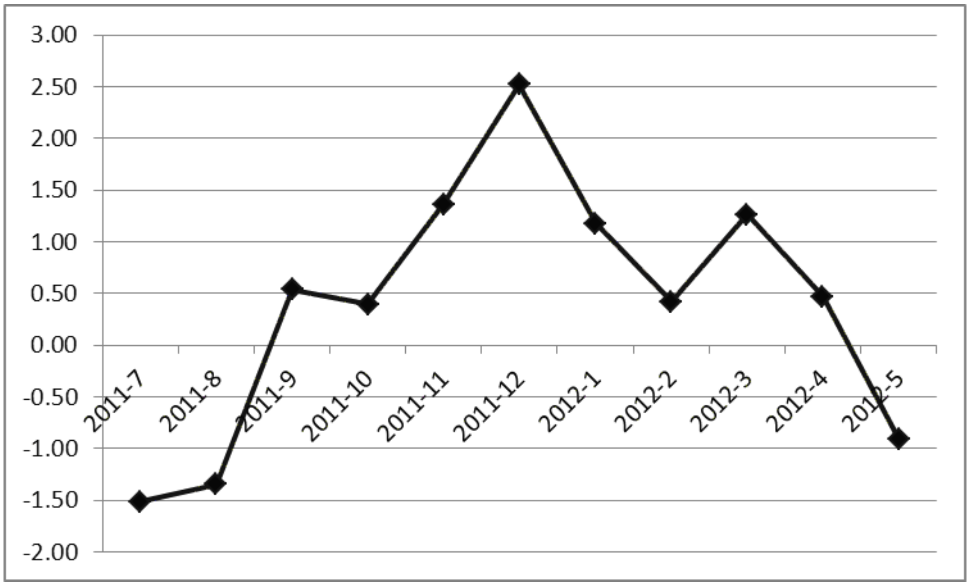


Figure 3: NAO index for the months including the 2011-2012 cold season.

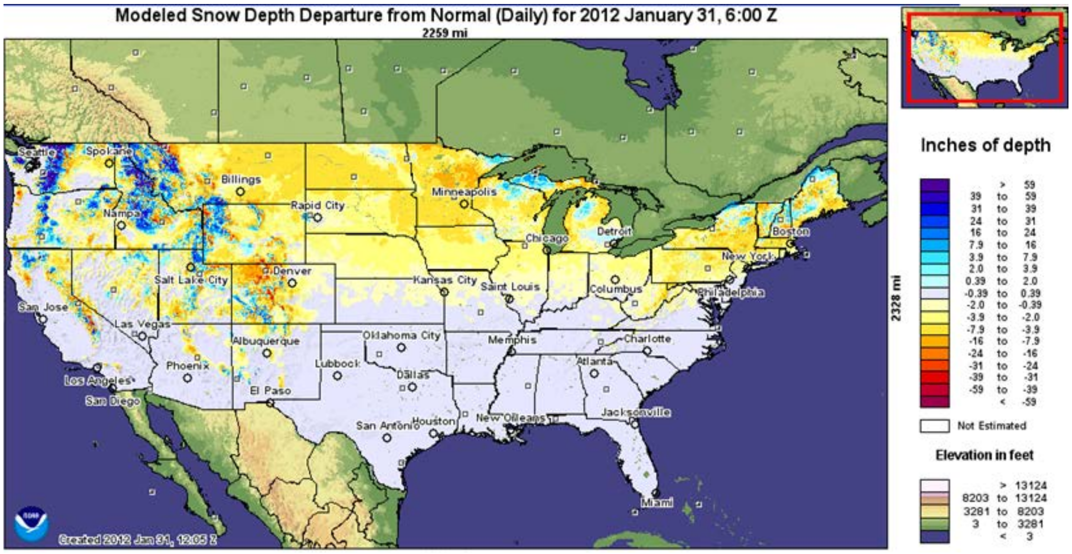


Figure 4: Snow depth departure from normal on 31 January, 2012 (NOHRSC).

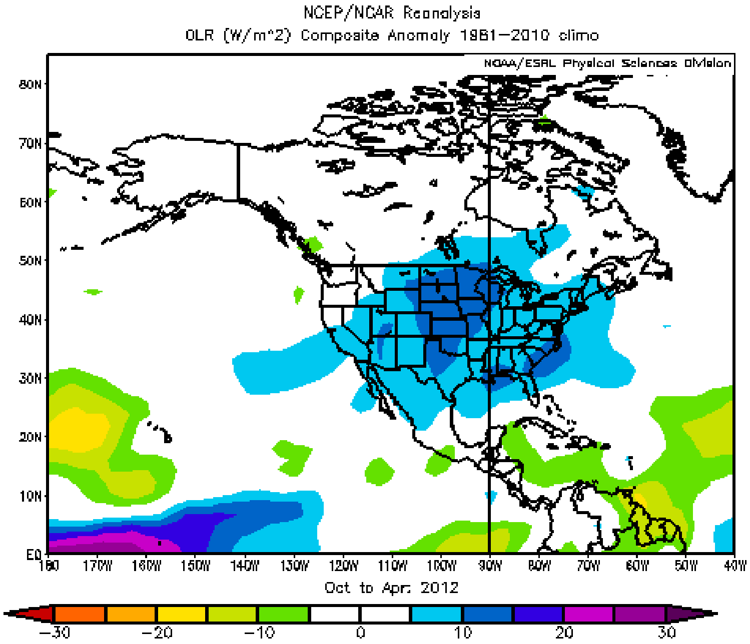


Figure 5: Seasonal average (Oct 2011 to Apr 2012) outgoing longwave radiation (OLR) anomalies (NCEP Reanalysis).

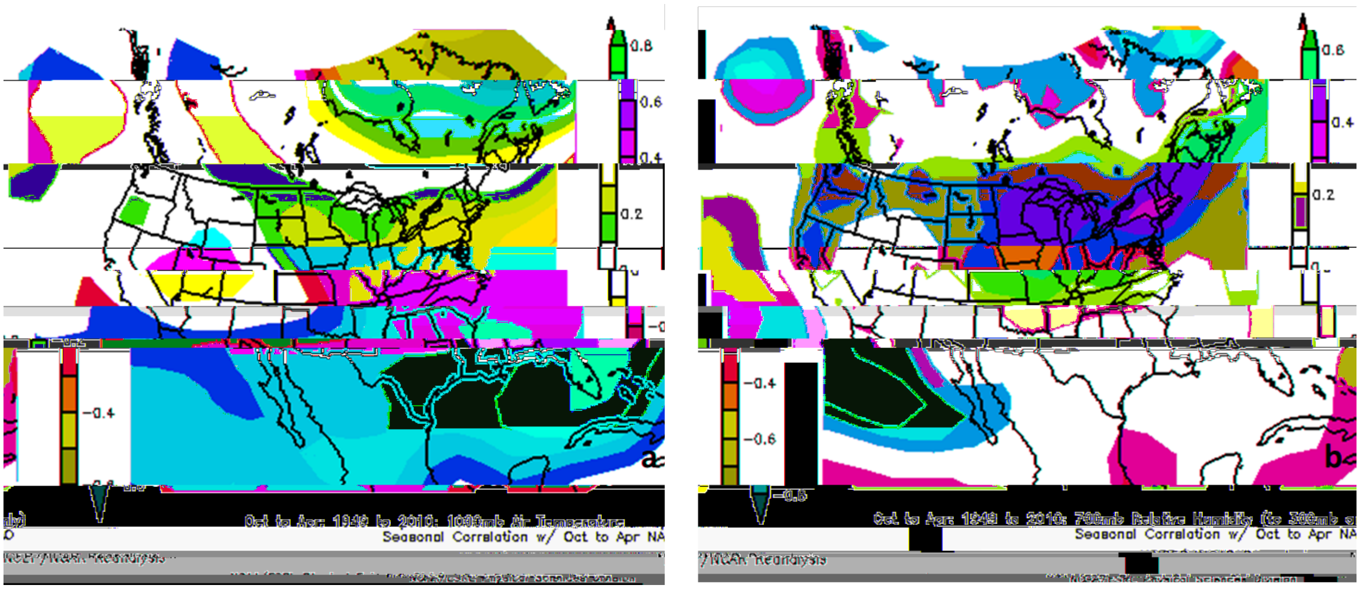


Figure 6: Seasonal anomaly correlations (October to April) for 1000 hPa air temperature (a) and 700 hPa relative humidity (b) with the NAO. Positive 1000 hPa temperature anomalies and negative 700 hPa relative humidity anomalies are correlated with the positive phase of the NAO. (NCEP/NCAR Reanalysis)

Figure 7: (a) Surface analysis from 00 UTC on 30 October, 2011 (WPC/OPC) and (b) Total 48-hour snowfall accumulation ending at 12 UTC on 31 October, 2011 (courtesy of NOHRSC).

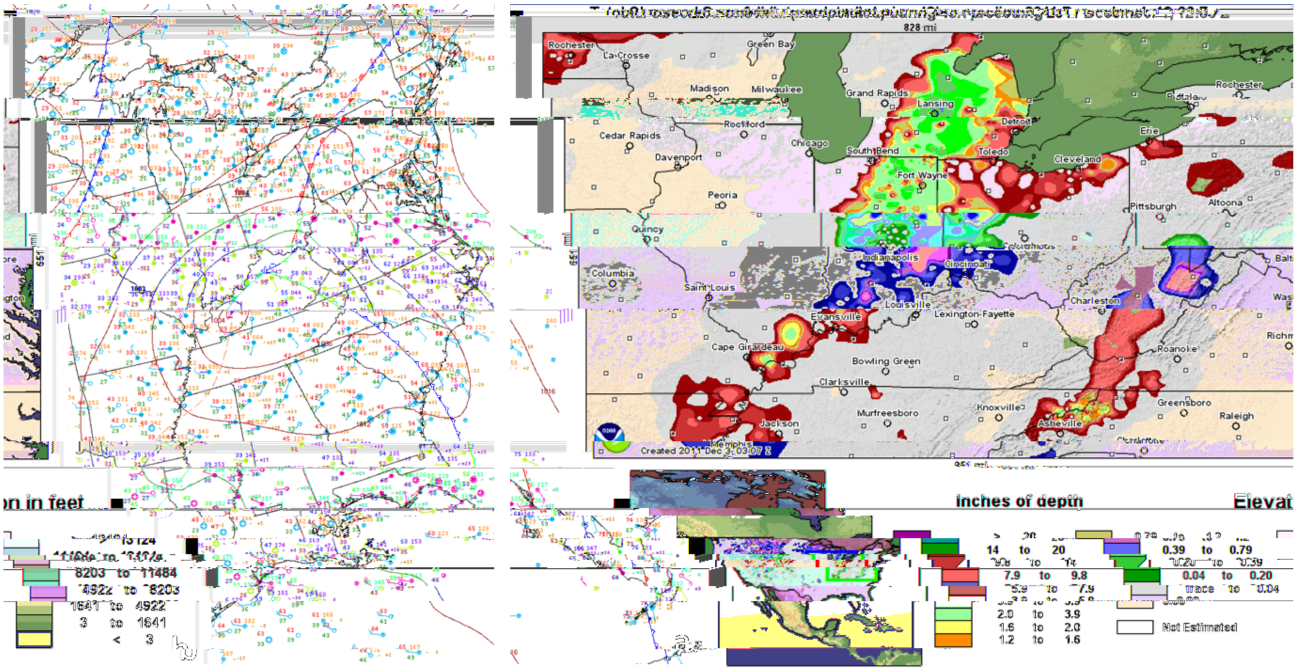


Figure 8: Observed 48-hour snowfall (interpolated) ending at 12 UTC on 1 December, 2011 (a) (NOHRSC), and surface analysis from 00 UTC on 29 November (b).

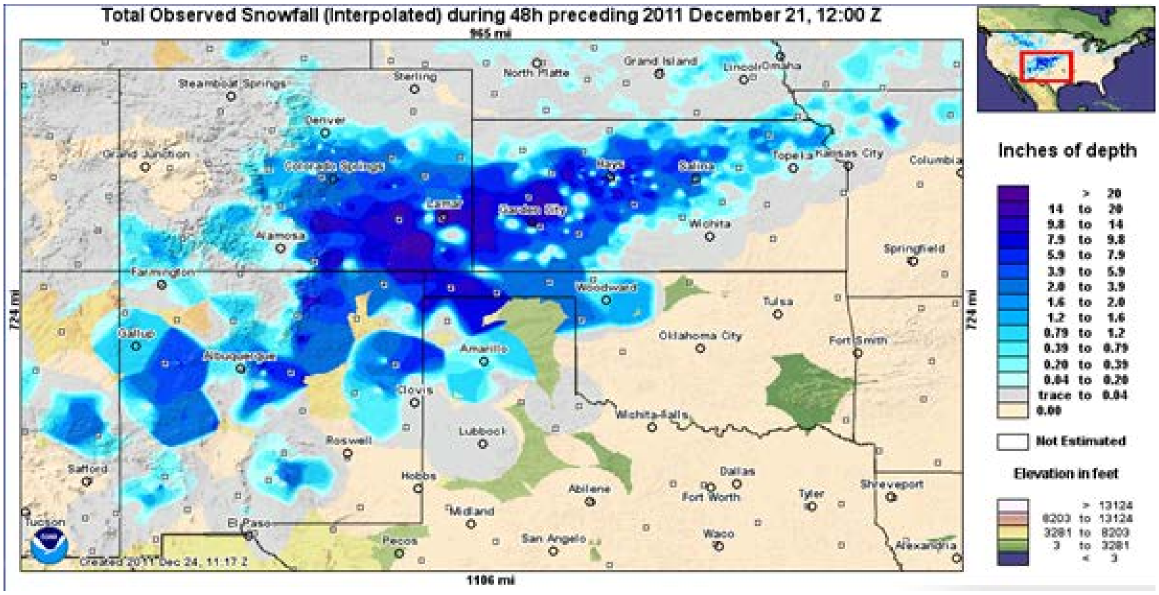


Figure 9: Observed 48-hour snowfall ending at 12 UTC on 21 December, 2011.

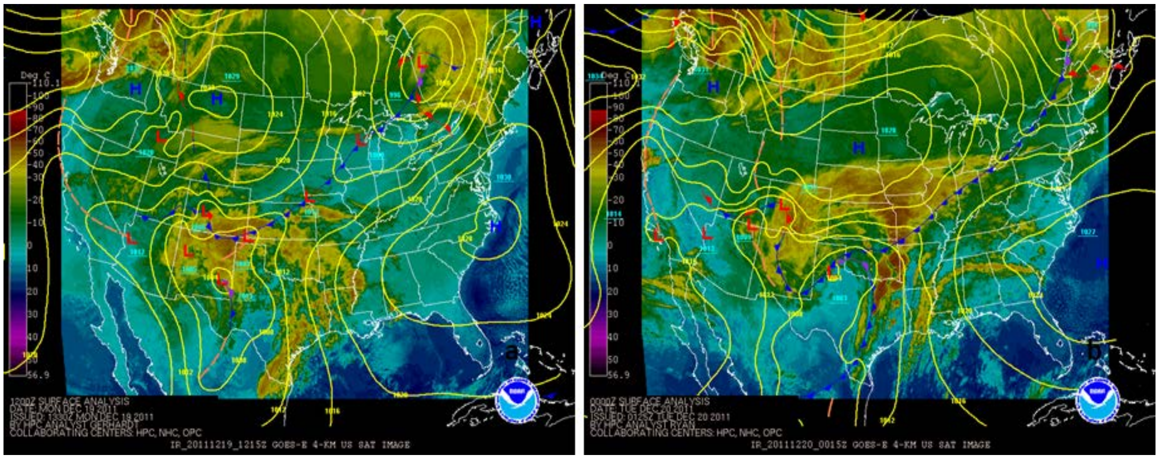


Figure 10: Surface analysis overlaid on infrared satellite imagery from 12 UTC on 19 December (a) and 00 UTC on 20 December (b), 2011.

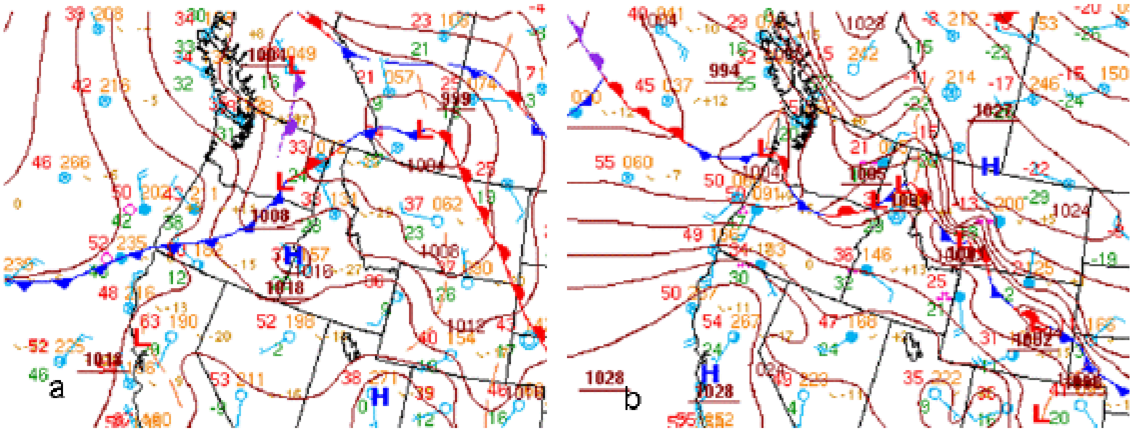


Figure 11: Surface analyses from 00 UTC on 15 January (a) and 00 UTC on 19 January, 2012 (b).

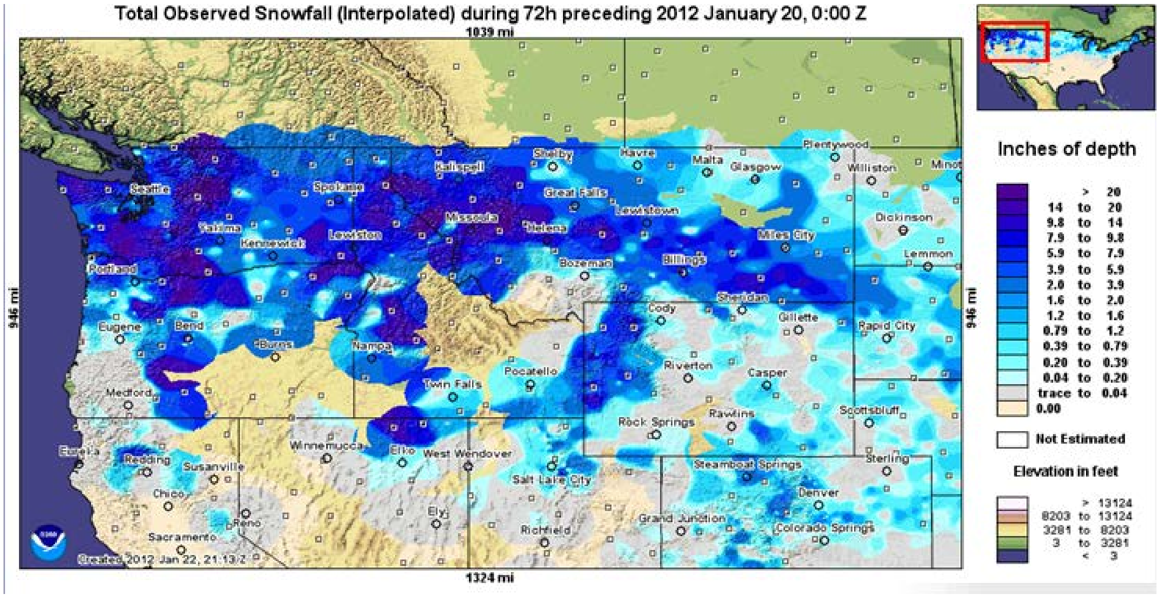
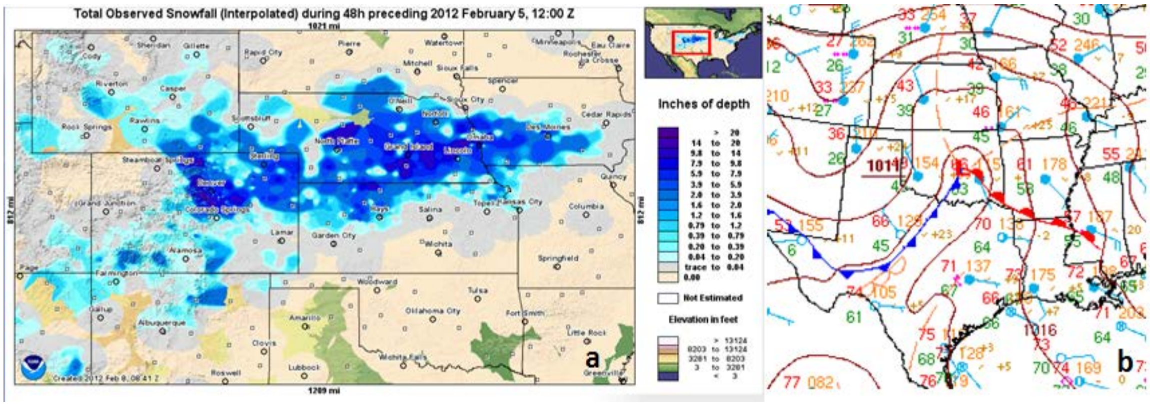
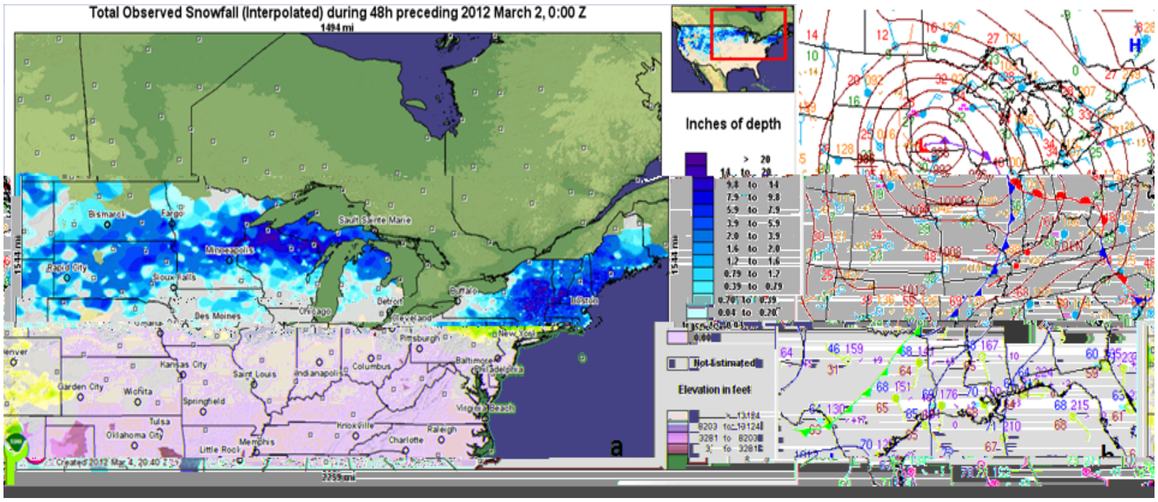


Figure 12: Total observed snowfall from 00 UTC 17 January to 00 UTC 20 January, 2012 (NOHRSC).



Total Observed Snowfall (Interpolated) during 48h preceding 2012 February 5, 12:00 Z

Figure 13: Total observed snowfall from 12 UTC on 3 February (a) (NOHRSC) and surface analysis from 00 UTC on 4 February (2012).



Total Observed Snowfall (Interpolated) during 48h preceding 2012 March 2, 0:00 Z

Figure 14: Total observed snowfall from 00 UTC on 28 February (a) (NOHRSC) and (b) surface analysis from 12 UTC on 29 February, 2012.

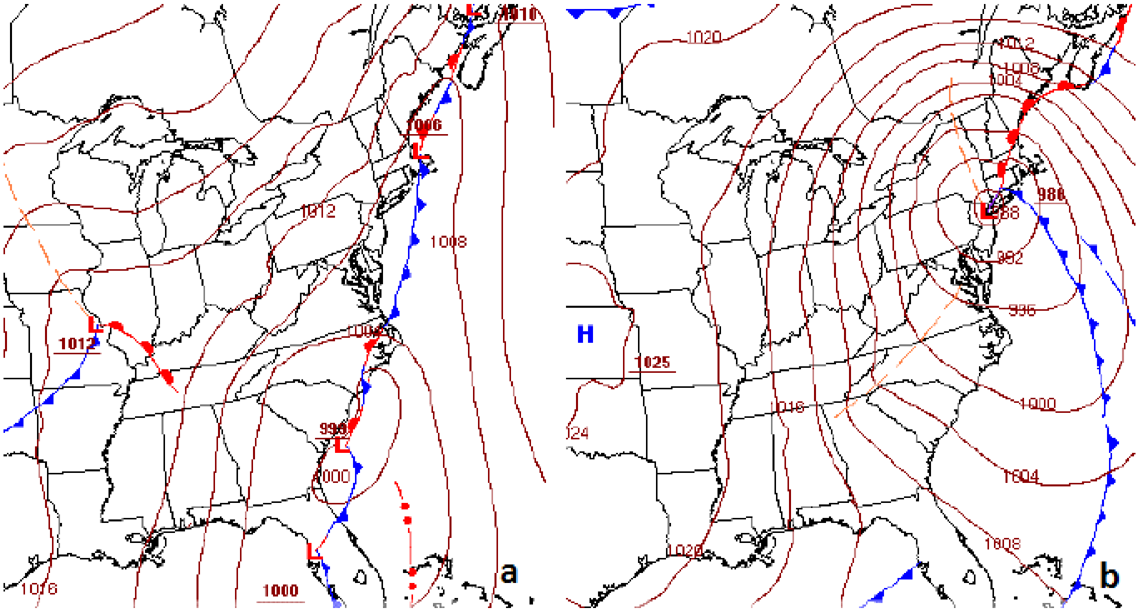


Figure 15: Surface analysis from 12 UTC on 22 April (a) and 12 UTC on 23 April (b), 2012.

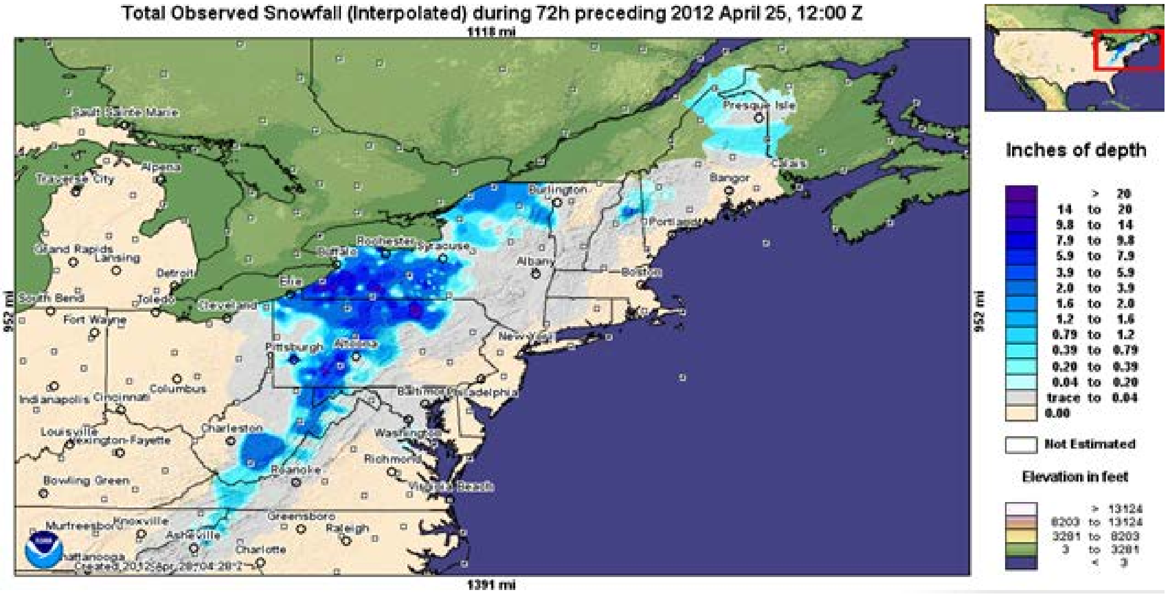


Figure 16: Total observed snowfall from beginning at 12 UTC on 22 April and ending at 12 UTC on 25 April, 2012 (NOHRSC).