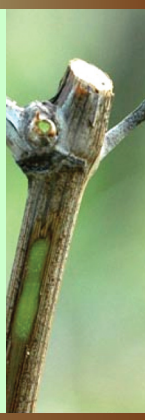
The Easter Freeze of April 2007

A Climatological Perspective and Assessment of Impacts and Services

Technical Report 2008-01

A NOAA/USDA technical report



PREFACE

An extreme climatic event such as the early April 2007 freeze, with its wide coverage and significant impacts exceeding two billion dollars across the central and eastern two-thirds of the United States, requires broad-ranging post analysis. What were the societal impacts? What happened meteorologically and why? How does this extreme event fit into our climatological record? What can we learn about our service from a national, regional, and local perspective to provide better service in the future? These are the key questions addressed in this report.

This project is representative of a general need for such assessments. Through efforts such as this, we can systematically document the impact of climate extremes while continuously evaluating ways to improve services to the United States. Moreover, this report involves key federal, regional, and state partners in the climate community. It is only through the combined efforts of our partners that we can best summarize the scope, impacts, and services provided in extreme climatic events.

Ray Wolf
NOAA/National Weather Service
October 2007

ACKNOWLEDGMENTS

A report of this scope is possible only with contributions from a number of talented and dedicated people. Recent efforts by NOAA, and in particular the National Weather Service (NWS), to rebuild climate partnerships, both within and outside the agency, were important in making this report possible. Key contributions from federal, regional, and state-level climate partners from 15 states documented the freeze impacts on the local level. Contributions from NOAA's Climate Prediction Center (CPC), National Climatic Data Center (NCDC), and the NWS, plus agricultural assessments from the United States Department of Agriculture (USDA), provided background information documenting the large-scale perspective of this event, which includes an evaluation of NWS services.

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ACRONYMS

AO	Arctic Oscillation
AFD	Area Forecast Discussion
CONUS	Continental United States
CPC	Climate Prediction Center
CRN	Climate Reference Network
HPC	Hydrometeorological Prediction Center
HPRCC	High Plains Regional Climate Center
HWO	Hazardous Weather Outlook
MOS	Model Output Statistics
MRCC	Midwestern Regional Climate Center
NASS	USDA National Agricultural Statistics Service
NCEP	National Center for Environmental Prediction
NCDC	National Climatic Data Center
NDFD	National Digital Forecast Database
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
SC	State Climatologist
USDA	United States Department of Agriculture
WFO	Warning and Forecast Office

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EXECUTIVE SUMMARY

Unseasonably warm weather in March 2007 over the eastern half of the United States prompted early growth of many agricultural and horticultural crops, ranging from wheat in the Central Plains to fruit trees and pastures across the Southeast and parts of the Midwest. March monthly temperatures averaged between 2 and 6°F above normal in these areas, and this was the second warmest March on record for the entire U.S.

Arctic cold followed in early April with over 1500 weather stations breaking or matching record low temperatures. The magnitude and duration of the cold temperatures was particularly noteworthy in a climatological sense. Low temperatures in the teens occurred throughout the eastern half of the country, and freezing temperatures lasted almost a week in some areas. The duration of the cold combined with strong winds hindered efforts to take freeze protection measures for high value horticultural crops.

Agricultural and horticultural crops which started premature spring growth due to the warm March were thus highly susceptible to the freezing temperatures. Freeze damage was reported in nearly every state from Colorado and Oklahoma east to Virginia and Georgia. Preliminary damage estimates indicate total freeze-related losses will exceed the 2 billion dollar mark, though subsequent drought, especially in the Southeast, also negatively impacted crops causing additional losses.

The National Weather Service provided advance warning of the Arctic freeze. The first indication of freeze potential in Climate Prediction Center products occurred in the 6-10 day issuance on March 29 and the U.S. Hazards Assessment on March 30. National Digital Forecast Database verification indicated forecasts made 6 days prior to the one of the coldest days of the freeze did not reflect the cold outbreak (April 1 forecast for April 7), though 3-day forecasts were very good. Text products such as the Hazardous Weather Outlook, Area Forecast Discussion, and Freeze Warnings were assessed in Central Region and provided timely information. In addition, special efforts were made to utilize web pages and media contacts to insure the broadest possible dissemination of the threat.

Findings from a survey of Central Region Warning and Forecast Offices indicate services could be improved by establishing and utilizing closer ties with University Extension Service specialists and USDA field offices. Specifically, input from University Extension Service specialists should be used to determine the need for Freeze/Frost products each season, not solely calendar dates or climatology. Second, USDA field offices, in particular the Farm Services Agency, can be an excellent source of impact information for regional reports and Storm Data.

Event Overview

Introduction

The April 3-10 2007 Cold Wave blasted much of the central Plains, Midwest and Southeast with Arctic air. For the entire month, April temperatures across the contiguous U.S. were near average, ranking 38th coolest since 1895 (113 years), although below average temperatures are apparent in these affected regions (Figure 1). The most significant impact of this cold wave was related to the timing and duration of the event in concert with crop development. Winter wheat across the central Plains and Midwest, blooming fruits across parts of the Midwest and southern U.S., and emerging corn in the South were among the hardest hit agricultural and horticultural crops.

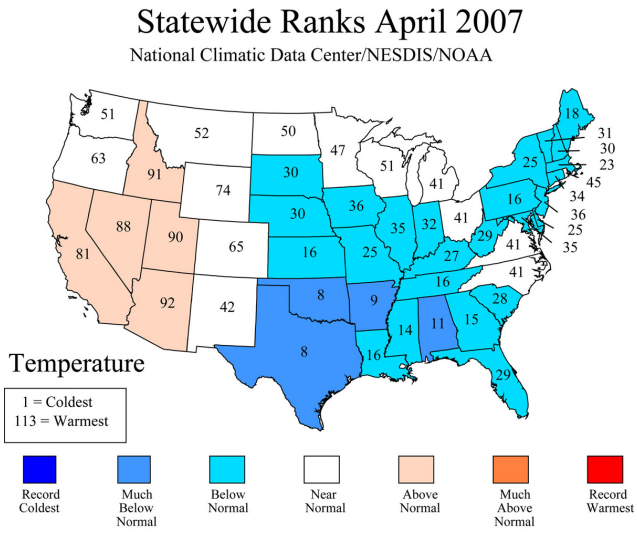


Figure 1. April statewide temperature ranks. *Source:* NCDC.

Some of the more notable cold weather-related impacts reported in the media, but not detailed in this report, include cancellation of outdoor sporting events, cancellation or reduced attendance at Easter services and related events, lower retail sales, and increased energy consumption and cost. Environmental effects to wildlife, forests, etc. will occur though are hard to specify. Finally, losses of ag-related jobs such as fruit pickers and custom harvesters were expected due to the crop losses, but were not factored into loss estimates in this report.

Several factors made this cold wave more harmful to agricultural interests than similar events in the past. March 2007 was exceptionally warm across a large portion of the U.S. from the northern Plains through the Mississippi Valley and into the Southeast (Figure 2, upper right), and in fact the second warmest on record nationally. A dominant ridge of high pressure entrenched across the contiguous U.S. allowed average monthly temperatures to exceed the average by more than 6°F. The prolonged warm spell led to premature spring growth for many plants and trees across the region. In contrast to the warmth across the Continental United States (CONUS), cold air was

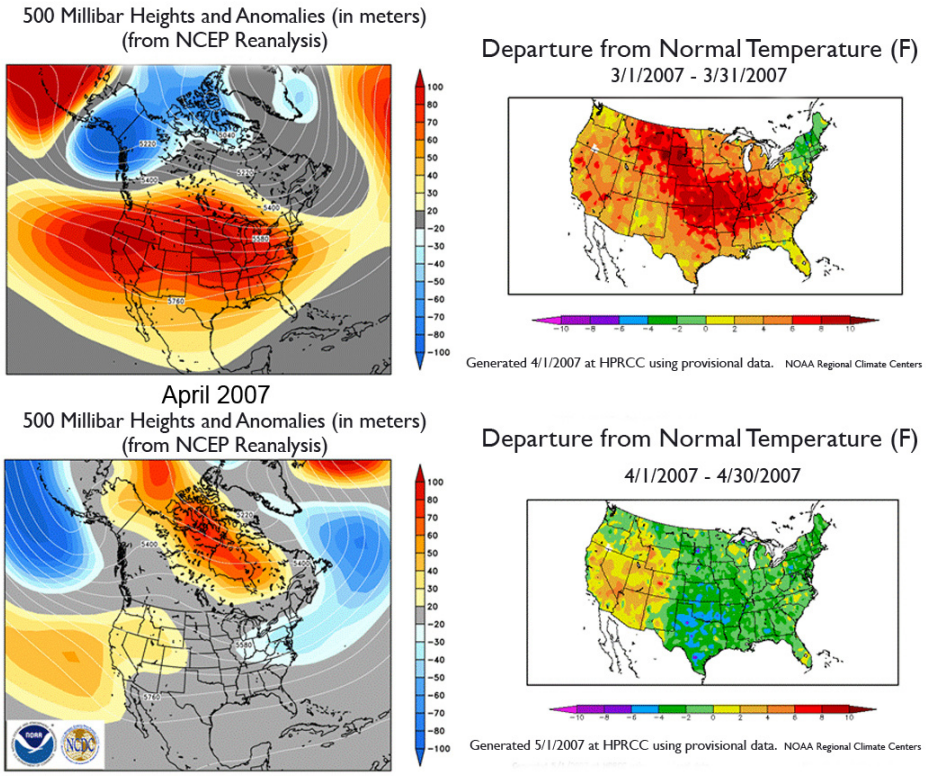


Figure 2. March 500mb heights and anomalies (upper left, m), departure from normal surface temperatures (upper right, °F); April 500mb heights and anomalies (lower left, m), and departure from normal surface temperatures (lower right, °F). *Sources:* 500mb data NOAA CPC; surface data High Plains Regional Climate Center.

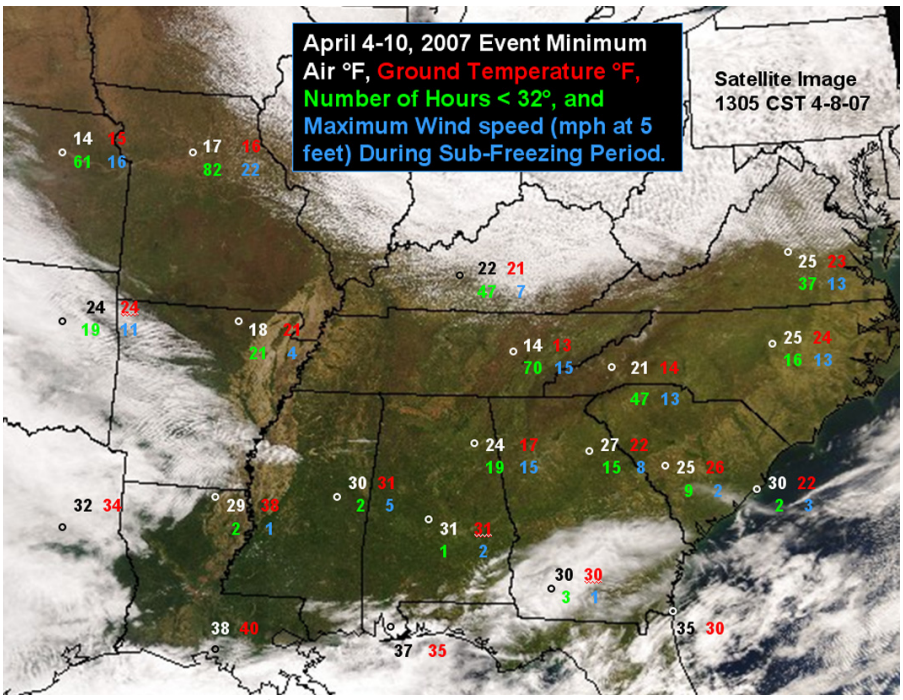


Figure 3. Climate Reference Network data as labeled. *Source:* NCDC.

entrenched across much of Alaska, making it the 3rd coldest March on record for the state.

In early April, a shift in the upper level flow pattern brought this cold Arctic air southward into the central and eastern U.S. The record-breaking cold air penetrated much of this region from April 4-10 bringing near-record to record cold temperatures to parts of the central Plains and much of the Southeast. Temperatures in some locations dropped into the teens and lower 20s overnight, with many hours of sub-freezing temperatures on multiple and subsequent days (Figure 3). As many as four to five nights of extremely cold temperatures coupled with sustained desiccating winds during the sub-freezing period made this event more harmful for plants and trees, and brought extensive losses in excess of an estimated 2 billion dollars to agricultural and horticultural interests.

Data from the Climate Reference Network (CRN) across the central Plains and Southeast are shown in Table 1. During the time of the killing freeze, several CRN stations reported minimum temperatures in the teens. These include Batesville, AR (18°F), Manhattan, KS (14°F), Chillicothe, MO (17°F) and Crossville, TN (14°F). The number of hours the minimum air temperature was below 32°F across much of the region was considerable.

Table 1. Temperature and wind data from the U.S. Climate Reference Network for April 4-10, 2007.

STATION WIND	MINIMUM AIR TEMP °F	MINIMUM IR TEMP °F	NO. OF HOURS MIN AIR TEMP					MAX 10-SEC WIND (mph)	AVG SPEED
			≤32°	≤28°	≤24°	≤20°	≤16°		
Gadsden, AL	24	17	19	11	0	0	0	15	5
Selma, AL	31	31	1	0	0	0	0	2	0
Batesville, AR	18	21	21	17	7	2	0	4	2
Watkinsville, GA	27	22	15	2	0	0	0	8	3
Newton 8, GA	30	30	3	0	0	0	0	1	0
Manhattan, KS	14	15	61	28	16	9	2	16	7
Bowling Green, KY	22	21	47	23	9	0	0	7	1
Monroe, LA	29	38	2	0	0	0	0	1	0
Chillicothe, MO	17	16	82	54	21	5	0	22	9
Newton, MS	30	31	2	0	0	0	0	5	4
Asheville, NC	21	14	47	27	9	0	0	13	3
Durham, NC	25	24	16	3	0	0	0	13	4
Stillwater, OK	24	24	19	8	0	0	0	11	4
Blackville, SC	25	26	9	3	0	0	0	2	<1
McClellanville, SC	30	22	2	0	0	0	0	3	0
Crossville, TN	14	13	70	45	16	7	3	15	4
Charlottesville, VA	25	23	37	11	0	0	0	13	3

NOTE: All wind data is for only the hours during which the temperatures were < 32°F and were measured at 5 feet above ground level.

Table 2. Selected record temperatures (°F) April 7-10, 2007.

7 April 2007	STATION ID	New /Tied Record	Previous Record	Previous Date
HUNTSVILLE INTL AP, AL	014064	25.0°F	26.0 °F	3 Apr 1992
GLASGOW, KY	153246	18.0°F	20.0 °F	6 Apr 2007
BOONVILLE, MO	230817	19.0°F	20.0 °F	4 Apr 1975
CALIFORNIA, MO	231189	19.0°F	19.0 °F	3 Apr 1975
WASOLA, MO	238754	20.0°F	21.0 °F	4 Apr 1987
CAESARS HEAD, SC	381256	16.0°F	20.0 °F	7 Apr 1982
LAFAYETTE, TN	404987	20.0°F	22.0 °F	11 Apr 1973
8 April 2007	**STATION ID**	**New /Tied Record**	**Previous Record**	**Previous Date**
ANNISTON METRO AP, AL	010272	26.0°F	26.0 °F	17 Apr 1905
MUSCLE SHOALS AP, AL	015749	26.0°F	26.0 °F	7 Apr 2007
EVENING SHADE 1 NNE, AR	032366	20.0°F	20.0 °F	7 Apr 1994
HOT SPRINGS 1 NNE, AR	033466	24.0°F	25.0 °F	10 Apr 2006
WEST MEMPHIS, AR	037712	25.0°F	26.0 °F	7 Apr 2007
GREERS FERRY DAM, AR	032978	26.0°F	26.0 °F	7 Apr 1971
LITTLE ROCK ADAMS FLD, AR	034248	28.0°F	28.0 °F	7 Apr 1971
DES ARC, AR	031968	28.0°F	29.0 °F	7 Apr 2007
LOUISVILLE 1 E, GA	095314	26.0°F	28.0 °F	1 Apr 1987
MACON MIDDLE GA AP, GA	095443	28.0°F	29.0 °F	1 Apr 1987
ALMA BACON CO AP, GA	090211	30.0°F	31.0 °F	1 Apr 1987
CAMILLA 3 SE, GA	091500	32.0°F	32.0 °F	13 Apr 1940
MOUND CITY, KS	145528	16.0°F	16.0 °F	3 Apr 1975
IOLA 1 W, KS	143984	19.0°F	19.0 °F	7 Apr 2007
STEARNS 2 S, KY	157677	15.0°F	18.0 °F	3 Apr 1992
SOMERSET 2 N, KY	157510	18.0°F	18.0 °F	3 Apr 1992
LONDON FAA AP, KY	154898	19.0°F	21.0 °F	7 Apr 1982
W KERR SCOTT RSVR, NC	319555	20.0°F	20.0 °F	9 Apr 1972
ROCKY MOUNT WILSON AP, NC	93759	23.0°F	25.0 °F	10 Apr 1985
ELIZABETH CITY FAA AP, NC	312724	27.0°F	29.0 °F	8 Apr 1982
FAYETTEVILLE REGL AP GRANNIS F, NC	93740	27.0°F	28.0 °F	10 Apr 1985
ELIZABETH CITY COAST GUARD AIR, NC	13786	27.0°F	27.0 °F	10 Apr 1985
WILMINGTON INTL AP, NC	319457	29.0°F	30.0 °F	20 Apr 1983
UNION 8 S, SC	388786	20.0°F	21.0 °F	7 Apr 1950
DILLON, SC	382386	24.0°F	24.0 °F	1 Apr 1964
COLUMBIA WSFO AP, SC	381939	26.0°F	26.0 °F	20 Apr 1983
SUMMERVILLE 4W, SC	388426	27.0°F	28.0 °F	20 Apr 1983
CHARLESTON INTL AP, SC	381544	30.0°F	30.0 °F	10 Apr 1972
SULLIVANS IS, SC	388405	32.0°F	32.0 °F	6 Apr 1975
ROSCOE, SD	397277	2.0°F	2.0 °F	7 Apr 2007
GREENEVILLE EXP STN, TN	403679	16.0°F	18.0 °F	7 Apr 1982
WOODBURY 1 WNW, TN	409866	18.0°F	18.0 °F	3 Apr 1992
SMITHVILLE 2 SE, TN	408405	18.0°F	19.0 °F	7 Apr 2007
CROSSVILLE AP, TN	402197	20.0°F	20.0 °F	7 Apr 2007
KINGSTON SPRINGS, TN	404876	20.0°F	21.0 °F	3 Apr 1992
BRISTOL AP, TN	401094	21.0°F	21.0 °F	7 Apr 1982
DRESDEN, TN	402600	22.0°F	23.0 °F	11 Apr 1973
ATHENS, TN	400284	22.0°F	22.0 °F	3 Apr 1992
SELMER, TN	408160	22.0°F	23.0 °F	4 Apr 1987

LAWRENCEBURG FILT PLT, TN	405089	22.0°F	22.0 °F	11 Apr 1973
NASHVILLE ASOS, TN	406402	23.0°F	23.0 °F	7 Apr 1982
LENOIR CITY, TN	405158	23.0°F	24.0 °F	3 Apr 1992
MEMPHIS INTL AP, TN	405954	28.0°F	29.0 °F	4 Apr 1987
CHISOS BASIN, TX	411715	25.0°F	25.0 °F	6 Apr 1996
ROBERT GRAY AAF, TX	03902	32.0°F	32.0 °F	10 Apr 1973
MERCEDES 6 SSE, TX	415836	35.0°F	36.0 °F	10 Apr 1938
ZAPATA 1 S, TX	419976	38.0°F	38.0 °F	3 Apr 1987
9 April 2007	**STATION ID**	**New /Tied Record**	**Previous Record**	**Previous Date**
ROCK MILLS, AL	017025	24.0°F	24.0 °F	9 Apr 2000
BATESVILLE L&D 1, AR	030460	23.0°F	23.0 °F	8 Apr 2007
STUTTGART 9 ESE, AR	036920	28.0°F	28.0 °F	8 Apr 2007
PINE BLUFF, AR	035754	29.0°F	29.0 °F	8 Apr 2007
LIVE OAK, FL	085099	31.0°F	31.0 °F	1 Apr 1987
LAFAYETTE 3SW, GA	094941	22.0°F	22.0 °F	11 Apr 1973
MONTICELLO 3 NE, KY	155524	18.0°F	18.0 °F	8 Apr 2007
ROCHESTER FERRY, KY	156882	20.0°F	20.0 °F	8 Apr 2007
DONIPHAN, MO	232289	17.0°F	17.0 °F	8 Apr 2007
ARCADIA, MO	230224	18.0°F	18.0 °F	8 Apr 2007
ELIZABETHTOWN 3 SW, NC	312732	24.0°F	24.0 °F	10 Apr 1985
CELINA, TN	401561	18.0°F	22.0 °F	19 Apr 1983
LIVINGSTON RADIO WLIV, TN	405332	19.0°F	19.0 °F	8 Apr 2007
NEAPOLIS EXP STN, TN	406435	19.0°F	19.0 °F	8 Apr 2007
COOKEVILLE, TN	402009	20.0°F	20.0 °F	8 Apr 2007
COLUMBIA 3 WNW, TN	401957	20.0°F	20.0 °F	20 Apr 1983
PULASKI WWTP, TN	407459	22.0°F	22.0 °F	8 Apr 2007
KNOXVILLE EXP STN, TN	404946	22.0°F	22.0 °F	3 Apr 1992
HUNTINGDON WTP, TN	404417	23.0°F	25.0 °F	3 Apr 1992
SAMBURG WR, TN	408065	23.0°F	23.0 °F	8 Apr 2007
BROWNSVILLE, TN	401145	25.0°F	25.0 °F	8 Apr 2007
WHITNEY DAM, TX	419715	28.0°F	29.0 °F	11 Apr 1989
STILLHOUSE HOLLOW DAM, TX	418646	30.0°F	31.0 °F	7 Apr 1996
FREER, TX	413341	35.0°F	35.0 °F	8 Apr 2007
10 April 2007	**STATION ID**	**New /Tied Record**	**Previous Record**	**Previous Date**
BROOKLET 1 W, GA	091266	30.0°F	30.0 °F	9 Apr 2007
KASKASKIA RIV NAV LOCK, IL	114629	22.0°F	23.0 °F	8 Apr 1990
CAIRO 3 N, IL	111166	26.0°F	26.0 °F	9 Apr 2007
NEW BERN CRAVEN CO AP, NC	316108	29.0°F	29.0 °F	15 Apr 1950
WALTERBORO 1 SW, SC	388922	26.0°F	26.0 °F	9 Apr 2007

Records

Between April 4 and 10, there were 1,237 broken and 321 tied daily minimum temperature records in the contiguous U.S. These records are based on the historical daily observations archived in NCDC's TD-3200 data set and reports from Cooperative Observers and First Order National Weather Service stations. The numbers are preliminary and subject to change pending final quality control. A subset of these reports are in Table 2. Additional data consisting of the coldest temperature recorded during the period organized by state and climate division are in tabular format in Appendices A and B, respectively, and in Figure 4 for climate division numbers. Additional information is available at an NCDC web page focusing on the April freeze: http://www.ncdc.noaa.gov/oa/climate/research/2007/apr/apr-cold-event.php

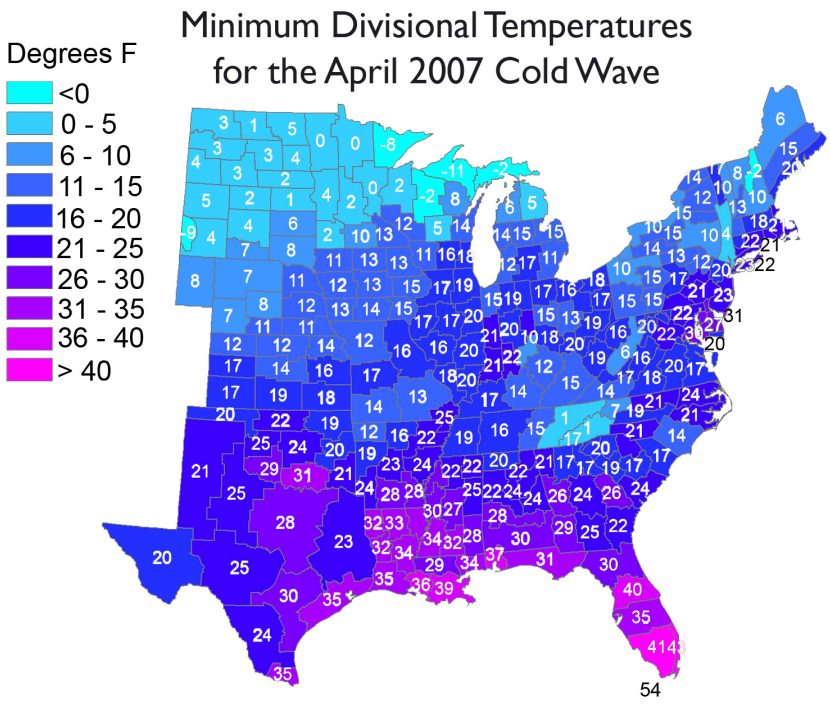


Figure 4. Lowest temperature reported by climate division during the April 4-10 freeze. *Source:* NCDC.

by this pattern allowed Arctic air to penetrate into the central and eastern United States.

Some of the areas that saw March temperatures 6 to 10°F above normal averaged 2 to 6°F below normal for April (Figure 2, lower right). This was especially the case for the Plains states from Kansas south through Texas. During the period of the freeze, April 4-10, average temperature anomalies ranged from +15°F or so in Alaska to -15°F or so in the Midwestern U.S., illustrating the strong teleconnection between Alaska and the central and eastern CONUS at this time of year. By contrast, the precipitation pattern was unremarkable, showing a tendency for below-median rainfall in the center of the coldest and warmest temperature anomaly regions.

March and April Circulation Patterns

Figure 2 illustrates the marked change in circulation pattern that took place from March to April. The 500 mb height anomaly map for March (upper left) shows that nearly the entire CONUS had above normal heights, with positive anomalies centered over the Midwest and central West Coast regions. This means the jet stream was displaced well north of normal, resulting in temperatures more like late spring than late winter. Many locations in the U.S. posted monthly temperatures more than 8°F above normal, mainly in the central and northern Plains and the Midwest. Ten states reported one of the five mildest Marches on record, with Oklahoma the warmest and Kansas the second warmest.

The April pattern stood in stark contrast to March (Figure 2, lower left). Specifically, during April 4-10, 2007, the circulation was highly amplified, with deep 500mb height troughs south of the Aleutians and from the Great Lakes to New England (Figure 2, lower left). Strong anomalous ridges covered Asia, the Western Arctic, western, central and northern Canada, the northeastern north Atlantic and central Europe. Modest positive 500mb height anomalies covered the far western United States. The anomalous wind flow implied

On the synoptic scale, the precursor to the onslaught of cold air was a surface low pressure system moving from the central Rockies into the Mid-Mississippi River Valley on April 2-3. Cold air, as evidenced by surface high pressure of 1048mb and sub-zero temperatures, was developing in central Canada. By April 4, the low pressure system had moved into the Great Lakes with a cold front dragging south through the Appalachians and across the Gulf Coast (Figure 5). The ridge of high pressure stretched from its center in Canada southward across the Plains to the Texas Gulf Coast. This pattern changed little during the next three days, accounting for the longevity of the event. Eventually, the surface high started to weaken on April 8, and the ridge axis moved eastward into the Great Lakes and mid-Atlantic region on April 9-10.

The change in weather from March to April was part of a significant Northern Hemisphere circulation pattern change. Figure 6 is time series graph of the Arctic Oscillation (AO) showing an index change from a positive 2 in March to negative 2 in early April. A negative AO is usually distinguished by a trough aloft in the northern Pacific near the Alaskan Aleutians, high pressure in the North Atlantic near Greenland, and a swath of low pressure to the south from the eastern U.S. across the Atlantic to Europe (Figure 7). In early April, a similar, although not identical, pattern

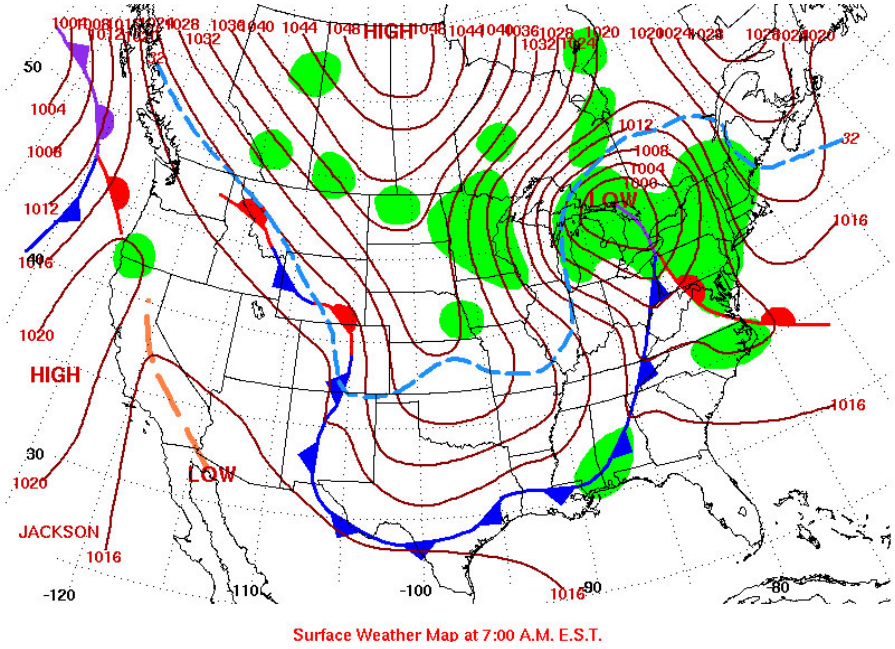


Figure 5. Surface weather map for 7 am on April 4, 2007. Contours are isobars every 4 mb. Standard frontal symbols apply, and shaded areas indicate precipitation. *Source:* NCEP.

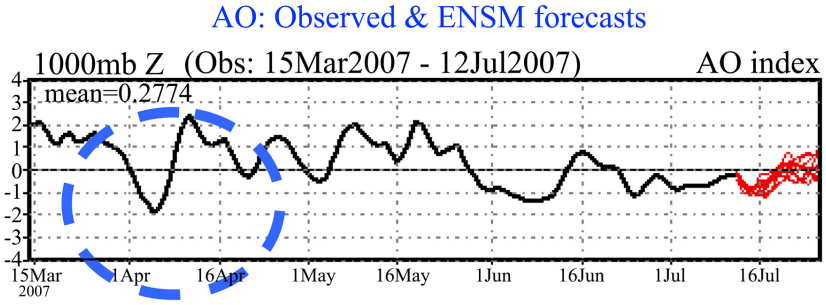


Figure 6. Time series of the Arctic Oscillation (AO). *Source:* CPC.

developed across the Pacific and Atlantic basins. The accompanying composite of temperature impacts shows the warmth associated with a positive AO and the cold associated with a negative AO. In short, the hemispheric shift in circulation during early April which caused the jet stream to plunge southward and transport frigid air into a large part of the country occurred concurrently with a shift in the AO index.

Impacts to Agriculture and Horticulture

National Overview

A severe and historic early April freeze followed record-setting March warmth, damaging a variety of crops from the central and southern Plains eastward into the Ohio and Tennessee Valleys and the Southeast. On April 7-8, monthly record lows were established in several locations—including Jackson, Tennessee, and Paducah, Kentucky—that had just experienced record-high average temperatures for March.

On the state level, Oklahoma had experienced its warmest March on record (tied with 1907 and 1910), and it had been among the ten warmest in 19 other states from Oregon and California eastward to Kentucky and Tennessee. Days later, a widespread, multi-day freeze struck the Plains, Midwest, and South. A partial list of commodities harmed by the cold outbreak included jointing- to heading-stage winter wheat, emerged corn, tree fruits (blooming and beyond), and numerous specialty and nursery crops. In addition, new growth of pastures, alfalfa, and red clover was burned back by the freezes. Crop growth stages, a factor indicating potential susceptibility to freeze damage, are listed for the most severely impacted crops in Table 3.

a. Winter Wheat

The winter wheat crop was harmed by the freeze in a nine-state area of the South and Midwest. Freeze damage was also reported on the central and southern Plains, particularly in Kansas and Oklahoma. For the Southern and Midwestern states, a comparison to 2006 provides a reasonable approximation of yield reductions due to the freeze. Drought may also have contributed to yield reductions in parts of the Southeast, while a combination of factors (wetness in late 2006 and early 2007; dryness in May 2007) may have helped to reduce yield potential in the Ohio Valley.

However, it is exceedingly difficult to quantify freeze damage on the central and southern Plains because last year's (2006) drought-ravaged crop cannot be used

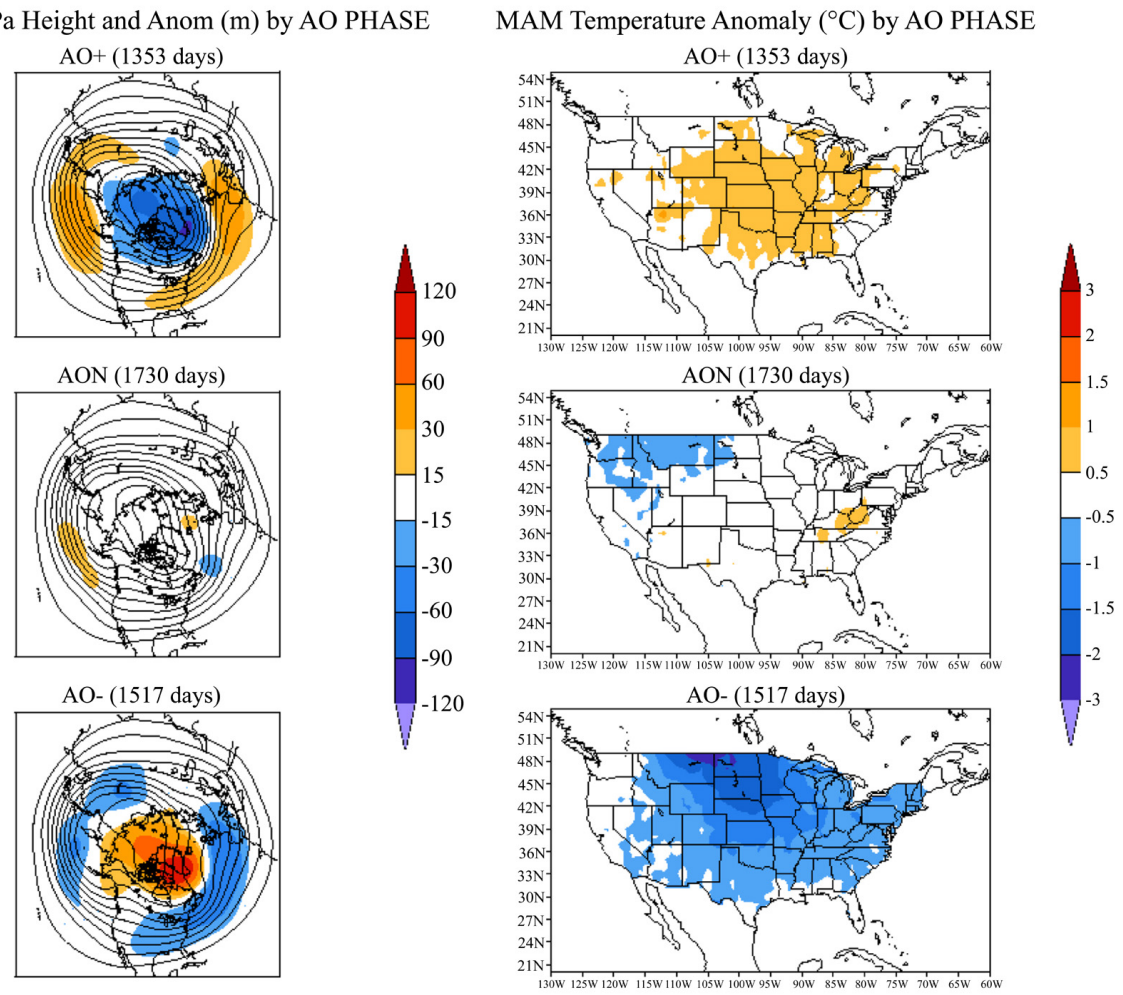


Figure 7. 500mb height pattern and anomalies, and surface temperature anomalies by phase of the Arctic Oscillation. *Source:* CPC.

as a baseline, and because there were no pre-freeze estimates of yield or production. In addition, wetness caused quality and disease problems for the Plains' maturing wheat, blurring the distinction between freeze damage and rain-related impacts.

In the absence of quantitative measures for Kansas and Oklahoma, one indicator of crop quality degradations due to the freeze (and other factors, such as unfavorable wetness and disease pressure at harvest time) is the crop condition report from USDA/National Agricultural Statistics Service (NASS). Wheat conditions at selected times—pre-freeze, post-freeze, and current—are listed in Table 4 for Kansas and Oklahoma, along with the nine-state Southern and Midwestern freeze-affected region.

In this nine-state area, the direct decline in winter wheat production from 2006 to 2007, mostly due to the April freeze, was 37.490 million bushels (Tables 5 and 6). At the preliminary 2007 winter wheat price of $6.65 per bushel, direct freeze losses reached $249.3 million.

Factoring in this year's increased acreage, the 2007 production potential—based on 2006 yields—could have reached nearly 260 million bushels. Thus, winter wheat lost to the freeze in this nine-state area potentially totaled around 66 million bushels, which at 2007 prices equates to about $439 million.

b. Corn

Emerged corn was burned back or killed in early April, depending upon the severity of the freeze and the stage of development. Newly emerged corn was the most likely to survive the freeze, with more developed plants prone to irreversible damage. Reports indicated that freeze-damaged corn was replanted, when possible, or alternate crops were planted.

Table 3. State agricultural reports from April 8, 2007, provided a partial picture of crop stages at the time of the cold snap. Five-year average refers to 2001-2006.

Winter Wheat Jointing and Heading		
State	**% Jointing**	**% Heading**
Louisiana	N/A	71
Arkansas	N/A	44
Mississippi	90	40
Georgia	91	32
Texas	N/A	16
Oklahoma	88	13
South Carolina	N/A	11
Tennessee	76	N/A
Kansas	65	N/A
Indiana	21	0
Colorado	9	0
Ohio	4	0
Nebraska	3	0
Corn Emerged		
State	**Percent**	**5-Year Average**
Mississippi	85	36
Louisiana	76	50
Texas	55	46
Arkansas	46	20
South Carolina	45	24
Tennessee	22	2
Oklahoma	19	1
Peaches Blooming or Beyond		
State	**Percent**	**5-Year Average**
Georgia	97	89
Tennessee	85	71
Apples Blooming or Beyond		
State	**Percent**	**5-Year Average**
Tennessee	62	42
Georgia	51	23

With the exception of Illinois, Indiana, Missouri and Kentucky, corn is a minor commodity in the freeze-affected states. Only Kentucky, which accounted for 1 percent of the national corn production total from 2000-2004, registers on the national scale. At the time of the freeze, corn was not yet emerged in the key Midwestern production states, however, early corn had emerged in some southern states where damage was reported and replanting was necessary.

c. Peaches

USDA's August 10 *Crop Production* report (latest available at the time of this writing) provided the latest peach production estimates (Table 7). South Carolina and Georgia traditionally have the second- and third-highest peach production totals behind California. In 2006, California accounted for 70 percent of U.S. peach production, followed by South Carolina (6 percent) and Georgia (4 percent). This year, the number two and three peach production states were New Jersey (3 percent) and Washington (2 percent). In 2007, California's share climbed to 82 percent of total U.S. peach production.

South Carolina's estimated 2007 peach production of 9,000 tons represents an 85 percent reduction from last year. At the 2006 state price of $749 per ton, this year's 51,000-ton reduction in the peach crop represents a potential loss of $38.2 million. According to USDA/NASS, South Carolina's "severe post-bloom freeze in early April destroyed much of the peach crop. Many growers reported no peaches for harvest this season. Damage was reported across the entire state, with equally severe losses reported in both of the primary growing areas."

Georgia's estimated 2007 peach production of 13,000 tons represents a 68 percent reduction from last year. At the 2006 state price of $892 per ton, this year's 28,000-ton reduction in the peach crop represents a potential loss of $25.0 million. According to USDA/NASS, "freezing temperatures [in Georgia] on April 7 and 8 severely damaged the crop, while dry spring conditions reduced fruit size. However, quality of harvested fruit has been excellent."

For the contiguous 11-state area listed above, total peach losses for 2007 (compared to 2006) reached 113,545 tons. The 2007 production of 36,245 tons represented a 76 percent decline from the previous year. These 11 states accounted for 14.8 percent of the U.S. peach production in 2006, but that number declined to 3.5 percent in 2007. Nearly 70 percent of the total tonnage losses in 2007 occurred in South Carolina and Georgia. Losses, based on 2006 prices, totaled around $63 million in South Carolina and Georgia, and around $99 million in the complete 11-state area listed above.

Table 4. USDA/NASS wheat condition in percent rated poor or very poor by state through the growing season.

Winter Wheat Rated Very Poor to Poor by USDA/NASS				
State	**April 1**	**April 22**	**June 10**	**July 8**
South Carolina	1%	50%	70%	N/A
Kentucky	5%	80%	64%	N/A
Tennessee	3%	84%	57%	N/A
Alabama	14%	36%	49%	N/A
Arkansas	6%	64%	48%	48%
Missouri	8%	64%	54%	47%
Oklahoma	8%	8%	26%	38%
Kansas	4%	41%	35%	37%
North Carolina	3%	39%	38%	35%
Illinois	9%	29%	27%	21%
Indiana	12%	30%	23%	21%
United States	6%	21%	20%	25%

Table 5. State-level winter wheat yield, 2007 estimate vs. 2006 observed.

State	2007 Winter Wheat Yield Estimate	2006 Yield	Change (2007 Minus 2006)
Tennessee	39.0 bushels per acre	64.0	-25.0 bushels per acre
S. Carolina	28.0 bushels per acre	50.0	-22.0 bushels per acre
Arkansas	40.0 bushels per acre	61.0	-21.0 bushels per acre
Kentucky	51.0 bushels per acre	71.0	-20.0 bushels per acre
N. Carolina	39.0 bushels per acre	59.0	-20.0 bushels per acre
Indiana	55.0 bushels per acre	69.0	-14.0 bushels per acre
Missouri	42.0 bushels per acre	54.0	-12.0 bushels per acre
Georgia	38.0 bushels per acre	49.0	-11.0 bushels per acre
Illinois	57.0 bushels per acre	67.0	-10.0 bushels per acre

Table 6. Nine-state (KY, TN, NC, SC, AR, IL, MO, IN, & GA) Harvest Area, Yield, and Production, 2007 vs. 2006.

2007 Harvested Area	4.155 million acres (11.2% of U.S. total)
2006 Harvested Area	3.758 million acres (12.1% of U.S. total)
Change from Last Year	Up 10.6%
2007 Yield Estimate	45.1 bushels/acre
2006 Yield Estimate	61.8 bushels/acre
Change from Last Year	Down 27.0%
2007 Production Estimate	187.390 million bu. (12.2% of U.S. total)
2006 Production Estimate	232.145 million bu. (17.9% of U.S. total)
Change from Last Year	Down 19.3%

Table 7a. South Carolina and Georgia Peach Production (in 000 tons) by year.

Year	Peach Production (in 1,000 tons)	
	South Carolina	Georgia
2005	75	40
2006	60	41
2007	9	13

Table 7b. Summarizes peach losses (in tons) of all Southeastern and Midwestern states:

State	2007 Production	2006 Production	Loss (Tons)
S. Carolina	9,000	60,000	51,000
Georgia	13,000	41,000	28,000
Illinois	1,000	11,370	10,370
Missouri	15	6,390	6,375
N. Carolina	1,000	5,630	4,630
Arkansas	100	4,200	4,100
Alabama	6,000	9,000	3,000
Virginia	2,100	4,000	1,900
Tennessee	0	1,900	1,900
West Virginia	4,000	5,200	1,200
Kentucky	30	1,100	1,070
11 States	**36,245**	**149,790**	**113,545**

Table 8. Apple production and losses (million pounds)

State	2007 Production	2006 Production	Loss
N. Carolina	50	173	123
Missouri	5	53	48
Ohio	55	102	47
Illinois	10	52.5	42.5
Indiana	30	55	25
Georgia	3	13	10
Tennessee	0.1	10	9.9
Kentucky	0.8	6.9	6.1
Iowa	1.8	6.7	4.9
S. Carolina	0.5	3.0	2.5
10 States	**156.2**	**475.1**	**318.9**

d. Apples

USDA's October 12 2007 *Crop Production* report (latest available) provided the latest apple production estimates. Substantial freeze losses were reported in ten states across the Southeast and the Midwest. Table 8 summarizes apple losses in million pounds.

Apples losses in the ten-state area totaled 318.9 million pounds in 2007, representing a 67 percent production decline from the previous year. These ten states accounted for 4.8 percent of U.S. apple production in 2006, but just 1.7 percent of the 2007 production total. Based on 2006 prices, those 318.9 million pounds of apples lost to the freeze were worth about $76 million.

e. Pecans

The October 12 2007 *Crop Production* report (latest available) indicated that freeze-induced pecan losses were confined to Arkansas, Kansas, and Missouri. In those three states, production fell from 5.3 million pounds in 2006 to 1.8 million pounds in 2007. Missouri suffered the most extensive losses, with production plummeting 99.5 percent from 1.1 million pounds to just 5,000 pounds.

f. Other Crops

Table 9 provides a state-by-state snapshot of crops rated at least 25 percent very poor to poor, in large part due to the April freeze. Crops harmed by the Southeastern drought are not included. Numbers were culled from the June 10 USDA/NASS state agricultural summaries.

Agricultural impacts were summarized from official USDA information, including the *Crop Production* report, *Crop Progress* summaries, and state reports.

Table 9. Crops rated at least 25 Percent Very Poor to Poor by USDA/NASS on June 10.

State	Commodity	VP to P
Georgia	Apples	91 percent
	Pecans	38 percent
Illinois	Red Clover	36 percent
N. Carolina	Peaches	93 percent
	Apples	80 percent
	Oats	41 percent
	Rye	34 percent
S. Carolina	Apples	70 percent
	Oats	44 percent

Disaster declarations

The USDA declared nearly **1000 counties in 24 states** disaster areas due to freezing temperatures during the first part of April (Figure 8). This means that farmers in the counties declared, and counties contiguous to those, may be eligible for low interest emergency loans from the USDA's Farm Service Agency.

For point of reference at the time of the freeze, severe to extreme drought was beginning to develop in eastern Mississippi, Tennessee, Alabama, northern Georgia and the western Carolinas. By mid-autumn, drought conditions had spread covering most of the Southeast and increased in intensity to exceptional levels.

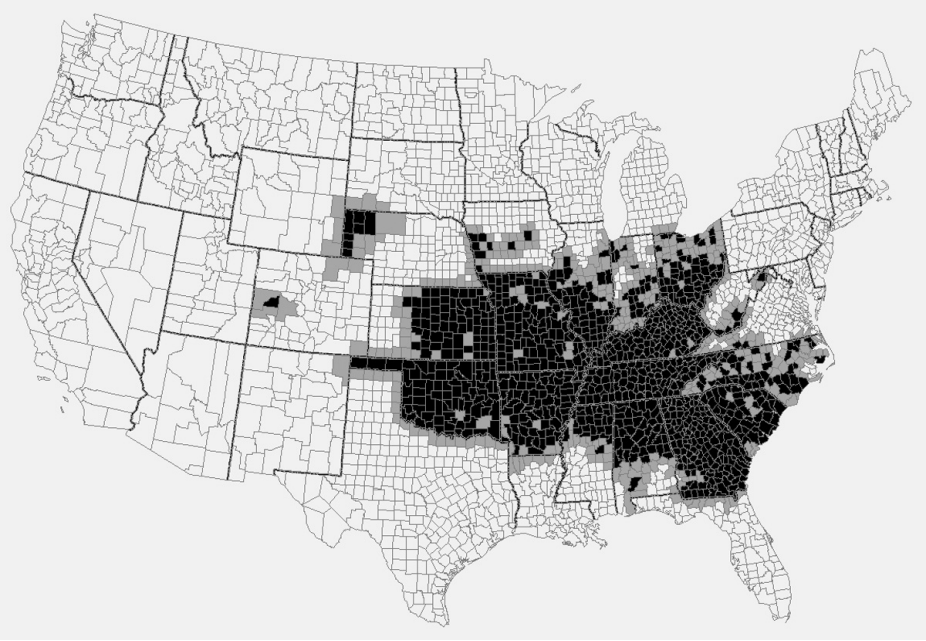


Figure 8. Counties declared disaster areas by the USDA Farm Services Agency (FSA) (in black) and counties contiguous (gray). *Source:* USDA FSA.

STATE REPORTS

Dollar losses are conservative estimates based on information available to state agricultural specialists at the time, and are subject to change. In some cases, these estimates may deviate from USDA values due to differing assumptions in making the estimates. In general, only direct losses to the freeze were included, though it can be difficult to determine and separate impacts of the freeze when other weather anomalies such as drought and flooding, and associated agronomic factors (e.g., disease, insects, market factors) have also negatively (or in some cases, positively) impacted crops and crop prices. Also, losses to the nursery industry are not comprehensive and are included only for a few states where information was available. Nationally, the nursery industry is valued at $150 billion and provides 2 million jobs, according to Ron Gelvin from the North Carolina Association of Nurserymen.

Table 10 denotes the total estimated loss by state. Details for each state follow.

Alabama

Sub-freezing temperatures in Alabama during the week of April 4-10 covered the northern and central portions of the state resulting in significant damage to fruit crops, winter wheat, and corn. Many locations dropped down into the mid-20s°F, and a few spots dipped to around 20°F. The number of hours below freezing ranged between 9 and 46 in north Alabama. Strong winds and the duration of the freeze hampered crop protection efforts in unsheltered areas.

a. Winter Wheat and corn

An estimated 50 percent of the winter wheat crop was lost due to the freeze. Assuming a $5 bushel cash price and an estimated loss of 70,000 acres producing 30 bu/acre, the yield loss is 2.1 million bushels which

Table 10. Financial loss estimates for agricultural and horticultural crops by state due to the April 4-10 freeze, in millions of dollars.

State	Losses ($millions)
Alabama	13.4
Arkansas	116
Colorado	N/A
Florida	N/A
Georgia	400
Illinois	152.4
Indiana	48
Iowa	4
Kansas	66.5
Kentucky	133.5
Mississippi	29
Missouri	400
Nebraska	N/A
North Carolina	105
Ohio	115
Oklahoma	350
South Carolina	39.3
Tennessee	50
Virginia	N/A
West Virginia	1
Total	**2023.1**

totals $10.5 million. Around 150,000 acres of corn needed replanting. At an estimated cost of $50 per acre (could range from $40-100 per acre depending on seed cost), corn replanting cost about $750,000. In some cases, alternative crops were planted instead of replanting corn. To make matters worse, farmers who replanted to corn and had no irrigation (vast majority), lost their crop to the summer-fall drought. This was aggravated by the fact that replanted corn matured later in the summer when it was just too hot and dry. Losses related to the freeze for the purpose of this report are those associated with replanting, and do not include these subsequent effects resulting from the combination and drought and late planting dates.

b. Horticultural Crops

Losses estimated for horticultural crops were based on the 5-yr yield average and the 2006 pricing, and are as follows: peaches, 80 percent loss at $6.8 million; apples, 95 percent at $760,000; blueberries, 90 percent at $520,000; blackberries, 90 percent at $74,000; plums, 60% at $48,000; and strawberries, 30 percent at $96,000. In addition to these direct yield losses, smaller fruit size was noted. Total horticultural losses are estimated at $2.178 million. Combined with wheat and corn losses, the total agricultural and horticultural loss for Alabama resulting from the freeze is estimated at **$13.4 million**.

These assessments of the impacts of the freeze were provided by Alabama Cooperative Extension Service specialists Paul Mask (wheat), Robert Goodman (economist for agronomic crops) and Deacue Fields (economist for horticultural crops) and reports from the USDA NASS.

Arkansas

Losses were widespread in Arkansas in both agricultural and horticultural crops.

a. Winter Wheat and Corn

Wheat yields were quite variable, and damage resulted based on the wheat stage of growth at the time of the freeze. In addition, nearly one-third of the corn crop needed to be replanted. Total losses in these crops are estimated at around $100 million dollars, assuming a cash price of $5 per bushel for wheat. Corn losses were estimated at $7 million dollars for replanting. Impacts to warm season pastures were also observed, but are difficult to quantify.

b. Horticultural Crops

Horticultural crops took a significant hit with about 80% of all fruit production wiped out. Apples and peaches were a total loss. Other losses include blackberries (75 percent), grapes (90 percent, including some killed to the ground), blueberries (85 percent) and pecans (20-30 percent overall, most in the north). Strawberries fared much better, especially if protected. In addition, the freeze has caused total loss of some fruit trees and increased disease susceptibility in others. Economic losses for these crops are not available.

Approximately half of the early tomato crop was lost as was some early sweet corn. Subsequent growth delays, due to the cold temperatures combined with the freeze damage, resulted in an estimated $8-10 million in losses. Total losses in Arkansas are likely to exceed **$116 million**.

These assessments of the impacts of the freeze were provided by Jason Kelley (wheat and corn), M. Elena Garcia (fruit crops), and Craig Anderson (vegetables) with the University of Arkansas Extension Service and reports from the USDA/NASS.

Colorado

Freeze damage in Colorado was limited to the West Slope (western one-third of the state) fruit growing regions. An estimated 25 percent of the fruit crop was lost (primarily peaches and apples, plus a variety of other crops as well), though economic losses were somewhat countered by higher produce prices resulting from the limited supply. Growth of wheat on the eastern plains had not advanced far enough to be susceptible to the freezing temperatures.

Florida

While spotty areas of freezing temperatures and/or frost occurred in the panhandle and northern peninsula of Florida and caused some minor damage to vegetables, no significant losses were reported by the USDA/NASS.

Georgia

Freezing temperatures during April 6-9 significantly affected Georgia agricultural production with total production value losses of $257.5 million. Greatest values of loss were reported for blueberries, peaches, and pecans. The following losses occurred: blueberries $64.9 million, peaches $28.1 million, pecans $26.9 million, small grains $19.1 million, and livestock grasses $47.8 million. The balance of production value losses are for vegetables and fruits. Total losses for reported commodities are greater than 75 percent of normal production value for peaches, blueberries, and apples. Losses are greater than 30 percent for small grains, tobacco, livestock grasses, and cantaloupes. Freezing temperatures are estimated to have contributed to losses ranging from **$368.9 million** to **$430.4 million**.

This information is from "Georgia Economic Losses Due to April 2007 Freeze," a report by Archie Flanders, John McKissick, and Tommie Shepherd of the University of Georgia College of Agricultural and Environmental Sciences Center for Agribusiness and Economic Development.

Illinois

In Illinois, March temperatures were 47.5°F, 6.4°F above normal and the sixth warmest March since statewide records began in 1895. Locations in Illinois averaged 9.1 days with temperatures at or above 70°F. The highest daily high temperatures for the month averaged 80.3°F. March statewide growing degree days (base 50°F) were 154, compared to a normal of 43 – 3.6 times higher than average. As a result, plant development was much further along than is typical for this time of year. The warmest period was from March 21 to April 3 with temperatures 15.6°F above normal and the second warmest March 21-April 3 period since 1900.

The warm temperatures in March and the first three days of April were followed by dramatically colder temperatures as a very strong cold front brought Arctic air into the region. The coldest period was from April 4-9 with temperatures averaging 14.0°F below normal and the second coldest April 4-9 period since 1900. The lowest daily low temperatures for this period averaged 20.9°F statewide. In general, the lowest low temperatures ranged from 18-20°F in northern Illinois, 18-22°F in central Illinois, and 22-24°F in southern Illinois. The cold temperatures were accompanied by windy conditions, causing strong vertical and horizontal mixing of the atmosphere. As a result, even less-exposed locations suffered damage and many traditional methods for protecting against freezes did not work. Hourly temperature records at the airport in Carbondale, Illinois, in the heart of the area most affected by the freeze, indicate that the temperature remained at or below 32°F for 47 hours between April 4-9, at or below 28°F for 25 hours, and at or below 24°F for 3 hours.

a. Wheat

The June 2007 USDA acreage and yield estimates for wheat reflect a 16.5 percent reduction in the acreage of harvested wheat with approximately 80 percent of this reduction (about 130,000 acres) due to the freeze.

The June report projected yield at 55 bushels per acre in Illinois. Given the excellent weather in 2007 until the freeze, yields could have surpassed the record 68 bu/acre yield in 2006. Assuming the yield would have been 70 bu/acre without the freeze, it is estimated that Illinois would have harvested 21.25 million more bushels than will be harvested at 55 bu/acre. At a cash price of $5 per bushel at the end of June, the estimated loss due to the freeze would be $106 million. Only when final harvest numbers are in can the final impact of the freeze be determined.

b. Corn

At the time of the freeze, corn planting in most of the state was just starting with less than one percent of the acreage planted as of the April 9 crop condition report. Some fields in southern Illinois were probably damaged and there was some replanting. Since replanting occurred early and there has been generally favorable weather, the overall impact of the freeze on corn harvest is expected to be minimal.

This assessment of the impacts of the freeze on wheat and corn was provided by Emerson Nafziger, Extension Agronomist with the University of Illinois Urbana-Champaign.

c. Fruit Crops

While the April freeze severely damaged both peach and apple crops, the peach crop was hardest hit. Approximately 80 percent of the peach crop is grown south of Interstate I-64 and experienced 100 percent losses from this event. The remaining 20 percent is grown in Calhoun County where losses were approximately 50 to 60 percent. Together this resulted in a 90 percent loss of the crop. According to the USDA, the 2005 peach crop in Illinois was valued at $13.8 million. Ninety percent of that equals $12.4 million in losses from the April freeze.

The apple crop faired somewhat better. Approximately 65 percent of the apple crop is grown south of Interstate I-64 and experienced 100 percent losses from this event. The remaining 35 percent of the apple crop is spread out across central and northern Illinois. The damage from the April freeze diminished northward. Some damage was reported in central Illinois and was on the order of 20 percent while none was reported in northern Illinois. Taken together, the apple crop loss was on the order of 70 percent. According to the USDA, the 2005 apple crop in Illinois was valued at $14.3 million. Seventy percent of that equals $10 million in losses from the April freeze.

The combined losses from the peach and apple crop equal $22.4 million. While damages in other fruit crops are likely, for example strawberries, blueberries, etc., the dollar amounts are unknown.

This assessment was based on percentage damage estimates provided by Dr. Mosbah Kushad, University of Illinois extension specialist in fruit and vegetable crops.

d. Forage Crops

According to the USDA, Illinois has 400,000 acres in alfalfa and 330,000 acres in other kinds of hay. Media reports estimated that the April freeze may have cut yields in the first cutting of alfalfa by 30 to 60 percent. Using an estimate of a normal yield of 1 ton per acre for the first cutting of alfalfa with an estimated value of $100 per ton and total acreage of 400,000, a 30 percent reduction equals a loss of $12 million while a 60 percent reduction equals a loss of $24 million. Losses to the remaining hay acreage are unknown at this time.

This assessment was based on media reports with alfalfa yields and dollar value per acre from Dr. Robert Kallenbach, University of Missouri, as cited in the estimates of losses in Missouri compiled by Pat Guinan.

On June 7, the USDA granted Illinois Governor Rod Blagojevich's request to designate 55 Illinois counties as natural disaster areas. The crops most impacted by the freeze were peaches and winter wheat. Total losses in Illinois are about **$152.4 million**.

Indiana

The timing of the cold weather that impacted Indiana crops in early April was not in itself unusual. Subfreezing temperatures are expected at this time of year, although the intensity of January-like minimums in the teens was unusual, even in northern Indiana.

The significant damage to crops occurred rather because of the unusual warmth during the preceding weeks in March. Growing degree-day accumulations before April arrived were running near 150, about three weeks ahead of schedule in most of Indiana. This March

warm period caused an early break from dormancy and encouraged advanced plant development. The more developed plants were located in southern Indiana, and it was this part of the state which suffered the greatest damage when the intense April cold arrived.

The early April freeze devastated Indiana fruit crops. Damage to wheat, hay, and vegetables was also considerable.

a. Fruit

The Indiana peach crop of about 400 acres was nearly a total loss. Its value is estimated at $750,000. About 70 percent of both grapes and blueberries were destroyed by the cold. Indiana has about 400 acres of grapes typically valued at $1.5 million and 600 acres of blueberries worth $4 million. Around one half of the 2,000 acres of apples were impacted. That loss is estimated at $3 million. Apricot and sweet cherry trees were also hard hit.

b. Wheat

The hard freeze of April 6-8 hurt wheat in far southwest Indiana the most. Yield this year is estimated to be only half of normal in that region. After the April freeze, wheat appeared to be completely flattened by the frost. In other areas of Indiana, however, the wheat damage does not appear to be widespread. It is isolated to those varieties that broke dormancy first or were within low areas of the field. Yields are down an average of 12 bu/acre and 50,000 acres planted were never harvested. Compared to 2006 yields adjusted for fewer acres planted and a $5 bushel cash price, wheat losses from the freeze are estimated at $39.5 million.

c. Hay

Hay is harvested three or four times a year. The largest yields are usually taken on the first cutting, and it was this growth that suffered large yield declines due to the early April freeze. First harvest losses ranged from 20 to 70 percent across the state. These losses played a part in the current widespread hay shortage in Indiana.

d. Vegetables

Above ground parts of plants were generally killed by the cold if they were not protected by straw or other coverings. In many types of vegetables, roots are able to generate new above ground growth and eventually produce a yield.

Total estimated losses for Indiana agriculture and horticulture are around **$48 million**.

Iowa

A period of intense cold weather prevailed across Iowa from April 3-10, 2007. Overnight low temperatures fell well below freezing every night from the 3rd-4th through the 7th-8th, with hard freezes persisting across northern and western Iowa for two additional nights. Relatively few daily record low temperature records were set during this period; however, the persistence of the cold was unprecedented for this early April time period. Daily statewide temperature averages are available for Iowa for the period from 1893 through 2007. Temperatures across Iowa for the period April 4-13, 2007 were the lowest on record during this time period, averaging 31.2ºF, or 14.6ºF below normal, and 2.2ºF colder than any previous April 4-13 time period.

Official minimum temperatures during this cold spell varied from 11ºF at Sanborn in northwest Iowa to 21ºF at the Burlington Airport in southeast Iowa (Figure 9). These temperatures are well below the thresholds required to inflict severe damage to tender vegetation. Unfortunately, these extremes were recorded for five to seven consecutive nights. Most locations across the northern two-thirds of Iowa recorded at least 40 consecutive hours with temperatures at or below freezing, while the southern third of the state endured 16 to 20 consecutive hours of freezing weather (Figure 10). These long durations of freezing weather were repeated two to three times throughout the state during this episode. Finally, wind speeds were strong throughout

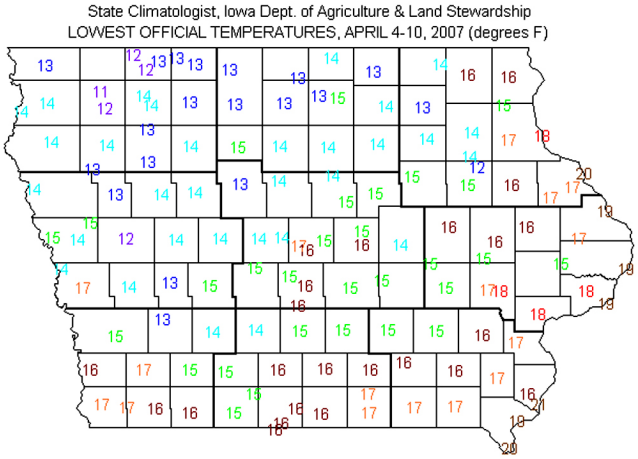


Figure 9. Lowest official temperature (°F) in Iowa. *Source:* Harry Hillaker, State Climatologist, Iowa Dept. of Agriculture and Land Stewardship.

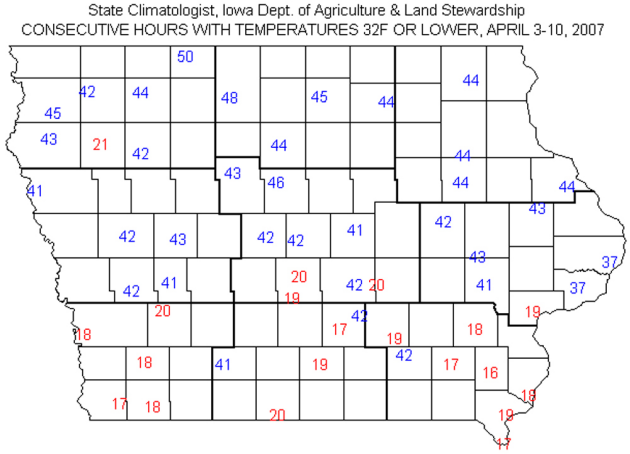


Figure 10. Consecutive hours with temperatures of 32°F or lower in Iowa from April 3-10, 2007. Hours of freezing temperatures equal to or greater than 30 in blue, less than 30 in red. *Source:* Harry Hillaker, State Climatologist, Iowa Dept. of Agriculture and Land Stewardship.

most of this cold period, thus rendering useless all of the typical freeze protection measures that depend upon light or calm winds to be effective.

Prior to this freeze event, Iowa had endured a variety of weather. The second one-half of the winter season (January 13 to March 7) had been unusually cold and snowy. This period was highlighted by perhaps the worst ice storm in Iowa's history on February 24-25 across the northeastern one-half of the state, followed by a crippling blizzard across northwest Iowa on March 1-3. However, this prolonged period of winter weather came to an abrupt end during the second week of March. Temperatures climbed above normal on March 8 and soared to 80ºF at Keosauqua by March 13 (Iowa's earliest 80ºF reading in 7 years). The final 11 days of the month each averaged at least 10ºF above normal, culminating in a high of 84ºF at Sioux City on March 26 (Iowa's highest temperature for so early in the year since 1991). Overnight low temperatures were in the lower 60s in some areas, with no freezes recorded anywhere in the state from March 24 through April 2. The ten day period of March 22 to 31 averaged 57.3ºF across Iowa, 16.7ºF above normal. A warmer late March period had only been recorded once in Iowa since daily averages became available in 1893 (60.6ºF in 1910). This very mild late March period prompted vegetation to come out of dormancy unusually early, and set the stage for the severe freeze damage of early April. Without this mild March weather, it is likely vegetation would not have developed sufficiently to have been damaged by the severe cold of early April.

Agronomic and horticultural impacts in Iowa were not as significant as Missouri and Kansas since crops had not progressed as far as locations further south, although 10 counties received a disaster declaration from the USDA. Damage was most widespread in the central and southern parts of the state. Total losses for agriculture and horticulture in Iowa are estimated around **$4 million**. Losses occurred in the first cutting of alfalfa, apples, grapes, summer raspberries and blackberries, stone fruits (peaches, plums, cherries, apricots) and onions. Strawberries that remained under mulch avoided damage. Of the horticultural crops, apples and grapes suffered the most significant impacts according to Dr. Patrick O'Malley, Iowa State Extension fruit and vegetable specialist, and account for the largest portion of monetary losses.

Kansas

Separating the damage caused by the April freeze from other weather factors has been something of a challenge in Kansas. The freeze was followed by excessive rain and flooding in many areas of the state. Here are some of the damages in major production areas directly attributable to the freeze:

a. Wheat

Two weeks after the freeze, 26 percent of the crop was reported as severely damage; 25 percent of the crop

was estimated as moderately damaged. At harvest, 1.3 million acres had been abandoned. Conservatively, a third of the acres abandoned were due to the freeze damage, with the remainder due to flooding and hail damage. Total loss in production is estimated at 13 million bushels. Given an April price point of $5 a bushel, this would result in a $65 million loss. In addition, much of the wheat in the affected area had quality issues. This presents a problem for the coming year, as availability of quality, regionally suitable seed wheat is limited. Shifts to less well adapted varieties could result in increased disease and/or pest pressure in the coming wheat season.

b. Alfalfa

Most of the first cutting was lost to freeze damage. Subsequent cuttings were lower in quantity and quality compared to average. In addition, approximately 25 percent of the acreage will either be replanted or shifted to other uses.

c. Fruit Production

Almost the entire production of apples, pears, plums, cherries and other orchard fruits was lost. Value of production lost (based on 2002 numbers) is estimated at over $1.5 million.

The total loss in Kansas is estimated at **$ 66.5 million**, not including alfalfa losses.

Kentucky

The cold weather outbreak of April 4-10, 2007 had a devastating impact on Kentucky agricultural concerns, both private and commercial. According to weather observations archived by the University of Kentucky Agricultural Weather Center, 7 weeks of above normal temperatures prior to the cold outbreak, with four to six days of very rare high temperatures in the 80s°F in March created a "biological explosion" of record early-spring growth.

The second part of this agricultural disaster was, in fact, the record cold outbreak of April 4-10. Plant and crop growth, and even field activity, had advanced to a point that was two to four weeks ahead of schedule for Kentucky. Fruit trees had advanced to the bloom stage. Wheat was advancing, and significant acres of corn had already been planted and emerged with the growing point above ground. Some damage would have occurred with even one day of frosty temperatures, but to experience four mornings with record and near-record low temperatures in the lower to mid 20s°F, and even some locations with temperatures in the teens, was well below the normal range for the state.

There is a third part to the agricultural disaster for Kentucky – and that is the long-term or residual impact to the state, especially, since dry weather conditions continued to develop during the spring months after a very difficult March and April. And while it is very difficult to put specific numbers to freeze-related losses, the losses were very real and will create impacts for months to follow.

Following are comments, damage, and cost estimates from specialists at the University of Kentucky, College of Agriculture.

a. Wheat

Estimated losses are about $63 million at this point. Those numbers: about 50 percent of the original crop has been destroyed and planted to corn or soybeans. Probably as much as 70 percent of the original crop will not make acceptable yields. The remaining 30 percent will average about 50 percent yield. These dollar losses are based on wheat grain price, acres intended for harvest and anticipated yields prior to the freeze. We have not included losses on wheat straw contracts. Many producers in Kentucky sell wheat straw for horses, houses, and construction.

b. Corn

Estimated losses are about $5 million. We estimate that about 100,000 acres of corn was replanted. The initial planting cost about $50/acre. The replanting cost another $2 million (about $20/acre). Most seed

companies provided a huge discount on replant seed. *This assessment was provided by Dr. Chad Lee, University of Kentucky extension specialist in small grains.*

c. Fruit Trees and Fruit Crops

The University of Kentucky Horticulture Research Farm in Lexington, Kentucky recorded five nights in a row with temperatures as low as 22°F - much too low for the majority of fruit crops to survive. Asian pears particularly were hit hard, as were peaches and cherries.

"The freeze killed all the flowers on the Asian pear trees, but it also caused some wood damage," reported Dr. John Strang, University of Kentucky extension specialist for fruit and vegetables. "We've pretty much lost all the peaches in the state except for a few select areas. The freeze pretty well eliminated stone fruit crops."

Strang said some varieties of raspberries will produce a partial or full crop, but most of the blackberry fruit have been lost for the year. Strawberry growers will have a partial crop. Blueberries also took a significant hit. Growers still need to maintain the fruit trees, vines, and bushes for the remainder of the season. Strang said growers may have to make tough decisions about trees with partial crops about whether or not the reduced crop is going to be worth spraying 15 to 16 times. *This assessment was provided by Dr. John Strang, University of Kentucky extension specialist for fruit and vegetables.*

John Strang, UK College of Agriculture Extension Fruit and Vegetable Specialist, investigates blackberry freeze damage at the UK Horticulture Research Farm. *Photo by Aimee Nielson*

For an estimated $20 million fruit tree and fruit crop commercial industry, damage estimates are near $16 million.

d. Grapes

Extensive damage was observed on grapevines due to the above normal temperatures in March followed by four nights of damaging low temperatures during the Easter weekend. All cultivars, regardless of heritage, suffered damage. However, the extent of damage varied with vineyard location, cultivar phenology (stage of development), species, and the level of canopy management applied by the vineyard owner.

Vineyards in northern Kentucky fared considerably better in terms of primary bud damage compared to central Kentucky vineyards, as the vines in northern Kentucky were not as advanced in phenology and were still mostly dormant. Vineyards in western Kentucky fared the best mainly due to cultivar heritage, since French-American hybrids have the highest cropping potential due to fertile secondary and latent buds.

Vineyards in the central portion of the state, where a majority of the acreage is located, suffered the most losses, as some vines had as many as four leaves unfolded and shoots longer than eight inches. Across the state, the late ripening vinifera varieties were the last to break bud, so visual damage to the vines was minimal even 2 weeks after the freeze event. However, due to the sap flow already in the conductive tissues, damage is expected irrespective of cultivars, but especially in the cultivars of vinifera. It is still difficult to estimate the extent of the damage and crop loss and put a dollar figure on it at this point.

Growers are looking at a 50-90 percent crop loss depending on what varieties they have," according to Dr. Kaan Kurtural, University of Kentucky College of Agriculture viticulturist. "It's especially disappointing for new growers - ones who got started last

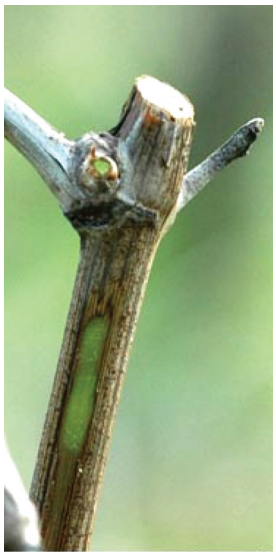
Table 11. Projected fruit and nut crop losses from the Easter freeze.

Crop	Projected Crop Loss (%)	Projected Crop Loss Range (%)
Apple	90%	60 - 100 %
Pears	100%	
Peaches	98%	0 - 100 %(One grower has a crop on 2 peach varieties)
Plums	100%	
Cherries	100%	
Pawpaws	100%	
Grapes	60%	0 - 100%
Blackberries	90%	
Raspberries	0%	
Blueberries	90% Varies by variety and area of state	
Stawberries (matted row)	50%	25 - 75%
Pecans	85%*West end of state hurt more	
Hickories	60%	
Black Walnuts	*Depends on if variety was leafed out	
Persian Walnuts	100% There is serious wood injury	
Chestnuts	*	

*** It is still very difficult to assess damage on some crops, because of variety differences, flower buds that are not visible yet and wood injury, growth vigor, and pollination effectiveness that are not readily assessable at this time.**

Table 12. Estimate of Kentucky fruit crop value - 2007.

Crop	Acres	Yield/A & Price	Gross return/A	Estimated crop value ($)	Estimated crop loss (%)	Estimated loss from freeze ($)
Apple	1000	400 bu/A @ $20.50/bu	$8,200	$8,200,000	90	$7,380,000
Peaches	500	280 bu/A @ $20.00/bu	$5,600	$2,800,000	98	$2,744,000
Pears	30	400 bu/A @ $20.00/bu	$8,000	$240,000	100	$240,000
Grapes, fruit	400	6.2 T/A @ $.50/lb	$6,200	$2,480,000	60	$1,488,000
Grapes, vine replacement						$512,000
Strawberries	210	8,000 lb @ $1.75/lb	$14,000	$2,940,000	50	$1,470,000
Blackberries	110	4,000 qt @ $2.00/qt	$8,000	$880,000	90	$792,000
Raspberries	40	4,000 lb/A @ $2.00/lb	$8,000	$320,000	0	$0
Blueberries	120	6800 pt@ $1.25=$8,500 1700 pt@ $1.50=$2,550	$11050	$1,326,000	90	$1,193,400
Other Fruit	25		$4,000	$100,000		
Total	2,435			$19,286,000		$15,819,400



Some buds on grape vines may appear alive now, but fail later this summer.
Photo by Aimee Nielson

year. They are looking at a year's loss in growth and hence bringing them into productivity later than they would've expected."

"If they had been dormant, they would have been cold hardy down to 10°F," he stressed. "Unfortunately, buds that were pushing out were only hardy down to 24°F and those that had three to four leaves were only hardy down to 28°F. The freeze killed about 50 percent of the buds and shoots the first night and the temperatures kept consistently going down."

According to Dr. Kurtural, it is still hard to put a value on the crop at this point, but conservatively he estimated just the crop loss at around $2 million for growers, including replants.

UK Viticulturalist Kaan Kurtural checks grape vines at the UK Horticulture Research Farm after the 2007 Easter Freeze. He believes it may have wiped out 50 to 90 percent of Kentucky's grape crop.
Photo by Aimee Nielson

The grape crop had a 60% projected crop loss and a projected loss range of 1-100%.

This assessment was provided by Dr. S. Kaan Kurtural, University of Kentucky extension viticulturist.

e. Tobacco

No significant impact, according to Dr. Gary Palmer, UK Tobacco Extension Specialist.

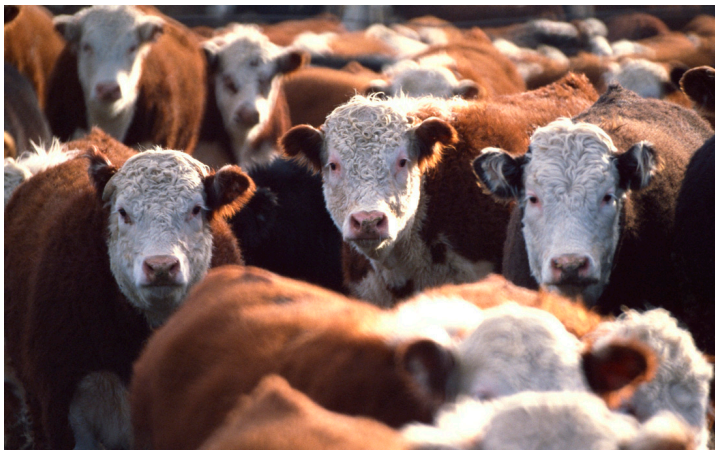
f. Forages and Pastures

Based on county reports, overall grass hay fields or grass/legume stands are producing 50 percent of normal crops, mainly due to freeze impact, but also due to dry conditions. Well managed stands (good fertility) are closer to 60 to 65 percent of normal, with "catch crop" stands (no management) producing 35 to 40 percent of normal. For most producers, the spring harvest on grass stands makes up the majority of the yield, so these reductions are significant. In the long term, the freeze does not seem to have affected grass stand persistence. Subsequent growth has been limited by dry conditions.

Alfalfa stands vary widely. Growth at the time of the freeze was up to 20 inches in the western part of the state and about 8 inches in the northeastern part of the state. All topgrowth was frozen back. Some producers in the west cut this wilted topgrowth to make a partial hay or silage crop. In short, though, spring alfalfa yields are down. There was some stand thinning in some cases. Other stands show weakened regrowth. The final impact has yet to be determined. For the most part, though, alfalfa stands are recovering and should return to normal summer production with adequate moisture.

"Conservative estimates of the impact of the abnormal spring weather on the state's hay production is $45 million. Damage from the early April freeze was severe, but yield reductions, especially for grass stands, were exacerbated by below normal rainfall throughout most of the state," according to Drs. Ray Smith and Garry Lacefield, University of Kentucky Extension Forage Specialists.

This assessment was provided by Drs. Ray Smith and Garry Lacefield, University of Kentucky extension forage specialists.



g. Livestock, including Goats

In addition to wheat damage, the freezing temperatures also limited the amount of forage available for the first cutting in hayfields and for grazing. This left many livestock producers searching for an alternative feedstuff for their animals. Cost of this impact is unknown.

There has been a high death loss in goat kids due to unseasonable cold weather during normal kidding periods, February and March. Goats are bred to kid later in the year to avoid cold weather kidding. This year many farmers were not prepared for the weather conditions. I would estimate a 12-15 percent loss due to cold weather alone. Cost: $500,000 according to Terry Hutchen, Extension Goat Specialist.

Total impact to Kentucky agriculture: **$133.5 million**.

Mississippi

Impacts of the April 2007 freeze event were both more damaging and, at the same time, less damaging as a result of unusual climate factors preceding the event. The first factor was the abnormally warm March temperatures. Statewide, March temperatures were a little over 5°F above normal. In the northern part of the state, where the freeze event was most pronounced, March temperatures averaged almost 7.5°F above normal. The second factor was that the statewide average rainfall for March was only a little over 1.5 inches, far below normal and the driest March on record in many places in the state. As a result, plant development was somewhat different than would be typical for this time of year, and freeze damage was consequently highly variable. For example, winter wheat was about two weeks ahead of schedule phenologically, and early heading stages are extremely sensitive to freezing temperatures, so wheat suffered significant damage. However, fruit was also ahead of schedule and was past the growth period during which freezing temperatures are most damaging (March 15-April 1 in Mississippi), so fruit escaped freeze damage.

The coldest period was from April 7-8 with temperatures averaging as much as 22.0°F below normal. Freezing temperatures were reported during this three-day period in about the northern one-third of the state. The lowest low temperature was 22°F at Iuka in the northeast corner of the state and Sardis Dam in the north central part of the state. Hourly temperature records indicate that the temperature remained at or below 32°F between April 7-8 for 12 hours at Tupelo, 6 hours at Memphis (representative of the northwest corner of the state), two hours at Greenville, and 11 hours at Columbus. No freezing temperatures were recorded for any length of time at or south of Jackson in the central part of the state.

a. Wheat

Before the freeze event, the wheat crop was forecast to be one of the best in recent history with 350,000 acres planted and record yield potentials of 65-70 bu/acre. Freeze injury occurred primarily north of a line from Clarksdale to Columbus (Figure 11). Damage in the freeze area varied substantially with yield reduction ranging from 10-100 percent depending upon wheat stage of development at the time of the freeze. Wheat yields in the freeze area ranged from 0-85 bu/acre, but averaged about 45 bu/acre, so average wheat yield loss was about 40 percent. Some growers chose to abandon heavily damaged wheat and benefited from earlier planted soybeans on the same fields.

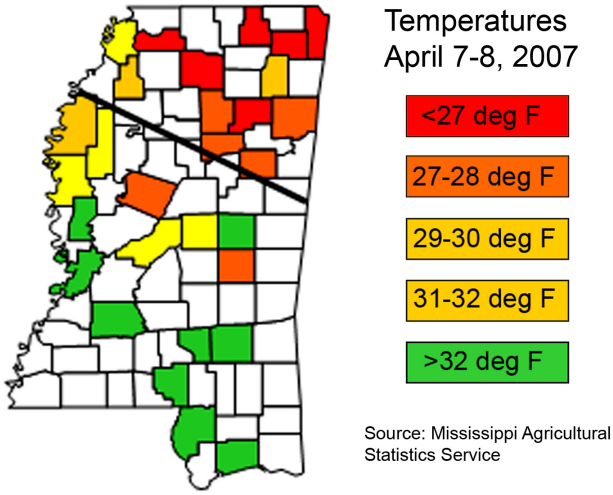


Figure 11. Lowest temperature and freeze damage axis (black) in Mississippi. *Source:* USDA Mississippi Agricultural Statistics Service.

b. Corn

Mississippi growers planted about 980,000 in corn in 2007, nearly 95 percent of which had been planted at the time of the freeze. Injury was most significant in the same zone as for wheat (Figure 11). Since the growing point of the plant was protected below the soil surface at that point in the crop's development, most plants recovered from the freeze. About 15-20 percent of the corn acreage was replanted statewide due to the late freeze. Since replanting occurred early, the overall impact of the freeze on corn harvest was minimal, with no loss documented as a result of the freeze.

This assessment of the impacts of the freeze on wheat and corn was provided by Dr. Erick Larson, Grain Crops Agronomist with Mississippi State University.

c. Fruit Crops

Damage to blueberries during the late freeze event was actually beneficial. Freeze damage thinned the bushes somewhat, allowing for larger berries on the remainder of the plants. No economic loss was reported. Tomatoes and watermelons, grown mainly in the southern part of the state did not suffer freeze damage, but production and yield was slowed by the cold temperatures that did penetrate to the southern parts of the state during the freeze event.

This assessment was based on percentage damage estimates provided by Dr. David Nagel, Extension Professor, Plant and Soil Sciences, Mississippi State University.

Wheat yield potential in Mississippi given the acreage planted and estimates above tallies 22,750,000 bu. USDA/NASS estimated a statewide yield of 18,480,000 in 2007 with some acreage not harvested. The difference of 4,270,000 bushels at $5 bu would tally an estimated loss of $21.3 million. Around 960,000 acres of corn was planted in Mississippi according to the USDA NASS. If 20% needed to be replanted at an estimated cost of $40/acre, that would total around $7.7 million. Thus total losses for Mississippi are estimated at **$29 million**.

Missouri

The record cold spell that affected all of Missouri during April 4-9, 2007 was nothing short of incredible and disastrous. The average temperature for the six-day period was 16-19°F below normal statewide. A major weather pattern shift in the form of an Arctic cold front swept through the state on April 3 and sent temperatures tumbling to record low levels for most locations, especially over Easter weekend (April 7-8).

During Easter weekend, temperatures plummeted to the mid- and upper teens over much of the state, shattering previous records. Some locations experienced their latest spring date where the mercury dipped below 20°F. For example, on Easter morning, Joplin, Missouri dropped to 19°F and tied their all time record low for the month of April. Figures 12 and 13, respectively, show the minimum temperatures that occurred statewide during this cold wave and the number of hours Columbia, Missouri was below freezing throughout the event.

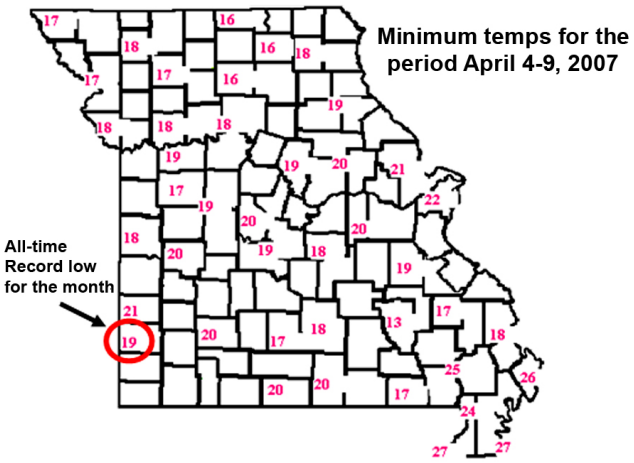


Figure 12. Minimum temperatures in Missouri for April 4-9, 2007. *Source:* Pat Guinan, State Climatologist, University of Missouri Columbia.

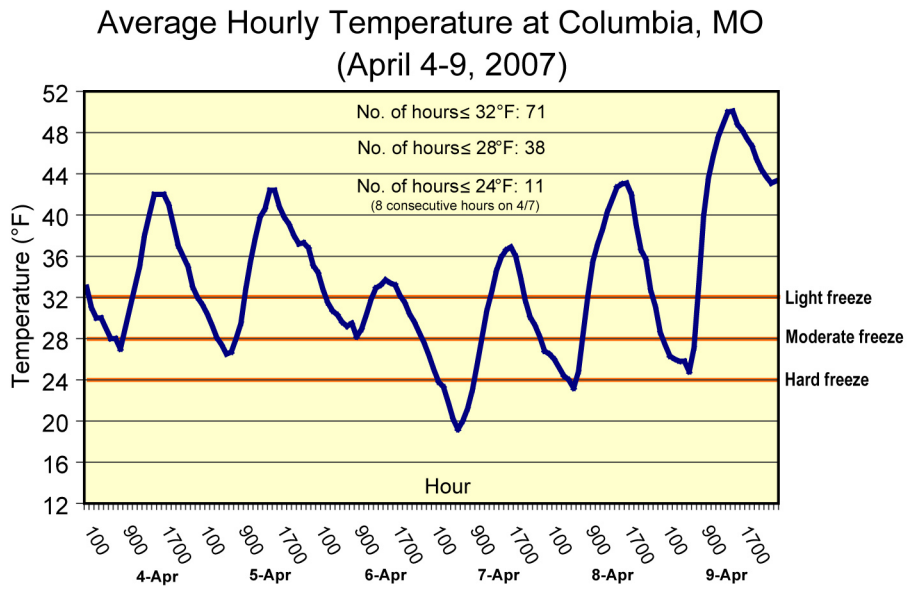


Figure 13. Average hourly temperatures and critical values at Columbia, Missouri for April 4-9, 2007. *Source:* Pat Guinan, State Climatologist, University of Missouri Columbia.

What made the situation more troubling was the unusual warm spell prior to the cold wave. Using Columbia as a midpoint for the state, Figure 14 shows the unprecedented nature of this event when the third warmest March 21-April 3 period on record abruptly transitioned to the coldest April 4-April 9 period on record. The average temperatures during the two week period of March 21-April 3 were 14-16°F above normal across Missouri and quickly spurred vegetative growth. This set the stage for a major disaster to sensitive vegetation as record cold temperatures, which had been bottled up in northern Canada and Alaska for weeks, poured southward and encompassed the eastern half of the United States.

Another harsh ingredient of the freeze event was the wind associated with it. Strong winds persisted throughout the coldest period and prevented any successful effort of mitigating freeze effects. For 39 consecutive hours, beginning 5 a.m., April 6 through 7 p.m. April 7, the average 10 ft. hourly wind speeds at Columbia ranged from 10-16 mph with gusts approaching 30 mph. During this time, the temperature remained at or below 32°F for 34 hours.

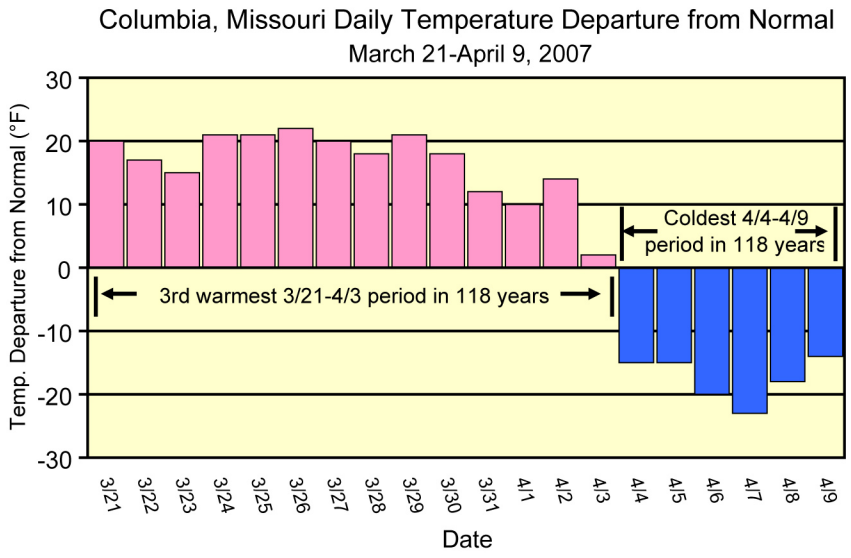


Figure 14. Temperature departure from normal for Columbia, MO for the period March 21-April 9, 2007. *Source:* Pat Guinan, State Climatologist, University of Missouri Columbia.

Unfortunately, the impacts for Missouri were widespread. It was an economic burden for agricultural producers and commercial interests, not to mention the freeze damage homeowners experienced in their yards and gardens. Cost estimates and impacts on agricultural and horticultural interests for Missouri are discussed in this report, and, are not all encompassing by any means. According to preliminary cost estimates from various agricultural and horticultural experts, the losses incurred from the April freeze exceed **$400 million** in Missouri. This estimate does not include supplementary losses experienced by small nurseries, retail garden centers, farmers markets, homeowners, etc. The Easter Freeze of 2007 will go down as an historical and memorable event for many, with lingering effects that will last indefinitely.

a. Fruit and Nut Crops

The fruit and nut crop industry was hit especially hard by the April freeze event. Many fruit and nut varieties were in bloom at the time of the freeze and particularly vulnerable to freezing temperatures. According to Dr. Michele Warmund, University of

Missouri Professor of Horticulture who specializes in fruit crops, "The only other freeze that had a greater impact was the Armistice Day Freeze of 1940 when whole fruit trees were lost due to the rapid drop in temperatures in autumn. I would say that this year was the most devastating spring freeze on both trees and small fruits." Table 13 gives Dr. Warmund's economic assessment of damage incurred on various commercial fruit and nut crops grown in Missouri.

b. Grapes

According to Dr. Keith Striegler, Director of the Institute for Continental Climate Viticulture and Enology at the University of Missouri, the freeze damage incurred by grapes in Missouri was unprecedented. The total bearing vineyard acreage for Missouri is approximately 1,300 acres, and 50-60 percent of the grapes were lost. Southern Missouri vineyards took the biggest hit and, with the exception of only a few varieties, the grape crop was wiped out. Plant damage to some grape varieties in southern Missouri will result in yield reductions for next year's crop. The average annual value of the grape crop in Missouri is approximately $4,000,000, and this year's 50-60 percent crop loss translates to about a $2,000,000 economic loss. These figures are reported as farm gate value – additional losses through reduced value-added opportunities and irreplaceable fruit will likely be incurred.

c. Forage Crops

Dr. Robert Kallenbach, Associate Professor and State Forage Extension Specialist at the University of Missouri, expressed that it is difficult to accurately assess damages for forage crops, but he was willing to give an estimate. According to Dr. Kallenbach, "There are just under 500,000 acres of alfalfa in Missouri and nearly everyone lost a significant portion of the first crop, especially in northern and central Missouri. If we assumed a 1 ton per acre yield loss (which is fairly conservative) and the hay would be valued at $100 per ton (also conservative), then losses are about $50 million."

Dr. Kallenbach also stated: "As for cool-season grasses, which comprise over 10 million acres in Missouri, I would estimate a 25 percent annual yield loss. Most of this forage is pasture for beef cattle, so it is hard to give it an exact value. However, if we estimate a half-ton per acre loss and value the forage at $50 per ton, then the losses would be in the range of $250 million."

d. Winter Wheat

Gene Danekas, Director of the Missouri Agricultural Statistics Service, provided the following synopsis on the winter wheat crop in Missouri.

Table 13. Freeze-related losses and value by crop.

Apples (90% loss) 4,000 acres X 250 bushels/acre = 1,000,000 X $12/bushel	= $12,000,000 10% survival	**= $10,800,000 loss**
Peaches (100% loss) 2,500 acres X 250 bushels/acre = 625,000 bushels X $12/bushel	= $7,500,000 0% survival	**= $7,500,000 loss**
Blueberry (95% loss) 75 acres X 10,000 pounds/acre = 750,000 lbs. X $1.50/lb	= $1,125,000 5% survival	**= $1,068,750 loss**
Blackberry (95% loss) 100 acres X 6,800 pounds/acre = 680,000 lbs. X $1.50/lb	= $1,020,000 %5 survival	**= $969,000 loss**
Strawberry (100% loss) 100 acres X 9.500 pounds/acre = 950,000 lbs. X $1.50/lb	= $1,425,000 0% survival	**= $1,425,000 loss**
Pecan (80% loss) 9.000 acres X 400 pounds/acre = 3,600,000 lbs. X $1.30/lb	= $4,680,000 20% survival	= $3,744,000 loss
	Total Loss:	= $25,506,750

"Based on our figures released on June 29, 2007, there were 1,050,000 acres of wheat planted with 850,000 acres for harvest as grain. Due to the extended wet weather after the freeze, many producers that may have chose to abandon the wheat for another crop were prevented from entering the fields for an extended period, during which time the wheat seemed to recover better than earlier anticipated. Due to the freeze, there were about 100,000 acres more abandoned than normal over the past five years. Also, our June 1 yield forecast is 42 bushels/acre, 11 bushels below the previous five year average. Assuming all this effect were due to the frost (some may have been due to the early May flooding, but not much), I would calculate the following:

"100,000 acres lost at 53 bushels/acre = 5.30 million bushels from lost acres
850,000 acres at 11 bushels/acre loss = 9.35 million bushels below normal
Total bushel potential loss = 14.65 million bushels

"A June 28, 2007 mid-Missouri cash price of approximately $5.10 per bushel equals a $74.72 million loss to potential farm gate wheat sales."

Additionally, Ann Ulmer, an economist with the University of Missouri's Commercial Agriculture Program, issued the following statements in a 2007 winter wheat condition report for Missouri that was updated on June 29, 2007:

"The *March Acreage Intentions for 2007* report released by the USDA/NASS estimated 1.05 million acres of wheat planted. Based on the number of acres planted, a historical (2000-2006) harvest rate of 89 percent of acres planted and an average yield of 53 bushels per acre, Missouri would expect to harvest 49.4 million bushels of wheat. The June 29 *Crop Release* (USDA, NASS) estimated that 850,000 acres of wheat will be harvested. Assuming a production yield of 45 bushels per acre, 38.3 million bushels of wheat will be harvested. At $5.50 per bushel Kansas City cash price, this 11.1 million bushel difference equates to an income decrease of over $61 million to Missouri producers."

e. Corn

On April 17, 2007 the Governor of Missouri requested Damage Assessment Reports from all 114 Missouri counties due to the freeze. According to these reports, the Bootheel region of southeastern Missouri was most affected by the April freeze, and thousands of acres of corn had to be replanted which resulted in significant economic losses. Costs associated with seed, fuel, labor, lower quality seed than original selections and less yield potential all contributed to the loss. Corn losses were also reported in some southwestern and central Missouri counties.

According to Greg Pfeffer, an agronomist with Pioneer, the following estimate was given for St. Genevieve county and every county south of there that raises corn in southeastern Missouri (Figure 15):

90% of the corn was planted (ca. 500,000 acres)
60-75% of this planted corn was up (ca. 300,000-375,000 acres)
2/3 of that which was up was replanted (200,000-250,000 acres)

The County Emergency Board damage assessment report from Mississippi County stated there was

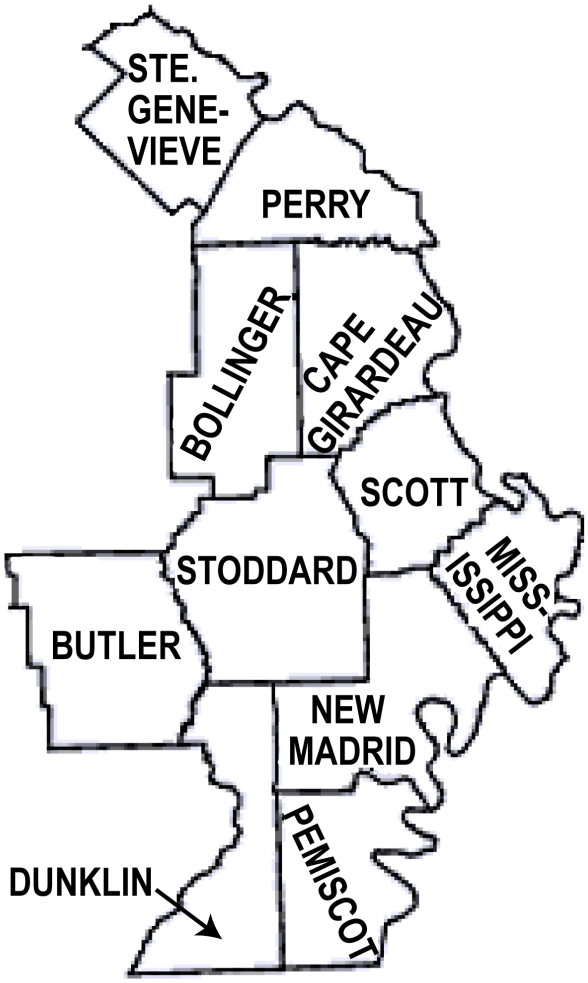


Figure 15. Counties in the Missouri Bootheel. *Source:* Pat Guinan, State Climatologist, University of Missouri Columbia.

an estimated 25 to 35 dollars per acre in expenses only for replanting. Using a $30 per acre replanting expense, and the 200,000 to 250,000 acres estimate for replanting in southeastern Missouri, translates to $6-7.5 million that was spent only for replanting in southeastern Missouri.

f. Landscape

Dr. Chris Starbuck, a University of Missouri Associate Professor in Plant Sciences, wrote an article in May on the freeze injury to landscape plants in Missouri, and the following are excerpts from his report:

"Damage to landscape plants from the Easter freeze of '07 has become increasingly evident with the return of more normal temperatures. Many trees, shrubs and herbaceous landscape plants were in full bloom, with extensive, succulent leaf and stem growth when the temperature dropped to the mid- or lower 20s over much of the state. Since flowers and new shoots have little cold tolerance, most plants exhibited brown petals and foliage. Fruit growers around the state have reported partial or total crop loss. While some species, such as river birch and redbud, sent forth new shoots to fairly quickly replace those killed by the freeze, other species were only just beginning to show signs of recovery in the last week of April. For many plants, it may be months before the extent of the damage can be accurately assessed. In some cases, there may have been severe damage to the bark or to the vascular connections to buds and stems. This may result in a gradual dieback of stems or even death of entire plants of relatively cold sensitive species like Japanese maple and butterfly bush. In some cases, plants that appear to be recovering may collapse with the first heat because of vascular damage. Stem damage may also lead to increased incidence of canker-causing diseases like fire blight and anthracnose. Given that the Easter freeze of 2007 is unprecedented, it is hard to predict the extent of damage it has inflicted on landscape plants."

Two large commercial nurseries in Missouri were adversely affected by the April freeze and the following estimates were gathered from each of the nursery stock producers:

100,000 3-gallon nursery stock containers valued at $9.50 each translates to $950,000 loss
500,000 tree seedlings at 0.30 each amounts to a $150,000 loss
A variety of seeds were lost at an estimated $250,000
Total loss: $1,350,000

The other nursery stock producer reported a loss of 37,519 trees x $8/tree = $300,152. Most of these trees were sweet cherry cultivars.

Other producers were obviously affected, including additional nurseries, retail garden centers, and farmers markets in Missouri. Homeowners with gardens and vulnerable trees, flowers, and shrubs were also affected by the freeze. The magnitude of the hard freeze is nothing short of amazing, considering all 114 counties in Missouri were affected. When including all the economic impacts of this event on agriculture and horticulture, and the far reaching impacts on communities as a whole, the April freeze will likely rank as one of the costliest natural disasters on record for Missouri.

More detailed comments from University of Missouri Extension Agronomists across the state are in Appendix C. These comments were gathered during the latter half of June when more information was available in regard to the damaging effects of the freeze on vegetation.

Nebraska

a. Wheat

Early assessments of the impacts of the freeze on the wheat crop were estimated at less than 5 percent of the total kill; that is, enough damage was done that the producer tilled the field and replanted it with another production crop (corn in most instances). There is considerable debate as to whether a majority of these fields would have come back enough to provide harvestable yields. As a result of the price of corn and the time of year, these producers decided not to wait

so that they could collect insurance and purchase corn seed from a supply stock that was exceptionally tight.

The uniqueness of this event was the following period of very moist conditions that invaded much of the Central Plains. The wheat crop was not far enough along to cause significant damage to the crowns of individual plants, thus allowing for secondary tillers to form and fill in the fields. Unfortunately, the wet conditions promoted several diseases, the worst being rust. Yield results on this year's crop show a wide range, with most fields between 20 and 60 bu/acre. The most popular variety fared the worst in terms of yield and look the brunt of the rust infestation. During the past two years, it has been the number one yielding variety averaging 60 plus bu/acre, with a few locations approaching 100 bu/acre.

In terms of monetary losses, it is difficult to estimate due to a number of factors. With the problems in Kansas and Oklahoma adding over $2.50 per bushel to the price of wheat, as well as the ongoing problems to wheat crops across the globe, marketing of this year's crop could be very lucrative, and producers will sit on some of their yield for awhile. Total projected income from this year's crop is not yet available and will not probably be released until late this fall. Initial projections are that average statewide yields could drop slightly, but the yield decline will be more than offset by the price increase. However, there is going to be a large disparity between individual producers (some with returns of over $360 per acre, others in the $120-150 range [insurance may make up for some of the yield decline]).

b. Alfalfa

Alfalfa was hit the worst. The initial estimate is a 30 percent production decline across the southern one-third of the state. Like wheat, the crop grew out of the freeze, but the leaf matter was contained at the top of the canopy with nothing underneath. Moisture also contributed to significant blight problems. Lower quality, resulting from a very high ratio of stems to leaf matter coupled with low protein content, is not what one wants if one is a milk producer. Since first cutting has the biggest yield of the cuttings, there is concern that there may not be enough high quality feed as we enter the winter season. Replacement cost for feed stock may become excessive during the second half of the winter. Across northeastern Nebraska, alfalfa yield reductions were averaging less that 15 percent, with quality rated as average. The physical distance of 150 plus miles from southern Nebraska meant that the crop was just breaking dormancy and was not affected to the extent of southern Nebraska.

c. Landscape

The most significant losses in urban areas were to Japanese Maples and a few non-native tree species. This year is a prime example of why people need to be cautious about using the newly revamped growing zone maps. They are now based on the 1990 period to present, but offer nothing in the way of determining freeze variability. It is true that trees that can safely grow in warmer zones may be suited to a more northward placement (temporary or permanent yet to be debated) according to the latest zone maps. However, they are ill suited to handle

the hard cold snaps that can occur all the way into the first part of May across the northern and central Plains, and this year was just a reminder of that fact.

North Carolina

A very strong cold front moved through North Carolina on April 4, 2007 leading to several nights of unseasonably low temperatures over Easter weekend and causing widespread damage to crops in North Carolina. The N.C. Department of Agriculture and Consumer Services and other agencies are working to determine the extent of the losses. Current estimates put crop losses at **$105 million** (Table 14). The estimates could change as farmers and agriculture officials continue to assess damage.

Table 14. Summary of freeze-related losses in North Carolina.

Commodity	Acres Affected	Total $ Lost
Corn	243,867	$15,196,127
Wheat	275,454	$13,262,897
Pasture	71,360	$303,391
Oats	10,951	$560,465
Rye	6,720	$347,520
Barley	24,770	$1,154,054
Tobacco	230	$584,022
Hay	38,487	$1,019,726
Irish Potatoes	10,048	$1,555,204
Fruit & Vegetables	21,250	$31,180,220
Crop Total	703,137	$65,163,626
Nursery	20,064	$40,069,700
Crop Grand Total	723,201	$105,233,326

North Carolina Department of Agriculture and Consumer Services Agricultural Statistics Division
Sum of counties or commodities may not add to state total due to rounding.
100 counties reporting (Preliminary Data)

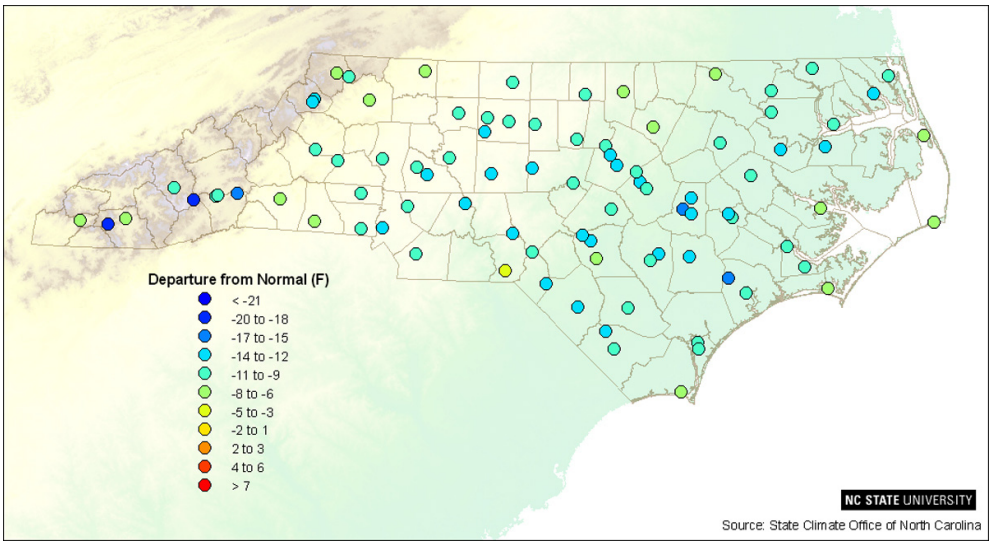


Figure 16. Departure from normal of minimum temperatures during the Easter freeze period (April 5-11, 2007) in North Carolina. The cool colors and negative values show how the minimum temperature for the entire state was below normal during this period. *Source:* Mark Brooks, State Climate Office of North Carolina.

Figure 16 displays the departure from normal of minimum temperatures during the Easter freeze period (April 5-11, 2007). The cool colors and negative values show how the minimum temperature for the entire state was below normal during this period. Figure 17 depicts the lowest observed minimum temperature for that same time period.

The U.S. Department of Agriculture has designated 47 North Carolina counties as disaster areas because of the Easter weekend freeze. The USDA also included 46 contiguous counties as part of the designation for assistance. Figures 18 and 19 denote the acreage affected and the monetary losses by county, respectively.

Ohio

The freeze of April 4-10, 2007 had a significant effect on agricultural productivity in Ohio. The impact of the freeze, however, is closely linked to a preceding extreme warm spell that took place during March and early April. Other climatic events having some effect on the net impact of the freeze include the unusual winter of 2006-2007 and a moderate summer drought that dominated through the core of the growing season. Regarding the preceding winter, December 2006 was the sixth warmest on record in Ohio (of 113 Decembers since 1895), and January was the seventeenth warmest since 1895. The following month, however, was the fourth coldest February on record. March 2007 returned to the ways of the early winter and was the 15th warmest such month on record. The core of the warm period was March 22-28 when high temperatures remained in the upper 70s and low 80s°F around the state. Overnight low temperatures remained uncomfortably high in the upper 50s to low 60s in the central and southern parts of Ohio. Perhaps significant is the fact that the northernmost portions of the state experienced winter-like air temperatures in the upper 30s and low 40s°F on the morning of the 25th, thus re-

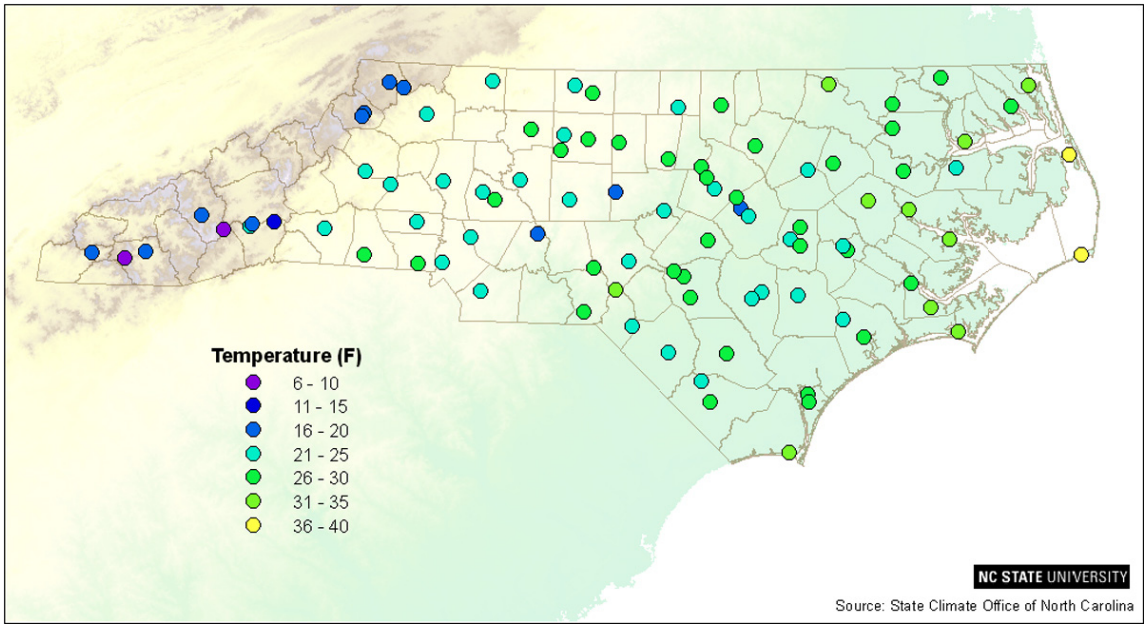


Figure 17. Lowest minimum temperature during the Easter freeze period (April 5-11, 2007) in North Carolina. *Source:* Mark Brooks, State Climate Office of North Carolina.

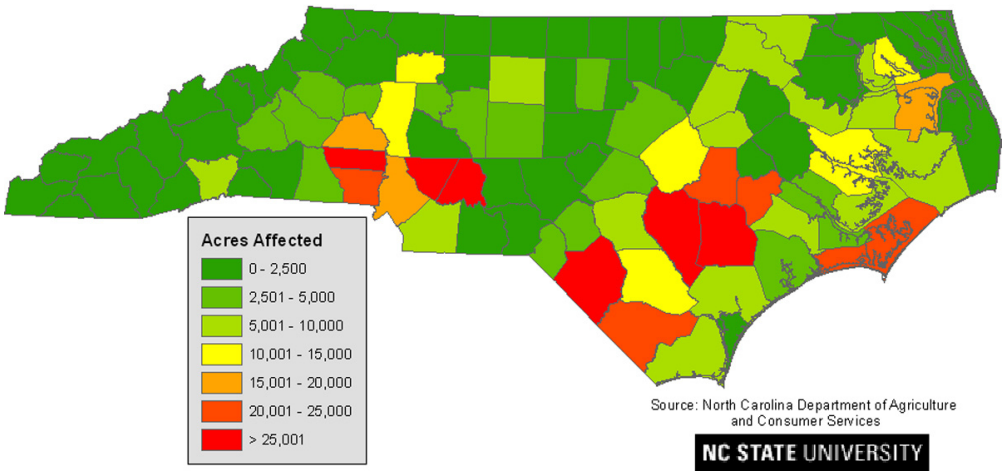


Figure 18. North Carolina acres, per county, affected by the Easter 2007 freeze. *Source:* Mark Brooks, State Climate Office of North Carolina.

straining any early greening. Daytime maxima in the north were generally in the mid-70s°F at the peak of the mild weather.

The warm March weather was followed by a hard freeze lasting seven days from April 4-10. Air temperatures stayed below freezing for four days in northern Ohio (April 5-8), and as far south as Columbus, the air stayed at or below freezing for nearly 40 hours around the coldest day (April 7). In far southern Ohio at Piketon, the high temperature on the 7th was 35°F and the overnight low was 24°F, and overnight minima were below freezing each night from April 5-10. The same applied at Cincinnati where temperatures were below freezing from April 4-10, with a minimum of 23°F on the 6th. These minimum temperatures are at, or near, record lows. Thus, while it is somewhat unusual for these cold conditions to exist in early April, it is the combination of the preceding warm spell with the hard freeze that set the stage for the agricultural damage in the state.

A brief overview of agricultural damage from the freeze and earlier weather events is given below. Outside of the forage estimates (below), extension specialists indicated that it would be very difficult to provide dollar estimates of crop losses due to the freeze. Estimates will be made in autumn, after harvests, and they will be made in conjunction with the designation on June 7,

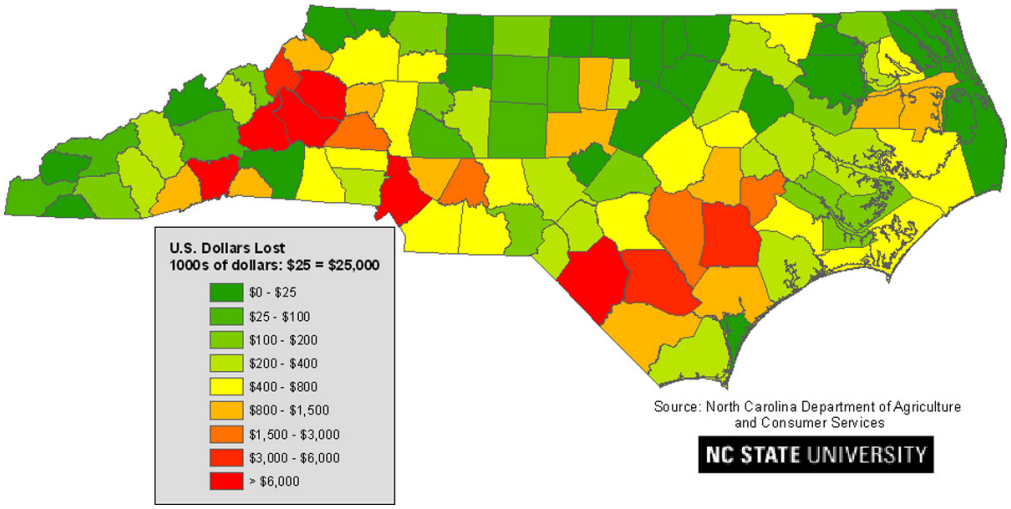


Figure 19. North Carolina dollars, per county, in crop losses because of the 2007 Easter weekend freeze. *Source:* Mark Brooks, State Climate Office of North Carolina.

2007, of all 88 Ohio counties as natural disaster areas due to losses caused by frost and freeze conditions in April. The designation permits the distribution of low-interest emergency loans from the Farm Service Agency.

a. Forage (Alfalfa Hay and Grass Hay)

Alfalfa was strongly frosted back in the southern part of Ohio, and this delayed the first alfalfa harvest by a minimum of two weeks. In the northern part of the state, alfalfa had been slower to leave dormancy and only the tips were injured. Frost damage disappeared rather quickly, and the first harvest was delayed by only a few days (less than a week). By mid-August it is expected that a reduction of at least 35 percent is expected in alfalfa production from normal and a reduction of 21 percent in grass hay. Prices of grass hay have nearly doubled from last year ($103 *vs.* $55 per ton) while those of alfalfa have risen to $160 per ton from $126 per ton. Given current year prices and total acreage, the losses for both alfalfa and grass hay are expected to be around $130 million in Ohio. Additionally, pastured cropland losses may total as much as $81 million at 2007 prices. While some of the total $211 million in forage losses are due to the April freeze, it is difficult to separate those losses from that which additionally occurred due to the very dry summer.

b. Tree Fruit

Apples in the northern one-third of Ohio were largely unaffected by the freeze, as trees were largely in dormancy and/or blossoms were little damaged. In the southern two-thirds of the state, apple growers suffered major loses or had no crop at all. Damage to the Ohio peach crop was highly variable depending on the particular microclimate of the orchard. Sites in northern Ohio are known to have survived the freeze. USDA estimates of apple loss in Ohio are $16.3 million.

c. Nursery Fruit

Damage to nursery fruits was highly variable in Ohio, often governed by the microclimate of the nursery itself. Matted row strawberries appeared to be little affected by the freeze, and conditions just preceding harvest in late spring (dryness) may have been more important. Farmers involved in investment-heavy strawberry plasticulture appear to have suffered greater investment losses, perhaps as much as 60 percent of crops in the southern part of the state. Ohio has less than 200 acres of blueberry crop, about 30 percent of which was lost in southern Ohio, while the north was largely dormant at the time of the freeze.

Bramble damage was also variable. Blackberries were largely lost in southern Ohio, while the crop was 50-70 percent of normal in the north. The summer red raspberry crop is expected to be 60 percent of normal, while fall red raspberries have been unaffected by the freeze, although the continuing drought may be an issue with these crops. Black raspberry damage was sufficient enough that southern Ohio may only get a 50 percent of normal crop, while the northern part of the state will suffer far less damage. Part of the problem with the berries is that the winter was not cold enough or long enough to harden the berry bushes.

Given the points discussed, a total estimate due to the freeze in Ohio is cautiously estimated at **$115 million**, or roughly half of the total losses estimated this season.

Information for this report has been provided by Marc Sulc, Ohio State University Forage Extension Specialist; Diane Miller, Ohio State University Extension Fruit Specialist; Matthew Kleinhenz, Horticulture/Crop Scientist, Ohio State University; Shawn Wright, Horticulturalist, Ohio State University; and Rick Borland, Ohio Farm Service Agency.

Oklahoma

The northeastern part of Oklahoma was the hardest hit by the freezing temperatures in early April, although freezing temperatures occurred at least briefly over all but the south central part of the state. Figures 20 and 21 depict the number of hours below 32°F and 24°F, respectively, which was sufficiently cold to cause significant damage to winter wheat and various horticultural crops, and minor damage to pastures and early planted corn.

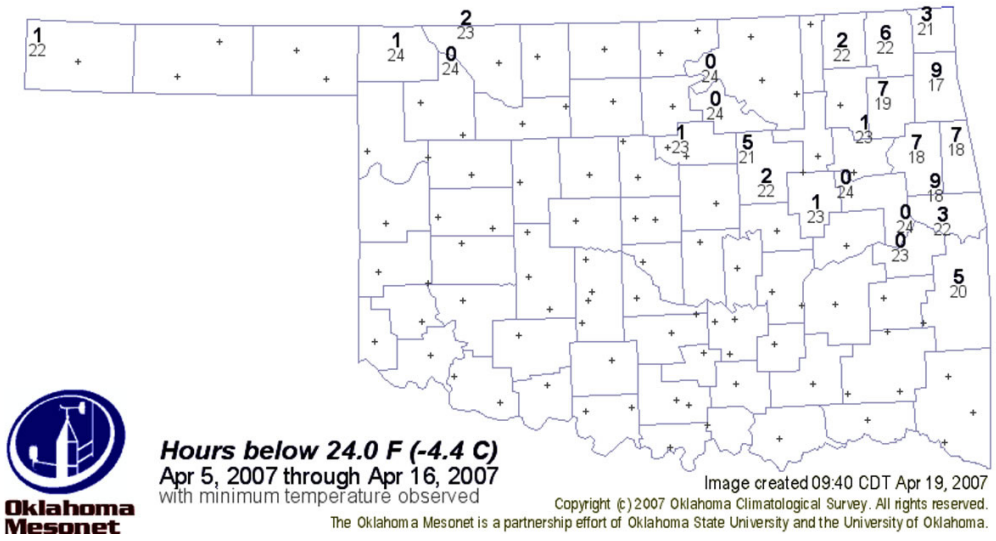


Figure 21. Number of hours below 24°F between April 5-12, 2007 in Oklahoma. *Source:* Oklahoma Climatological Survey.

Impacts to the wheat crop varied from total losses in the northeast, some loss in the central part of the state, and above normal yields in the southwest and panhandle. In addition, heavy rain caused some lodging and additional losses not related to the freeze. Thus, impacts are difficult to ascribe reliably solely to the freeze. It is estimated that one-half of the potential wheat yield in Oklahoma was not realized, which is around 70 million bushels. Assuming a $5 per bushel cash price, this would value wheat losses at $350 million.

The pecan crop was nearly a total loss in the north and northeast, and 60 percent of the grape crop was lost. There were minor losses to peaches. Some sweet corn and early beans needed to be replanted, but losses to vegetable crops were minor overall. Overall, horticulture losses in dollar value are dwarfed by the winter wheat losses; thus the Oklahoma estimate of **$350 million** is a reasonable estimate overall.

These assessments of the impacts of the freeze were provided by Oklahoma Cooperative Extension Service specialists Jeff Edwards (wheat), Eric Stafne (fruits and nuts), Lynn Brandenberger (vegetables), and reports from the USDA/NASS.

South Carolina

A cold air outbreak on April 6-10, 2007 set numerous low temperature records. Temperatures dipped well below freezing on the morning of April 8 (Figure 22). Columbia Metro Airport measured 26°F, and temperatures remained below freezing in Columbia for eight hours. The lowest temperature in the state was 17°F, recorded by an NWS cooperative observer in Pelion. The primary impact was to the state's peach orchards, which had set early blooms due to warmer than normal temperatures experienced in March. The April freeze event negatively affected the apple and winter wheat crops. As a result, the USDA designated 41 of 46 counties primary natural disaster areas.

a. Fruit Crops

South Carolina is the nation's second largest peach grower. The April freeze devastated South Carolina's peach crop. 2007 production was down 79 percent (only 18,000 pounds harvested) from 2006's 100,000,000 pound harvest worth $37,474,000. Using 2006 harvest

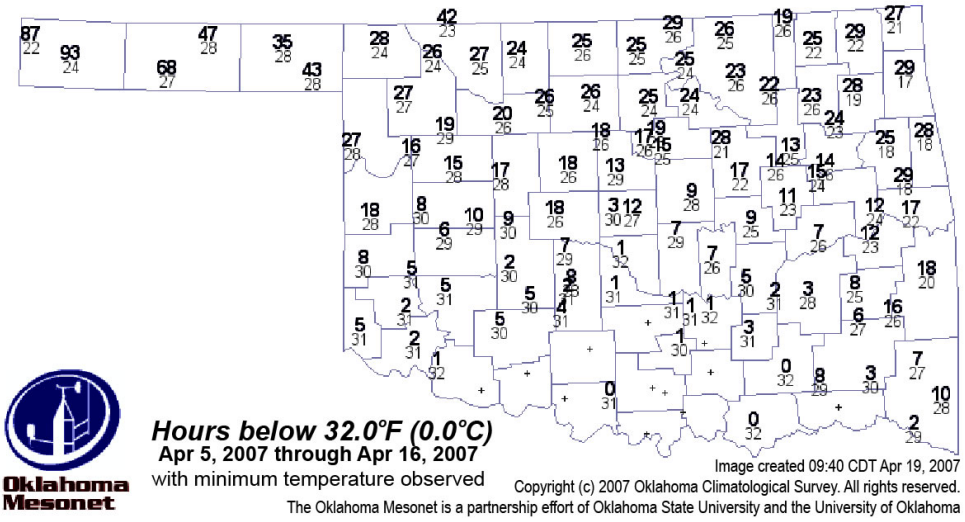


Figure 20. Number of hours below 32°F between April 5-12, 2007 in Oklahoma. *Source:* Oklahoma Climatological Survey.

prices, the April freeze event cost the South Carolina peach growers over $29 million, not including the cost of trees killed by the freeze.

South Carolina's 2007 apple harvest was only estimated to be 500,000 pounds, down about 80-90 percent compared to 2006 and previous years' harvests. The 2006 harvest was 2,400,000 pounds valued at $374,000, which would imply a loss of $300,000 this year.

b. Winter Wheat

Winter wheat yields were down 39 percent from the 2006 harvest, or nearly 2 million bushels, even though more acres were planted and harvested for 2007 than 2006. Two million bushels, assuming a cash price of $5/bushel, would total a $10 million loss.

Thus the total agricultural and horticultural related losses in South Carolina would be **$39.3 million**.

Tennessee

Freezing temperatures resulted in a total loss of fruits and vegetables in some areas, and significant losses nearly everywhere else. Approximately one-third of the wheat crop was destroyed or damaged to some extent in what one agricultural specialist described as the worst spring freeze he had ever seen.

Winter wheat in south Tennessee was totally wiped out while some grain was harvestable in other parts of the state. The early planted and early maturing varieties, which had developed the most at the time of the freeze, suffered the greatest losses. Early planted corn was also wiped out by the freeze. Around 200,000 acres of corn was replanted at about $50 acre, which tallies at $10 million. Losses for winter wheat are estimated at $30 million using a $5/bushel price.

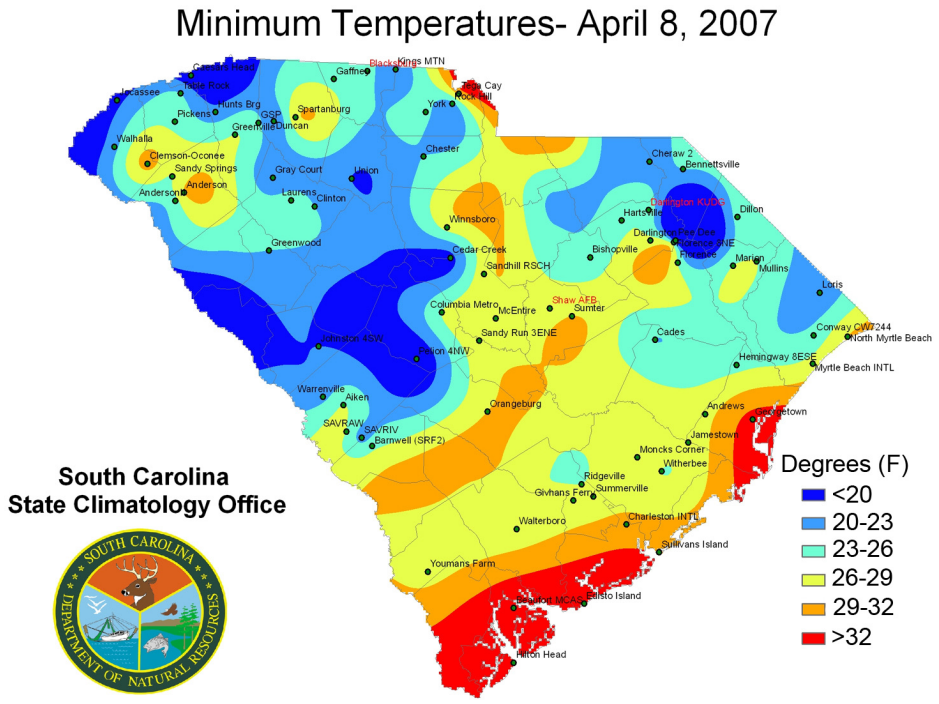


Figure 22. Analysis of observed minimum temperatures for April 8, 2007 in South Carolina. *Source:* Mark Malsick, South Carolina State Climatology Office.

Stone fruits (peaches, cherries, plums, apricots) and blueberries suffered total losses. Other losses include apples, 80 percent; grapes, 70 percent; and strawberries, 25 percent. This totals ~$13 million, not including the loss of trees/vines and next year's production. In addition, nursery peach tree growers lost 75 percent of their trees estimated at ~$7 million.

For vegetables, only minor impacts to early sweet corn and tomatoes were noted.

Total agricultural and horticultural losses for Tennessee are **$50 million**.

These assessments of the impacts of the freeze were provided by Tennessee Cooperative Extension Service specialists Chris Main (wheat), Angela Thompson (corn), Dave Lockwood (fruits and nuts, Annette Wszelaki (vegetables), and reports from the USDA/NASS.

Virginia

Temperature anomalies in Virginia ranged from 6-12°F above normal the two weeks prior to the freeze and from 5-10°F below normal during the freeze. Most areas experienced minimum temperatures in the 20s°F. The unusually warm weather prior to the freeze advanced development of some crops, making them more susceptible to the freeze. Both advective and radiational freezes occurred, and for several nights made freeze protection efforts difficult.

a. Forages and Small Grains

In general, these crops were slightly affected by the freeze, but impacts, especially in the forages, were complicated by subsequent dry weather that limited regrowth and recovery.

b. Fruit Crops

Fruit crops suffered variable losses depending on the location in the state and crop stage of development. Regional reports suggested losses as follows: Asian pears, 80-100 percent; grapes, 25 percent; apples and peaches, ~90 percent; strawberries and blueberries, 50-60 percent; and unspecified losses to cherries. For grapes, more freeze injury occurred in the central and south than in the north. Mesoscale differences in topography and siting also affected resultant damage.

Information for this state was provided by USDA/NASS and Virginia Cooperative Extension Service reports.

West Virginia

Temperatures in West Virginia in the two weeks prior to the April freeze averaged around 10-16°F above normal, helping some crops break dormancy. In contrast, temperatures during the two weeks of cold weather associated with the freeze averaged between 6 and 11°F below normal. Minimum temperatures in the mid teens to lower 20s°F were widespread across the state.

Initial reports indicated damage was widespread across the state particularly, affecting fruit crops, especially the early developing varieties. The degree of damage varied depended on the particular crop and microclimate. In the hardest hit areas, there was significant fruit loss of peaches and cherries, and substantial damage to the apple crop. Peach losses are estimated at around $0.7 million, assuming 1200 tons lost at $578/ton. Given the additional crops affected, total losses in West Virginia are estimated at around **$1 million**.

Information for this state was provided by USDA/NASS reports.

NWS Service Assessment

Climate Prediction Center Products

The 8-14-day forecast issued March 27, 2007 underforecast the amplitude of the 500mb pattern (Figure 22, top left). This resulted in only the northern quarter of the U.S. forecast to have below-normal temperatures, and called for above normal temperatures in the South (Figure 23 top center).

Figure 24 shows the 6-10 day forecast made March 29 (top row, 500mb heights, temperature anomaly, and precipitation anomaly), and the corresponding verifying data in the bottom row. This was the first CPC extended-range forecast to correctly capture the upper air height and surface temperature patterns associated with the April 4-10 cold wave.

Figure 25 depicts the U.S. Hazards Assessment also issued 30 March, 2007, three days before the Arctic air started spilling into the U.S. It largely echoes the

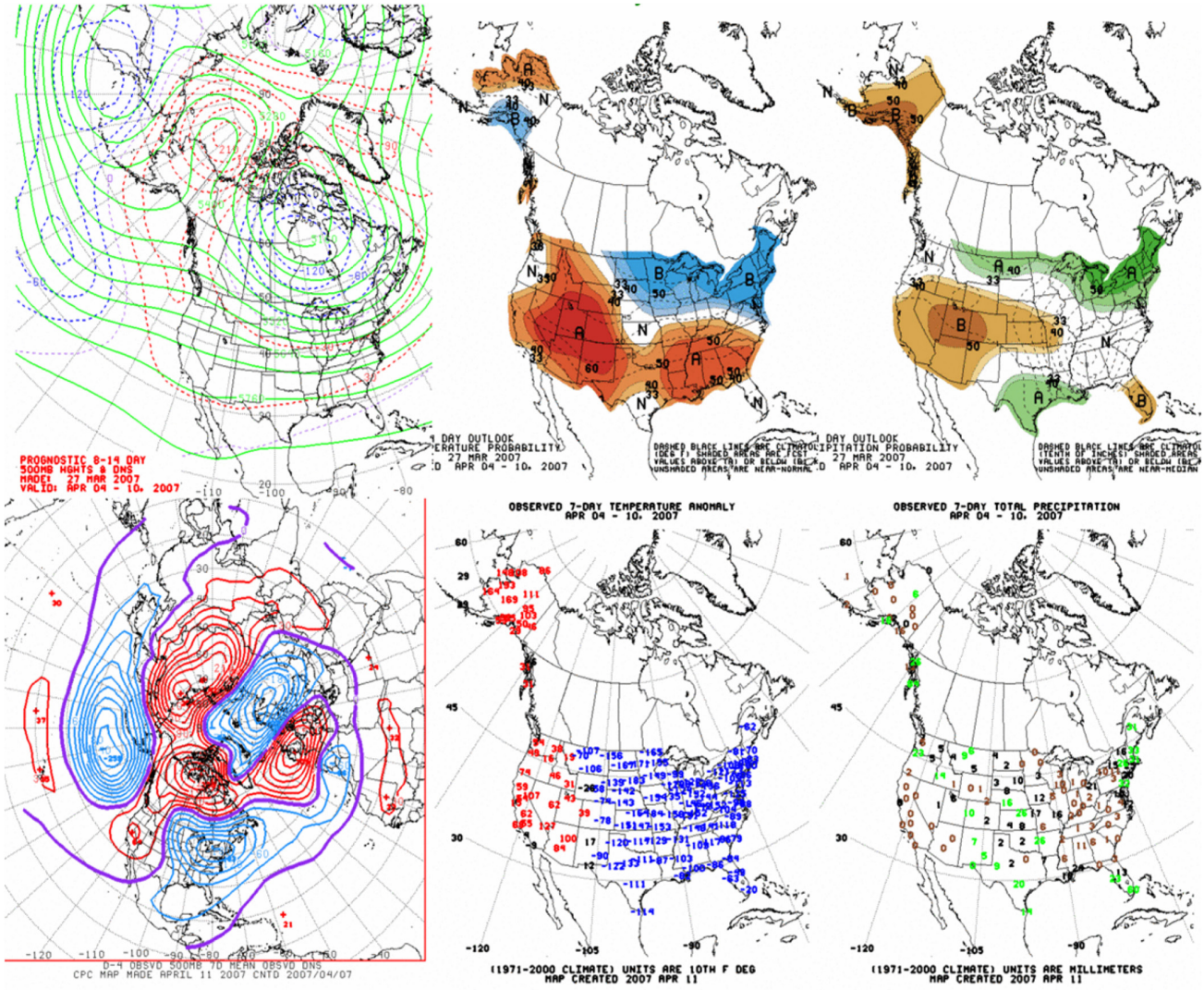


Figure 23. 8-14 day forecast issued 27 March 2007 and verifying data. Top row from right to left – forecast 500mb heights, forecast surface temperature probabilities (B=below normal, A=above normal), and forecast precipitation probabilities (B=below normal, A=above normal); bottom row – observed 500mb height anomalies and surface temperature (°F) and precipitation anomalies (mm)for the 7-day period April 4-10. *Source:* CPC.

6-10 day forecast made the same day and calls attention to the possibility of a freeze. This was the first U.S. Hazards Assessment to warn of a freeze.

National Digital Forecast Database Verification

A cursory review of temperature forecasts from the National Digital Forecast Database (NDFD) is presented. However, this aspect of the assessment is one that deserves more attention than can be afforded here. Specifically, a more thorough review of temperature verification statistics and temperature forecast techniques is recommended.

Figure 26 (a-c) depict the NDFD (top) and the Global Forecast System gridded MOS (bottom) mean absolute error of the 12UTC temperature forecast issued 6 days (a), 3 days (b), and 1 day (c) before the peak of the cold event on April 7, 2007. Forecasts were verified against the Real-time Mesoscale Analysis produced at the National Center for Environmental Prediction (NCEP). Forecasts colder than those verified are indicated by the cool colors (blue-violet), and forecasts verifying warmer are indicated by the warm colors (yellow-red). Forecasts within 1 or 2°F are indicated by the white areas.

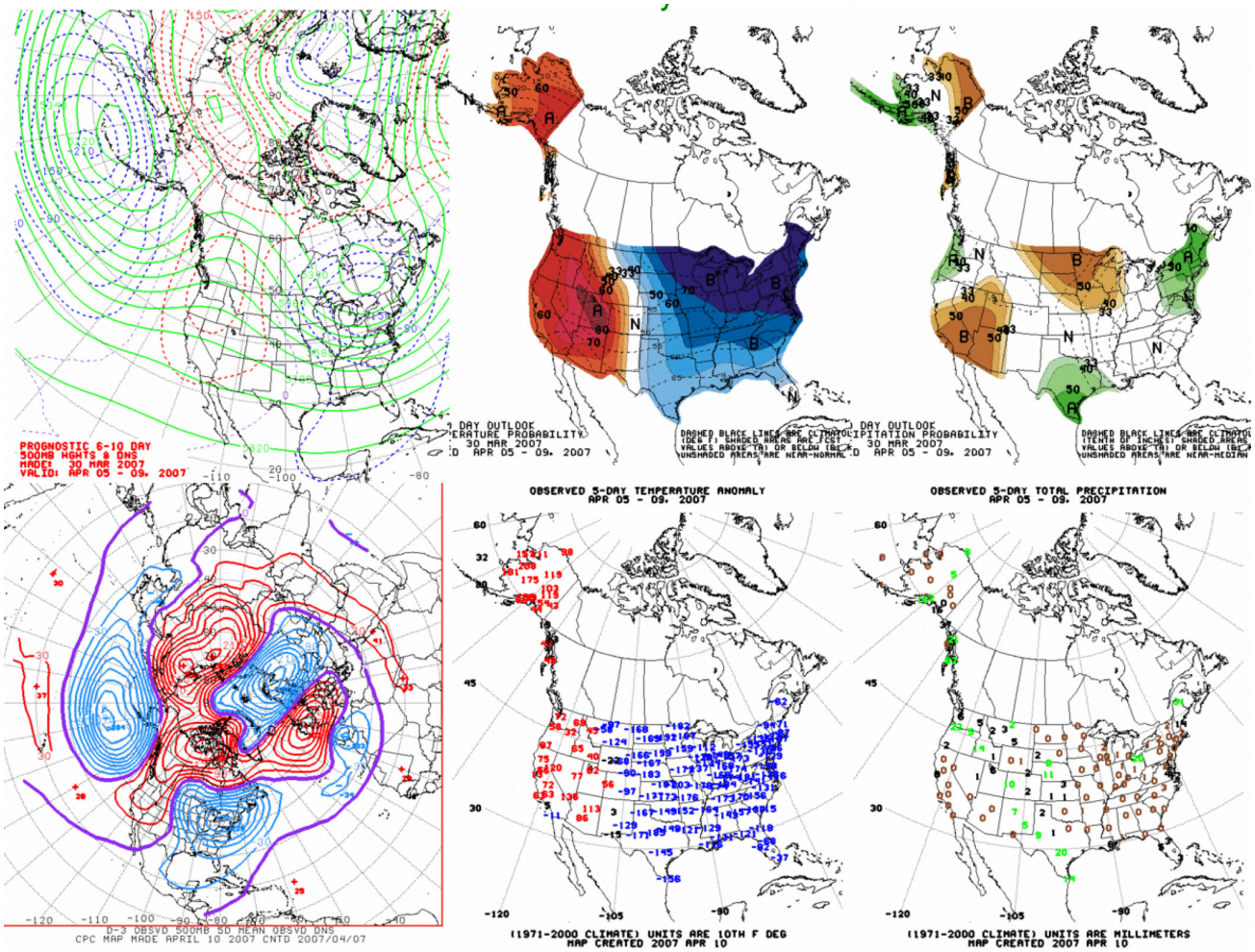


Figure 24. 6-10 day forecast issued 30 March 2007 and verifying data. Top row from right to left – forecast 500mb heights, forecast surface temperature probabilities (B=below normal, A=above normal), and forecast precipitation probabilities (B=below normal, A=above normal); bottom row – observed 500mb height anomalies and surface temperature (°F) and precipitation anomalies (mm)for the 7-day period April 4-10. *Source:* CPC.

Some general trends can be noted from these figures. First, excluding the Great Lakes region, both MOS and NDFD forecasts showed a significant warm bias over the eastern two-thirds of the nation on Day 6. By Day 3, this bias had been reduced substantially, though it appears the MOS overforecast the cold compared to NDFD from Oklahoma eastward through the Ohio River Valley. Finally on Day 1, forecast NDFD error was minimized over much of the region (excluding a cold bias along the edge of the cold air mass from the Southern Plains to the Gulf Coast). MOS error was relatively more significant in the heart of the cold air mass from Iowa southeast into the western Ohio River Valley.

Although CPC outlooks indicated the change to cold weather and freeze threat over the eastern part of the U.S. in their products issued March 29 and 30, this information did not translate into NDFD forecasts at the longer time ranges (Day 6), probably because the extent and magnitude of the cold was not forecast by the Hydrometeorological Prediction Center (HPC) or MOS. These products are used as forecast guidance by NWS Warning and Forecast Offices (WFOs) in preparing NDFD forecasts for days 4-7.

Central Region WFO Products

Twenty-one Central Region WFOs completed a survey to assess the type and quality of products and services provided prior to and during the freeze event, and to help determine Best Practice recommendations for providing a higher level of support in future freeze events. The offices surveyed are shown in Figure 27, and a copy of the survey questions is in Appendix D.

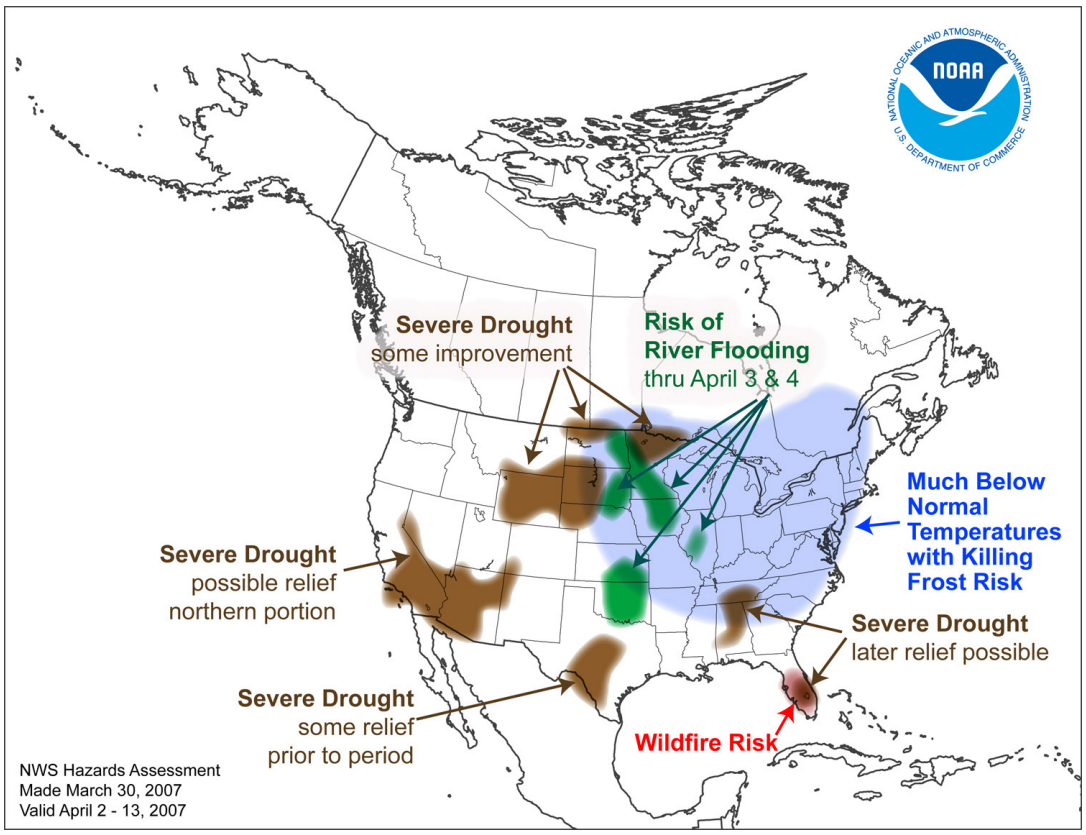


Figure 25. U.S. Hazards Assessment issued 30 March 2007. The freeze threat was noted for the northern and central Plains, the Midwest, much of the East Coast, and parts of the Southeast. *Source:* CPC.

Two-thirds of the offices surveyed mentioned the freeze threat in their Hazardous Weather Outlook (HWO) prior to the event, up to as much as 5 days in advance (Figure 28a). Offices that did not mention the threat may have thought freezing temperatures would not have any impacts given the time of year, as crops are typically not yet at a growth stage susceptible to freezing temperatures. Indeed, this freeze occurred **well** before the average last freeze date (*i.e.*, typical beginning of the growing season), especially in the northernmost offices. But as noted earlier, unusually warm March temperatures allowed crops to start developing quite early and thus become susceptible to freezing temperatures. Of the offices surveyed that did not mention the threat in their HWO, all were in the northern part of the survey area.

Nearly all (86 percent) of the offices mentioned the freeze threat in their Area Forecast Discussion (AFD) prior to the event, and the majority did so at least three days prior to the onset of freezing temperatures (Figure 28b). The AFD is aimed toward a more technical audience where it is easier to discuss forecast uncertainties compared to the HWO, perhaps a reason why more offices mentioned the threat in their AFD than the HWO.

About half (52 percent) of the offices surveyed issued a Freeze Warning prior to the event. Average lead time was 18 hours, and the Warnings verified for nearly every area issued. Again, the half of the offices that did not issue Freeze Warnings (48 percent) likely did not do so because they did not perceive a potential impact in their area. In some cases, this assumption was incorrect as the abnormally warm March temperatures allowed crop development to advance well ahead of what is typically expected in early April, thus making the crops vulnerable to freezing temperatures. Of the 10 offices that did not issue a freeze warning, 4 reported damage from the freeze.

One of the challenges faced by forecasters was the number of consecutive days of freezing temperatures. Typically when a threat is possible longer in the future (about 36 hours or so), a Watch is issued (*e.g.*, with Winter Storms). However, that has not been past

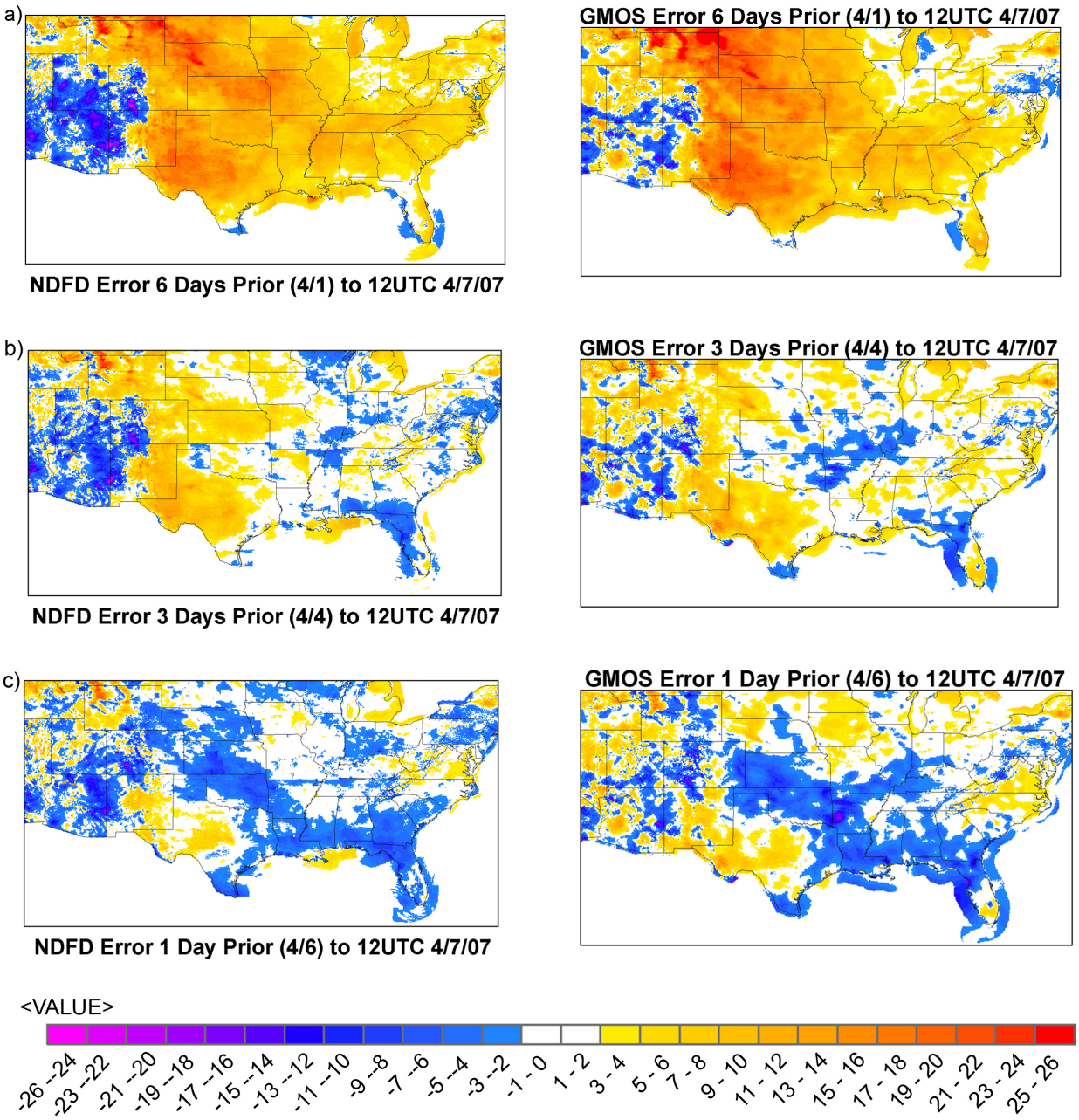


Figure 26 (a-c) depicts the NDFD (left) and the Global Forecast System gridded MOS (right) mean absolute error of the 12 UTC temperature forecast issued 6 days (a), 3 days (b), and 1-day (c) before the peak of the cold event on April 7, 2007. Forecasts colder than those verified are indicated by the cool colors (blue-violet), and forecasts verifying warmer than forecasted temperatures are indicated by the warm colors (yellow-red). Forecasts within 1 or 2°F are indicated by the white areas.

practice in WFOs for freeze events, even though NWS policy permits such a product. This was complicated by the forecasters' high degree of confidence that Warning conditions would occur a couple of days in advance. Thus, only 13 percent of the offices surveyed issued a Freeze Watch for this event.

Two survey questions focused on products and procedures that proved particularly useful or hindered efforts to provide high quality service.

1) Procedures that worked well:

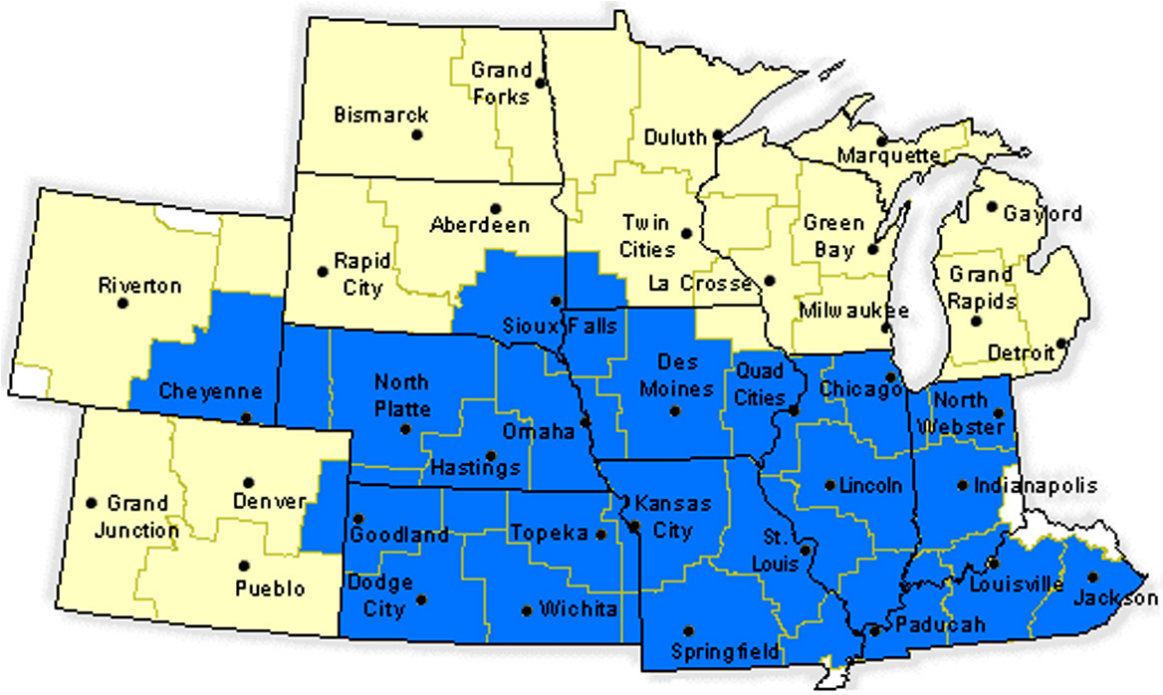


Figure 27. NWS Central Region WFOs (in blue) who participated in the survey of products and services for the April 3-10 freeze event. *Source:* NWS Central Region.

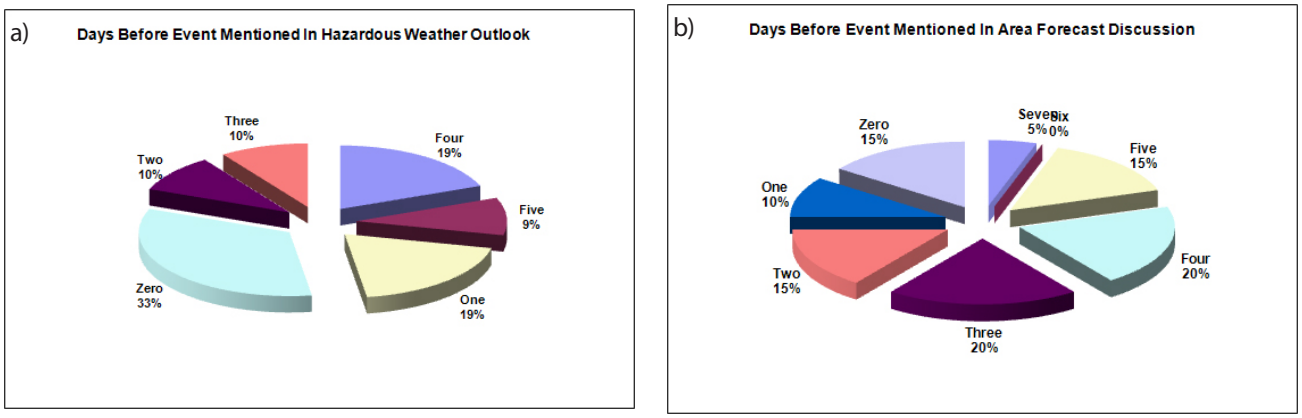


Figure 28. Number of days prior to and per cent of offices mentioning a freeze threat in their (a) Hazardous Weather Outlook and (b) Area Forecast Discussion. *Source:* NWS Central Region.

- The HWO and AFD provided useful lead time regarding the freeze threat, up to several days in advance. Special Weather Statements were also used in some cases.
- Freeze Warnings, where issued, provided significant lead time prior to the onset of freezing temperatures.
- Web stories/headlines and Top News of the Day provided "front page" coverage for our Internet users.
- Use of media interviews to highlight the forthcoming threat increased visibility.
- Coordination by a few offices with state agencies regarding the status of agricultural and horticultural crops which documented the susceptibility to freezing temperatures supported forecaster decisions to issue Freeze Warnings.
- Internal WFO preparedness on freeze products and procedures, which were determined via customer input prior to the event, led to staff issuing the ap-

propriate products at the appropriate times in line with customer needs.
- High-resolution NDFD grids (2.5km) allowed a more realistic presentation of cold temperatures in areas of complex terrain.

2) Opportunities for improvement:

- Lack of knowledge regarding crop status and susceptibility to freeze damage – too much reliance on calendar freeze dates vs. what is going on in the current growing season.
- Collaboration: (1) the challenge faced by attempting to forecast an extreme event in the day 4-7 timeframe of the forecast and forecasters' tendencies to avoid doing so; (2) issues related to overreliance on calendar dates to determine freeze threat lead to reluctance to issue Freeze Warnings.
- Confusion regarding the use of specific products, i.e., the role of the Special Weather Statement vs. the HWO and Freeze Warnings; and the use of Freeze Watch when the threat is very likely to occur more than 36 hours later. Policy guidance issued mid-event regarding Watches by Central Region further confused the issue as some offices followed the guidance and others did not.
- CPC outlooks provided slightly more than one week advance notice of the change to colder weather in the eastern U.S. and the potential for a freeze. Unfortunately, this information did not transition into Day 6 and 7 forecasts produced by HPC and WFOs.

Summary and Recommendations

Overall services provided by NWS Central Region offices during this extreme event were quite good. Information flow was excellent, with widespread and generally early use of the HWO, AFD, web page, and support from media partners all used to spread the word about the freeze. These were all common practices at the offices surveyed.

As with any event, there are lessons learned which if applied routinely in future events, can increase the quality of service as well as facilitate collaboration. These are:

1) Issuance of Freeze Warnings should be based on potential impacts to agriculture, horticulture, nurseries, and home gardens rather than calendar dates. Variable climatic conditions from year to year result in the freeze threat not necessarily occurring at the same time every fall and spring. This was acutely evident in this event.

2) Develop and utilize ties with University Extension Service specialists, state climatologists, USDA Farm Service Agencies, and other partners to: (1) determine when freezing temperatures are a threat; and (2) to gather quality, detailed post-event impact information for regional reports and event documentation (*e.g.*, StormData). A person in each office could be designated as an agricultural focal point to address points 1) and 2).

3) To insure consistency amongst offices, some policy issues need to be clarified. Specifically, the use of the Freeze Watch should be clarified, particularly for events such as this when the event is highly likely to occur more than 36 hours in advance.

4) Use of the SPS and HWO to convey essentially the same information should be addressed, as use of both these products seems redundant and potentially confusing to customers.

5) Efforts should be made to translate CPC medium-range forecast skill into NDFD Day 6 and 7 forecasts; *e.g.*, the new Hazard grids.

6) Additional efforts to review temperature verification statistics and forecast methodologies, such as the use of standardized anomalies charts and GIS-based verification, may lead to ways of improving the technical aspects of the forecast quality of this extreme event. There is an opportunity for future research to review this topic in more detail than could be addressed in this report.

APPENDIX A

Lowest Temperature Measured in the State From April 5-10, 2007

State Minimum	Station Name	Minimum
Alabama	BELLE MINA 2 N	20
Arkansas	LEAD HILL	12
Connecticut	NORFOLK 2 SW	17
Delaware	GREENWOOD 2NE	27
Florida	GLEN ST MARY 1 W	30
Georgia	MINERAL BLUFF #2	17
Georgia	MOUNTAIN CITY 2 SW	17
Illinois	JACKSONVILLE 2E	16
Indiana	MADISON SEWAGE PLANT	10
Iowa	SANBORN	11
Kansas	BURR OAK 1N	12
Kansas	HILL CITY 1E	12
Kentucky	DIX DAM	12
Louisiana	CLINTON 5 SE	29
Maine	CLAYTON LAKE	6
Maryland	OAKLAND 1 SE	17
Massachusetts	WORTHINGTON	14
Michigan	HERMAN	-11
Minnesota	EMBARRASS	-8
Mississippi	IUKA	22
Mississippi	SARDIS DAM	22
Missouri	MARYVILLE 2 E	12
Nebraska	ARTHUR	7
Nebraska	BARTLETT 4S	7
Nebraska	HERSHEY 5 SSE	7
Nebraska	VALENTINE MILLER FIELD	7
New Hampshire	MOUNT WASHINGTON	-2
New Jersey	SUSSEX 2 NE	20
New York	GLENS FALLS FARM	4
North Carolina	MT MITCHELL	1
North Dakota	BELCOURT KEYA RADIO	1
North Dakota	VELVA 3 NE	1
Ohio	CIRCLEVILLE	13
Oklahoma	UPPER SPAVINAW PORT	19
Pennsylvania	COUDERSPORT 7SE	10
Rhode Island	NORTH FOSTER 1 E	21
South Carolina	CAESARS HEAD	17
South Carolina	LAKE CITY 2 SE	17
South Carolina	PELION 4 NW	17
South Dakota	MEDICINE MOUNTAIN	-9
Tennessee	MT LECONTE	1
Texas	DELL CITY 5SSW	20
Texas	MOUNT LOCKE	20
Vermont	MOUNT MANSFIELD	8
Virginia	BURKES GARDEN	14
West Virginia	SNOWSHOE	6
Wisconsin	HURLEY	-2

APPENDIX B

Lowest Temperature Measured Within the Climate Division (CD) From April 5-10, 2007

State Minimum	CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8	CD9	CD10	Overall
Alabama	20	22	22	24	24	28	30	37			20
Arkansas	12	16	22	19	23	24	24	26	28		12
Connecticut	17	22	22								17
Delaware	28	27									27
Florida	31	30	40	35	41	43	54				30
Georgia	21	17	17	26	24	26	29	25	22		17
Illinois	17	19	17	17	20	16	20	18	20		16
Indiana	15	19	18	21	20	21	21	22	10		10
Iowa	11	13	13	12	13	15	13	14	15		11
Kansas	12	12	14	17	14	16	17	19	18		12
Kentucky	17	14	12	15							12
Louisiana	32	33	35	32	34	29	35	36	39		29
Maine	6	15	20								6
Maryland	20	30	27	21	29	22	19	17			17
Massachusetts	14	18	21								14
Michigan	-11	-2	6	5	14	15	15	12	17	11	-11
Minnesota	0	0	-8	4	2	0	2	10	13		-8
Mississippi	27	22	22	30	27	25	34	32	28	34	22
Missouri	12	16	17	14	13	25					12
Nebraska	8	7	11		8	12	7	11	11		7
New Hampshire	-2	10									-2
New Jersey	20	23	31								20
New York	14	10	12	23	4	15	17	14	10	15	4
North Carolina	1	7	21	19	21	14	21	24			1
North Dakota	3	1	5	3	3	4	4	3	2		1
Ohio	17	16	18	15	13	18	17	18	20	19	13
Oklahoma	20	22	19	25	24	20	29	31	21		19
Pennsylvania	12	24	21	22	17	13	15	15	15	10	10
Rhode Island	21										21
South Carolina	17	20	21	17	19	17	24				17
South Dakota	5	2	1	-9	4	4	6	7	8		-9
Tennessee	1	15	16	19							1
Texas	21	25	28	23	20	25	30	35	24	35	20
Vermont	8	10	13								8
Virginia	17	20	18	22	16	14					14
West Virginia	16	16	19	6	17	20					6
Wisconsin	2	-2	8	12	5	14	11	16	18		-2

APPENDIX C

Detailed comments from University of Missouri Extension Agronomists

Alix Carpenter, Northeast Region

- 80 percent loss of cherries
- 100 percent loss of apricots
- 25 percent loss of cool season grasses
- 30-35 percent loss of alfalfa

Wheat was not as severely affected by the freeze in northeast Missouri (Lewis, Marion, Monroe, Ralls, and Pike counties); I'd estimate damage in the 10-20 percent range. We have had several areas which experienced loss, but from conditions not related to the freeze (primarily grub feeding). No corn had been planted at the time of the freeze, resulting in no damage to report.

Todd Lorenz, Central Region

In addition to first cutting alfalfa, first cutting red clover was also a total loss. Red clover mixed in cool season grasses (typically fescue) was partially protected by the grass, but was still set back substantially.

Matt Herring, East Central Region

Data about crop losses in Franklin County have been limited and without a lot of scientific merit. Farmers have told me they have harvested 40-70 bushels/acre wheat which is a normal range for the county. I believe that if the wheat didn't look good by the first part of May that it was harvested for hay or simply destroyed and planted to either corn or soybean. I think the freeze had an important impact on early planted wheat, probably taking 50-70 percent of the yield in these fields. There were a few hundred acres of corn emerged during the freeze and I understand most of that was replanted. I doubt that affected yield as they were able to replant in a fairly timely fashion. Forages were negatively impacted. First cutting of alfalfa was reduced by 75-80 percent due to the freeze and an early cutting. Most of the alfalfa has recovered nicely. Cool season grass and grass/clover hay yields have been reduced by 0-50 percent - there seems to be a lot of variability in these losses. I have wondered how much yields may be reduced this year simply because fertilizer prices were high and farmers may have cut back to save money.

Richard Hoorman, East Central Region

Some farmers destroyed wheat and went to corn. Many did not due to weather issues and stage of growth concerns about getting a good kill. This information colors the wheat yields I have been hearing about. Most wheat is averaging around the upper 20 lbs/bu. I hear a lot that around 30 is the most common with a wide range of test weights. A few people are reporting low 50's with good test weight >58 lb/bu. Due to the price, I've heard that folks are OK with the yields.

Hay tonnage is down. Most common is hay, yielding only 70 percent of normal. There have been a few reports of 50 percent of normal. Most hay was not put up at the premium stage of growth due to wet weather and planting of full season beans. However, reports are that the "color" was good even if the fescue was flowering. It seems that more forage acreage is being hayed due to concerns over availability of forage later this year.Many comment that all of previous years' hay has been depleted, and that there are no reserves.

Damaged alfalfa that was clipped and sprayed in a timely fashion recovered nicely. Fields not clipped had a mixed response to the freeze damage. I had reports of slow recovery, weeds, and even evidential crown deaths. I suspect from accumulation of pest pressures. Damaged fields were planted with corn.

Pat Miller, Southwest Region

- Pecans are damaged at least 90 percent from what Bill Reid at KSU tells me.
- First wheat cut I heard made 25 bu. with test weight of 51 lbs/bu. Hay yields are 50 percent. Pas tures look bad.
- First cutting alfalfa was gone. Leaf disease because all the rain got the regrowth.
- We lost all the corn that was up - maybe 10 percent. A lot of the other corn got planted late because of the rain. We had a lot of spots where crops were drowned out, and some of that was replanted.

Ted Fry, South Central Region

- 70 percent loss each of grapes, blueberries, blackberries.
- 90 percent loss of strawberries as some were protected.
- 25 percent loss cool season grasses and fescue seed.
- My cool season veggies except for onions and peas are doing fine.
- Wheat that had higher doses of nitrogen resulted in greater losses (a normally good practice that back fired).
- Losses also incurred for oak mast production for wildlife, walnut and pecan harvest, and injury to woody ornamentals.

Mike Milam, Southeast Region

For wheat, I have seen yields mostly in the 40-60 bushel range. Last year, SE Missouri averaged 61 bushels. The guy who made 60 bushels made 100 in the same field last year. We lost about 50 acres of watermelons which were grown on plastic. The grower had to scrounge around to find enough plants to make up the shortfall. We also had damage done to pecan trees with most not producing nuts this year.

Anthony Ohmes, Southeast Region

Wheat 3 year average has been around 65 bushel in Mississippi County. Reports from various folks indicate to me the average will be around 40-45 bushels... later planted wheat faired much more than early planted. By early, I mean October wheat which is the ideal window in most years. Fortunately for this county, we did not experience as much cold (we dropped down for two days to 26) as other areas and our wheat was not as far ahead as further south as well.

Corn was planted 7 to 14 days earlier than normal with planting starting in mid-March rather than late March. Any corn planted prior to March 27 (28) had to be replanted or should have been replanted. Many sandy loam acres are typically planted starting around this time but typically come up more slowly and into progressively warmer weather, rather than coming up in 4-5 days and then experiencing a ground freeze.

All fruit was damaged... peaches gone... lost some trees, both ornamental and production.

Jeff House, Southeast Region

Wheat

- Have verified as low as 18 to as high as 66 bu/acre wheat yields.
- Solid average should be in the 45-50 bushel range, yields off 20 - 30 bushels/A consistently. The 66 bushel verification field has produced 100 bu/acre wheat before.
- Late planted fared better than early; sandy soil seemed to do better.
- Didn't see a lot of stalk freeze damage, but it was there in some fields.

Corn

As previously stated, we were 80-85 percent done with corn when the freeze hit. Anything planted before March 29-30 being a total loss, which amounts to about 70-80 percent of acres planted before the freeze. I don't have an acre figure; let's just say it was a lot.

Alfalfa

What little alfalfa we have has perked back up after a first/second cuttings. The growers that cut it IMMEDIATELY after the freeze had the best re-growth. Don't think we lost any in New Madrid County but some was definitely thinned.

Pecan

The pecan trees put out new leaves and several went ahead and flowered, but I have not looked at any for small nuts. Some trees were REALLY slow about getting new growth.

Hay

Finally got into some hay this weekend, and looks like yields are down from at least 30 percent to as much as 70 percent.

Gerald Bryan, Southeast Region

Wheat yields from damaged fields have been 15 to 40 bu. The 15 bu. was from a late planted field that looked OK--no seedhead damage, but lower stem damaged. The adjoining field was a different variety, planted at the same time (late) and yielded 40. Kernels are small with many small heads. Hay yields are 33-50 percent lower than average. Pastures are still short and never recovered. Alfalfa that was clipped or baled to remove damaged top growth recovered and made good second cutting.

APPENDIX D

WFO products and services survey for the freeze event of April 3-10, 2007

This survey is designed to gather information from each WFO regarding aspects of service provided prior to and during the freeze event of April 3-10, 2007. Early estimates indicate this event may lead to over a billion dollars in losses due to the freezing temperatures. Your participation is part of a multi-agency assessment of the impact of, and services provided for, this event. Your response by June 7 is most appreciated.

1. How many days prior to the first occurrence of freezing temperatures was this threat mentioned in the Hazardous Weather Outlook? in the Area Forecast Discussion?

2. If your office issued freeze warnings or advisories, what are the POD, FAR, and lead time for the warnings/advisories issued prior to and during the event? If your office did not issue freeze warnings (e.g., too early in the season), please note that here. Did your office utilize a Freeze Watch? (Yes/No)

3. What procedures worked particularly well for providing service during this event? This may include items such as forecast/grid techniques or procedures to dissemination methods such as a web story, press release, direct contact to stakeholders, etc.

4. What issues, if any, did you face that hampered efforts to provide service during this event?

5. What reports of damage/impacts have you received from your CWA?

6. Is there anything else you wish to add about the event?

PHOTOGRAPHY CREDITS

Cover Page/Table of Contents Collage/page 27, leaf damage:
Grant Goodge, STG, Inc., Asheville, North Carolina

Page 19:
John Strang, UK College of Agriculture Extension Fruit and Vegetable Specialist, investigates blackberry freeze damage at the UK Horticulture Research Farm: Aimee Nielson

Page 21:
UK Viticulturalist Kaan Kurtural checks grape vines at the UK Horticulture Research Farm after the 2007 Easter Freeze: Aimee Nielson

Buds on grape vines: Aimee Nielson