North Dakota Climate Bulletin

Winter 2022-23 Volume: 17 No: 1

In This Issue

Produced by
Adnan Akyüz, Ph.D.
State Climatologist

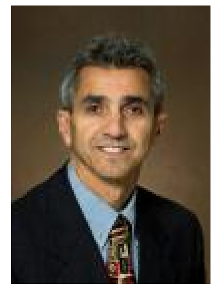
Graphics
NCEI, SPC, CPC, NOAA, USDM

Contributing Writers
G. Gust
A. Schlag
M. Ewens

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, North Dakota.

The average winter temperature was 2 degrees cooler than average, making it the 73rd coldest winter on record. Precipitation-wise, the statewide accumulation was 0.46 inches wetter than average, making it the 21st wettest winter on record. Wet conditions in the eastern and central parts of the state eliminated the drought and created major flood potential in much of the Red River Valley and the James River watershed. Dry conditions continued in northern parts of the state, which maintained abnormally dry (D0) and moderate drought (D1) conditions in these parts of the state. Increasing spring flood risk in North Dakota is discussed in detail in the "Hydro Talk" section. Readers will also enjoy a special topic on atmospheric rivers in the "Science Bits" section.

Overall, 224 records were tied or broken, including temperature- and precipitation-related occurrences across the state.

Detailed monthly climate summaries for December, January, and February can be accessed at www.ndsu.edu/ndsco.

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

Hoar Frost (Tanya Akyüz)

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 winter season (Dec. 1, 2022, through Feb. 28, 2023) was 1.97 inches, which was the same as the last season (fall 2022), but 0.3 inches more than last winter (winter 2021-22) and 0.46 inches more than the 1991-2020 average winter precipitation (Table 1). This would rank 2022-23 as the 21st wettest winter since such records began in 1895.

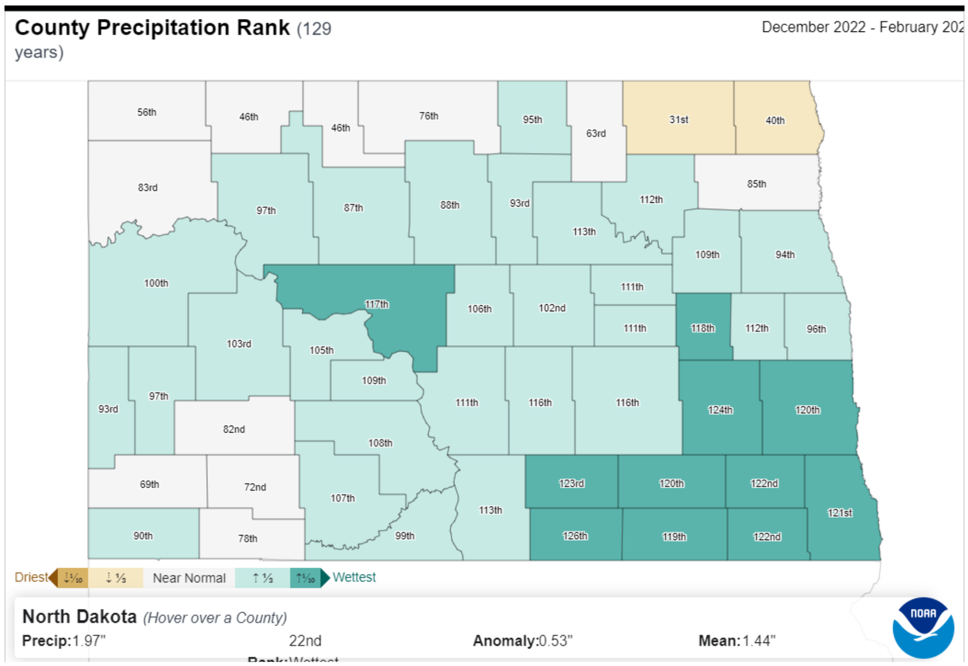


Figure 1. Precipitation rankings in the winter of 2022-23 for North Dakota. (NCEI, National Oceanic and Atmospheric Administration [NOAA])

The counties shaded in brown in Figure 1 indicate a drier-than-average winter in 2022-23. In contrast, the counties shaded in green in the same figure indicate wetter-than-average conditions, and white indicates near-average conditions. The numbers inside the counties are the precipitation rankings, with 1 being the lowest ranking (driest) and 129 being the highest ranking (wettest).

The greatest seasonal precipitation accumulation of the season was 4.8 inches, recorded in Jamestown, Stutsman County. The greatest seasonal snowfall accumulation was 51.7” in Jamestown, Stutsman County.

Based on historical records, the state average winter precipitation showed a slight negative long-term trend of 0.01 inches per century during this period of record since 1895. The state’s highest and lowest seasonal winter average precipitation ranged from 2.99 inches in 1969 to 0.59 inches in 1990. The “Historical Winter Precipitation for North Dakota” time series (Figure 2) visually depicts these statistics.

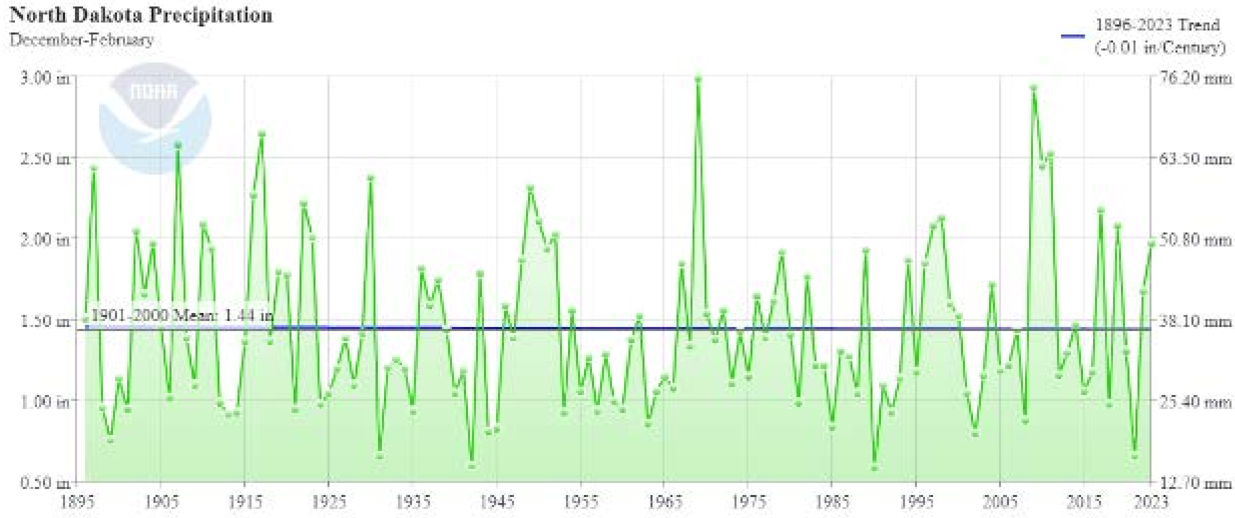


Figure 2. Historical winter precipitation time series for North Dakota.

Table 1. North Dakota W*inter* Precipitation Ranking Table.[1]

Period	Value	Normal	Anomaly	Rank	Wettest/Driest Since	Record Year
Winter 2022-23	**1.97”**	**1.51”**	0.46”	**108th driest** **21st wettest**	**Driest since 2022** **Wettest since 2019**	**0.59” (1990)** **2.99” (1969)**

[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 (Dec. 1, 2022, through Feb. 28, 2023) was 11.4 F, which was 32.1 degrees cooler than the last season (fall 2022) but 0.7 degrees warmer than last winter (winter 2021-22). It was 2 degrees cooler than the 1991-2020 average winter temperature, ranking winter 2022-23 as the 73rd coldest (56th warmest) winter since such records began in 1895 (Table 2).

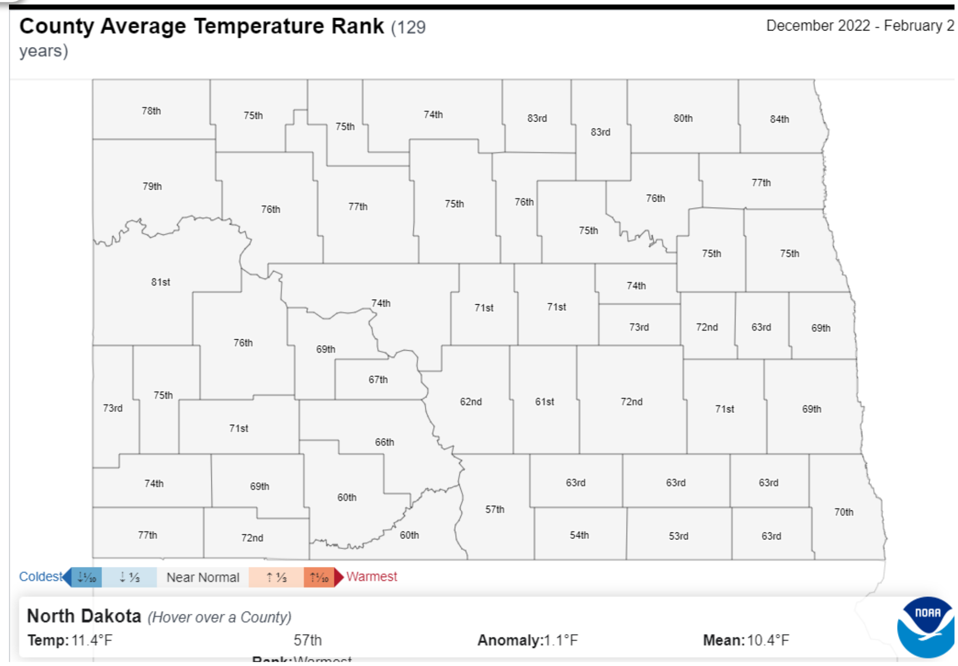


Figure 3. Temperature rankings in the winter of 2022-23 for North Dakota. (NCEI, NOAA).

The counties shaded in white in Figure 3 indicate near-average conditions. The numbers inside the counties are the temperature rankings, with one being the lowest ranking (coldest) and 129 being the highest ranking (warmest).

Based on historical records, the average winter temperature has shown a steep positive trend of 4.5 degrees per century since 1895 (the highest long-term temperature trend in the U.S.). The state's highest and lowest seasonal winter average temperatures ranged from 22.2 F in 1987 to -3 F in 1936. The "Historical Winter Temperature for North Dakota" time series (Figure 4) visually depicts these statistics.

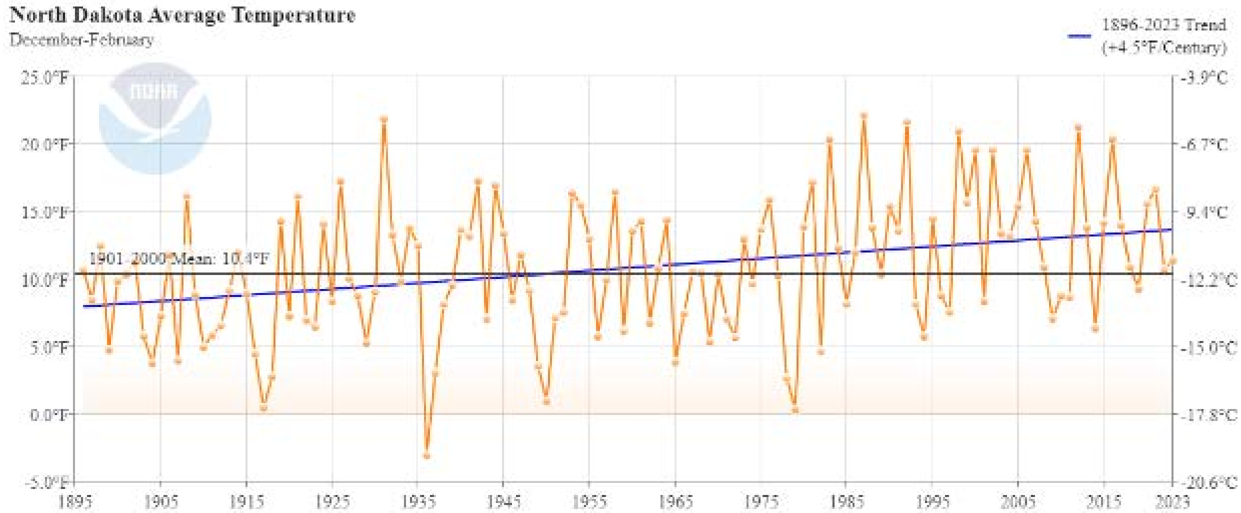


Figure 4. Historical winter temperature time series for North Dakota.

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

Period	Value	Normal	Anomaly	Rank	Warmest/Coolest Since	Record Year
Winter 2022-23	**11.4 F**	**13.4 F**	**-2 F**	**73rd coolest** **56th warmest**	**Coolest since 2022** **Warmest since 2021**	**-3 F (1936)** **22.2 F (1987)**

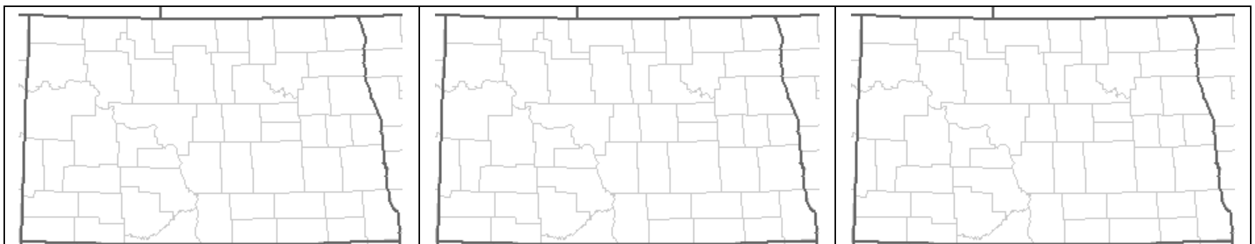
[2] NOAA National Centers for Environmental Information, Climate at a Glance: Statewide Time Series: www.ncdc.noaa.gov/cag.

Storms and Record Events

State Tornado, Hail and Wind Events for Winter 2022-23

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

	December 2022	January 2023	February 2023	Seasonal Total
Tornado	0	0	0	0
Hail	0	0	0	**0**
Wind	0	0	0	**0**
Total	**0**	**0**	**0**	**0**



December 2022 North Dakota Storm Events | January 2023 North Dakota Storm Events | February 2023 North Dakota Storm Events

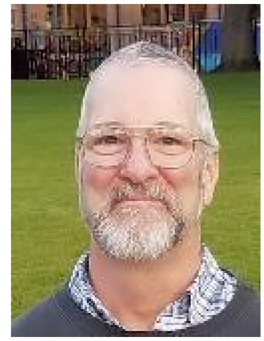
Figure 5. Geographical distribution of the storm events in the table above in each month. The dots are color-coded for each event (red: tornado; blue: wind; green: hail).

State Record Events for Winter 2022-23

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	December	January	February	Seasonal Total
Highest daily max. temp.	0	0	2	**2**
Highest daily min. temp.	7	1	2	**10**
Lowest daily max. temp.	15	0	60	**75**
Lowest daily min. temp.	6	0	25	**31**
Highest daily precipitation	40	6	7	**53**
Highest daily snowfall	42	2	9	**53**
Total	**110**	**9**	**105**	**224**

Seasonal Outlook



Spring 2023 Outlook

By M. Ewens[3]

The meteorological winter months of December 2022 through February 2023 exhibited a very stormy pattern across portions of the western and northern U.S., with a secondary maximum in precipitation through the mid-South and Appalachian regions. The driving force, a third-year La Niña, helped establish a pattern of persistent upper low pressure over the western U.S. and a broad high-pressure ridge over the southeast U.S. This allowed a parade of systems to produce welcome rain and snow over areas impacted by severe drought across the Western U.S. and northern Plains. Dry weather over portions of the western High Plains has allowed drought to intensify.

As La Niña fades to ENSO neutral, lasting impacts will diminish, but the residual climate forcing favors several climate regimes this spring. A colder-than-median temperature pattern is likely over the Northwest into portions of the northern Plains. At the same time, widespread warmth is expected over the Southwest U.S. across the Mid- and Deep South, then up the Ohio Valley and Eastern Seaboard. Drier weather is expected in the Four Corners region, while a wetter regime is predicted over the mid-Mississippi, Ohio River Valley and parts of the mid-Atlantic region.

With seasonal to warmer and drier conditions forecast, drought is expected to continue and perhaps intensify where it currently exists. Most notably, drought intensification is expected over the southwest and western High Plains into the Rio Grande. Drought conditions will show some mitigation/improvement through the inter-mountain west, the northern Plains and portions of the Midwest.

The 90-day climate outlook from the CPC is available at www.cpc.ncep.noaa.gov/products/predictions/90day.

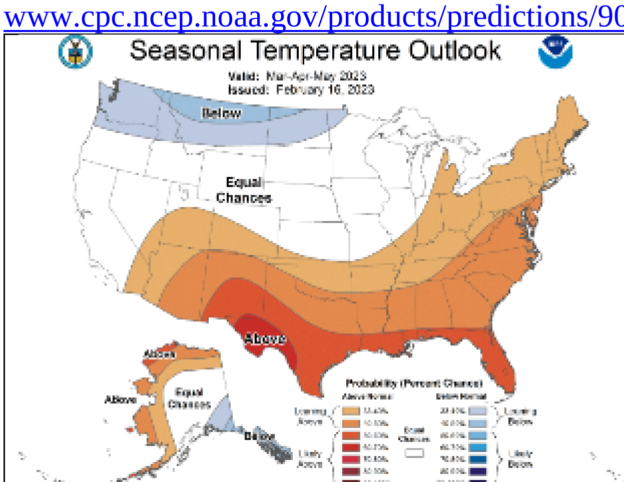


Figure 6a. Mar 2023 through May 2023 temperature outlook. (Climate Prediction Center, NOAA)

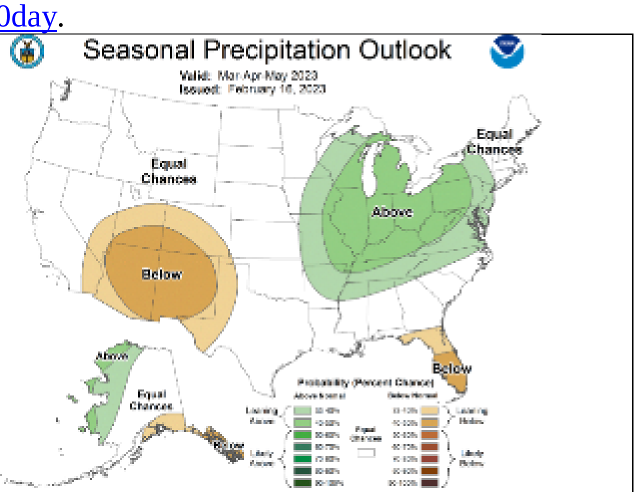


Figure 6b. Mar 2023 through May 2023 precipitation outlook. (Climate Prediction Center, NOAA)

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

Hydro-Talk

Increasing Flood Risk

By A. Schlag[4]

After a long and, at times, brutal winter, I think it's safe to say we are finally closing in on the spring melt season. That shouldn't surprise anyone because it's near the end of March. Anyway, let's talk about how this winter has unfolded and where it puts us with respect to overall flood risk.

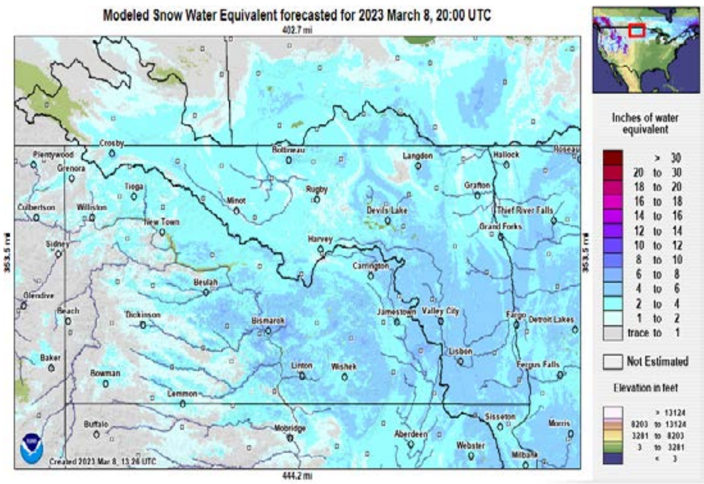


Figure 7. NOHRSC Depiction of Snow-Water Equivalent across North Dakota.

First up is the snowpack across the state. In Figure 7, we see the tremendous disparity in Snow-Water Equivalent (SWE) across North Dakota. A general rule of thumb for the state is to have something between two and three inches of SWE in the normal range going into the spring melt season. The darker blue shading on the map represents the parts of the state with greater than four inches of SWE, with areas east of Bismarck up into the Devils Lake and Red River basins with five inches common and locally up to seven inches of water on the ground. This brings up another rule of thumb for me: I tend not to be overly concerned about the potential for widespread flooding in areas with less than four inches of SWE. Yes, high water can also occur with less than four inches of SWE, but it's usually of the minor or nuisance level of high water instead of widespread, high-impact flooding.

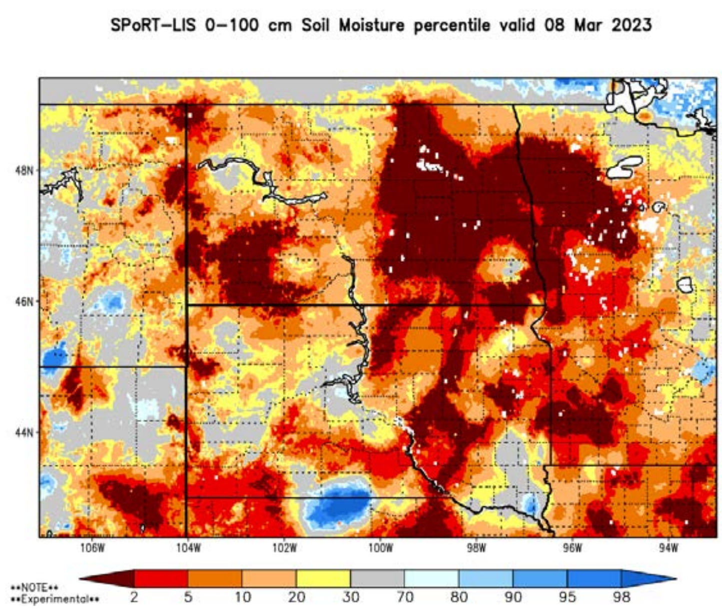


Figure 8. NASA's Most Recent Soil Moisture Rankings.

The snowpack started with a bang back in November and insulated the dry soils with a foot or more of snow from the unusually cold December. As winter progressed, that snow continued to do a great job of keeping sub-freezing temperatures from penetrating the ground to anything resembling a normal soil temperature profile for this time of the year. NDAWN soil temperatures are amazingly warm for early March. Indeed, locations such as Marion and Oakes out in the James River Basin have soil temperatures above freezing as little as two inches below the existing snowpack. Not only are these soils warm, but they also are

[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

exceptionally dry. Figure 8 shows the percentile rankings for soil moisture. The state has very large areas with soil moisture percentiles in the single digits. This suggests we see soils this dry about once every 30-plus years.

With an abundance of SWE and in the middle of what has been a wet (but cold) start to spring, these soils bring us the greatest hope for escaping widespread damaging floods. These warm and dry soils would provide us with a path out of what would, in most years, be an ominous expectation for flooding. Figure 9[5] shows the historical (blue line) and conditional (black line) probabilities for exceeding a given stage for the James River at LaMoure and the Red River at Fargo, respectively. While a person may argue that there's slightly more SWE in the Red River watershed, that is insufficient to explain the vastly different expectations for flooding. The difference in the two graphics is also directly related to the soils underlying the respective snowpacks. The Red River Valley contains large areas of clay-based soils versus the sandier soils of the James River Basin. These finer-grained clay soils can have 20-40% more porosities than sandy soils. However, the permeability leaves much to be desired as the sandy soils have greater permeability.

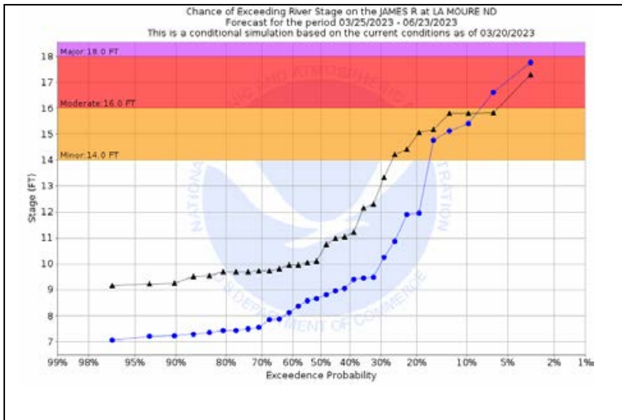


Figure 9a. Probability of Exceeding Given Stages for the James River at LaMoure.

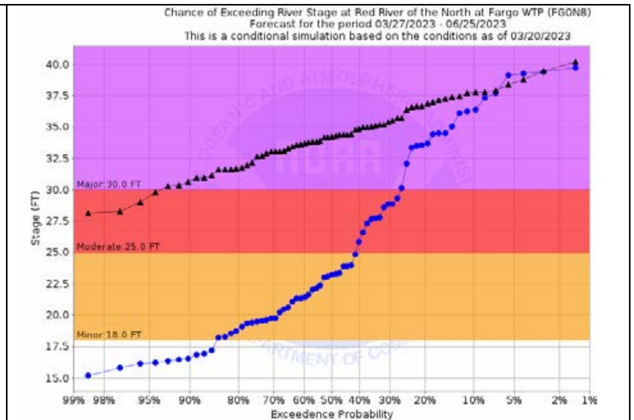
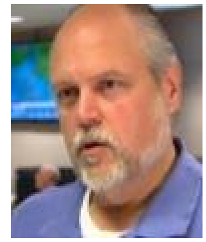


Figure 9b. Probability of Exceeding Given Stages for the Red River of the North at Fargo.

In short, the entire state has at least enough SWE on the ground to initiate runoff this spring. Areas with some of the greatest SWE also have the best soil conditions for minimizing runoff. So, while the visual out on the countryside suggests lots of runoff, the reality is that there's still a path to a slow melt via the cooler-than-normal weather expected through the remainder of March. This cooler-than-normal weather has recently added to the snowpack. Still, at this point, we would prefer to stay cooler than normal, especially since our daily average high temperatures are now above freezing. A slow melt would be the best for all involved.

[5] Figures 9a and b will be updated on 4th Thursday of every month with the latest data on soil and snowpack are incorporated into the models with up to 40 or more years of climatologic data.

ndsco **Science Bits**



Cry me an Atmospheric River: From California to North Dakota

By G. Gust[6]

Throughout the fall and winter of 2022-23, national weather news was obsessed with an *atmospheric river* that repeatedly pummeled the state of California. The results were torrential rains, flooding at lower elevations, and deep snow in its mountain ranges for months.

From San Francisco through the Los Angeles Basin down to San Diego, winter season precipitation (Dec. 16, 2022, through March 15, 2023) ranged from 125% to more than 300% of normal along the coast, across the Central Valley, and deep into the Sierra Range. Coastal communities, including LA, have seen their first snowfall in decades.

> **Atmospheric rivers:**
> Instead of liquid water flowing along the ground, and atmospheric river is an immense band of water vapor moving through the atmosphere. The U.S. Geological Service calls them the largest "rivers" of fresh water on Earth!

Figure 10 (below) shows the percent of normal precipitation for the Water Year 2023 from Oct. 1, 2022, through March 15, 2023, across the Western and Great Plains states. Note the large areas of above-normal precipitation, which appear to expand from coastal California, across the Great Basin states, and into the northern Plains states.

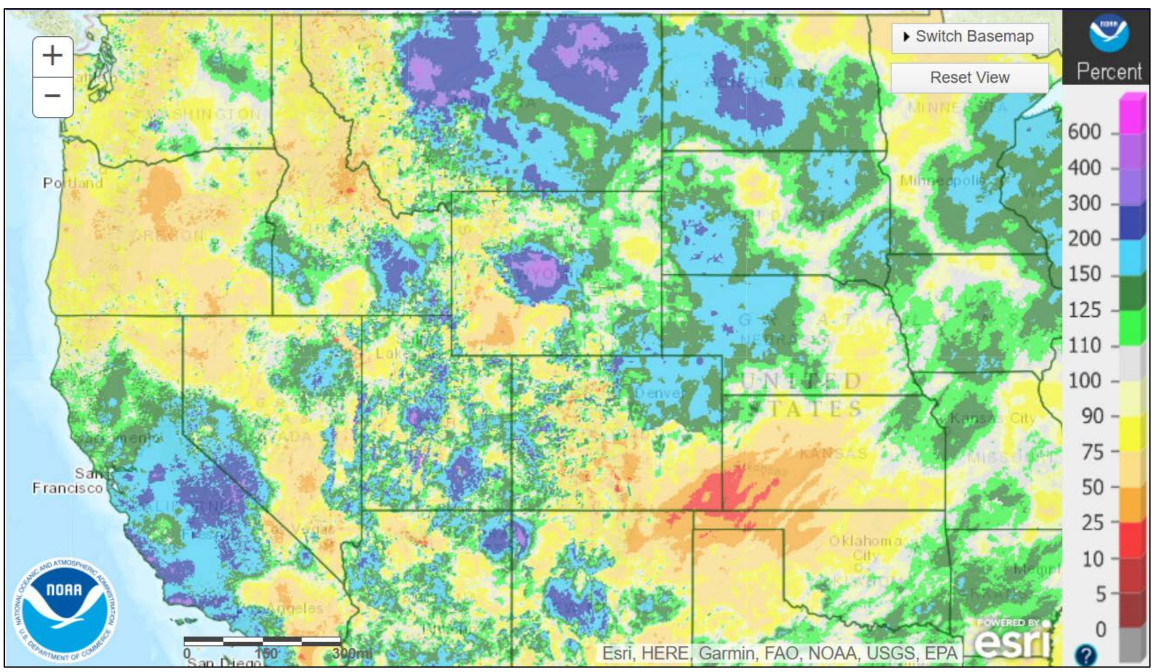


Figure 10. The Water Year 2023 to-date precipitation, percent of normal, from Oct. 1, 2022 through March 15, 2023. Courtesy of NOAA/NWS Advanced Hydrologic Prediction Service [https://water.weather.gov/precip/].

---

[6] The corresponding author, Greg Gust, is meteorologist at the N.D. Department of Emergency Services. Email: ggust@nd.gov

Making the *Tele*-Connections.

A few key components came together to produce the cohesive precipitation pattern which often extended from the tropical Pacific Ocean across the coastal and Intermountain West and into North Dakota:

Part 1: The Pineapple Express[7] is the name given to a deep atmospheric lower to mid-level moisture flow which originates just above the warm waters of the tropical Pacific Ocean near the Hawaiian islands and extends northeastward into the U.S. and Canadian west coasts. During the 2022-23 winter season, coastal California was mainly impacted by successive waves of moisture in this flow pattern, especially in December and January and again from late February into mid-March (and perhaps beyond).

Part 2: A recurring split 500-mbar jetstream flow pattern along the western North American coast, with a northern branch arching from far northwestern Canada down along the east flank of the Canadian Rockies into the northern Plains states and a southern branch cutting south off the west coast into coastal southern California and arcing back northeastward into the central Plains. This pattern tends to occur more often when the monthly Pacific North American (PNA) teleconnection is in a negative phase, which it happened to be this past November, December and February, leading into March. The northern branch funneled persistent cold air down into the northern Plains. In contrast, the southern branch carried moisture and energy across the southern Rockies, often forming a strong Colorado Low, tracking through the central and/or northern Plains states.

Part 3: Moist low-level flow from the south and/or southeast, reaching into the northern Plains states. In my Spring 2021 Science Bits article, I discussed the formation of a southerly low-level jet, another famous atmospheric river, and how this phenomenon taps into low-level moist air moving up from the Gulf of Mexico. In mid-winter, such deep Gulf flow is hard to come by. However, the following set of images shows how such an integrated pattern might come together for the March 21-23, 2023, period.

A Forecast Example, March 21-23, 2023.

Figure 11 (below) and its three sub-images A, B, C, show the forecast progression of the two atmospheric river moisture plumes, the *Pineapple Express* and the *southerly low-level jet*. These images show Integrated Water Vapor Transport (IVT) shaded in units of kg m-1 s-1, with 850 mbar/hPa (low-level) wind vectors to indicate mean moisture flow magnitude and direction, and sea level pressure in mbar/hPa, all from the NCEP GFS 12z model run on March 16, 2023.

Sub-image A represents the Day 5 forecast (120 hrs) at 12z on March 21. Note the Pineapple Express is moving into coastal southern California.

Sub-image B represents the Day 6 forecast (144 hrs) at 12z on March 22. Note the moisture plume moving across the southern Rockies and starting to interact with and strengthen the southerly low-level flow moving up from western Texas into the Dakotas.

Sub-image C represents the Day 7 forecast (168 hrs) at 12z on March 23. Note the much deepened (strengthened) low-pressure system centered on the Red River Basin, with extensive low-level moisture fetch up through the central Plains and into the western Great Lakes.

[7] One Pineapple Express: one part Colorado low, and one southerly low-level jet can equal a sizeable Northern Plains blizzard.

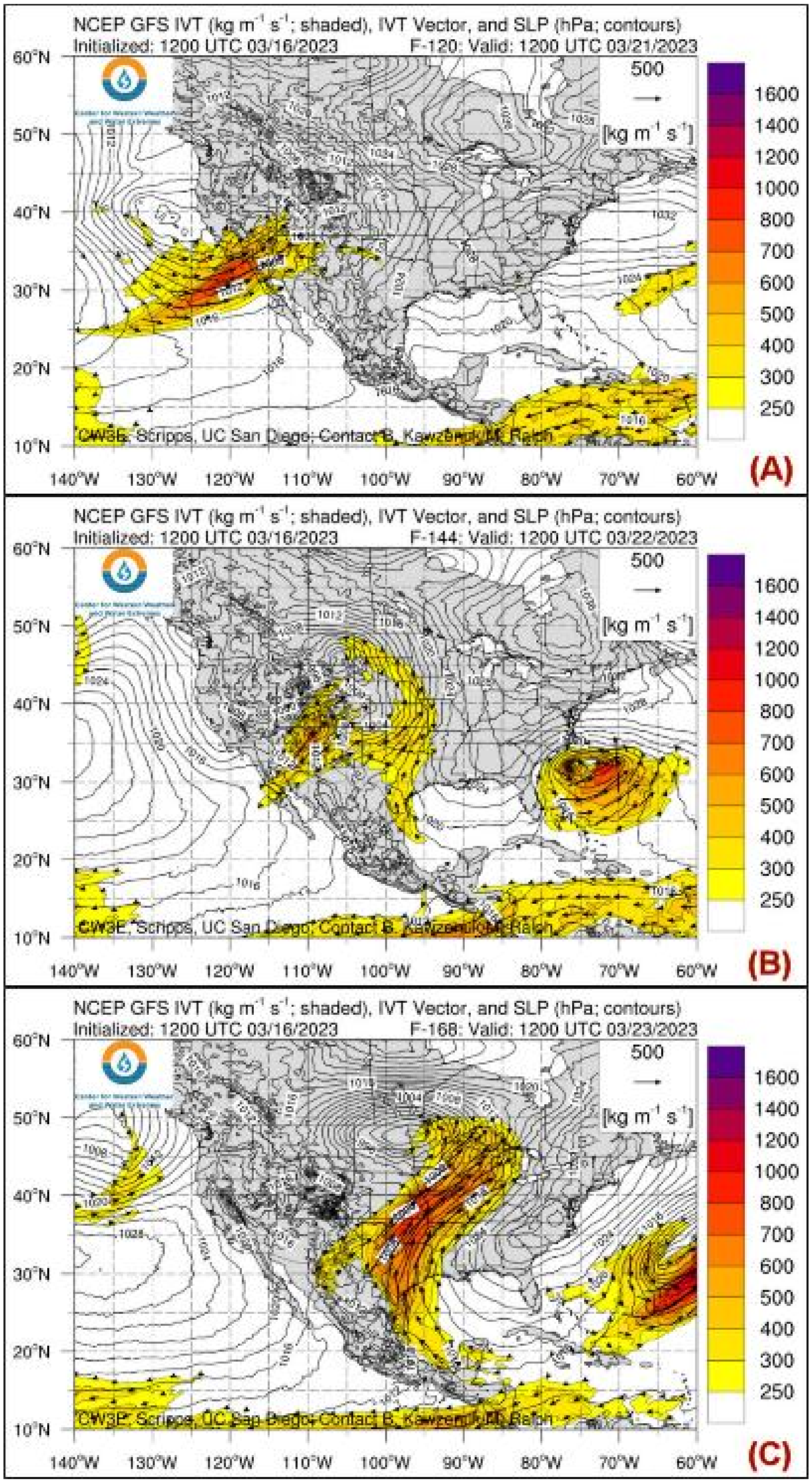


Figure 11. Integrated Water Vapor Transport (IVT) with 850MB (low-level) wind barbs, and sea level pressure from GFS 12z model run on March, 16 2023. Forecast for Day 5 (A), Day 6 (B) and Day 7 (C).

Terrain Impacts on Low-level Moisture Transport

I didn't speak about moisture transport and the issues of the terrain differences from the California coast through the mountains and into the Great Plains, but I could.

As we know, the terrain is a problem for low-level moisture transport. A storm crossing the various coastal, Sierra and Rocky Mountain ranges between San Diego and Oklahoma City will not be able to transport much of its Pacific moisture into the Great Plains.

I've attached a Google Earth Transect (Figure 12) of that path below. Starting at 0 ft mean sea level elevation off coastal San Diego and tracking to near Oklahoma City, there is the nearly 5kft (mean height) San Jacinto Range in far southern California, and the nearly 9.5kft (mean height) White and Black Mountain Ranges of eastern Arizona and western New Mexico, with all kinds of high plateau throughout the route.

Figure 12. Google Earth path and terrain transect running from coastal San Diego through to Oklahoma City.

Meanwhile, most of the moisture which usually materializes over the Great Plains states is likely to be of Gulf of Mexico origins, maybe with just a hint of the Pacific.

Sources:

USGS/Communications and Publishing. https://www.usgs.gov/news/featured-story/rivers-sky-6-facts-you-should-know-about-atmospheric-rivers

NOAA/NWS Advanced Hydrologic Prediction Service. https://water.weather.gov/precip/

NOAA/NWS Climate Prediction Center Teleconnections/PNA. https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/pna.shtml

NWS San Diego CA, Atmospheric River Weather updates via YouTube. https://www.youtube.com/watch?v=L0vRrln-LYA&list=UU_4xc0QQDujsK2ayfdTKW-w&t=168s

NOAA/Physical Sciences Laboratory, Atmospheric River Portal. https://psl.noaa.gov/arportal/

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[8].

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

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