North Dakota Climate Bulletin

Winter 2015-16

Volume: 10 No: 1

In This Issue

NDSCO

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From the State Climatologist

The North Dakota Climate Bulletin is a digital quarterly publication of the North Dakota State Climate Office, College of Agriculture, Food Systems and Natural Resources, North Dakota State University in Fargo, North Dakota.

This winter was the 6nd warmest and 50th driest on record statewide since 1895.

The state average winter temperatures increased 0.47 °F per decade during the last 122 years which is the record highest trend in the US including Alaska. On the other hand the state average precipitation showed a very small decrease during that period. Compared historically, an average household in the state accumulated nearly 900 fewer heating degree days this winter. That is an 18% saving compared to long-term average and 12% saving compared to last year's energy usage. There were 93 statewide records broken in highest daily minimum temperature category this season. A list of records for select locations with extended station history is given in page 18. The most notable record is the 73 degrees recorded on February 27, 2016 in Bismarck.

Weather highlights in each month as well as graphical displays of statewide temperature and precipitation, plus seasonal hydrologic and climate outlooks can be found later in this bulletin.

This bulletin can be accessed at http://www.ndsu.edu/ndsco/. This website hosts other great resources for climate and weather information.

Adnan Akyüz, Ph.D.
North Dakota State Climatologist

Lake Sakakawea by Vern Whitten

Weather Highlights

Seasonal Summary:

by Daryl Ritchison

December 2015 Summary and Statistics

The mild autumn of 2015 continued into December with temperatures across the state averaging from 5° to 10° above the 30 year average. Temperatures were consistently above average for most of the month. Although precipitation finished near average overall for the state, that precipitation, mostly in the form of snow was not evenly distributed. The central and northeastern portion of North Dakota finished with above average snowfall, whereas southeastern and western North Dakota were quite dry. What precipitation did fall occurred during two main events, one on December 1 and the other on December 15-16. Although it was not an exceptionally snowy month for most locations, Grand Forks was one exception as both of those storms hit the cooperative site at UND/National Weather Service. Those two storms in combination with some minor events dropped 15.3 inches of snow during the month there which was the 12th highest December monthly total on record for that location.

The statewide average precipitation was 0.57 inches which near the 1981-2010 normal of 0.52 inches. December 2015 average precipitation ranked tied for the 41st wettest in the last 121 years with a maximum of 1.21 inches in 2008 and a minimum of 0.05 inches in 1944.

The US Drought Monitor December 29, 2015 reported 39% of North Dakota in D0 (abnormally dry) conditions and 5% in moderate drought (D1) conditions. Both areas were confined to the southern and southeastern portions of North Dakota. (http://droughtmonitor.unl.edu/)

The statewide average air temperature was 21.1 °F which is above the 1981-2010 normal of 14.0 °F. December 2015 average air temperature ranked 13th warmest in the past 121 years with a maximum of 25.4 °F in 1939 and a minimum of -3.2 °F in 1927.

NDAWN's (North Dakota Agricultural Weather Network) highest recorded daily air temperature for December was 64 °F at Dickinson, Mott, Mandan and Fort Yates, North Dakota on December 9. The lowest recorded daily air temperature was -21 °F at Rugby, ND on December 27.

The top five December daily maximum wind speeds recorded from North Dakota NDAWN stations were 46.5 mph at Linton, 46.0 at Mott, 43.4 at Watford City and 43.3 at Bowman all on December 10. The strong wind was associated with a strong "Alberta Clipper" that moved through that region that day. A strong pressure gradient in combination with a low level jet on the back side of that low created the high wind. NDAWN wind speeds are measured at a height of 10 feet (3 m).

January 2016 Summary and Statistics

January is climatologically the second driest month in North Dakota with the state averaging just 0.49 inches of precipitation and most of North Dakota recorded well below average precipitation (snowfall) during the month. The one exception was associated with a narrow, yet heavy band of snow that fell just to the west and north of Fargo during the overnight hours of January 6 and 7. Harwood, ND recorded over 12 inches of snow from that system with others from Leonard, ND to Mahnomen, MN recording similar amounts. Because of the mesoscale nature of the heavy snow most locations 20 miles or farther away from that band recorded little if any snowfall that night. That event was followed by a blast of Arctic air that lingered for a stretch of about two weeks of well below normal temperatures including a couple of mornings with lows in the -30s near Fargo in the same area that recorded the abundant snowfall previously mentioned. Through January 25 average temperatures across the state were near or even below average, yet, the last week of the month was so mild, that the month average temperature did end up finishingn anywhere from 2° to 5° above normal.

The state average precipitation was 0.22 inches which is below the 1981-2010 normal state average of 0.49 inches. January 2016 state average precipitation ranked the 15th driest in the past 122 years with a maximum of 1.27 inches in 1916 and a minimum of 0.09 inches in 1942 and 1973.

The US Drought Monitor January 26, 2016 reported 25% of North Dakota in D0 (abnormally dry) conditions and 4% in D1 (Moderate Drought). Those areas were confined to the eastern and southeastern portion of North Dakota. (http://droughtmonitor.unl.edu/)

The state average air temperature was 14.6 °F which is above the 1981-2010 normal of 10.6 °F. January 2016 state average air temperature ranked the 24th warmest in the past 122 years with a maximum of 25.9 °F in 2006 and a minimum of -11.9 °F in 1950.

At the North Dakota NDAWN stations the highest recorded daily air temperature for January was 51 °F at Beach, ND on January 28. The lowest recorded daily air temperature was -32 °F at Leonard, ND on January 10.

The top five January daily maximum wind speeds recorded from North Dakota NDAWN were 53 mph at Hofflund, 52 mph at Berthold, 50 mph at Crosby, 49 mph at Turtle Lake and 48 mph at McHenry on January 27. NDAWN wind speeds are measured at a height of 10 feet (3 m).

February 2016 Summary and Statistics

February completed climatological winter the way it started with temperatures averaging above normal. Temperatures ranged from 5 to 8 degrees above average across much of North Dakota. With the exception of a few days in the first one-half of the month the 29 days of February were mostly above average. The warmest day was on February 27, when the NDAWN station in Fort Yates recorded a maximum of 72°. Although the Mandan NDAWN station reached 68° as did the Bismarck cooperative site (Weather Service Office), the Bismarck airport sensor recorded a maximum temperature of 73° that day which would be a new state record for the month. There were no widespread heavy rain or snow storms, but a narrow band of 2 to 5 inches of snow fell in northwestern North Dakota on February 14. Plus, the cooperative observer in Bottineau had five days with 2 inches of snow or more leading to a monthly total of 14.1 inches which is well above the average of 5.5 inches for that location

The state average precipitation was 0.43 inches which is right at the 1981-2010 normal of 0.44 inches. February 2016 state average precipitation ranked 52nd wettest in the past 122 years with a maximum of 1.59 inches in 1998 and a minimum of 0.07 inches in 1934.

The US Drought Monitor December 1, 2015 reported 68% of North Dakota in D0 (abnormally dry) conditions and 4% in D1 (moderate drought) which was spread over much of the state with the exception of the northeastern corner of North Dakota. (http://droughtmonitor.unl.edu/)

The state average air temperature was 25.8 °F which is above the 1981-2010 average of 15.7 °F. February 2016 state average air temperature ranked the 6th warmest in the past 122 years with a maximum of 29.6 °F in 1954 and a minimum of -14.1 °F in 1936.

The highest recorded daily air temperature at North Dakota NDAWN stations was 72 degrees at Fort Yates, February 27, which was the warmest February maximum in the 25 years that NDAWN has existed. The lowest recorded daily air temperature was -23 °F at Michigan on February 13.

The top five November daily maximum wind speeds recorded from North Dakota NDAWN stations were Mandan at 60 mph on February 7, Bowman wat 59 mph on February 6, Linton with 57 mph on February 7, Mandan with 56 mph on February 6 and Watford City with 56 mph on February 19. NDAWN wind speeds are measured at a height of 10 feet (3 m).

Winter 2015-16 Summary

According to the National Centers for Environmental Information (NCEI), climatological winter of 2015-2016 had a statewide average temperature of 20.5 degrees. That is 7.0 degrees above the 1981-2010 average temperature 13.5 degrees. That would rank the season as tied for the 6th warmest in the past 121 years. It was the warmest winter since 2011-2012 and besides that winter, the only other winters since 1895 that were warmer were in order of warmest to coolest; 1986-1987, 1930-1931, 1991-1992, 2011-2012, 1997-1998. It should be noted with the exception of 2011-2012, the other four warmest winter seasons in North Dakota were years with an El Ninõ present in the Pacific Ocean as was the case during this past winter as well.

The three month statewide average rainfall according to NCEI was 1.22 inches. That is 0.20 inches below the 1981-2019 average of 1.42 inches. That would rank as the 50th driest since such records started to be calculated in 1895. In other words, the winter of 2015-2016 was perceived as a dry season but actually finished close to normal across much of the state.

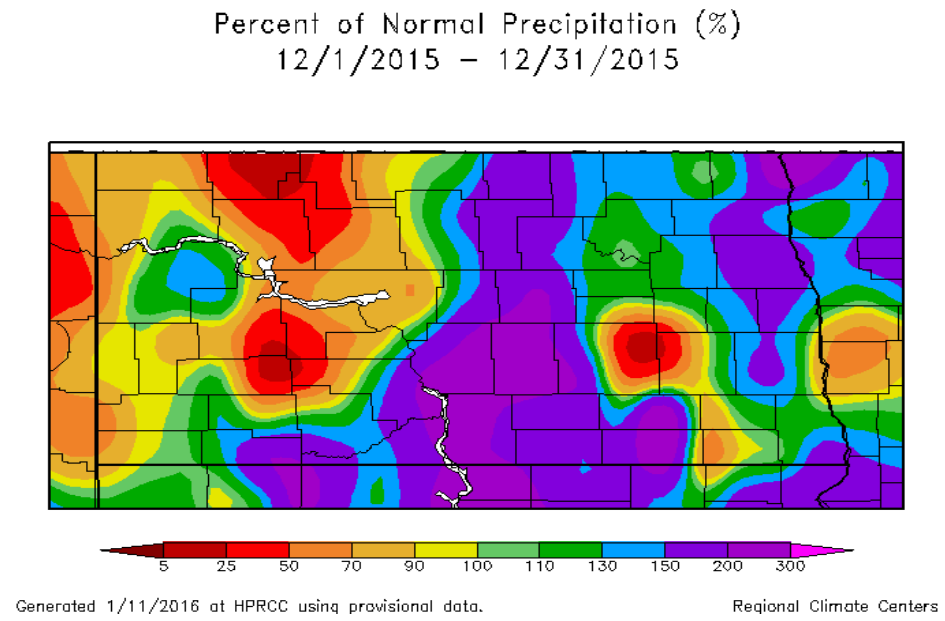
Season in Graphics

Winter 2015-16 Weather in North Dakota:

December 2015

Total Precipitation percent of mean (1981-2010)

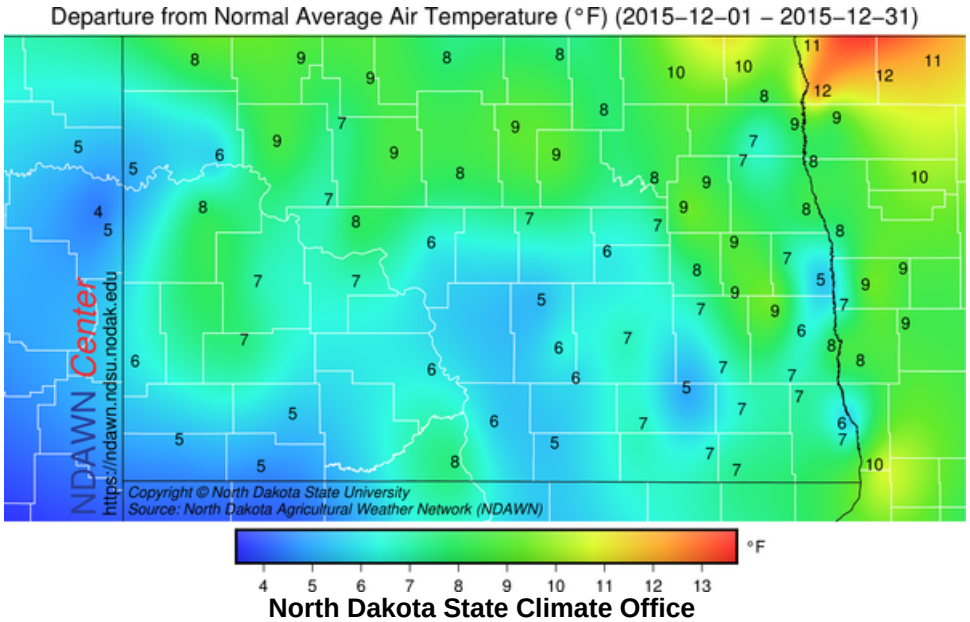
Precipitation Percent of Normal
(Data from High Plains Regional Climate Center (HPRCC))



North Dakota State Climate Office

Average Temperature (°F) Deviation from Mean (1981-2010)

Departure From Normal Monthly
Average Air Temperature in degrees F
(Data from North Dakota Agricultural Weather Network (NDAWN))



North Dakota State Climate Office

Season in Graphics

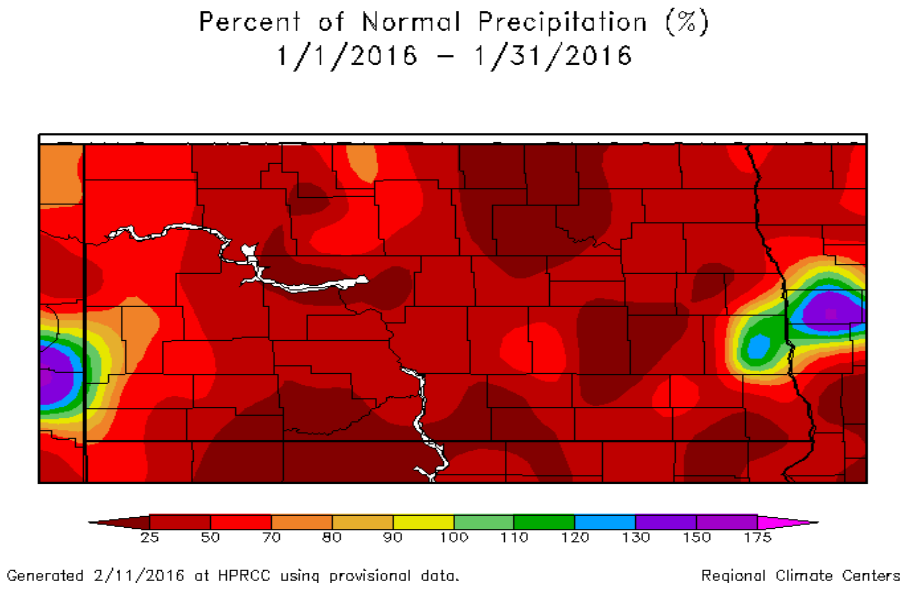
Winter 2015-16 Weather in North Dakota:

January 2016

Total Precipitation percent of mean (1981-2010)

Precipitation Percent of Normal

(Data from High Plains Regional Climate Center (HPRCC))

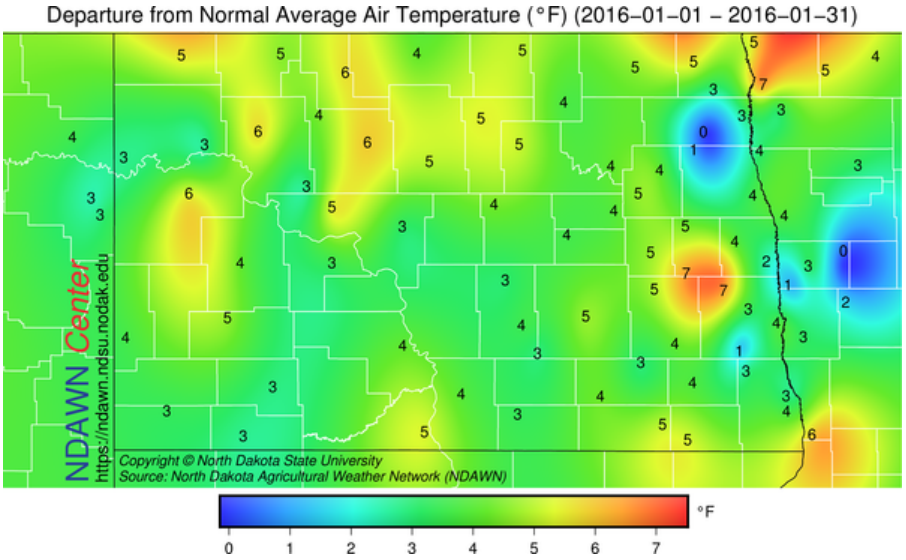


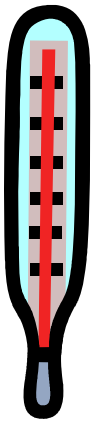
North Dakota State Climate Office

Average Temperature (°F) Deviation from Mean (1981-2010)

Departure From Normal Monthly
Average Air Temperature in degrees F

(Data from North Dakota Agricultural Weather Network (NDAWN))





North Dakota State Climate Office

Season in Graphics

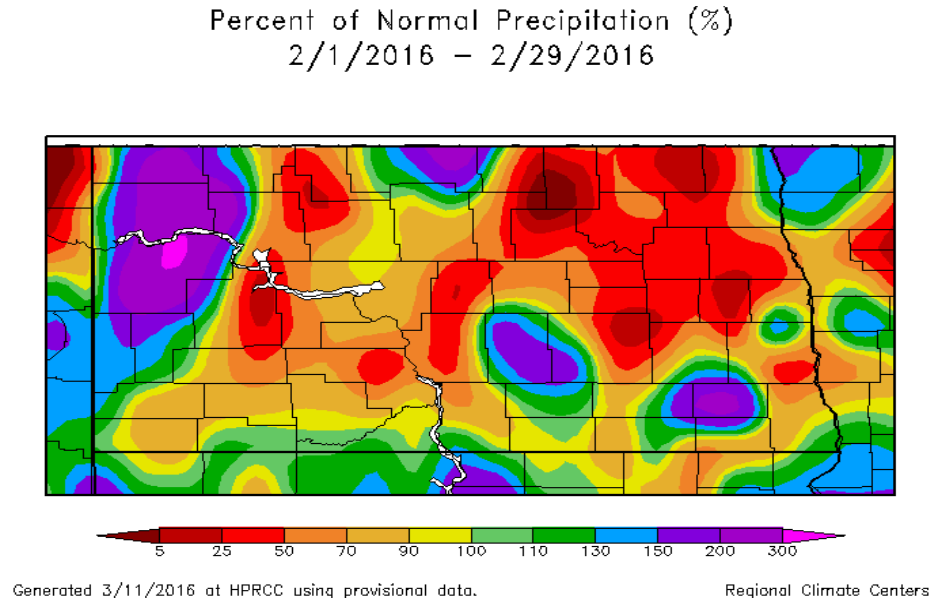
Winter 2015-16 Weather in North Dakota:

February 2016

Total Precipitation percent of mean (1981-2010)

Precipitation Percent of Normal

(Data from High Plains Regional Climate Center(HPRCC))

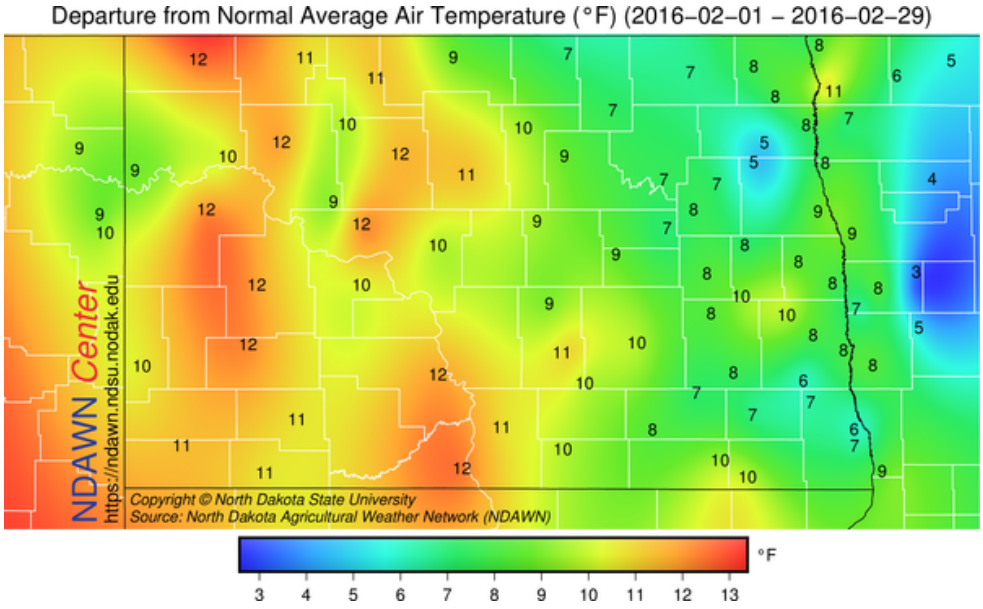


High Plains Regional Climate Center

Average Temperature (°F) Deviation from Mean (1981-2010)

Departure From Normal Monthly
Average Air Temperature in degrees F

(Data from North Dakota Agricultural Weather Network (NDAWN))



North Dakota State Climate Office

Season in Graphics

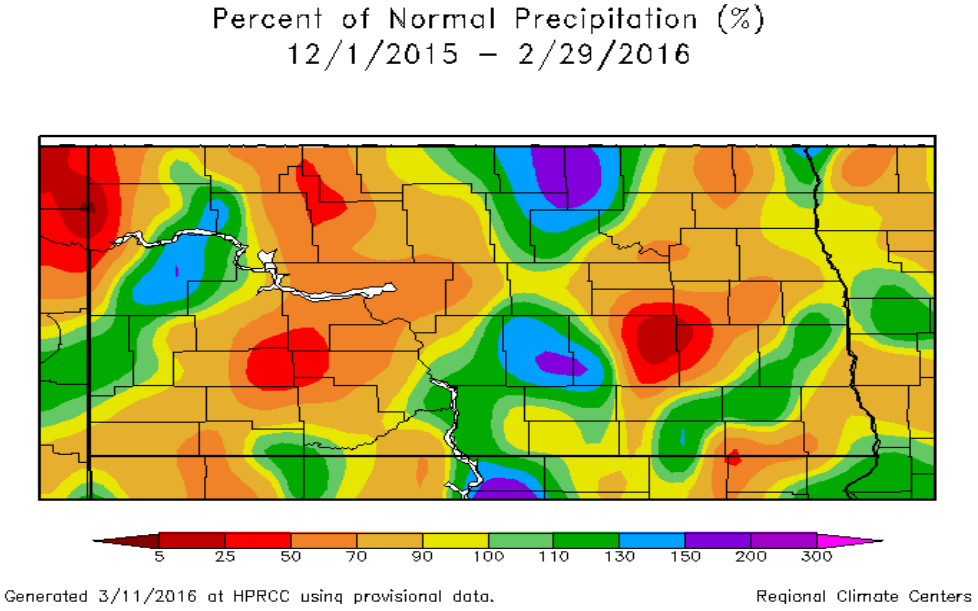
Winter 2015-16 Weather in North Dakota:

Winter 2015-16

Total Precipitation percent of mean (1981-2010)

Precipitation Percent of Normal

(Data from the High Plains Regional Climate Center (HPRCC))

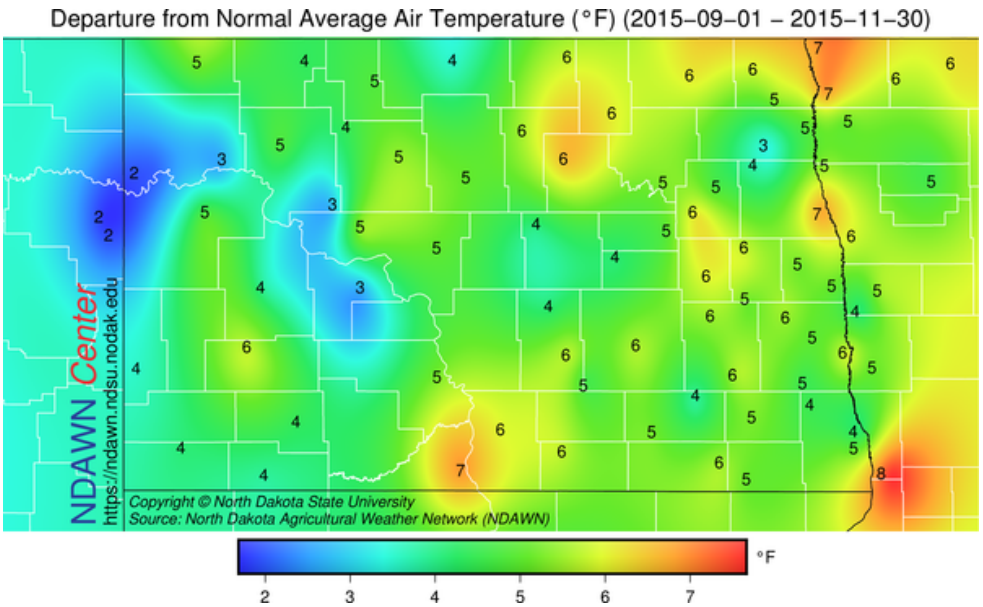


High Plains Regional Climate Center

Average Temperature (°F) Deviation from Mean (1981-2010)

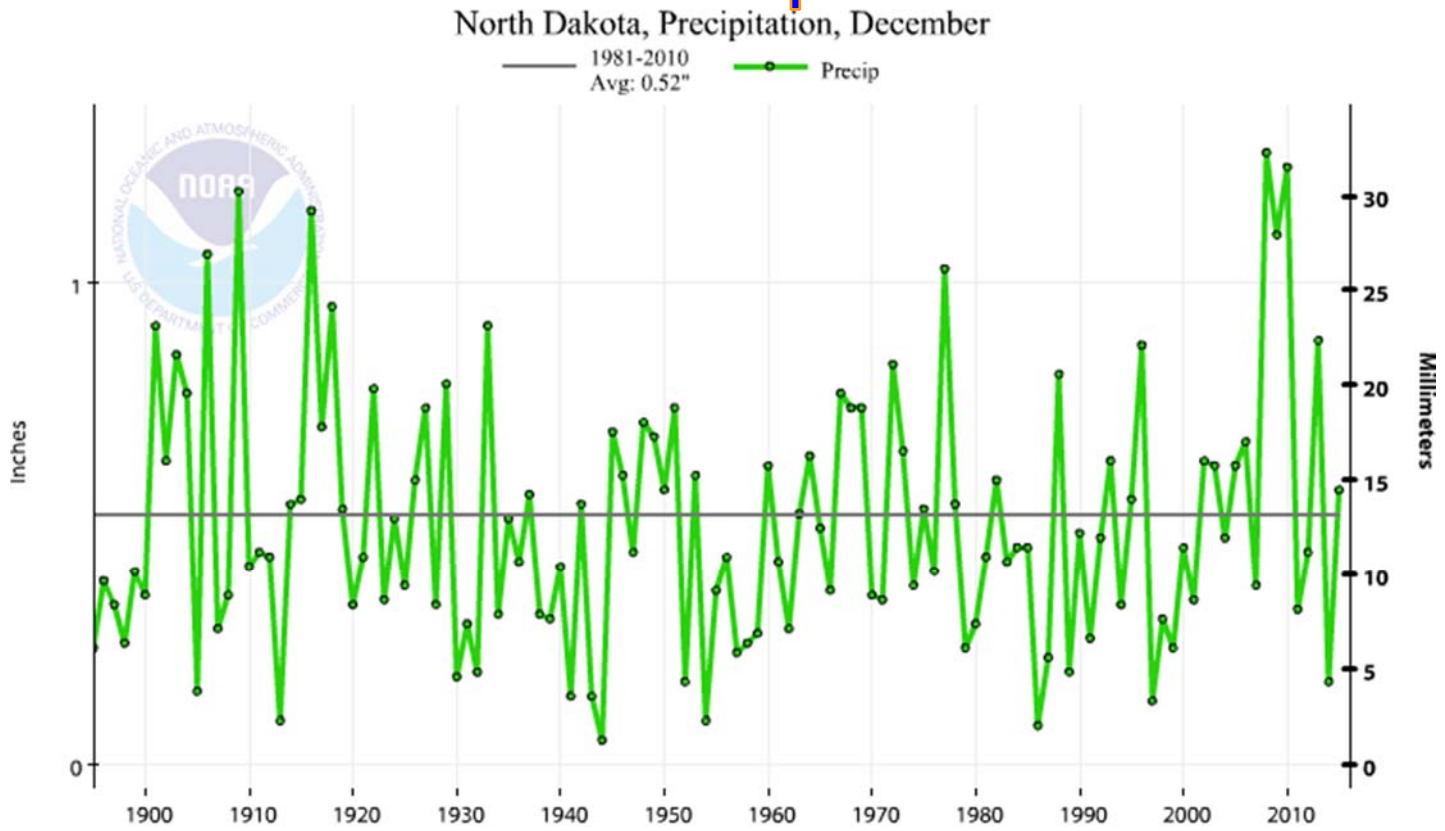
Departure From Normal Monthly
Average Air Temperature in degrees F

(Data from North Dakota Agricultural Weather Network (NDAWN))



North Dakota State Climate Office

Historical December Precipitation for North Dakota

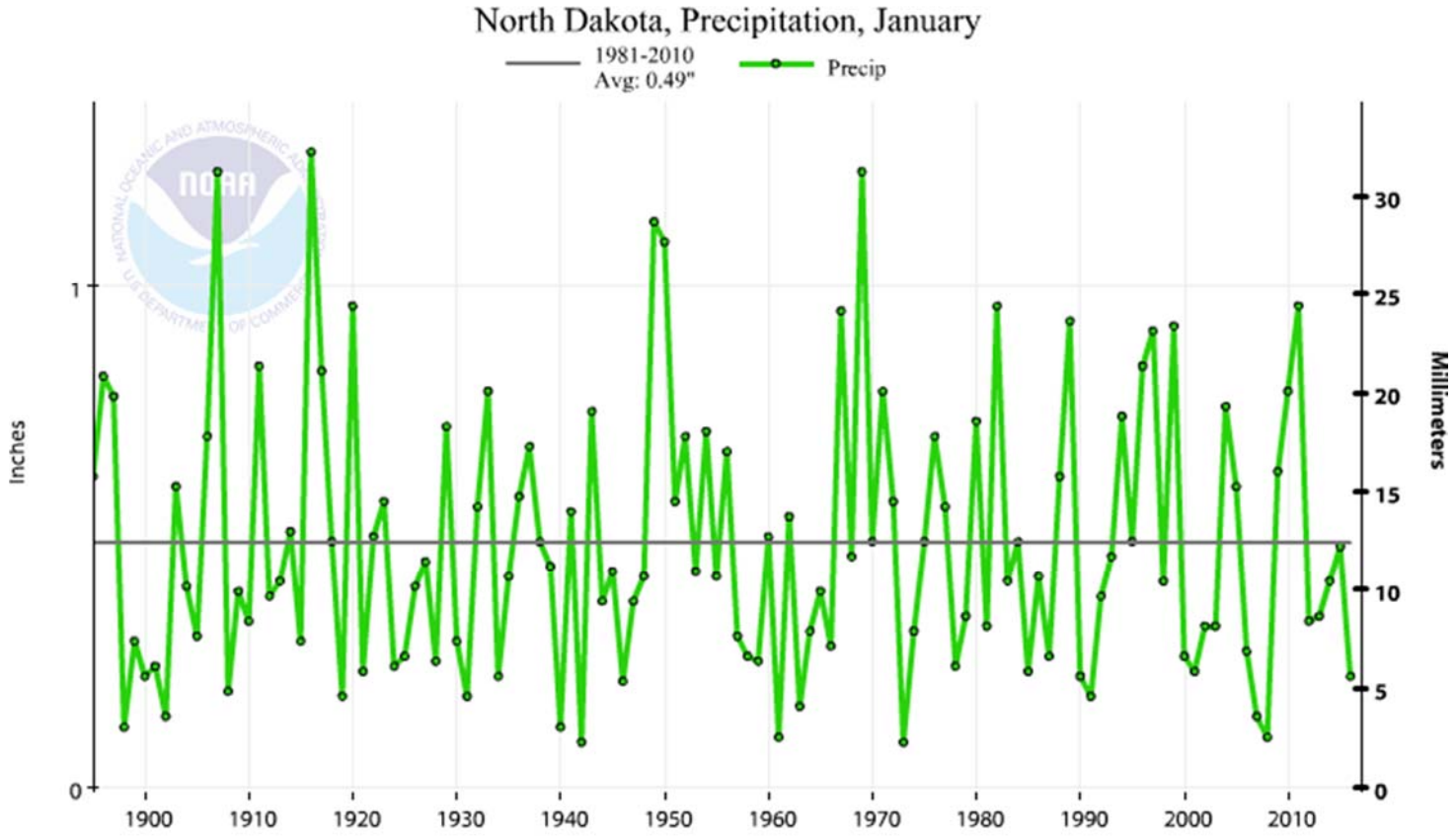


December Precipitation Statistics

2015 Amount: **0.57 inches**
Maximum: 1.27 inches in 2008
State Normal: 0.52 inches (1981-2010)

Monthly Ranking: 41st wettest
Minimum: 0.05 inches in 1944
Years in Record: 121

Historical January Precipitation for North Dakota

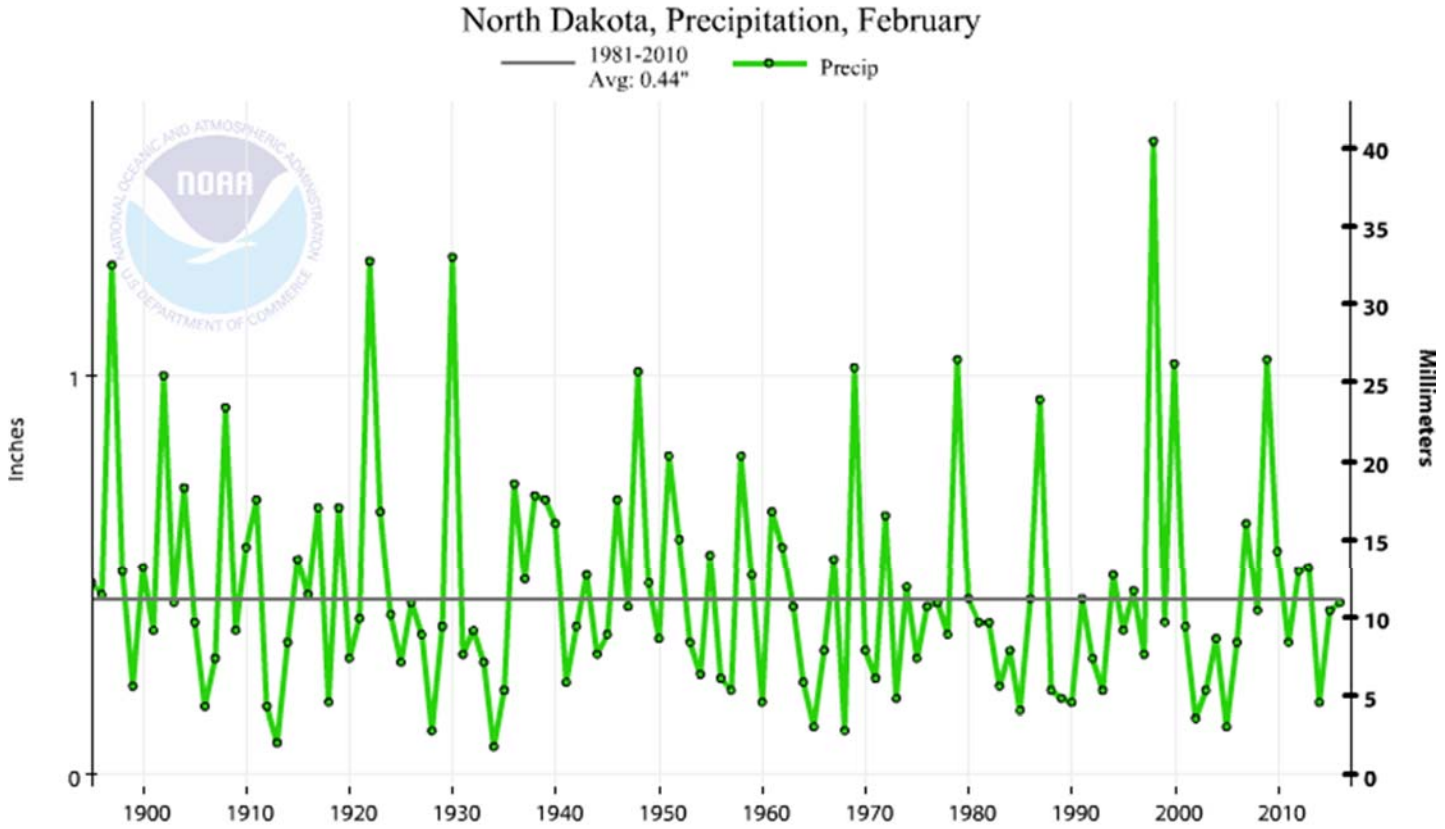


January Precipitation Statistics

2016 Amount: 0.22 inches
Maximum: 1.27 inches in 1916
State Normal: 0.49 inches (1981-2010)

Monthly Ranking: 37th wettest
Minimum: 0.09 inches in 1942 and 1973
Years in Record: 122

Historical February Precipitation for North Dakota

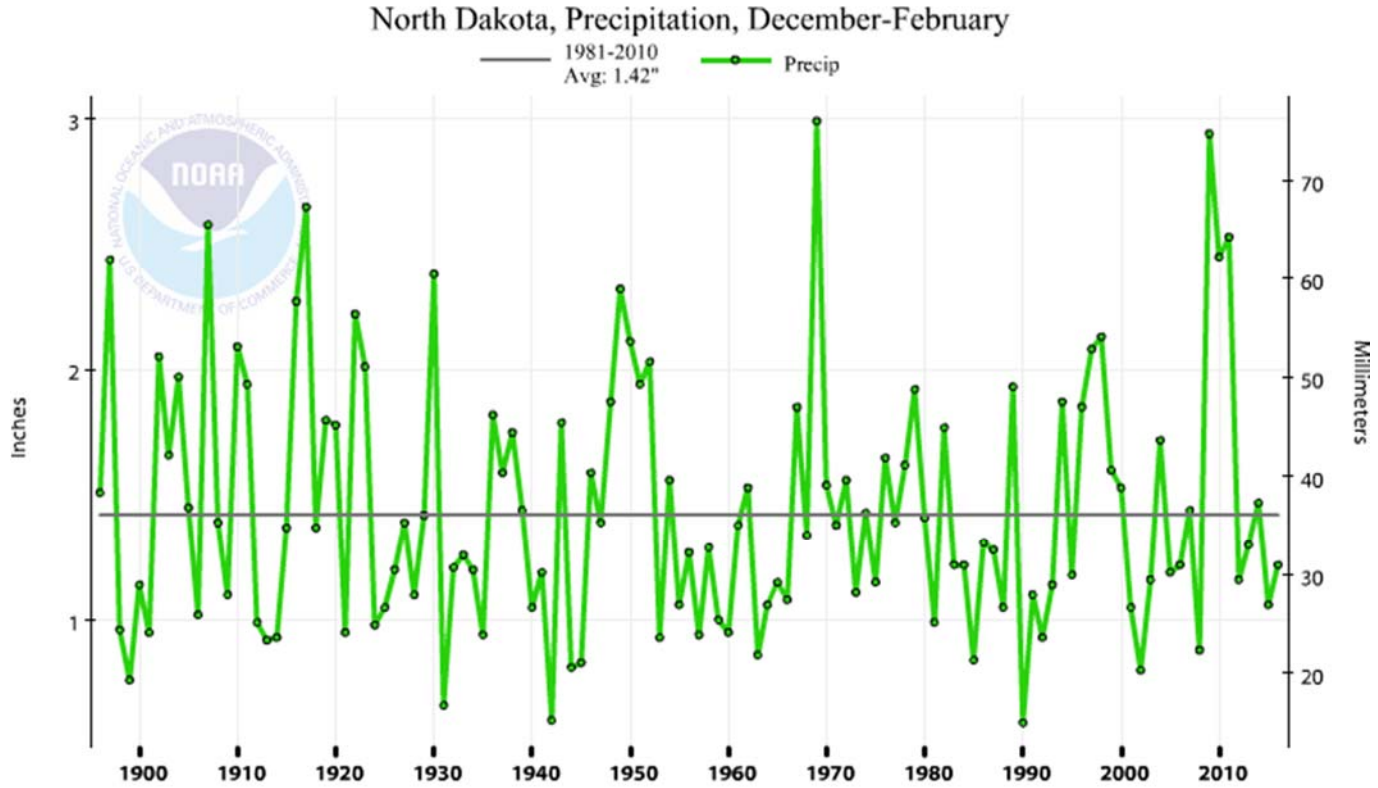


February Precipitation Statistics

2016 Amount: 0.43 **inches**
Maximum: 1.59 inches in 1998
State Normal: 0.44 inches (1981-2010)

Monthly Ranking: 52nd wettest
Minimum: 0.07 inches in 1934
Years in Record: 122

Historical Winter Precipitation for North Dakota

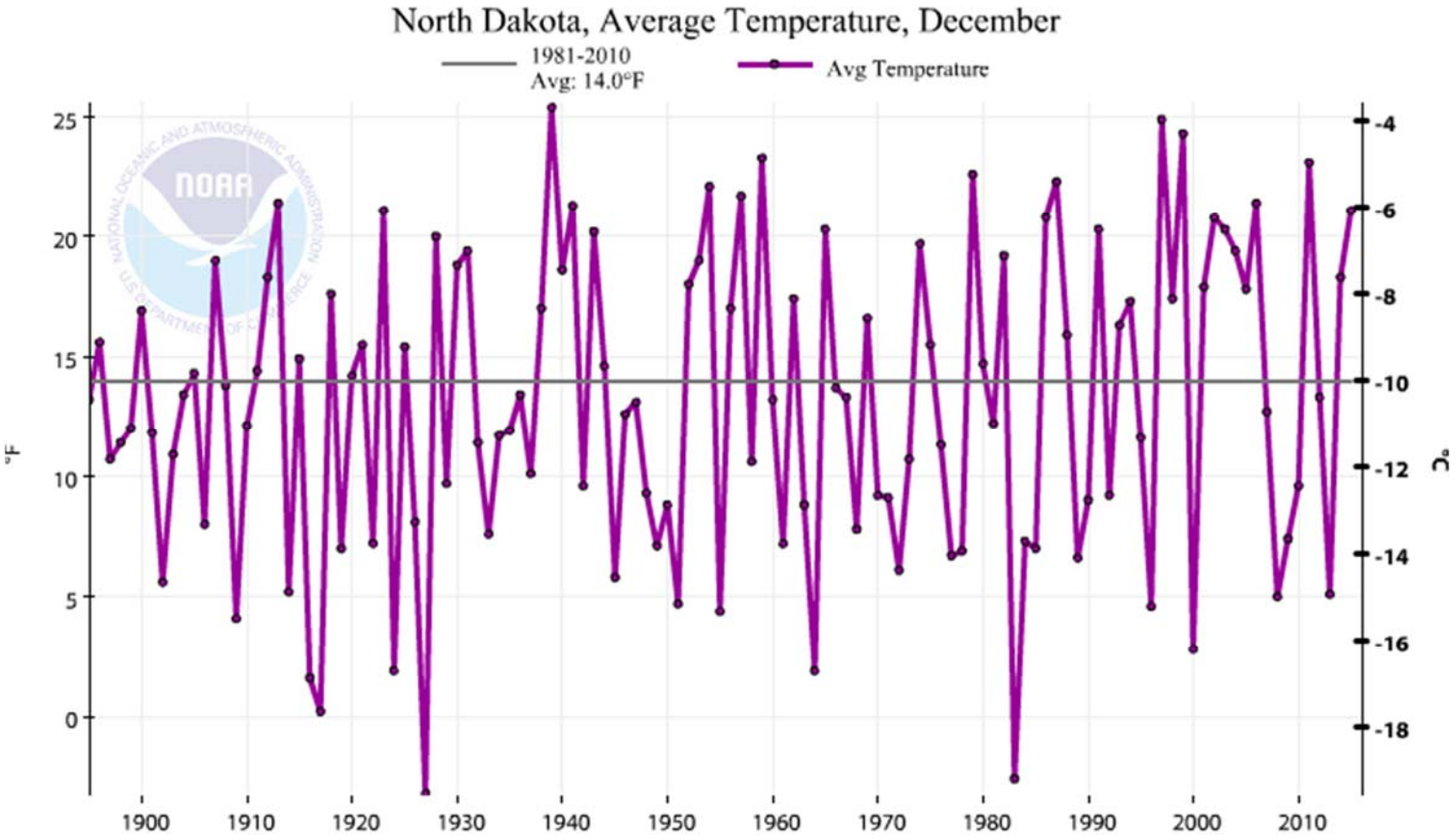


Winter Precipitation Statistics

2015-16 Amount: 1.22 **inches**
Maximum: 2.99 inches in 1968-69
State Normal: 1.42 inches (1981-2010)

Monthly Ranking: 50th driest
Minimum: 0.59 inches in 1989-90
Years in Record: 121

Historical December Temperature for North Dakota

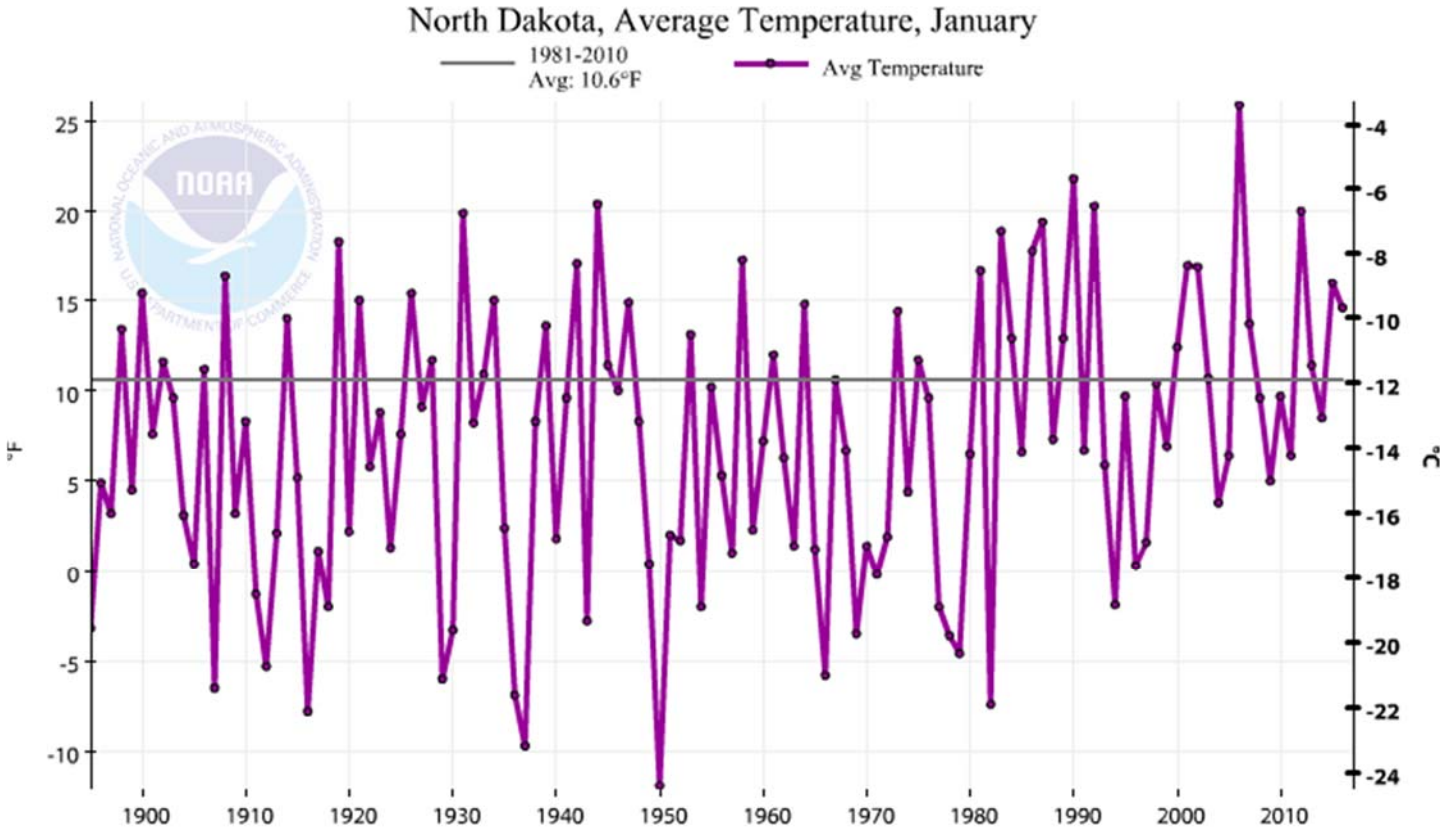


December Temperature Statistics

2015 Average: **21.1** °F
Maximum: 25.4 °F in 1939
State Normal: 14.0 °F (1981-2010)

Monthly Ranking: 13th warmest
Minimum: -3.2 °F in 1927
Years in Record: 121

Historical January Temperature for North Dakota

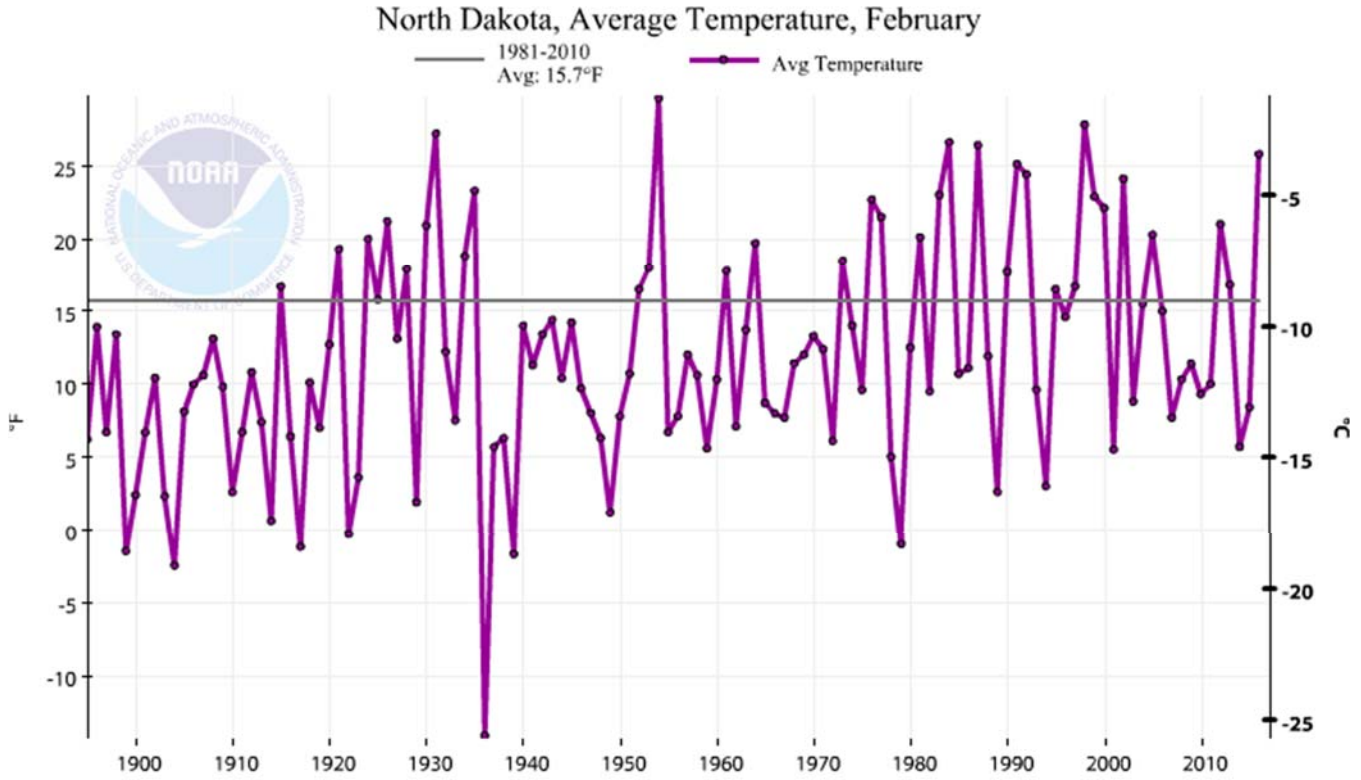


October Temperature Statistics

2015 Average: 14.6 °F
Maximum: 25.9 °F in 2006
State Normal: 10.6 °F (1981-2010)

Monthly Ranking: 24th Warmest
Minimum: -11.9 °F in 1950
Years in Record: 122

Historical February Temperature for North Dakota

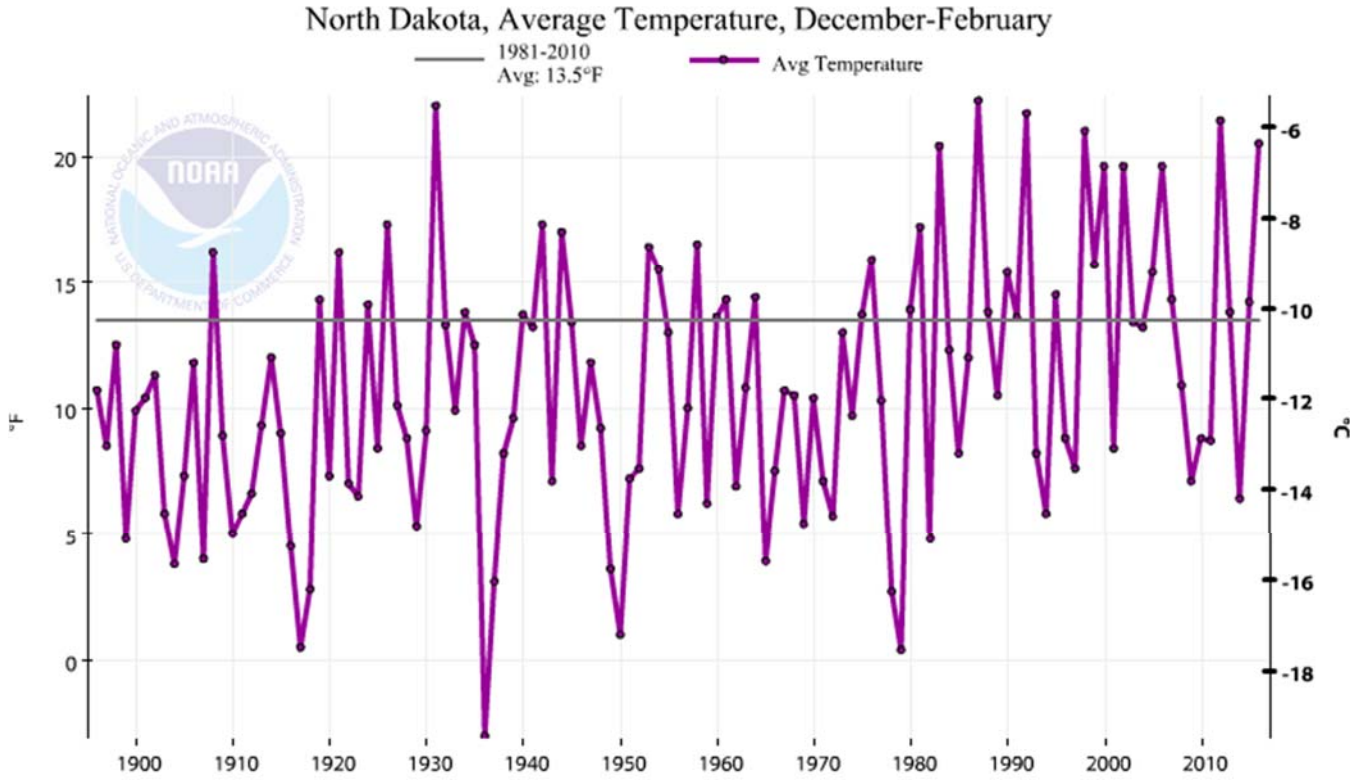


February Temperature Statistics

2015 Average: **25.8 °F**
Maximum: 29.6 °F in 1954
State Normal: 15.7 °F (1981-2010)

Monthly Ranking: 6th warmest
Minimum: -14.1 °F in 1936
Years in Record: 122

Historical Winter Temperature for North Dakota



Winter Temperature Statistics

2015-16 Average: **20.5 °F**
Maximum: 22.2 °F in 1986-87
State Normal: 13.5 °F (1981-2010)

Monthly Ranking: 6th warmest
Minimum: -3.0 °F in 1935-36
Years in Record: 121

Storms & Record Events

State Tornado, Hail, and Wind Reports for Winter 2015-16

by D. Ritchison

North Dakota Seasonal Total	Wind 0	Hail 0	Tornado 0
Reports by Month			
Monthly Total	**Wind**	**Hail**	**Tornado**
September	0	0	0
October	0	0	0
November	0	0	0

North Dakota Record Maximum Temperature Event Reports for Winter 2015-16

Date	Location	Type of Record	Previous Record
12/03/15	Minot Airport	50° F highest maximum temperature	Tied 50° in 1999
12/06/15	Minot Airport	53° F highest maximum temperature	47° in 1999
12/07/15	Bismarck Airport	55° F highest maximum temperature	54° in 1965
12/07/15	Minot Airport	51° F highest maximum temperature	47° in 1999
12/07/15	Minot Airport	49° F highest maximum temperature	Tied 49° in 1965
12/08/15	Minot Airport	54° F highest maximum temperature	Tied 49° in 1965
12/09/15	Jamestown Airport	55° F highest maximum temperature	54° set in 1990
12/09/15	Bismarck Airport	62° F highest maximum temperature	52° set in 2002
12/09/15	Dickinson Airport	62° F highest maximum temperature	58° in 1979
12/09/15	Minot Airport	62° F highest maximum temperature	48° in 1974
01/27/16	Fargo Airport	40° F highest maximum temperature	38° in 1892
01/29/16	Bismarck Airport	51° F highest maximum temperature	47° set in 1992
01/29/16	Minot Airport	48° F highest maximum temperature	44° set in 1992
02/06/16	Bismarck Airport	54° F highest maximum temperature	49° set in 1996
02/06/16	Minot Airport	51° F highest maximum temperature	46° set in 1996
02/19/16	Fargo Airport	48° F highest maximum temperature	47° set in 2012
02/19/16	Grand Forks Airport	44° F highest maximum temperature	42° set in 1996
02/19/16	Bismarck Airport	60° F highest maximum temperature	55° set in 1996
02/19/16	Minot Airport	51° F highest maximum temperature	50° set in 1991
02/26/16	Bismarck Airport	62° F highest maximum temperature	55° set in 1988
02/26/16	Dickinson Airport	58° F highest maximum temperature	Tied 58° set in 1988
02/26/16	Williston Airport	59° F highest maximum temperature	Tied 59° set in 1988
02/27/16	Fargo Airport	55° F highest maximum temperature	51° set in 1959
02/27/16	Jamestown Airport	61° F highest maximum temperature	55° set in 1988
02/27/16	Bismarck Airport	73° F highest maximum temperature	63° set in 1988
02/27/16	Dickinson Airport	66° F highest maximum temperature	Tied 66° set in 1992
02/28/16	Jamestown Hospital	62° F highest maximum temperature	55° set in 1905

Seasonal Outlook

Spring 2016 Climate Outlooks

by . R. Kupec[1]

Winter 2015/16 continued the trend from last year of warmer than average temperatures. Across the state, average temperatures for the season ran five to ten degrees above average with the west slightly warmer than the east. Winter precipitation was closer to average with the west slightly wetter and the east slightly drier. These trends have carried over into the beginning of the spring season.

Sea surface temperatures remain well above average in the Pacific Ocean but some signs of cooling are beginning to emerge. The Climate Prediction Center (CPC) believes this cooling trend will continue into summer 2016 with the strong El Niño event of the winter coming to an end and turning neutral or perhaps reversing to a La Niña by autumn. The key to our spring weather in North Dakota may depend on how quickly cooling occurs in the Pacific.

Whether the cooling is quick or slow, it seems likely that a warmer than average spring can be expected across the state. In past springs when average El Niño's have occurred March temperatures have been slightly below average, with April and May slightly above average statewide. For stronger El Niño springs the result are more mixed. March tends to be cooler in the west but warmer than average in the east. All parts of the state show significantly warmer Aprils and then slightly warmer than average Mays. March has already begun well above average statewide; the short term outlook is for some cooling which may bring the month closer to the average. It seems likely that the spring will be above average. The current CPC outlook has a 40 to 50 percent chance of above average temperatures for the spring across North Dakota (See Figure 1).

The El Niño signature with regards to precipitation is not as well defined as the temperature pattern. In both the average and strong El Niño scenarios March precipitations runs near average statewide and April tends to be slightly drier. Drier conditions seem to be slightly more enhanced in stronger El Niño events. In May both average and strong El Niños trend wetter than average in nearly the same proportion statewide. It is likely that when the numbers are calculated at the end of spring, a wetter May will offset earlier deficits and the season will be close to average.

The current CPC outlook agrees with this seasonal scenario and has an equal chance of above or below average precipitation across the state (See Figure 2).

The next CPC outlook will be out on March 17th and is available at:
http://www.cpc.ncep.noaa.gov/products/predictions/90day

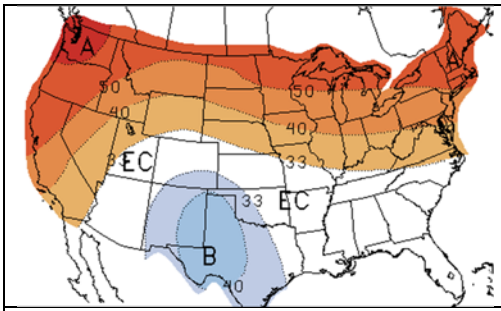


Fig 1. March through MayTemperature Outlook

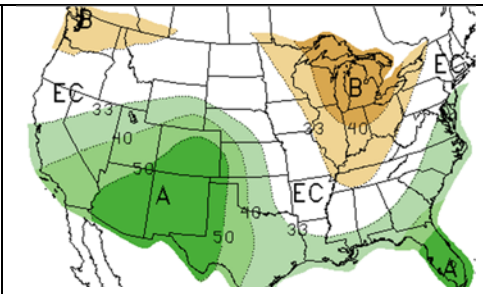


Fig 2. March through May Precipitation Outlook

Also, the North Dakota State Climate Office has links to the National Weather Service's local 3-month temperature outlooks for the upcoming year. Those forecasts can be found at: http://www.ndsu.edu/ndsco/data/enso/#c343262.

[1]The corresponding author: Rob Kupec is Chief Meteorologist - KVRR TV in Fargo, ND. rkupec@kvrr.com.

Hydro-Talk

North Dakota's Latest Hydrologic Status

by A. Schlag[2]

Wow, what a winter we have had through early March! For all but the most avid winter sports enthusiast, the general public has thus far been very appreciative of what Mother Nature has brought to the Northern Great Plains. A quick winter summary at NWS Bismarck Weather Service Office owned and operated Automated Surface Observation Systems located at airports across North Dakota as shown below gives us a little glimpse into just how nice this winter has been for us.

	December				January				February				Winter	
	Temperature		Precipitation		Temperature		Precipitation		Temperature		Precipitation		Precip	
Location	Avg	Dep	Inches	Dep	Avg	Dep	Inches	Dep	Avg	Dep	Inches	Dep	Total	Dep
Bismarck	22.1	5.9	0.91	0.42	17.1	4.3	0.21	-0.22	32.5	14.4	0.43	-0.08	1.55	0.12
Williston	21.7	7.8	0.55	-0.07	16.8	5.8	0.38	-0.21	29.3	12.4	0.75	0.36	1.68	0.08
Minot	24.5	9.1	0.47	0.09	18.4	6.2	0.57	0.06	28.7	11.7	0.37	-0.03	1.41	0.12
Jamestown	20.8	6.7	0.6	0.2	14.6	4.5	0.01	-0.45	24.2	9.1	0.11	-0.29	0.72	-0.54
Dickinson	23.4	5.5	0.3	0.02	18.2	1.9	0.16	-0.14	29.8	9.3	0.26	-0.07	0.72	-0.19

There are a few points in the above table that need to be made. First and foremost, precipitation itself has not been that much off of the 30-year normal. Indeed, three of the five locations used above are at or above the 30-year normal, while the other two are below normal. In general, this suggests it's been a fairly normal year given our hit-or-miss nature with regard to moisture. However, the very warm winter the region has experienced has left us with nearly zero moisture on the ground in early March. Melting, evaporation, and even sublimation has removed the vast majority of the received moisture before we got into our traditional spring melt season.

So where does that leave us, hydrologically speaking? I'm pretty sure that just about everyone agrees that without a substantial snowpack on the ground in early March that the risks of spring flooding are currently much lower than we are accustomed to over the past several years. However, localized spring flooding due to heavy spring rains is still a distinct possibility and we fully expect to issue at least a few flood warnings over the next couple of months due to heavy rains. It just won't likely be widespread or severe.

When it comes to river levels, our soils are already nearly frost free here in the Bismarck area (see: North Dakota Agricultural Weather Network Soil Temperature profiles for select locations here: https://ndawn.ndsu.nodak.edu/deep-soil-temperatures.html), and drying out quickly. This suggests that even with moderate amounts of spring rain, it may be difficult for dam owners to fill their reservoirs this coming spring. All of this can change with timely rains, but the odds are certainly lower than in recent springs and low water levels are likely to be as big of a concern going into spring for ecological reasons as flooding has been over the past several years.

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Science Bits

Quantifying a Trend in the NDAWN Deep-soil Temperatures

by Jonathan Woody[3]

The North Dakota Agricultural Network (NDAWN) publishes hourly soil temperature measurements at various depths at select locations across the state. Soil near the surface is affected by several environmental processes such as atmospheric temperature, snowpack, and sunlight, for example. During the winter months, the moisture in the soil near the surface freezes, and the deep soil measurements allow scientist to observe how deep this frozen soil extends into the earth. This seasonal freezing of the soil has important implications for industries such as agriculture and construction. So the question arises: with the NDAWN deep soil data available, are there any trends to be found?

Climate change has been observed to be more significant during the winter season in the mid and high latitudes. Until recently, attempts to quantify changes in the wintertime frozen soil, relied on taking only one measurement per year, the maximum yearly freeze depth. This however misses much of the dynamics in the seasonal soil freeze process. For example, if a deeper snowpack is present, the soil will be more insulated against nighttime cold temperatures, and may not freeze as deep if less snow where present. However, this soil might then stay frozen longer during the spring thaw, precisely because deeper snowpack might then keep the soil insulated from the warmer springtime temperatures. Needless to say, a lot of the dynamics of the seasonal soil freeze process have been missed when we just consider the maximum yearly freeze depth. So, in an attempt to capture more of the dynamics of the seasonal ground freeze process, we take advantage of the NDAWN daily deep soil temperatures. Specifically, we construct a new measurement, the Stored Quantity of Frozen Soil (SQFS). For starters, one could think of this as taking the ground freeze depth measurements on a daily basis. This would then allow us the opportunity to investigate many more aspects of the dynamics of the seasonal ground freeze process.

There is one caveat to the SQFS measurement, it is actually not just the daily depth of the frozen soil. To get a better understanding of the depth, imagine a scenario where two days ago the soil was frozen solid to a depth of three feet. Suppose there is no snow present to make things simpler. Then yesterday, miraculously, Farris Bueller's Day Off weather arrived and the temperature rose to seventy degrees Fahrenheit and the top two feet of the frozen soil thawed. The SQFS would then be measured at one foot yesterday, only the layer of soil from a depth of two feet to three feet remained frozen. Now, suppose that a record drop in temperatures this morning caused the top foot of soil to re-freeze. Assuming the soil at between the depths of two and three feet remained frozen, the SQFS would be two feet today. That is, the SQFS would be the sum of the two frozen bands of soil- one foot from the two to three feet range plus the foot from the surface to one foot deep range. So that was a lot of temperature changes in three days to get the point across. Before we continue, let us consider a fun fact: some of our friends in Spearfish, South Dakota experienced the world record for the most dramatic rapid temperature change. On January 22, 1943 at 7:30 a.m. MST, the temperature in Spearfish was -4 degrees Fahrenheit. When the Chinook winds picked up, the temperature two minutes later was +45 degrees Fahrenheit! The 49 degree jump in two minutes set a world record! An hour and a half later, the temperature hit a daytime high of 54 degrees Fahrenheit before the Chinooks died down and the temperature dropped right back down to -4 degrees Fahrenheit. The temperature change was so dramatic that it caused the plane glass windows in home across Spearfish to crack.

Now, back to the SQFS as constructed from the NDAWN deep soil temperature stations. If we are to try and detect any trends in this process, we need an appropriate statistical approach. The day to day measurements of the SQFS are strongly statistically correlated. If the SQFS is large one day, it is likely large the next. An additional complicating factor is that the SQFS may only take on positive values, you cannot have a negative quantity of frozen soil!

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To accommodate these statistical difficulties, one may adopt a "stochastic storage model" approach. To understand the word "stochastic," consider its famous appearance in an episode of The Simpsons. While trying to check out Ecosystem of the Marsh, twenty-three year old future Lisa fell in love with her future husband Hugh St. John Alastair Parkfield. They quarrel over who gets to read the book first as described by The Simpson's wiki page on the incident:
Hugh: I can read faster than you.
Lisa: I read at a 78th grade level.
Hugh: [opens book, slaps it on a table] Right here! [they both read frantically]
Lisa: [much later] Finish this page?
Hugh: Ages ago.
Lisa: Grr…
Hugh: I'll get the dictionary.
Lisa: Why?
Hugh: You'll see when you get there: the word "stochastic".
Lisa: [reading from the dictionary] "Pertaining to a process involving a randomly-determined sequence of observations".

Needless to say, the stochastic storage model is able to handle the sequence of daily observations of the SQFS process. One may also allow for a trend component in the model. One more difficulty, is that it does not suffice to evaluate the sites (eleven in the latest study) individually. One must consider the set of all locations in tandem. The resulting model is a multivariate stochastic storage model equipped to detect trends in the SQFS process. **The results indicated that all eleven sites experienced a negative trend in the SQFS from 1992 to 2012 (Table 1)** (end of the study period- this work started almost four years ago!). This is not to say that this will continue as a long term trend. Although the storage model approach adequately handles day to day correlation, longer scale climatological correlations exist, and can be confounded with trend estimates. So there is also much statistical work left to do in to better understand the trends that were detected. Additionally, further studies of the modeling methodology are underway.

Pdf of the upcoming article on the SQFS, or any of the code used in the models can be requested via email to Jon Woody at jrw677@msstate.edu.

Table 1. Trend Estimates for the Eleven Sites of North Dakota Agricultural Weather Stations (The table in greater detail including standard errors and z-scores is listed in an upcoming article in "Open Geosciences")

Location	***Trend Estimation***
Bottineau	-0.8969
Carrington	-1.4817
Dickinson	-0.7076
Fargo	-0.535
Grand Forks	-0.1311
Harvey	-0.858
Hettinger	-1.2317
Langdon	-0.9044
Minot	-0.9512
Streeter	-0.6005
Williston	-0.9783

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