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North Dakota Climate Bulletin

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In This Issue

Produced by
Adnan Akyüz, Ph.D.
State Climatologist

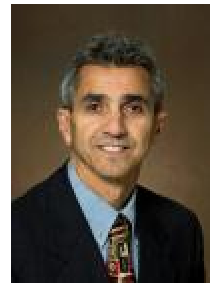
Graphics
NCEI, SPC, NOAA, USDM

Contributing Writers
M. Ewens
A. Schlag
G. Gust

North Dakota State Climate Office
www.ndsu.edu/ndsco

North Dakota State University

From the State Climatologist



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

The overall summer average temperature was 1.5 degrees warmer than average, which would make it the 22nd warmest summer on record. Precipitation-wise, the statewide accumulation was 2.05 inches drier than average, which would make it the 25th driest summer on record. Conditions prior to summer were opposite, wet and cool, which negated the impact of the current drought North Dakota is experiencing.

Overall, 140 records, including temperature- and precipitation-related occurrences across the state, were tied or broken. Additionally, 399 significant storms also were reported, including 13 tornadoes. The total number of tornadoes to strike North Dakota this year became 20 which is below the 1981-2010 average of 29 tornadoes per year.

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

Weather Highlights

Seasonal Weather Summary: By Adnan Akyüz

Precipitation

Using analysis from the National Centers for Environmental Information (NCEI), the average North Dakota precipitation for the summer season (June 1 through Aug. 31, 2022) was 6.57 inches, which was 1.23 inches less than the last season (spring 2022), but 0.1 inches more than last summer (summer 2021) and 2.05 inches less than the 1991-2020 average summer precipitation (Table 1). This would rank the summer of 2022 as the 25th driest summer since such records began in 1895.

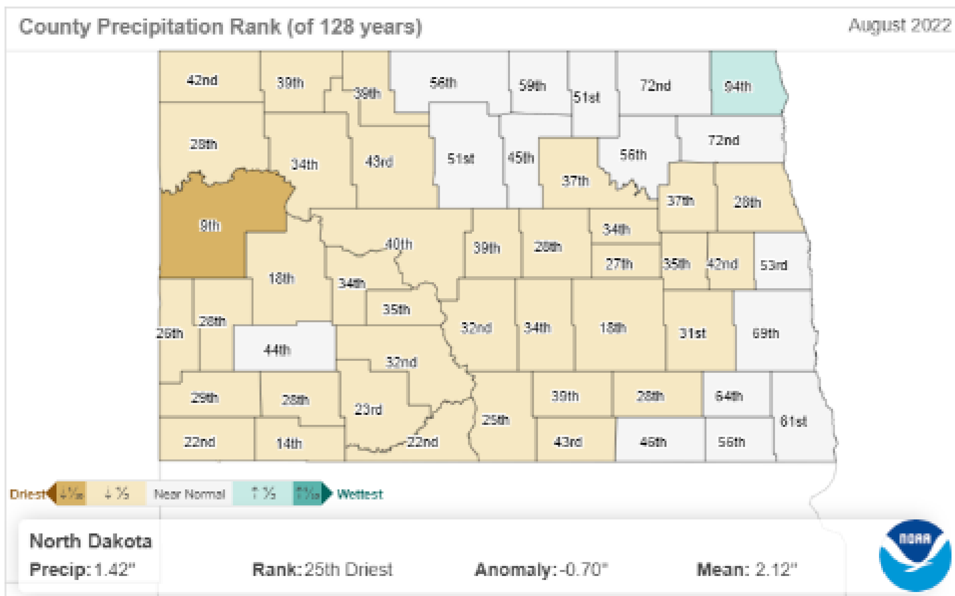


Figure 1. Precipitation rankings in summer of 2022 for North Dakota. (National Centers for Environmental Information, NOAA)

The counties shaded in brown in Figure 1 indicate drier-than-average conditions in summer 2022. On the other hand, the counties shaded in green in the same figure indicate wetter-than-average conditions. White shadings indicate near-average conditions. The numbers inside the counties are the precipitation rankings, with 1 being the lowest ranking (driest) and 128 being the highest ranking (the wettest)

The greatest seasonal precipitation accumulation of the season was 10.85 inches, recorded in Fargo, Cass County. The greatest seasonal snowfall accumulation was “trace,” recorded in Williston, Williams County.

Based on historical records, the state average summer precipitation showed a positive long-term trend of .008 inches per century during this period of record since 1895. The state’s highest and lowest seasonal summer average precipitation ranged from 3.32 inches in 1929 to 15.65 inches in 1993. The “Historical Summer Precipitation for North Dakota” time series (Figure 2) shows a graphical depiction of these statistics.

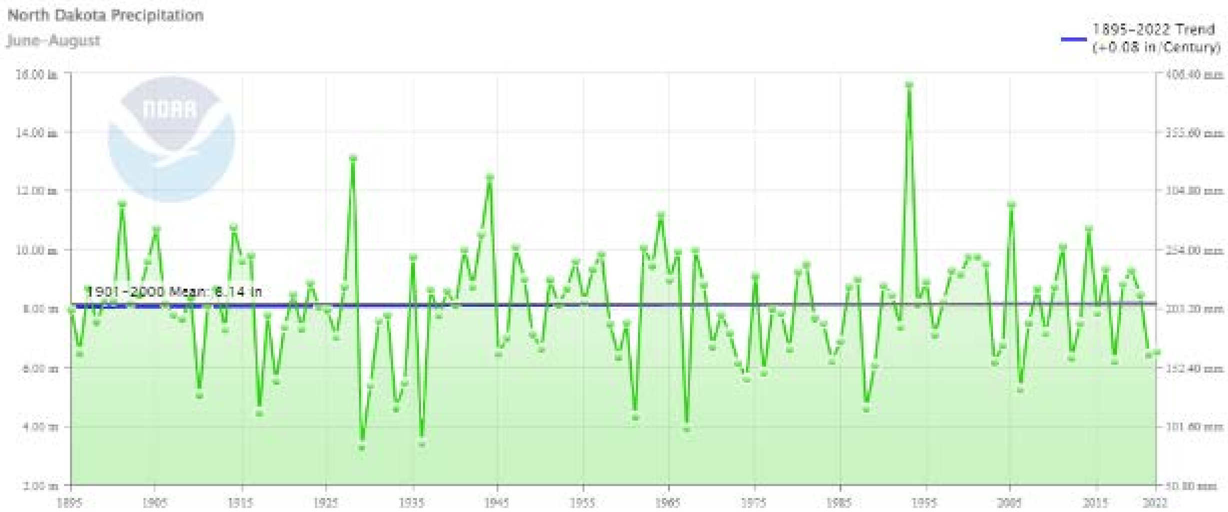


Figure 2. Historical summer precipitation time series for North Dakota.

Table 1. North Dakota Summer Precipitation Ranking Table[1].

Period	Value	Normal	Anomaly	Rank	Wettest/Driest Since	Record Year
Summer 2022	**6.57”**	**8.62”**	-2.05”	**25th driest** **104th wettest**	**Driest since 2021** **Wettest since 2020**	**3.32” (1929)** **15.65” (1993)**

[1] NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Time Series: www.ncdc.noaa.gov/cag.

Temperature

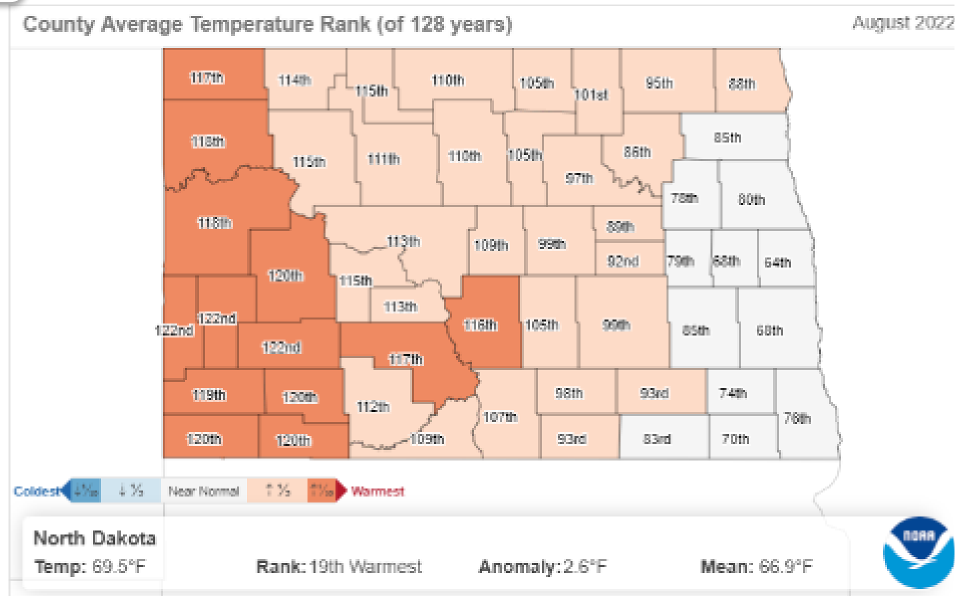


Figure 3. Temperature rankings in summer of 2022 for North Dakota. (National Centers for Environmental Information, NOAA).

The average North Dakota temperature for the season (June 1 through Aug. 31, 2022) was 68.2 F, which was 30.4 degrees warmer than the last season (spring 2022), but 2.5 degrees colder than last summer (summer 2021). It was 1.5 degrees warmer than the 1991-2020 average summer temperature, which would rank summer 2022 as the 22nd warmest summer since such records began in 1895 (Table 2).

The counties shaded in pink and brown in Figure 3 indicate warmer-than-average conditions. The numbers inside the counties are the temperature rankings, with one being the lowest ranking (coldest) and 128 being the highest ranking (the warmest).

Based on historical records, the average summer temperature showed a positive trend of 1.7 degrees per century since 1895. The state’s highest and lowest seasonal summer average temperatures ranged from 61.2 F in 1915 to 72 F in 1936. The “Historical Summer Temperature for North Dakota” time series (Figure 4) shows a graphical depiction of these statistics.

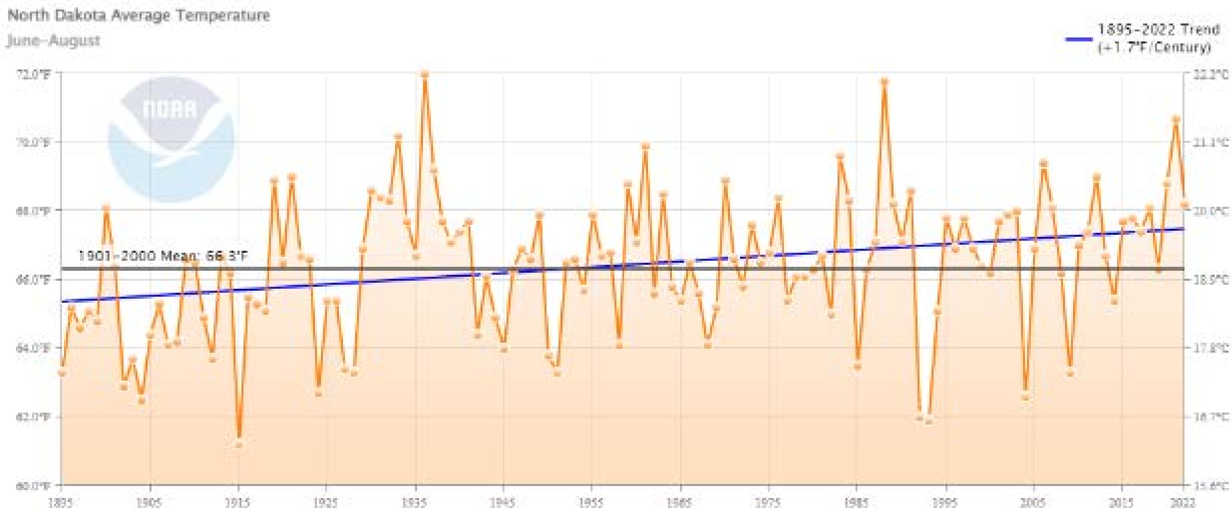


Figure 4. Historical summer temperature time series for North Dakota.

Table 2. North Dakota Summer Temperature Ranking Table[2].

Period	Value	Normal	Anomaly	Rank	Warmest/Coolest Since	Record Year
Summer 2022	68.2 F	66.7 F	1.5 F	107th coolest 22nd warmest	Coolest since 2019 Warmest since 2021	61.2 F (1915) 72 F (1936)

[2] NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Time Series: www.ncdc.noaa.gov/cag.

Drought: The D0 (Abnormally Dry Conditions) category in western North Dakota in the beginning of the season spread and intensified. By the end of the season, less than 1% of the state was in D1 (Moderate Drought), and nearly 28% of the state was in D0 categories. Figure 5 below shows the drought conditions at the beginning and the end of summer. Figure 6 shows the drought intensity and coverage on a time scale. Both of the figures show drought conditions spatially and temporally.

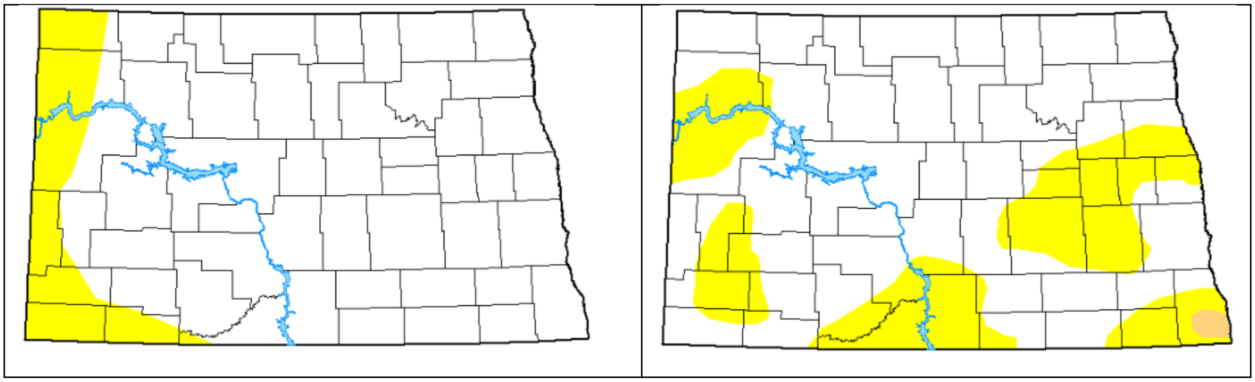


Figure 5. Drought Monitor map comparison for North Dakota in the beginning (on the left) and at the end (on the right) of summer 2022. (U.S. Drought Monitor)

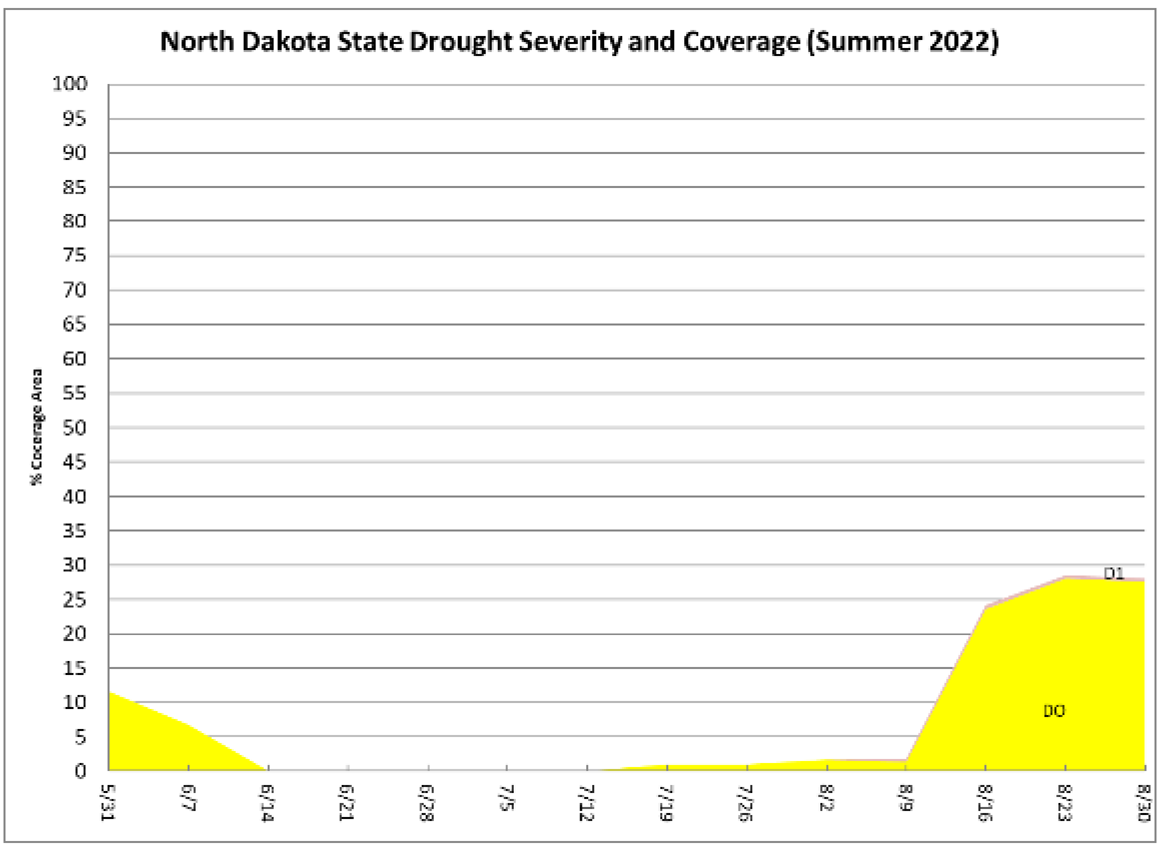


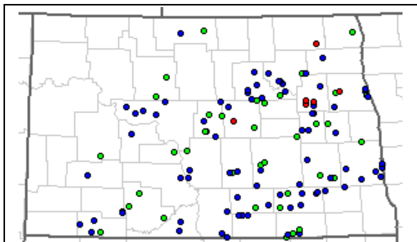
Figure 6. Statewide drought coverage in percentage and intensity (D0 through D4) in a time scale representing the state from the beginning to the end of the season, with a one-week resolution in summer 2022.

Storms and Record Events

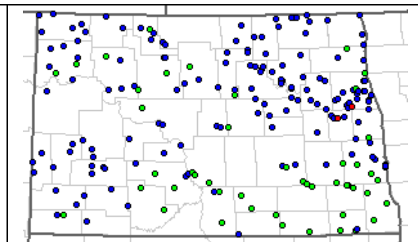
State Tornado, Hail and Wind Events for Summer 2022

Table 3. The numbers in the table below represent the number of tornados and hail and wind events accumulated monthly and seasonally.

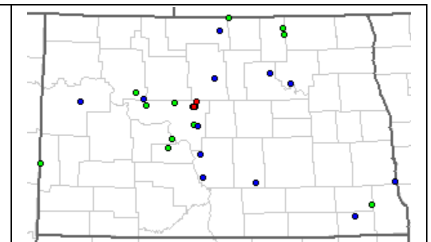
	June 2022	July 2022	August 2022	Seasonal Total
Tornado	6	2	5	**13**
Hail	42	57	12	**111**
Wind	87	176	12	**275**
Total	**135**	**235**	**29**	**399**



June 2022
North Dakota Storm Events



July 2022
North Dakota Storm Events



August 2022
North Dakota Storm Events

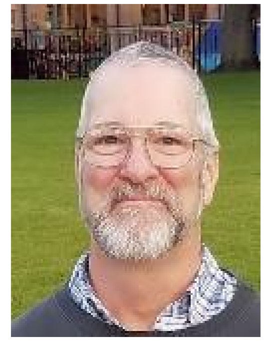
Figure 7. Geographical distribution of the storm events in the table above in each month. The dots are color-coded for each event (red: tornado; blue: wind; green: hail).

State Record Events for Summer 2022

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

Category	June	July	August	Seasonal Total
Highest daily max. temp.	29	4	4	**37**
Highest daily min. temp.	35	17	4	**56**
Lowest daily max. temp.	3	2	13	**18**
Lowest daily min. temp.	2	5	0	**7**
Highest daily precipitation	6	10	6	**22**
Highest daily snowfall	0	0	0	**0**
Total	**75**	**38**	**27**	**140**

Seasonal Outlook



Fall 2022 Outlook

By M. Ewens[3]

The meteorological summer months of June, July and August 2022 were generally warmer and slightly drier than normal across the Red River valley region. In fact, large sections of the northern United States saw temperatures averaging on the warm and dry side of normal. As is common during the convective season that is the period of the year when thunderstorms and showers dominate the precipitation patterns, there were some areas of the northern Plains that were on the cool and wet side. But these areas were the exception rather than the rule for the recent meteorological summer.

The summer 2022 outlooks were based largely on persistence, climatology and large-scale trends within the recent decades. With a near neutral ENSO in the Pacific during the summer, this was not much of a factor in the prediction for the summer months. That begins to change as we head into the fall and winter of 2022-23, as a relatively rare third La Nina forecast looks to be a significant factor in the climate across the northern Plains. From a historical standpoint, La Nina has relatively little influence on the temperature patterns in the October, November and December time, yet does exhibit a “dry forcing,” especially across southern North Dakota and through much of the North Central United States. Aside from the historical composites, there are optimal climate normal methods, constructed analog methods and soil moisture/multiple linear regression tools that help produce long-range forecasts. The North American Multi-Model Ensemble [MME], a combination of climate models from various meteorological centers such as UCAR, Environment Canada and the European Center for Medium Range Forecasting also contribute to the outlook process.

The next 90-day went outlook from the CPC should be available on Nov. 17, 2022 at www.cpc.ncep.noaa.gov/products/predictions/90day.

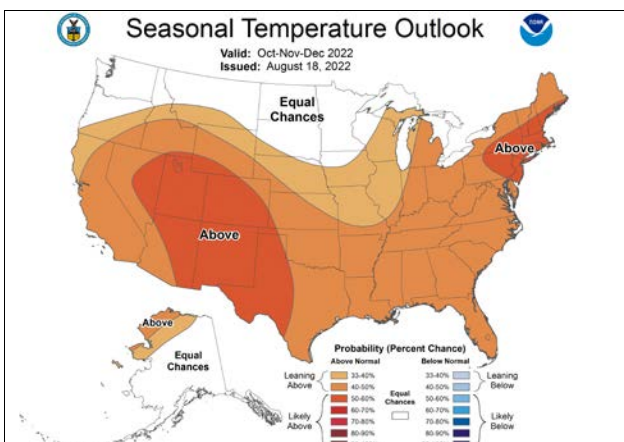


Figure 8a. October through December temperature outlook. (Climate Prediction Center, NOAA)

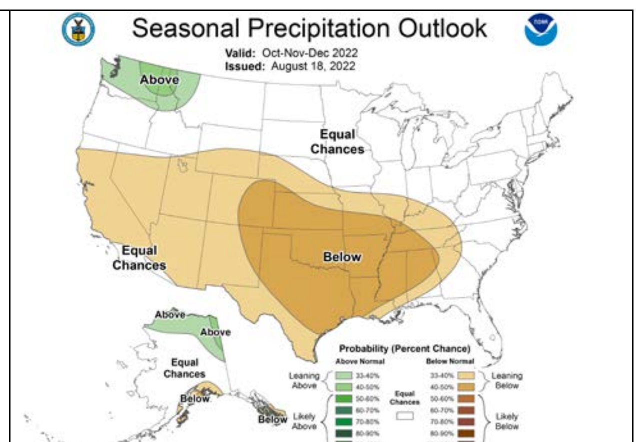


Figure 8b. March through May precipitation outlook. (Climate Prediction Center, NOAA)

[3] Corresponding author, Mark Ewens, Home on the Prairie Weather. Email: SLAPM7@msn.com

Hydro-Talk

The Drought Pendulum Continues to Swing — By A. Schlag[4]

Oh, well, it was nice while it lasted. I'm talking about the above-normal moisture we received this past spring. The abundant soil moisture shown in Figure 9 was a huge plus for the agricultural community as we entered June. After the past couple of years with drought being a persistent presence, we saw all drought designations removed from North Dakota by the middle of June, 2022. Not long afterwards, we started to see the pendulum swinging back towards a drier pattern with D0 being introduced in the very southeastern corner of North Dakota with the update to the US Drought Monitor on July 19, 2022. Fast forward to the most recent rendition of the U.S. Drought Monitor and we now see a slow but steady introduction and expansion of D0 and D1 levels of drought across the state, see Figure 10. Nonetheless, this abundant soil moisture would help carry our crops and pastures through a relatively dry second half of the summer. Water and heat stress started to show up in crops in August, but several articles in the media lately have discussed expectations for well above-average crop yields. At this point it is fair to say that the region is currently experiencing a meteorologic drought that so far has had minor impacts to crops and pastures. Similarly, little impact has been observed on streamflow across the state as USGS gages have generally remained in the 25th to 90th percentiles even with somewhat less-than-normal precipitation; see Figure 11 where the green and light blue dots represent locations within the above range.

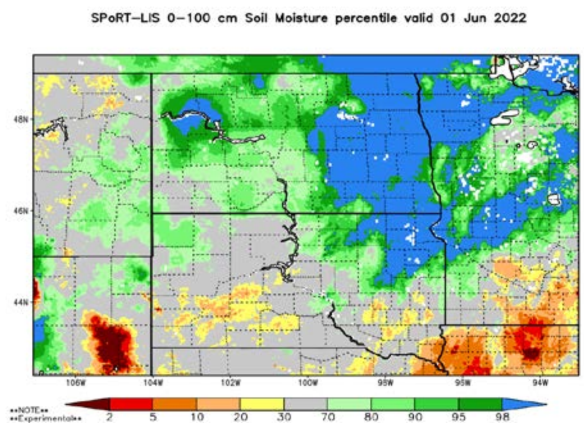


Figure 9. Root Zone Soil Moisture on June 1st, 2022.

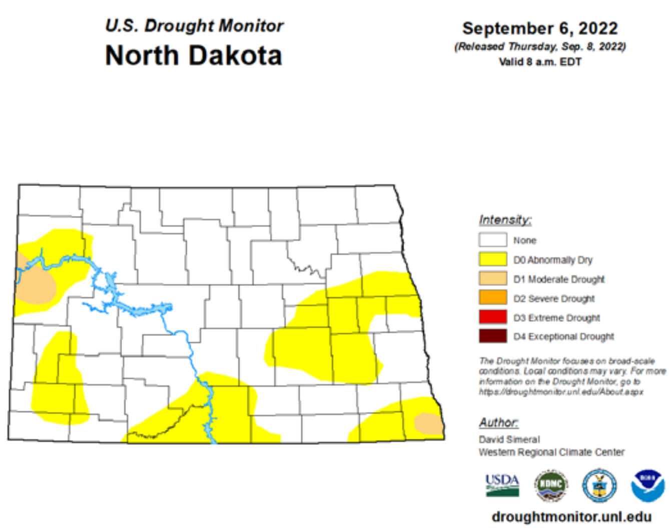


Figure 10. Drought Designations as of 6 September, 2022.

As we are now entering meteorologic fall, the question of "What should we expect for the coming winter?" is already being asked. When it comes to answering that, my very first resource is always the Climate Prediction Center's (CPC) discussion of the current status of the El Nino Southern Oscillation (ENSO), and its forecast for the same during the December-February heart of our meteorologic winter.

[4] 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

For the upcoming winter months, they are expecting a 60% chance for a third winter in a row impacted by La Nina weather in the United States. Under that scenario, La Nina has a known effect of slightly enhancing our risk for a cooler and wetter-than-normal winter. In fact, this article from Climate.gov shows the history of wintertime La Nina events and their precipitation outcomes from 1950-2017. Some of the more notable years for our region of the country were the winter La Nina events of 2008-09 and 2010-11 as both of those springs are memorable for the extreme amount of flooding across North Dakota. I don't write this in order to cause panic this far out from the spring of 2023, only so people know a distinctly cooler and wetter-than-normal winter is a real risk going forward. What is more difficult to ascertain, though, is the effect all of the other major climate drivers will have on this winter. ENSO is something that forecasters have demonstrated some skill in forecasting months in advance, but there are other significant climate drivers in the form of the Arctic Oscillation, the Pacific Decadal Oscillation, and North Atlantic Oscillation that all have the ability to either enhance or interfere with the normal expectation for a La Nina winter. Regrettably, these oscillations that can significantly impact our weather months from now are generally not as forecastable as the ENSO.

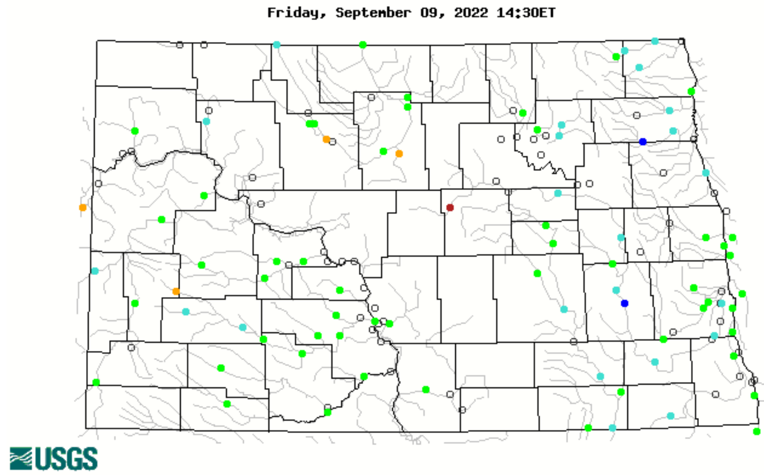


Figure 11. Streamflow Percentiles as of Sept 9th, 2022.

There are other resources from the CPC that we can use as guidance for our expectations. In particular, the whiskers distribution plots, such as the example shown in Figure 12, help us further understand the possible ranges we can expect for both temperature and precipitation.

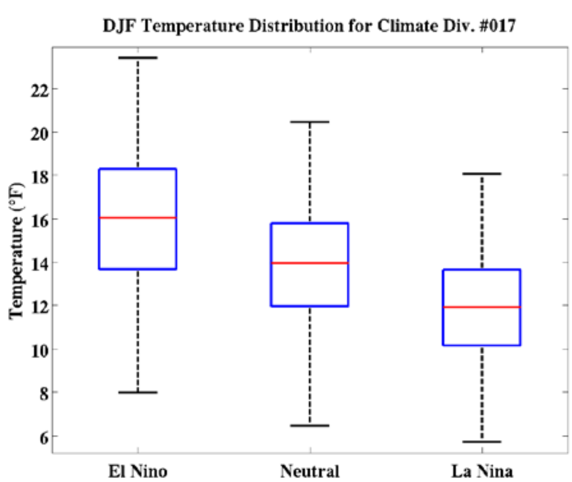
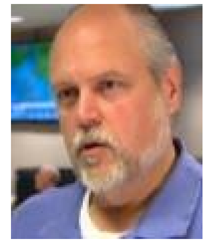


Figure 12. CPC December-February Temperature Distributions for Western North Dakota, Climate Division 17.

If one delves into the temperature and precipitation whisker distribution plots, the real problem with La Nina seems to be in a cooler and wetter-than-normal February, March and April. This effectively extends our snow accumulation season and potentially increases precipitation during our traditional spring snowmelt and flood season.

When it comes right down to it, we have a relatively short history of climatic data (remember, I'm a geologist/hydrologist by pedigree) on which to base our expectations, but if the trend over the past 60-70 years is used as a guide for us, we have a greater-than-normal risk of a cooler and wetter-than-normal winter and early spring. Hopefully this will help keep the currently expanding drought at bay before onset of the 2023 growing season. Of course, if there is anything at all I've learned over the years, it is that Mother Nature should have been a MLB pitcher for all the curves she throws at us.

Science Bits



Turbulent Eddies, Gusts and Plain Windy Conditions **By G. Gust[5]**

Breezing Through Life in the Northern Plains:

> *"Every wind is weakest in the spot from which it blows; as they proceed and leave their source at a distance they gather strength. Thus the winter in the north is windless and calm: that is, in the north itself; but, the breeze that blows from there so gently as to escape observation becomes a great wind as it passes on."* [2]
>
> *– Aristotle, circa 350 B.C.E*

What is wind? From Aristotle's ancient work titled *Μετεωρολογικά (Meteorologica)*, likely the first meteorology textbook series,[6] we can get a concept of how the ancient world viewed the interplay of what were then considered the four basic elements, earth, air, fire and water.

In Book 2, Part 4, Aristotle first describes wind as being *the motion of air*, whether it is a moist or dry vapor.The cause of that motion being largely attributed to the effects of either localized or large-scale heating and cooling of the air by fire, the sun! In Aristotle's time, no thought was given to the effects of planetary motion, as the Earth, flat or round, was considered to be still with the celestial dome all in motion around the Earth – topics discussed earlier in his Book 1.

Dr. John Dutton in his sterling work, *The Ceaseless Wind*, first printed in 1976, covers the whole schema of atmospheric motions, or winds, from the planetary scale down to storm scale or smaller flows, and details the basis for modern meteorological thought. [3]

In a much simplified nutshell, wind is considered to be a result of the Earth's daily rotation on its axis, combined with the differential heating of the Earth's surface, as modified by its overall topography, and with the wind's motion to be further affected by the Earth's surface friction or roughness. These main factors produce areas of higher or lower air pressure, both in the atmosphere far above our heads and much nearer the Earth's surface, with air then moving between those areas from high to low pressure in an attempt to balance the resultant pressure gradient forces.

One may also note that air molecules have mass, though much smaller than suspended dust particles or birds in flight – as was understood by the ancients. A rotating Earth moving relative to those suspended particles gives rise to a concept of wind. The direction and speed of the resulting wind is a much more complicated matter and far beyond the scope of this article.

Sensing Wind: Human beings sense wind in a variety of ways. We "feel" it brushing against exposed skin as our hairs are ruffled. We also feel the coolness or heating that a wind can bring as it either removes or adds heat from our skin (sensible cooling or heating), or as it may evaporate sweat from our skin (evaporative cooling).

We may "hear" the wind as it rustles the tree leaves or funnels, whistles and roars among trees or buildings and as it rattles our rain gutters. We may "see" the wind as it ruffles the hair of our pets or our neighbors' heads, as it creates waves across the surface of a pond, lake or field of grain, and as it carries dust or smoke across an open prairie.

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

[6] Frisinger, H. Howard, 1972: Aristotle and his "Meteorologica". *Bull. Amer. Meteor. Soc.*, Vol. 53, No.7, pp. 634-638. Online at: https://doi.org/10.1175/1520-0477(1972)053%3C0634:AAH%3E2.0.CO;2

The "taste" or "smell" of the wind may be as refreshing and clean on our lips or nose as a recent spring rain or as gritty, bitter and nasty as a passing vehicle's exhaust or the smoke from a distant fire. Hmmm, where is the smell of that backyard barbecue coming from?

Figure 13. An Automated Surface Observing System (ASOS) at an airport. The 10 meter tower hosts a wind vane and anemometer. Image courtesy of

Measuring Wind: Direct measurement of the wind normally comes in two parts, its direction and its speed, and typically in the horizontal plane.

Wind Direction: We determine the direction of the wind relative to where it is coming from – thus a north wind is blowing *from* the north. The smell of that backyard barbecue is coming from our neighbors to the north, as I'm writing this article. Tomorrow they may smell my barbecue in their yard as the wind shifts from the south.

Direction is typically measured in degrees of compass arc, from 0 to 360, where 0 and 360 are true north, 90 is due east, 180 is due south, and 270 is due west. A wind vane, either collocated with or affixed to an anemometer is used to determine the wind direction.

Wind Speed: Depending on the manufacturer, most high grade anemometers are comprised of either wind cups spinning on an axis, an impeller blade (propeller-like) spinning on an axis, or stationary acoustic/sonic sensors, though several other varieties exist.[4] All of these three main types are represented in official wind sensors spread across the North Dakota prairie.

Most wind sensors are measuring winds at 1-second intervals, but due to the response times of various types of sensors the 3-second average of those readings are used. Previous to the current 3-second wind gust standard there was a 5-second standard, largely due to the heavier and thus less responsive anemometer cups then in use.[5]

- **Sustained wind** is currently defined as the 2-minute average of 3-second winds, and may be reported at any interval from 2 minutes to 60 minutes, depending on the observing platform.
- **Wind gust** is the highest 3-second wind during the corresponding 2-minute period.
- **Peak wind or gust** may be reported as the highest wind gust recorded within a given hour, and may also be carried as the highest wind gust recorded during an entire day.

The Federal Meteorological Handbook Number 1 (FMH-1) identifies standards for surface-based meteorological observations across all federal agency programs, and in coordination with the World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO).

With few exceptions, these standards also apply uniformly to all meteorological observations taken in support of aviation, surface transportation, fire weather support, and a variety of agricultural, hydrologic and general commercial applications. For example, air temperature readings are taken by most types of stations at a height of around 5-6 feet above the ground, representing the typical standing level of an adult human face exposed in that environment.

Wind sensor heights can vary with application. Historically, wind observations varied in height from 5 feet to 50+ feet above the ground level, based largely on where a good exposure to the wind was attainable.

The current standard of 10 meters (30.8 ft.) is relatively new and dates to the NWS implementation of the ASOS: Automated Surface Observing System (Figure 13) in the early 90s, and now applies to most all aviation observations and most surface transportation weather observations, such as those produced by the DOT's Road Weather Information System (RWIS).

Agricultural and fire weather anemometer heights are the most notably different in that readings are generally taken closer to the crop, grassland or forest canopy levels to better capture the effects of wind on those vegetative surfaces.

The standard height for fire weather wind sensors, such as the RAWS: Remote Automated Weather Station in Figure 14, is only 20 feet (6 meters).[7]

Figure 14. A typical RAWS station. Image courtesy of the USDA, National Wildfire Coordinating Group.

NDAWN: North Dakota Agricultural Weather Stations[8] were originally configured with a 3-meter (9.8 ft.) tower. However, a growing number of those platforms are adding an additional 10-meter wind sensor tower to increase their overall versatility.

Figure 15. The NDAWN station located at Carrington 4N. Note the impeller type wind sensors located at 3 and 10 meters high on the tower. Image courtesy of the North Dakota Ag Weather Network.

The NDAWN sensor at Carrington 4N (Foster County), shown in Figure 15, is one of over 50 such stations that have wind sensors located at both 3-meter and 10-meter heights. Carrington 4N has the longest record of 10-meter winds, dating back to July 12, 2016.

Some interesting North Dakota wind gust records:

The highest wind gust reading on any North Dakota based NDAWN station at 3 meters, was 94.3 mph, recorded at Galesburg 4SSW (Cass County; est. 1995) on July 4, 2017. This was during a summer severe thunderstorm downburst event. The highest wind gust reading on any North Dakota based NDAWN at 10 meters was 85.2 mph, recorded at Fortuna 4N (Divide County) at 1:02 a.m. CST on Jan. 14, 2021. The corresponding 3-meter wind gust reading was 75.9 mph, recorded at 1:19 a.m. CST. This was during a winter high wind and/or blizzard episode. The current North Dakota state record for a *measured* wind gust is 135 mph (at standard heights). This was the result of thunderstorm downburst and outflow winds, on the evening of Sept. 15, 1997, and was measured around 8 p.m. MDT by the Sand Creek RAWS (Remote Automated Weather station) site, about 7 miles northwest of Amidon (Slope County), in far southwestern North Dakota.[9]

As you can see, North Dakota is truly a land of wind, with extreme winds possible in every season of the year, including summer. Check out the highest non-tornadic wind gust, largest hail size and strongest tornado reports in your county: https://www.weather.gov/media/bis/North_Dakota_County_Statistics.pdf

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[7].

North Dakota State Climate Office

College of Agriculture, Food Systems, and Natural Resources
North Dakota State University
304 Morrill Hall, Fargo, ND 58108
Climate Services: 701-231-6577

URL: www.ndsu.edu/ndsco
Email: Adnan.Akyuz@ndsu.edu

[7] *This work is supported by the USDA National Institute of Food and Agriculture, Hatch/Multi State project ND1005365.*