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North Dakota Climate Bulletin

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In This Issue

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NCEI, NDSCO, NDAWN, NOAA, CPC, USDM

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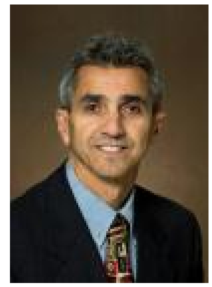
From the State Climatologist



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, Fargo.

The overall autumnal average temperature was 3.7 degrees cooler than average, and it was the 12th coolest on record and the coolest autumn since 1996. Precipitation-wise, the statewide accumulation was near average, but was the 42nd wettest autumn on record since 1895 in North Dakota. Overall, 12 high and a staggering 175 low daily temperature records were broken or tied. In addition, 77 daily precipitation records were broken or tied. A total of 264 records, including temperature- and precipitation-related occurrences across the state, were tied or broken.

Drought conditions improved throughout the season. By the end of the season, only the northern and northeastern parts of the state was experiencing a moderate drought. While the autumnal moisture was plenty enough to improve the drought conditions, will it pose a potential flood concern in spring? You will find the answer in the "Hydro Talk" section of this bulletin. The Science Bits section in this bulletin explains the soil moisture instrumentation advancement in ND.

Detailed monthly climate summaries for June, July and August, along with several other local resources for climate and weather information, can be accessed at www.ndsu.edu/ndsco/.

Adnan Akyüz, Ph.D., North Dakota State Climatologist

(Vern Whitten Photography)

Weather Highlights

Seasonal Weather Summary: By Adnan Akyüz

Precipitation

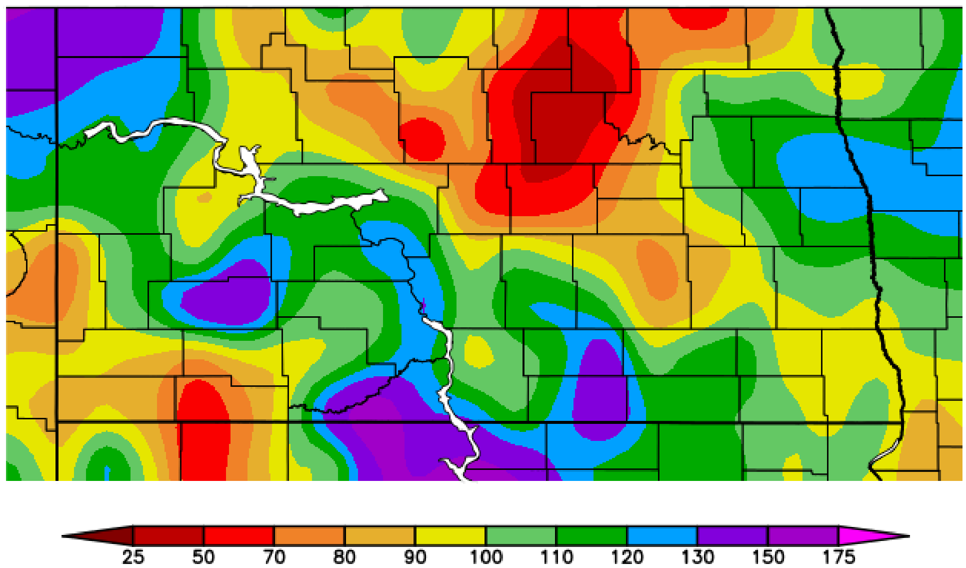


Figure 1. Precipitation percent of normal in Autumn 2018 for North Dakota. (North Dakota Agricultural Weather Network, NDSU)

Using analysis from the National Centers for Environmental Information (NCEI), the average North Dakota precipitation for the Autumn season (Sept. 1 through Nov. 30, 2018) was 3.81 inches, which was 5.1 inches less than the last season (summer 2018) but 0.78 inch more than last Autumn (Autumn 2017) and only 0.04 inch less than the 1981-2010 average Autumn precipitation. It also was the wettest Autumn since 2016 (Table 1). This would rank Autumn 2018 as the 42nd wettest autumn since such records began in 1895. The state's highest seasonal precipitation accumulation was 6.96 inches, which fell in Grand Forks, Grand Forks County. Figure 1 shows the percent of normal precipitation distribution geographically. Based on historical records, the state average Autumn precipitation showed a positive long-term trend of 0.75 inch per century during this period of record since 1895 (the highest seasonal trend in ND). The highest and lowest seasonal Autumn average precipitation for the state ranged from 7.25 inches in 1994 to 0.99 inches in 1976. The "Historical Autumn Precipitation for North Dakota" time series on Page 5 shows a graphical depiction of these statistics.

Table 1. North Dakota Autumn Precipitation Ranking Table.

Period	Value	Normal	Anomaly	Rank	Wettest/Driest Since
Autumn 2018	3.81"	3.85"	-0.04	83rd driest 42nd wettest	Driest since 2017 Wettest since 2016

Temperature

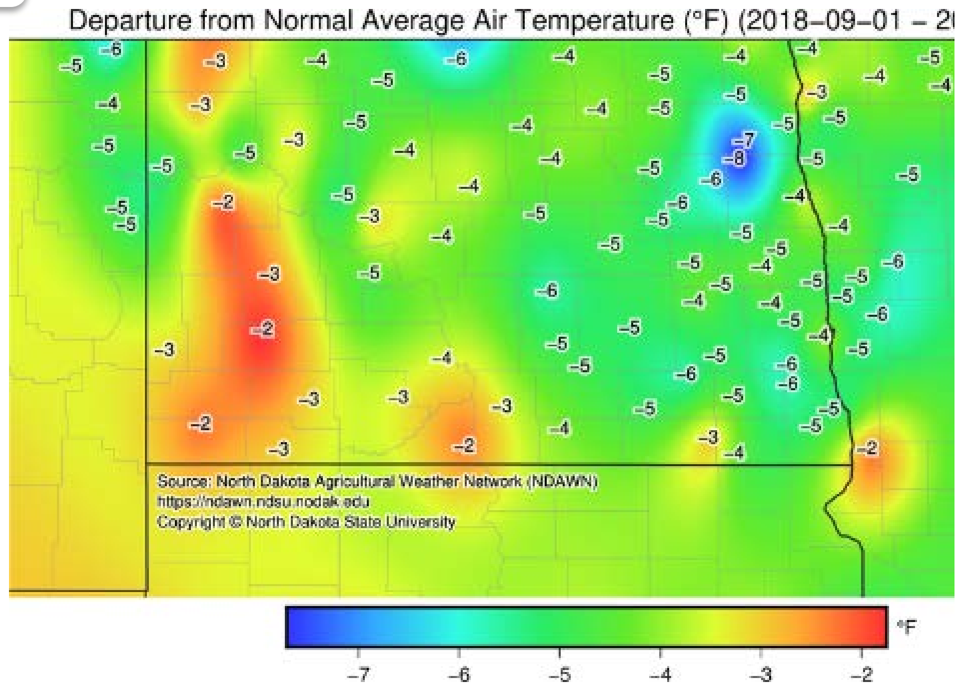


Figure 2. Temperature departure from normal in Autumn 2018 for North Dakota. (NDAWN)

The average North Dakota temperature for the season (Sept. 1 through Nov. 30, 2018) was 38.9 F, which was 29.2 F cooler than the last season (summer 2018), but 4.3 F cooler than last Autumn (2017) and 3.7 F warmer than the 1981-2010 average autumn temperature. It also was the coolest autumn since 1996. This would rank autumn 2018 as the 12th coolest autumn since such records began in 1895 (Table 2). Figure 2 shows the departure from normal temperature distribution geographically. The state's highest and lowest seasonal average temperatures were 56.6 F recorded in Riverdale, McLean County and 33.7 F recorded in Lake Metigoshe State Park, Bottineau County. Based on historical records, the average autumn temperature showed a positive trend of 0.17 F per decade since 1895. The highest and lowest seasonal Autumn average temperatures for North Dakota ranged from 49.1 F in 1963 to 32.2 F in 1896. The "Historical Autumn Temperature for North Dakota" time series on Page 6 shows a graphical depiction of these statistics.

Table 2. North Dakota Autumn Temperature Ranking Table.

Period	Value	Normal	Anomaly	Rank	Warmest/Coolest Since
Autumn 2018	38.9	42.6	-3.7	12th coolest 113th warmest	Coolest since 1996 Warmest since 2017

Drought: In general, overall drought conditions improved throughout the season with persistent rainfall in most drought-prone areas (Figure 4). By the end of the season, only 17 percent of the state was experiencing drought (a 25 percent reduction in coverage, compared with the beginning of the season). Figure 3 below shows the drought conditions in the beginning and the end of the Autumn.

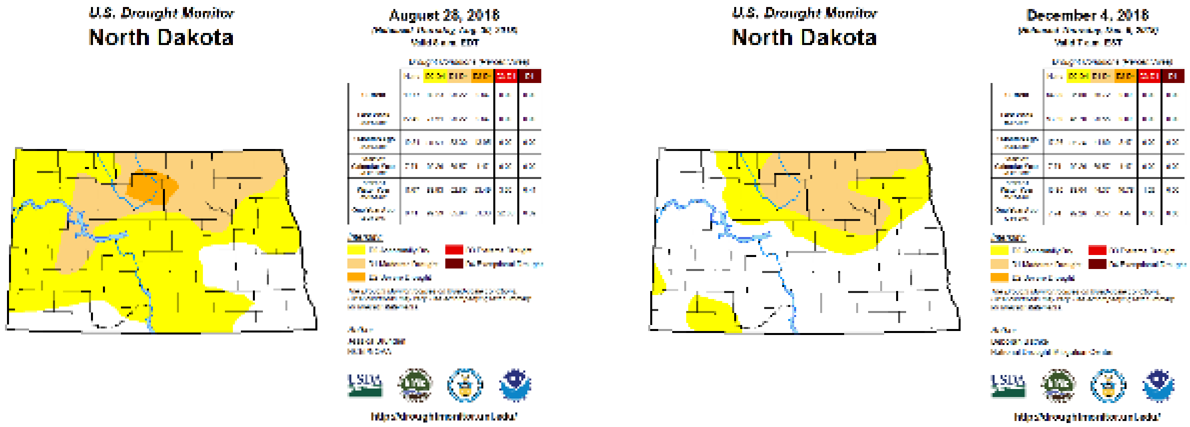


Figure 3. Drought Monitor map comparison for North Dakota in the beginning (on the left) and at the end (on the right) of Autumn 2018. (U.S. Drought Monitor)

Figure 4 below shows the statewide drought coverage in percentage and intensity (DO, D1, etc.) in time scale representing the state from the beginning to the end of the season, with a one-week resolution.

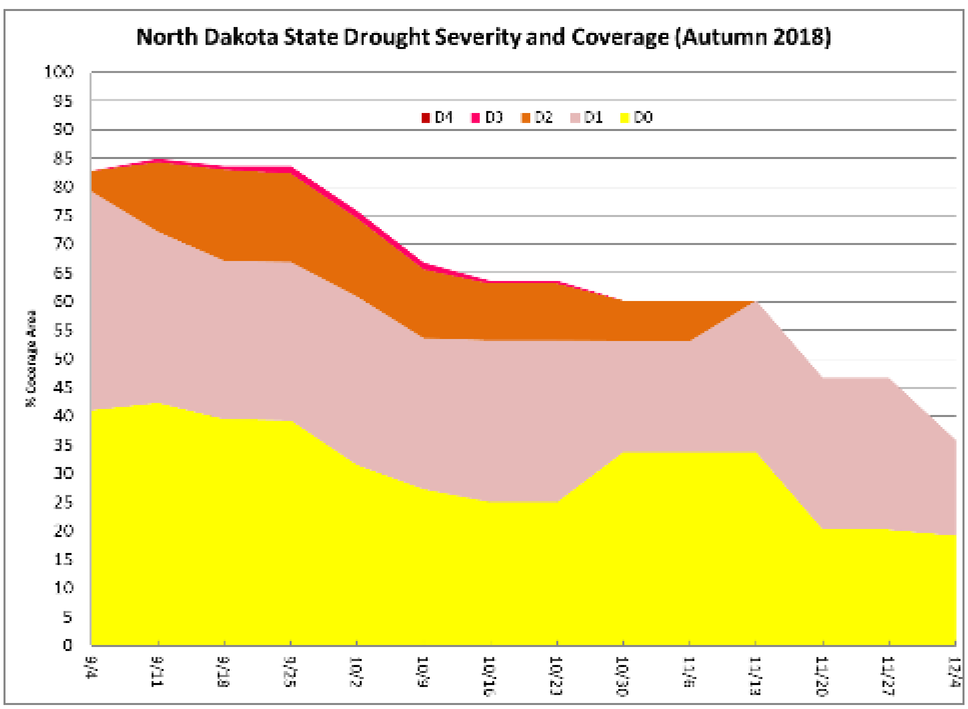
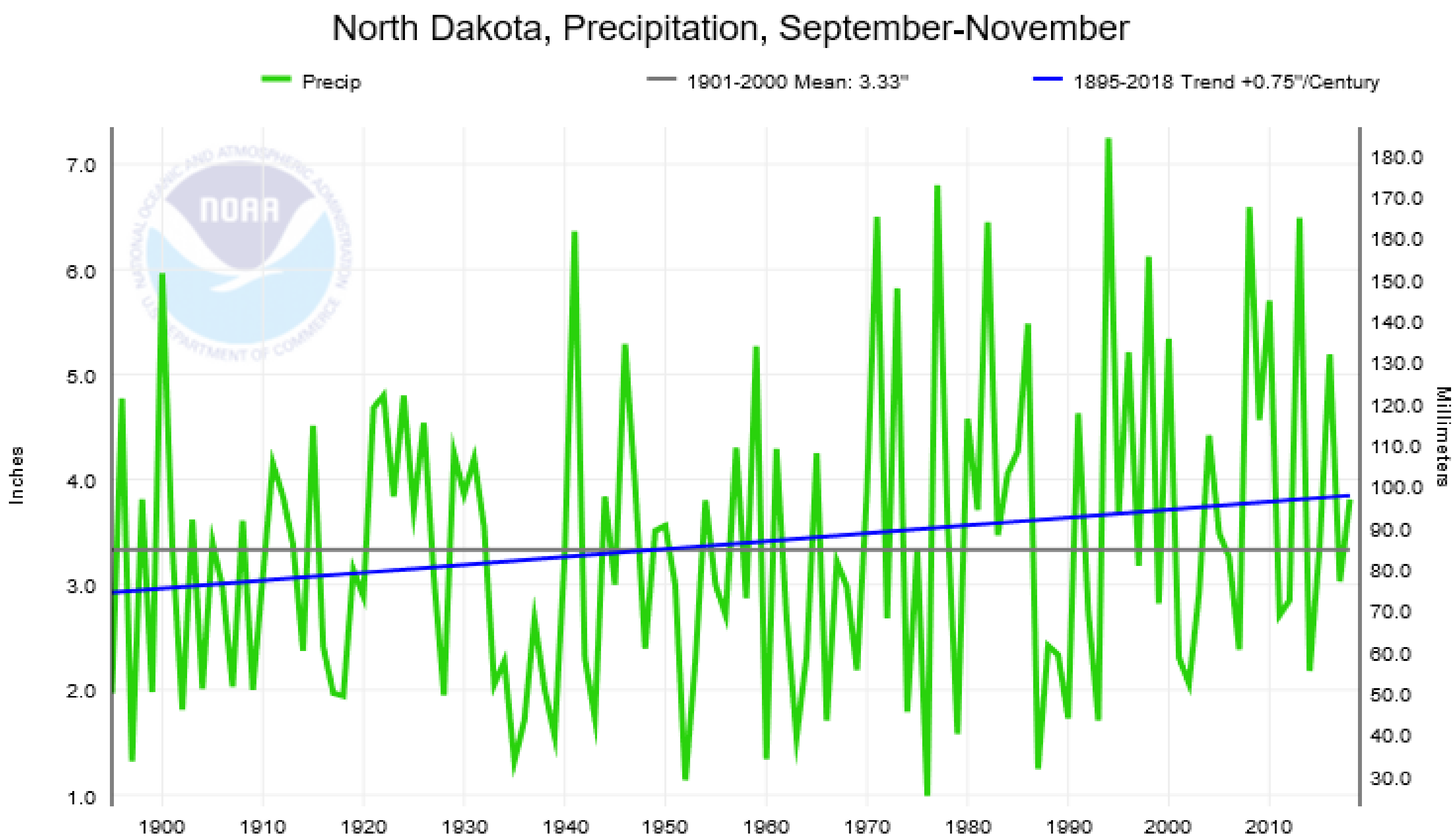


Figure 4. Statewide drought coverage (%) and intensity (Dx) in Autumn 2018. (USDM)

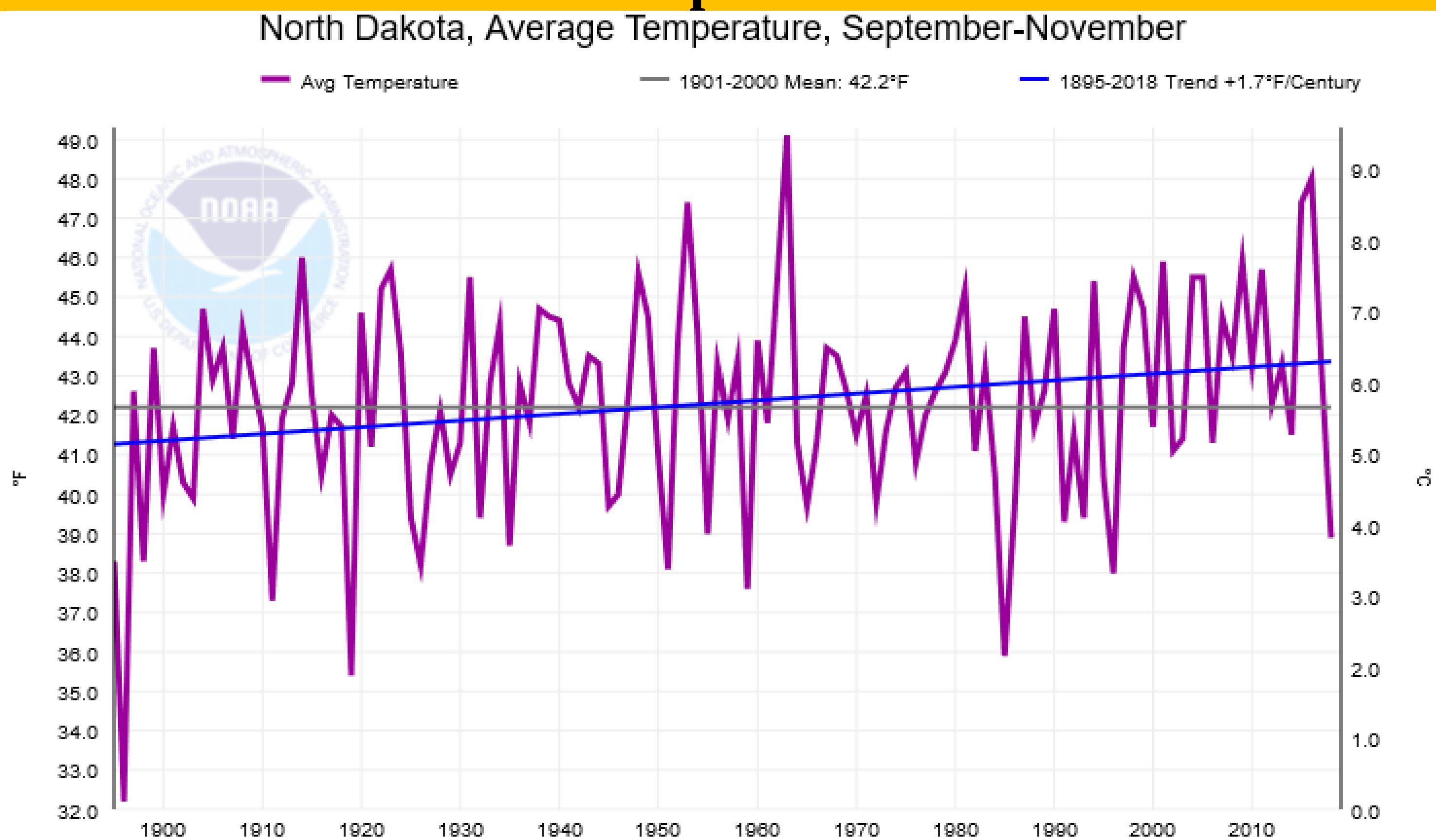
Historical Autumn Precipitation for North Dakota



Record high value: 7.25 inches in 1994
Record low value: 0.99 inch in 1976
Seasonal trend: 0.75 inch per century

Autumn 2018 value: 3.81 inches
1981-2010 average: 3.85 inches
Seasonal ranking: 42nd wettest autumn
Record length: 124 years

Historical Autumn Temperature for North Dakota



Record high value: 49.1 F in 1963
Record low value: 32.2 F in 1896
Seasonal trend: 0.17 F per decade

Autumn 2018 value: 38.9 F
1981-2010 average: 42.6 F
Seasonal ranking: 12th coolest autumn
Record length: 124 years

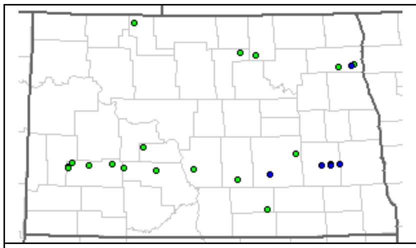
Storms and Record Events

State Tornado, Hail and Wind Events for Summer 2018

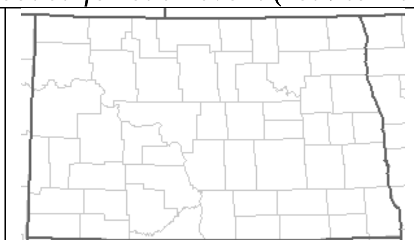
Table 3. Numbers in the table below represent the number of tornado, hail and wind events accumulated monthly and seasonally.

Month	Tornado	Hail	Wind	Total
September total	0	18	5	**23**
October total	0	0	0	**0**
November total	0	0	0	**0**
Seasonal total	**0**	**18**	**5**	**23**

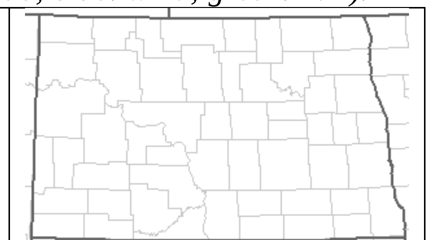
The graphics below show the geographical distribution of the storm events in the table above in each month. The dots are color-coded for each event (red: tornado; blue: wind; green: hail).



September 2018
North Dakota Storm Events



October 2018
North Dakota Storm Events



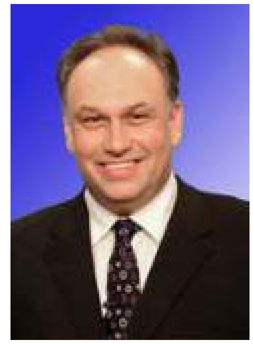
November 2018
North Dakota Storm Events

State Record Events for Autumn 2018

Table 4. Numbers in the table below represent the number of select state record events (records broken or tied) accumulated monthly and seasonally.

Category	September	October	November	Seasonal Total
Highest daily max. temp.	5	2	0	**7**
Highest daily min. temp.	3	1	1	**5**
Lowest daily max. temp.	14	104	15	**133**
Lowest daily min. temp.	0	31	11	**42**
Highest daily precipitation	16	6	12	**34**
Highest daily snowfall	2	34	7	**43**
Total	**40**	**178**	**46**	**264**

Seasonal Outlook



Winter 2018-19 Outlook

By R. Kupec[1]

Fall 2018 brought cooler than average temperatures to North Dakota and a highly variable precipitation pattern. The Fall Outlook called for a mild start that would then turn cold in November. It was also mentioned that sometimes with a developing El Niño in the southern Pacific, the cooling begins sooner. That is what happened this year. Pockets of North Dakota had above average precipitation, notably the central Red River Valley and southern Missouri River Valley. An area of much drier conditions ran from around Minot into the southeast corner of the state. In many ways this was a continuation of the summer precipitation pattern, where some spots received ample moisture and others remained dry. This and an early season snowfall were both projected in the Fall Outlook.

As we head into the middle of December, a strengthening El Niño is developing in the southern Pacific and we are beginning to see the first signs of the weather pattern in North America that goes along with it. Most often an El Niño brings above average winter temperatures to North Dakota. The El Niño this year is expected to be weak. The last weak El Niño winter brought temperatures that were 5 to 7 degrees above average for December and January. February turned much colder, with temperatures running 5 to 7 degrees below average. This February downturn in temperatures is noted in other El Niño events. I expect our usual variability in temperature this winter, overall the season will be 2 to 4 degrees above average.

Precipitation during an El Niño is often more variable than temperature. Typically average to slightly below average precipitation is noted and this is slightly more pronounced in the western part of North Dakota. Our last weak El Niño produced slightly below average moisture statewide. I would expect a similar result this winter.

The current Climate Prediction Center (CPC) Winter Outlook gives all of North Dakota a 40% chance of above average temperatures for the season (Figure 5a). The CPC has an equal chance of above or below average precipitation (Figure 5b).

The next 90-day outlook from the CPC should be available after Sept. 20 at www.cpc.ncep.noaa.gov/products/predictions/90day.

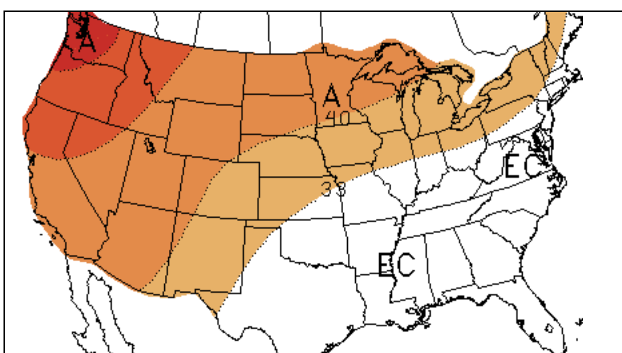


Figure 5a. December through February temperature outlook. (Climate Prediction Center, NOAA)

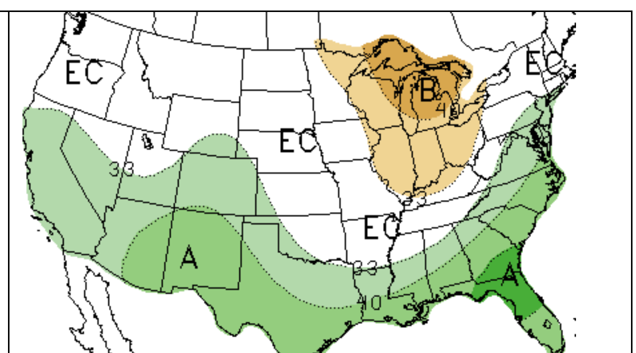


Figure 5b. December through February precipitation outlook. (Climate Prediction Center, NOAA)

[1] The corresponding author, Rob Kupec, is chief meteorologist at KVRR-TV in Fargo, N.D. Email: rkupec@kvrr.com

Hydro-Talk

Spring Flood Potential in ND **By A. Schlag[2]**

The official 2018-19 Winter Outlook has been in the news for a while now. Official estimates place the odds at 90% for a weak El Niño to form through the 2018-2019 winter and roughly a 55% chance it persists through early spring. Local research at WFO-Bismarck suggests that El Niño's of this variety favor temperatures a few degrees above average for the Dec – Feb "winter" season. Importantly, climatologists who work with the effects of El Niño Southern Oscillation (ENSO) swings have not yet observed the ocean and atmospheric coupling to declare an El Niño. This helps explain our recent winter-like October and November. While there has been a slight moderation of the expectations, the updated temperature outlook for Dec – Feb in Figure 5a of the previous section continues to favor a warmer than normal winter season.

Somewhat of a significant change has taken place in the precipitation outlook for Dec – Jan shown in Figure 5b. In the original winter outlook there was a strong signal for a drier than normal outcome in western North Dakota, Montana, and southern Canada. This has been replaced with the Equal Chances designation. The removal of this results from a lack of support from other climate tools. However, there are still some models, such as the well accepted CFSv2 that paints a picture of a warmer than normal and drier than normal December. So while there has been some tempering of the drier than normal expectations, there are still some indicators that lean towards this as the final outcome. While we've covered the expectations for "winter", we who live up in the Northern Great Plains know that the full definition of winter rarely ends for us in February. This makes the months of March and early April of interest to us as well, and when we look that far out during an El Niño affected winter/spring, we also tend to see a warmer than normal signature.

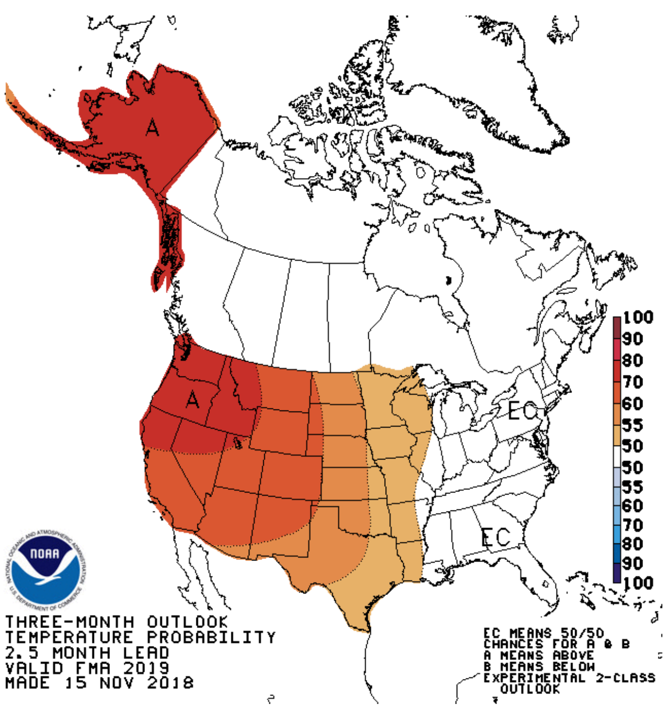


Figure 6. Temperature outlook for Feb - Apr.

This warm signal for Feb – Apr, as shown in Figure 6, is quite important to us as the expectations for higher temperatures increases as we go up into the Souris, Missouri, and Yellowstone basins. These headwaters are now expected to see not only warmer temperatures, but

[2] The corresponding author, Allen Schlag, is the service hydrologist at the NOAA's National Weather Service in Bismarck, N.D. Email: Allen.Schlag@noaa.gov

some indicators suggest an overall lower amount of moisture.

When we combine these effects with what some may just refer to as an early spring (colloquially defined as the widespread melting of the accumulated snowpack). For example, local research puts the peak streamflow after an El Niño as being about 10 days earlier than normal on the Souris above Minot. Volumes and rate of runoff also tend to be relatively modest after El Niño winters, and while research on all the mechanisms that lead to this has been inconclusive, some possible reasons are:

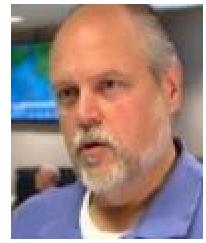
1. El Niño winters have longer and possibly more extreme periods of above freezing temperatures that lead to early melt and more sublimation and evaporation of available snowpack.
2. Overall less snow received during winter is also received in more numerous, but smaller events (trace to 1 or 2 inches) and that also increases evaporation and sublimation.
3. Earlier spring melts shorten the snow accumulation season and we miss out on stockpiling moisture from those heavy wet snows of late March and early April.
4. Early spring melts that occur in March have a much lower possibility of daytime temperatures getting into the 50-60 degree range which encourages much higher melt rates.

Despite having pre-wetted soils across central and western North Dakota which are one of the factors known to enhance/maximise runoff from a given snowpack, it looks like it will be difficult to build the kind of surplus snow that brought us the spring flooding of 2009-2011. Suffice to say that Mother Nature can always throw a curveball in the form of an over-powering Arctic Oscillation, or some other short-term influencer that overstays its welcome. However, my long-range expectations for spring 2019 are rather tempered right now.

In Summarv

Until something changes, I am expecting a relatively quiet spring flood season in 2019.

Science Bits



Oh, Soil Moisture: Where are you?

By G. Gust [3]

An update on efforts to improve the tracking of moisture within our soils.

As the growing season comes to a close and the frozen season kicks in (sometimes I think that we really are just a monsoonal, or two season climate!), we usually become less interested in the moisture that may be locked up within the soil and more concerned with whatever moisture has begun to pile up as a persistent snowpack on top of an otherwise frozen and seemingly lifeless landscape.

And up until now there were very few deep soil sensors for temperature or moisture across the Northern Plains region, and from late fall into early spring (at least for most weather, water, and climate purposes), we mainly considered our land of the frozen chosen as just that – frozen!

We readily recognize that neither soil moisture nor soil temperature are static entities during the summer months, when rainfall and sun-driven heat percolate throughout our soil strata allowing plant growth to flourish and excess moisture to move, either above or below the soil surface, into our streams and rivers.

Nor are they necessarily static in the winter months, when soils may cool and freeze at different rates and to quite different depths across a broad range of soil types, land-cover types, and the snowpack amounts.

Across the state we see these effects born out as the often higher and drier elevations in the southwest portions of the state near Bowman and Hettinger vacillate between periods of deep and extensive snow-over and largely snow-free open range land, while the lower and wetter land of the Souris/Mouse and Red River Basins in northern and eastern portions of the state stay perpetually snow-covered and markedly colder.

> Recent Science Bits articles have discussed some aspects of soil science, especially pertinent to our North Dakota agricultural community:
>
> - Winter 2015-2016 Science Bits, written by Jonathan Woody, discussed trends in NDAWN Deep-soil Temperatures… [https://www.ndsu.edu/fileadmin/ndsco/ndsco/bulletin/winter16.pdf]
> - Summer 2018 Science Bits, written by Joel Ransom, discussed drought stress in North Dakota's corn crop… [https://www.ndsu.edu/fileadmin/ndsco/ndsco/bulletin/summer18.pdf]
>
> However, neither of these articles specifically addresses what may be happening to the moisture within various layers of our soil, especially from late fall into early spring!

Measuring Moisture beneath the Soil Surface

Impetus: During the frozen season, deep soil temperature and moisture profiles may be evident in areas of excavation, as frost heaves in partially thawed ground, or as water levels in stock pond across the state. The impacts of such variations in deep soil moisture and temperature became readily apparent during the protracted spring thaws of 2009 and again in 2013.

[3] Greg Gust is the warning coordination meteorologist at the National Weather Service, Grand Forks, N.D. Email: gregory.gust@noaa.gov

In 2009, the initial record-setting flood crest which came through Fargo ND in late March was followed by a secondary flood crest in mid-April. That second crest was significantly reduced by soil thaw and moisture infiltration, especially within the Sheyenne River Sub-Basin, which had not yet occurred during the initial crest. Likewise, the May 1st 2013 flood crest at Fargo ND was mitigated by the record latest and slowest spring thaw cycle – one which again allowed for a significant soil thaw and moisture infiltration, this time in the Wild Rice and Bois de Sioux River Sub-Basins.

Projects: Beginning in 2013, various local, state and federal agencies began working on a thorough assessment of the Red River Basin's hydro-meteorological networks in an effort to find ways to improve the quality, density, and timeliness of the various surface-based observation platforms, especially as they affected hydrologic modelling. By the end of 2015, this initial gap-assessment had led to the establishment of a small experimental network of five deep soil moisture and temperature sensors in the far southern Red River Basin, funded through the Southeast Cass Water Resource District (CWRD). At the same time, an effort was spearheaded by both the MN and ND Silver-Jackets (a consortium of federal agencies) to find funding sources for a larger and more robust network of such sensors.

Since 2016, the of Silver-Jackets project has led to a growing number of soil sensors sets now stretching across much of the Red River Basin and steadily spreading into central and western reaches of the state.

Figure 7, shows the current distribution of near surface (10 cm) temperature data, and the deep soil temperature and moisture data available on the NDAWN website (NDAWN, 2018).

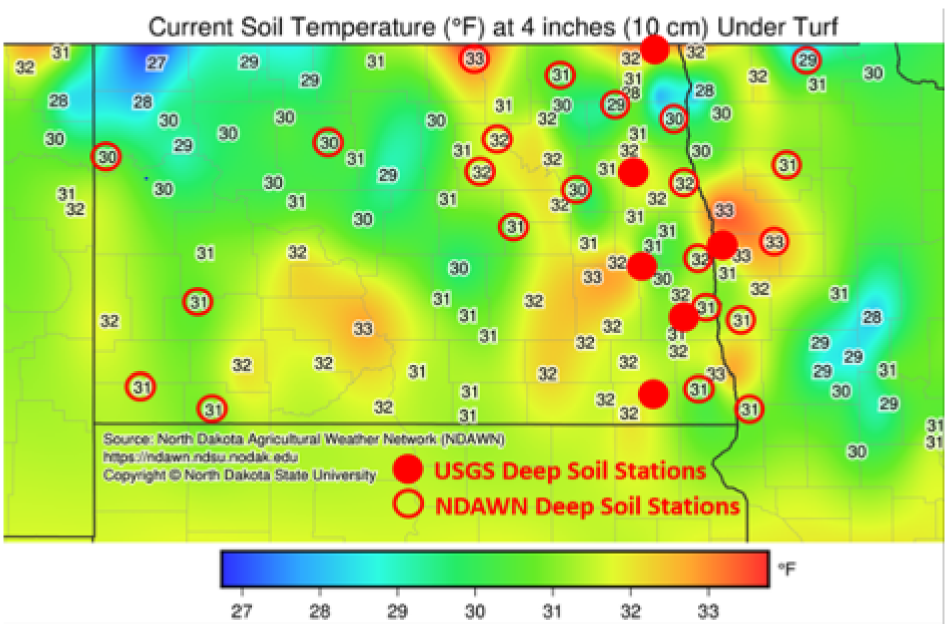


Figure 7. As of 19 Dec 2018, there were over 120 North Dakota Agricultural Weather Network (NDAWN) stations reporting 10cm soil temperature under both bare soil and turf conditions. At 20 of these stations there were additional deep soil temperature and moisture sets, here shown as opened circles. An additional 6 deep soil stations were co-located with USGS river gaging stations, here shown as closed circles.

Across the Red River Basin and the state of North Dakota there are currently (as of 19 Dec 2018) some 26 stations reporting both deep soil temperatures and moisture, and posted via the NDAWN website.

In the same geographical area covered by NDAWN, there are an additional 6 deep soil temperature and moisture stations operated by NOAA as part of the Climate Reference Network (CRN), and 3 stations operated by the USDA as part of the Soil Climate Analysis Network (SCAN).

Successes: In all, some 35 stations are now reporting at least daily reading of soil moisture and temperature at various levels between 20 and 100 cm (8 to 40 inches) deep in the ground, some even deeper, where once there was less than a half dozen. These stations are funded through a combination of local, state, and federal dollars covering their installation, maintenance, and day-to-day power and communications needs.

Spatial Variability: Of course, soil moisture can vary greatly over small distances due to high variability in convective season rain events - often one field can get soaked while an adjacent plot of land is left dry. And, given the wide variety of soil types we have to deal with we can have even greater variability in how that moisture moves vertically and laterally through the various top-soil and sub-soil layers. This explains why we would need such an extensive array of daily soil temperature and moisture measurements across the area, and such an increased detail within the Red River Valley. Figure 8, shows a low-resolution, nation-wide map of soil textures or types as used in NASA's Land Data Assimilation System (NLDAS, 2018).

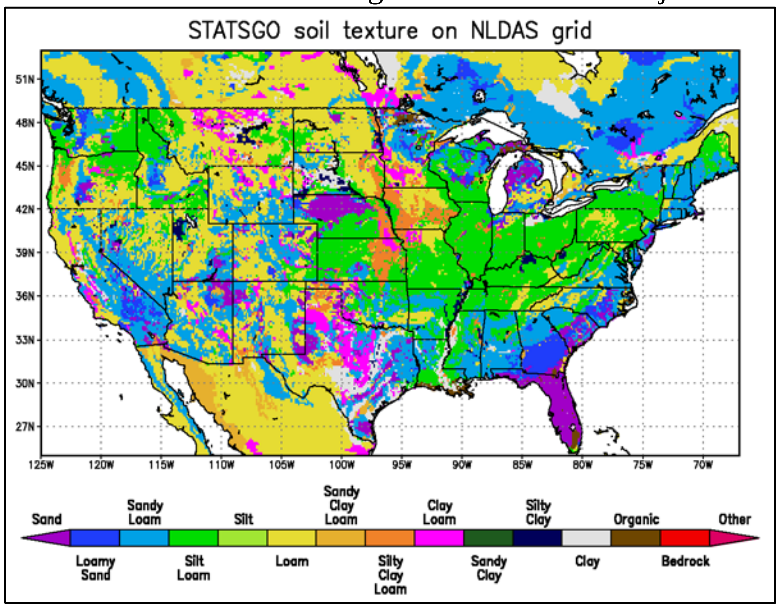


Figure 8. Soil textures or types as used in NASA's Land Data Assimilation System (NLDAS).

Soil Moisture data which is most readily available for either scientific study or practical applications comes from three main sources: 1) actual (in-situ) soil moisture measurements, as we've detail above; 2) airborne (remotely sensed) measurements, via aircraft and satellite; 3) and various computer models (Xia et al, 2015).

Remote Sensing: Periodic aircraft and satellite based measurements can help to expand our knowledge area around each ground-based sensor report by detecting similar near-surface radiative properties along their respective scan paths. The NWS' **National Operational Hydrologic Remote Sensing Center** provides airborne measurements of Soil Moisture, prior to snow cover, and Snow Water-Equivalent within the snowpack (check out **NOHRSC** at https://www.nohrsc.noaa.gov/snowsurvey/). These and other airborne platforms rely on reliable in-situ soil measurements to help maintain their sensor calibration and to improve over-all data assimilation.

The NASA **Soil Moisture Active Passive** (check **SMAP** at https://smap.jpl.nasa.gov/), launched in 2015, is a satellite based platform for detecting soil moisture using a variety of instrument packages. Where intermittent NOHRSC flights can cover numerous narrow ribbons of airspace and tie measurements to local ground-source observations, the more regular and broader (but lower resolution) satellite-based scans can help fill in the large gaps between such surface or aircraft measurements.

Models: Hourly, daily, or weekly ground based and/or remotely sensed measurements of soil temperature and moisture are then assimilated into a more detailed spatial analysis scheme through various modelling techniques. Each of these models has particular strengths and weaknesses, depending on their specific application. You can learn more about these assimilation schemes by checking the NASA and NOHRSC links listed above or the resources listed at the end of this article.

All of the information in this article has focused on getting the types of data needed to assess the current state of the soil temperature profile and moisture profile. Unlike the atmosphere, which is moving around us in a fairly rapid motion on an hour-by-hour basis, soil temperature and moisture properties are generally moving at a much slower rate through a highly variable soil medium. Perhaps a future article will focus on efforts underway to build a better forecast model for these soil properties.

The Next Step

Building a Soil Moisture Forecast!

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Contacting the North Dakota State Climate Office

Please contact us if you have any inquiries or comments, or would like to know how to contribute to this quarterly bulletin[4].

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