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In This Issue

Produced by
Adnan Akyüz, Ph.D.
State Climatologist

Graphics
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Contributing Writers
R. Kupec
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 fall average temperature was 4.8 degrees warmer than average, which would make it the third warmest fall on record. Precipitation-wise, the statewide accumulation was 0.96 inches wetter than average, which would make it the 19th driest fall on record. Conditions prior to fall also were warm, and North Dakota experienced the warmest nine-month (March through November 2021) period on record since 1895. The extreme drought conditions (D3) have continued 40 weeks since March 16, 2021, which is already the longest-lasting D3 on record since 2000 and is still ongoing in northwestern parts of the state. The 2021 drought also broke the largest and the longest extent in D4, D2 and D1 categories.

Overall, 246 records, including temperature- and precipitation-related occurrences across the state, were tied or broken. Twelve significant storms also were reported, including four tornadoes in October.

Detailed monthly climate summaries for September, October and November can be accessed at www.ndsu.edu/ndsco.

Cirrus-floccus above the Fargo skies. (F.A. Akyüz)

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 fall season (September 1 through November 30, 2021) was 4.96 inches, which was 1.19 inches more than the last season (summer 2021), and 3.75 inches more than last fall (fall 2020) and 0.96 inches more than the 1991-2020 average fall precipitation (Table 1). This would rank the fall of 2021 as the 19th wettest fall since such records began in 1895.

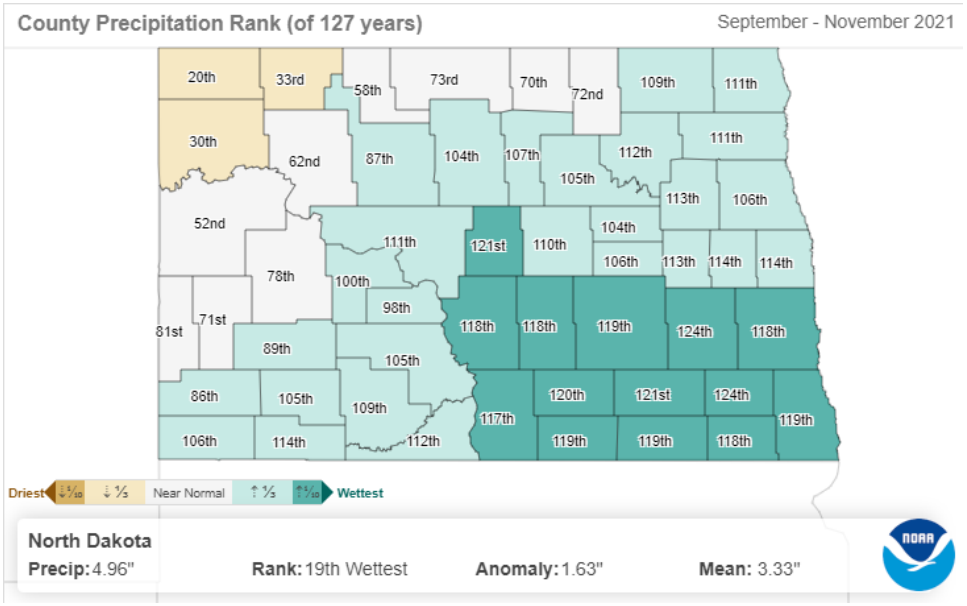


Figure 1. Precipitation rankings in fall of 2021 for North Dakota. (National Centers for Environmental Information, NOAA)

The counties shaded in brown in Figure 1 indicate drier-than-average conditions in fall 2021. Similarly, the counties shaded in green in the same figure indicate wetter-than-average conditions, and white shadings indicate near-average conditions. The numbers inside the counties are the precipitation rankings, with 1 being the lowest ranking (driest) and 127 being the highest ranking (the wettest).

The greatest seasonal precipitation accumulation of the season was 10.99 inches, recorded in Valley City, Barns County. The greatest seasonal snowfall accumulation was 9.7” recorded in Pembina, Penbina County.

Based on historical records, the state average fall precipitation showed a positive long-term trend of 0.87 inches per century during this period of record since 1895. The state’s highest and lowest seasonal fall average precipitation ranged from 8.92 inches in 2019 to 0.99 inches in 1976. The “Historical Fall Precipitation for North Dakota” time series (Figure 2) shows a graphical depiction of these statistics.

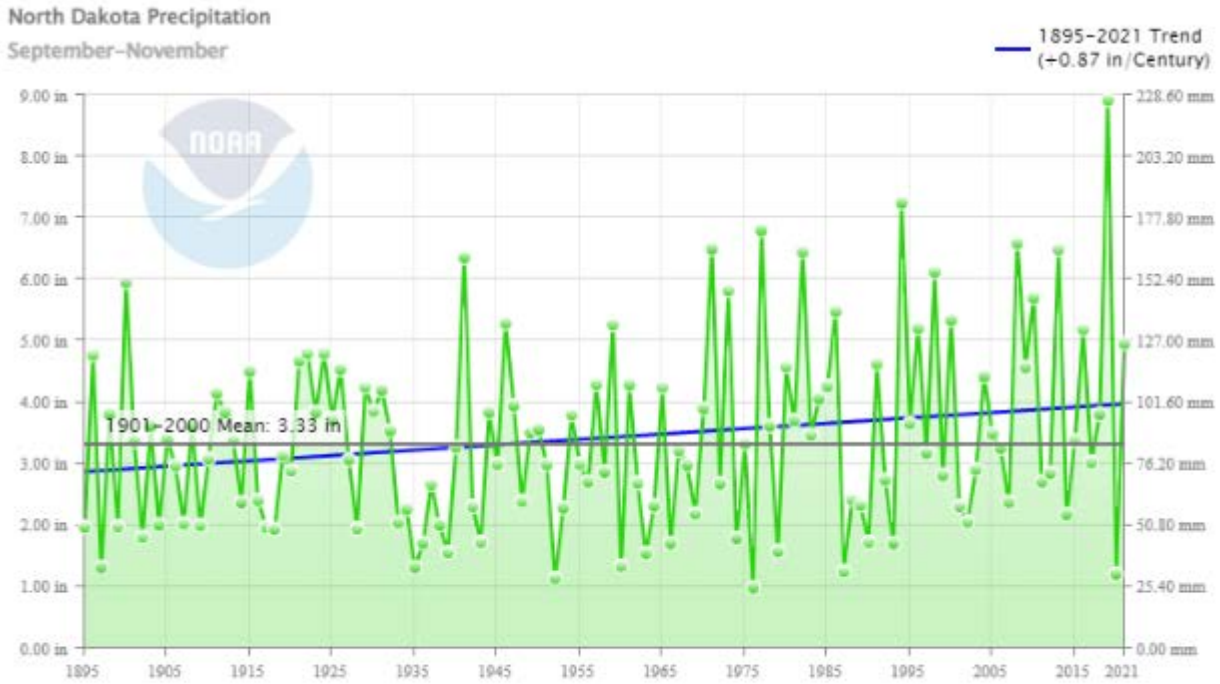


Figure 2. Historical fall precipitation time series for North Dakota.

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

Period	Value	Normal	Anomaly	Rank	Wettest/Driest Since	Record Year
Fall 2021	**4.96”**	**4”**	0.96”	**109th driest** **19th wettest**	**Driest since 2020** **Wettest since 2019**	**0.99” (1976)** **8.92” (2019)**

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

Temperature

The average North Dakota temperature for the season (September 1 through November 30, 2021) was 47.8 F, which was 22.8 degrees cooler than the last season (summer 2021), but 5.6 degrees warmer than last fall (fall 2020). It was 4.8 degrees warmer than the 1991-2020 average fall temperature, which would rank fall 2021 as the 3rd warmest fall since such records began in 1895 (Table 2).

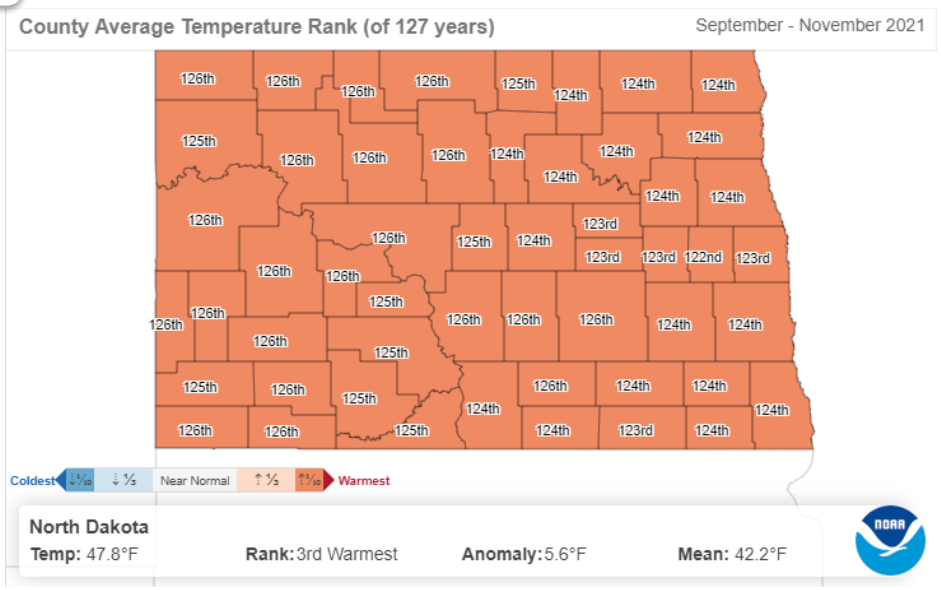


Figure 3. Temperature rankings in the fall of 2021 for North Dakota. (National Centers for Environmental Information, NOAA).

The counties shaded in peach 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 127 being the highest ranking (the warmest).

Based on historical records, the average fall temperature showed a positive trend of 1.7 degrees per century since 1895. The state's highest and lowest seasonal fall average temperatures ranged from 49.1 F in 1963 to 23.2 F in 1896. The "Historical Fall Temperature for North Dakota" time series (Figure 4) shows a graphical depiction of these statistics.

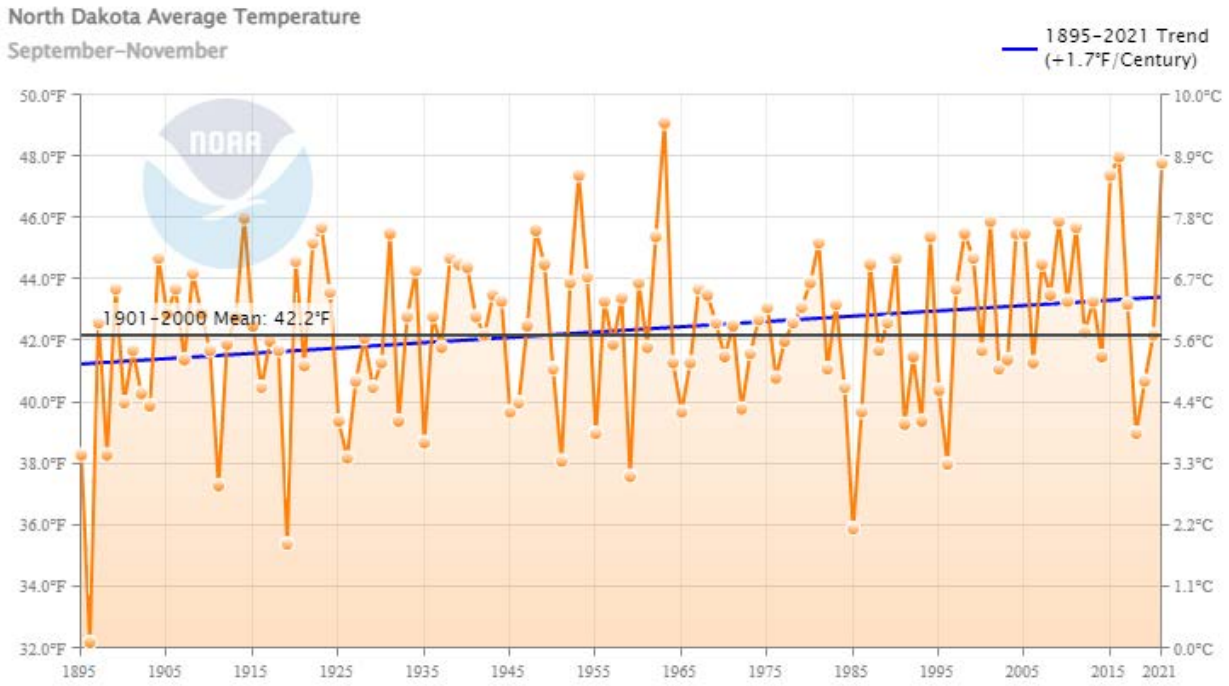


Figure 4. Historical fall temperature time series for North Dakota.

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

Period	Value	Normal	Anomaly	Rank	Warmest/Coolest Since	Record Year
Fall 2021	47.8 F	43 F	4.8 F	125th coolest 3rd warmest	Coolest since 2020 Warmest since 2016	32.2 F (1896) 49.1 F (1963)

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

Drought: The D4 (exceptional drought) occupying 6% of the state at the beginning of the season was eliminated by the end of the season to account for late-season precipitation. However, the timing of the rains had minimal benefit to agricultural communities. Also, the extreme heat during this period somewhat annulled the impact of rainfall. By the end of the season, 9% of the state was in the D3 (extreme drought) category. Forty-three percent of the state was in at least severe drought category, and 69% of the state was in drought by the end of the season. Figure 5 below shows the drought conditions at the beginning and the end of the fall. Figure 6 shows the drought intensity and coverage on a time scale. Both of the figures show drought conditions spatially and temporally.

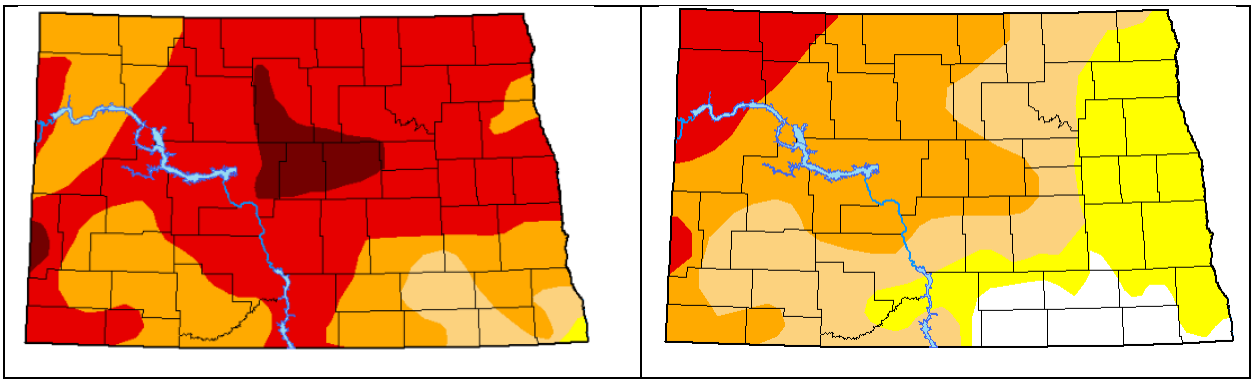


Figure 5. Drought Monitor map comparison for North Dakota in the beginning (on the left) and at the end (on the right) of fall 2021. (U.S. Drought Monitor)

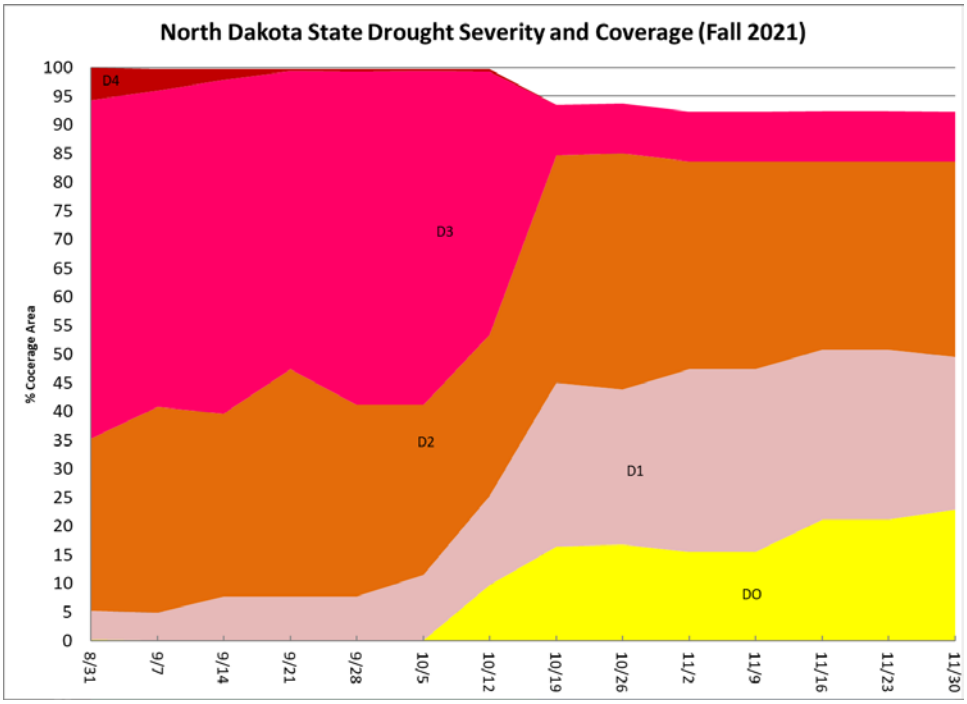


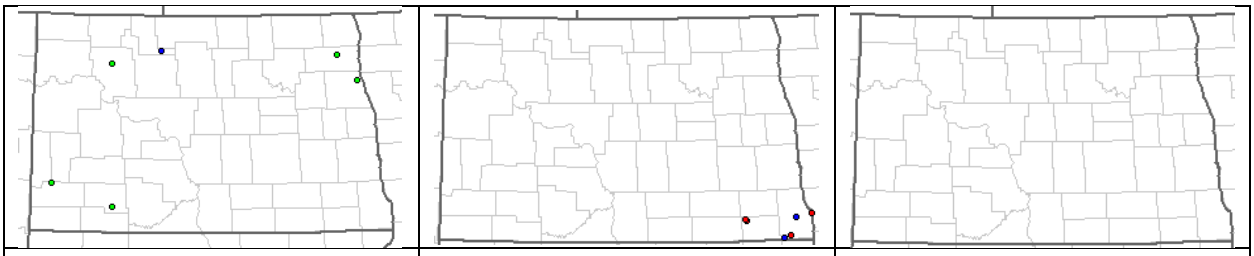
Figure 6. Statewide drought coverage in percentage and intensity (D.O. through D4) in a time scale representing the state from the beginning to the end of the season, with a one-week resolution in fall 2021.

Storms and Record Events

State Tornado, Hail and Wind Events for Fall 2021

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

	September 2021	October 2021	November 2021	Seasonal Total
Tornado	0	4	0	**4**
Hail	5	0	0	**5**
Wind	1	2	0	**3**
Total	**6**	**6**	**0**	**12**



September 2021 North Dakota Storm Events | October 2021 North Dakota Storm Events | November 2021 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 Fall 2021

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	September	October	November	Seasonal Total
Highest daily max. temp.	49	23	3	**75**
Highest daily min. temp.	33	32	16	**81**
Lowest daily max. temp.	1	0	0	**1**
Lowest daily min. temp.	0	0	0	**0**
Highest daily precipitation	6	62	12	**80**
Highest daily snowfall	0	1	8	**9**
Total	**89**	**118**	**39**	**246**

Seasonal Outlook

Winter 2021-22 Outlook

By R. Kupec[3]

Fall brought relief from the summer drought, with most locations seeing average to above-average precipitation across all but the northwest corner of North Dakota. Even with the increase in precipitation, temperatures continued to run well above average, with many locations reporting six to eight degrees above average. We are seeing a developing La Niña in the South Pacific, which typically brings warmer and drier than average autumns to the state. This fall, we had the warmer but not the drier, which means that the previous fall outlook was half correct on the warmer than average prediction.

Winters in North Dakota are colder than average by about 75% when La Niña is present in the Pacific Ocean. Last winter fell into the 25% of La Niña years with above-average temperatures. The correlation between precipitation and La Niña is weaker but trends towards more snow. Last winter also bucked that trend. What was more typical of a North Dakota La Niña winter was the extreme cold in February. Often La Niña winters start near average and turn colder later. December and January last year were just too warm to be brought down by a frigid February.

Given the developing La Niña, this winter should be colder than average, with the second half of winter being colder than the first. Precipitation should be greater than last winter but likely closer to or slightly above seasonal averages. Areas west of the Red River Valley have a marginally greater chance of seeing higher than average precipitation. The current Climate Prediction Center (CPC) Winter Outlook has a similar forecast. It calls for below-average temperatures but only for the western two-thirds of North Dakota (Figure 8a). The CPC precipitation forecast gives an equal chance of higher or lower than average precipitation (Figure 8b). The next 90-day outlook from the CPC should be available on December 16 at http://www.cpc.ncep.noaa.gov/products/predictions/90day

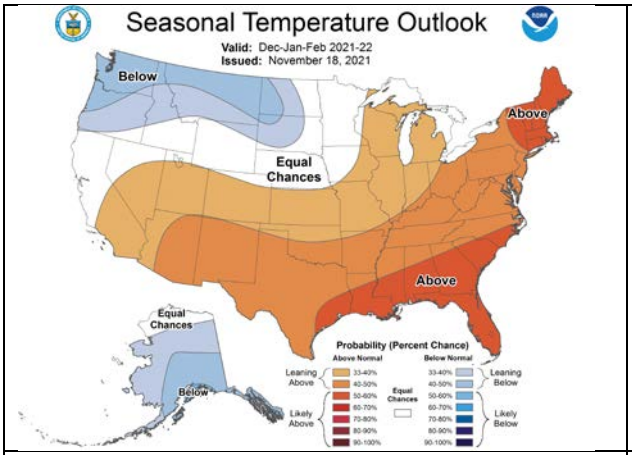


Figure 8a. Jan 2021 through Feb 2022 temperature outlook. (Climate Prediction Center, NOAA)

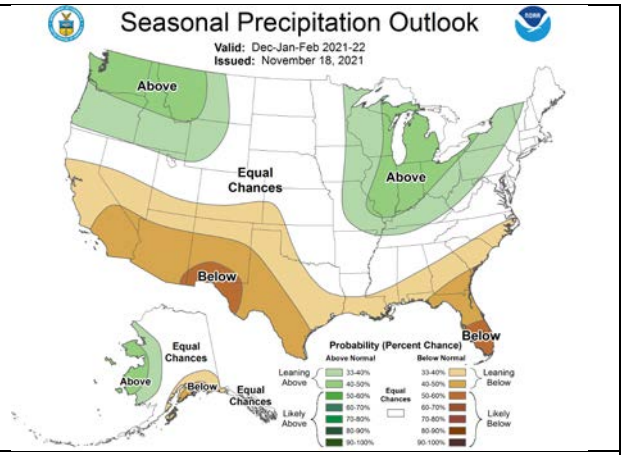


Figure 8b. Jan 2021 through Feb 2022 precipitation outlook. (Climate Prediction Center, NOAA)

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

Hydro-Talk

Brief Recap and Very Early Look at Spring

By A. Schlag[4]

This is the time of year when we sit back, reflect on how the most recent calendar year panned out, and start predicting how winter and spring will unfold. First and foremost, drought remains alive and well in North Dakota (Figure 9) even though the current drought depiction has shown considerable improvement over the past few months (Figure 10). Nonetheless, drought remains the 800-pound gorilla in the room. Figure 10 depicts that well over half of North Dakota remains under Moderate to Severe drought designations. The D4 or Extreme category of drought is most conspicuous by its absence. As Figure 10 suggests, conditions in south-central North Dakota have been more pronounced, while the very northwestern corner of the state has seen little to no improvement over the past six months. One of the key things driving improvement over the past few months has been soil moisture. In most of our growing season, soil moisture was often in the single-digit percentiles as warmer than average temperatures from June through much of August pushed evapotranspiration rates above normal levels.

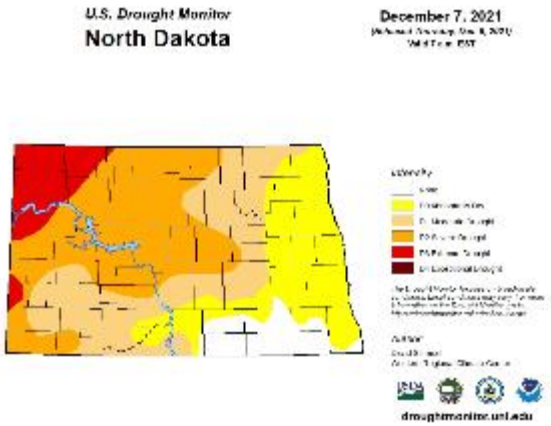


Figure 9. Most Recent U.S. Drought Map of December 7, 2021.

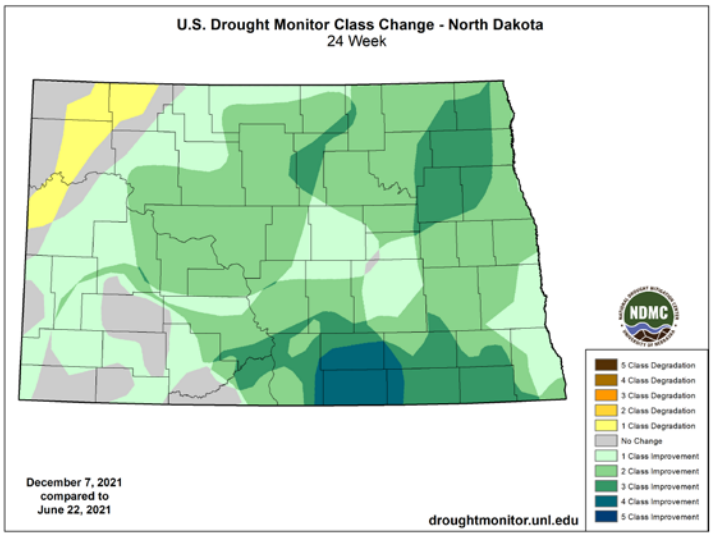


Figure 10. Drought Improvement Since Early Summer, 2021.

Regrettably, the increased soil moisture came at the tail end of the growing season, so pastures and native vegetation did little to take advantage of the opportunity. To some extent, this has left the state in a better position for the beginning of the 2022 growing season. Figure 11 depicts what soil moisture is stored in the upper 100 cm of the soil profile. Due to the winter season, this will

[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

primarily be preserved until spring. Additionally, while soils are better prepared for supporting vegetative growth next spring, they are not so wet as to likely restrict infiltration.

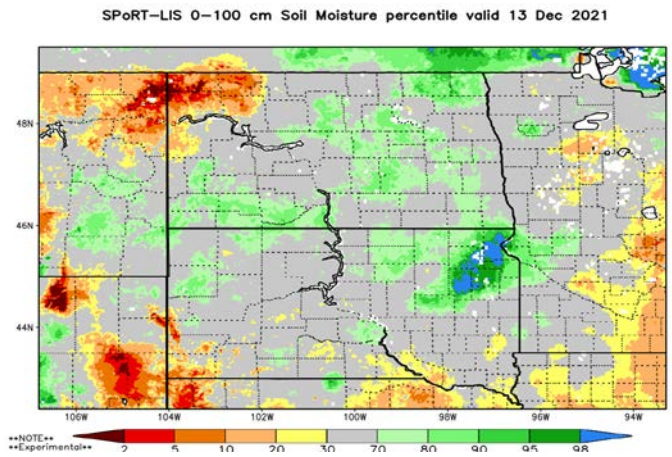


Figure 11. Soil Moisture Percentiles for Upper 100 cm.

This brings us to the present and leads to discussing how the current winter expectations and existing conditions will be reflected come spring 2022. First of all, as we near the middle of December, it has been a pretty mild entry into winter. However, the current La Nina is expected to carry through to spring, and with it, an overall cooler than average winter season is favored (see Figure 8a). On the precipitation side of things, La Nina has a less pronounced effect on North Dakota, and this leads to the Equal Chances designation where above normal, near-normal, or below normal are all equally likely (Figure 8b). However, the overall cooler weather pattern expected lends itself to better preservation of what snow is received for the eventual spring melt season. When we put this all together, it suggests that with what we now know and the most likely outcome for winter, there's a greater chance of having a near normal to above normal snowpack come spring than the very dry winter of last year. Also, since the soils are no longer desperately dry, this should help provide healthy runoff and even more moisture added to the soil, all while helping keep the risk of widespread flooding to a minimum.

All that being said, the coming spring melt season is still 90-120 days into the future, so talk with me come mid-March to see how well these early prognostications pan out.

Science Bits

Northern Lights up and Over Our Heads

By G. Gust[5]

Aurora Borealis

When the solar winds stir magic
Unleashed beauty a riot of color
It undulates and swells, ecstatic
In darkness I stand and wonder

Colors sublime capture my mind
Turmoil of life far, far away
Life on hold not counting time
Aurora Borealis forever and a day

Delice Arleen Skelly

Back in the early 2000s, I was walking home from an evening shift at the National Weather Service office in Grand Forks and looking up through the treetops, and I noticed bands of light arching overhead. I first thought of searchlights or the types of spotlights that might be used as an outdoor advertising gimmick, except it was well after midnight.

When I turned down my street, heading due north, I had my first clear view of what was occurring, and it was stunning! I walked down my street, turned into my yard, and sat on my back deck for much of the next hour, enraptured by the light show that was taking place directly over my head. The Aurora Borealis, more commonly called the Northern Lights, was arching in bands across the sky, from the northern to the southern horizon. And there were layers of these bands, multi-colored bands, crisscrossing bands, and undulating.

Previously, I had frequently watched the Northern Lights as they danced along the distant northern horizon, often as I traveled along U.S. Highway 2 across eastern Montana, North Dakota, or northern Minnesota in the late-night hours. And on those trips, the Northern Lights were that distant ribbon above the horizon, sometimes more vivid but most often just a glimmer.

November 4, 2021: Recently, almost all of North Dakota had an opportunity to experience one of these much rarer "full-dome" exhibitions. Such awesome displays aren't limited to the northern borderlands of our state. The ND Tourism website features Northern Lights imagery captured at locations across the state on various dates. Of course, the critical factors are finding an observation point that is away from city lights on a night when Northern Lights are most likely to occur and when the sky is (mostly) clear.

What are the Northern Lights? This is a quick dive into a pretty big topic, so I'll post a few good websites where one can dig into more details:

- NOAA's Space Weather Center
- NASA's Solar Storm and Space Weather FAQs
- University of Alaska, Fairbanks, Geophysical Institute Aurora Forecast
- NWS Bismarck ND and NWS Grand Forks ND , where you can find forecast for your local sky conditions.

[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

The Northern Lights and Southern Lights, Aurora Borealis and Aurora Australis, are the result of charged particles from the sun, tracking towards the Earth, and streaming towards either the North or South polar regions, as a result of our planet's global magnetic field. As these charged particles stream into the upper atmosphere above our polar regions, they interact with various gases, which then produce the light show we see from our Earth's surface.

The image at the right (Figure 12) is courtesy of NASA and their Space Place web article for kids on Aurora.

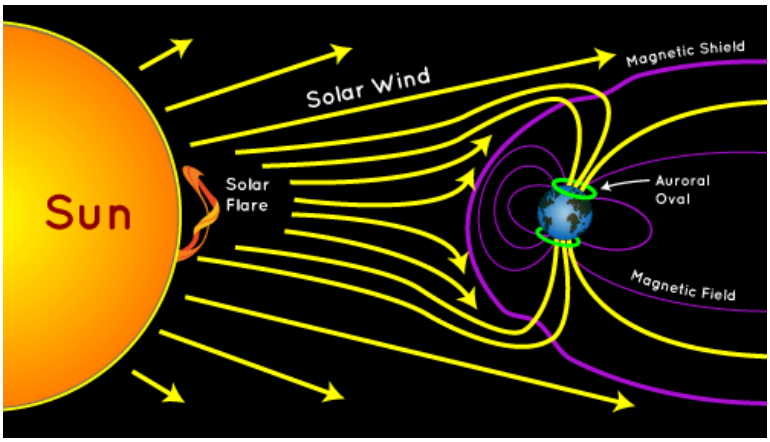


Figure 12. What is an Aurora, NOAA Science Jinks

Sun Spots: These dark areas on the sun's surface are some of the more easily observable features and have the longest records among Earth-based observers, with reliable observations dating from the 1500s through today. Check out Aurora Hunters for a chart of the roughly 11-year sunspot cycle, where higher numbers of sunspots indicate a stormier sun, and thus a higher frequency of sunspots, solar flares, and more charged particles reaching the Earth… thus more Aurora! Note that the last Solar Maximum was spread between 2012 and 2014, and we are currently pulling out of a Solar Minimum. Thus overall, aurora activity has been somewhat subdued for the past few years.

Solar Flare/Solar Prominence: These are local scale eruptions off the sun's surface that most often appear as flashes of light near the sun's surface and may extend out to the sun's outer atmosphere or Corona. Increased sunspot and solar flare activity will often produce an increase in Aurora.

Solar wind: This is the background stream of charged particles that is nearly continuously streaming out from the sun. On average, a charged particle ejecting from the sun reaches the Earth in 3-4 days.

Coronal Mass Ejection (CME): CMEs are often the "Big Events" for Aurora hunters. CME's are huge plumes of mass and energy in the form of plasma that eject from the sun's outer layer or Corona and are many, many times larger than the typical solar flare. This mass of material and its embedded magnetic field spreads outward from the sun at speeds of from 250 to 3000 km/s (155 to 1864 miles a second), reaching the Earth's orbit in from 0.75 days to 7.5 days. By comparison, the light from that same sun-based episode is traveling at the speed of light, some 300,000 km/s, and reaches the Earth in about 8 minutes and 20 seconds. Thus astronomers are able to see the solar flare or CME occurring long before the charged particles from that episode impact the upper reaches of our atmosphere.

So are you ready to become a solar storm chaser?

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[6].

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

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