NORTH DAKOTA STATE CLIMATE OFFICE ndsco

North Dakota Climate Bulletin

Fall 2016 Volume: 10 No: 4

In This Issue

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Graphics
NCEI, NDSCO, NDAWN

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www.ndsu.edu/ndsco

From the State Climatologist

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

This fall was the warmest and second wettest (the wettest fall since 2013) on record since 1895 statewide in ND. All 3 months of the season were well above normal. Furthermore, every day in November was warmer than normal. The statewide average temperature in November was 6.6°F warmer than last year when the previous November temperature record was broken. Overall in the fall season, there were 70 highest daily maximum temperature records either broken or tied. There were also 121 highest daily minimum temperature records either broken or tied. A total of 347 records were either tied or broken including temperature and precipitation related occurrences across the state.

Detailed monthly climate summaries for September, October and November can individually be accessed via: https://www.ndsu.edu/ndsco/resources/monthlyclimatesummary/

The bulletin will contain graphical displays of statewide seasonal temperature, precipitation, and the other weather highlights.

This bulletin can be found at http://www.ndsu.edu/ndsco/, along with several other local resources for climate and weather information.

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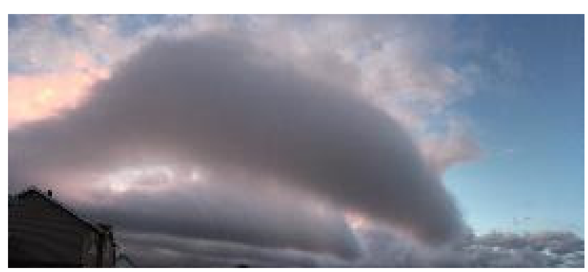

Fargo Gust Front on September 7, 2016, *by Akyüz*

Weather Highlights

Seasonal Weather Summary: By Adnan Akyüz

Precipitation

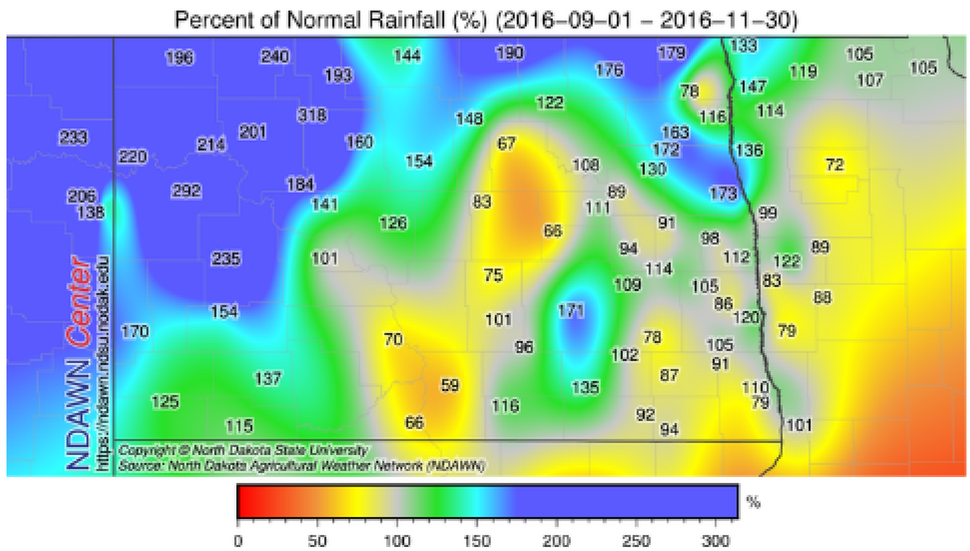

Figure 1. Precipitation % of Normal in Fall 2016 for North Dakota (NDAWN)

Using analysis from the National Centers for Environmental Information (NCEI), the average North Dakota precipitation for the fall season (September 1 through November 30) was 5.3 inches, which was 1.92" greater than last year, 1.45" greater than the 1981-2010 average fall precipitation and was the wettest Fall since 2013. This would rank fall 2016 as the 14th wettest fall since such records began in 1895. Figure 1 shows the percent of normal precipitation distribution geographically. Based on historical records, the state average fall precipitation showed an increasing trend of 0.08" per decade since 1895. The highest and the lowest seasonal fall average precipitation for the state ranged from the highest amount of 7.25" in 1994 to the lowest amount of 0.99" in 1976. The "Historical Fall Precipitation For North Dakota" time series on page 4 shows a graphical depiction of these statistics.

Red River Flood Potential: Even though it is too early to make a flood forecast for the Red River of the North, having a wetter than normal fall usually acts as a positive feedback for a flood in the following spring. The second indicator that we can utilize so far in advance is the Red River Stage level before the freeze up. The Red River was running at 16.28' from an arbitrary level as of December 2, 2016, at the Fargo location (The flood stage is 18' from the same arbitrary level at this location). That was considered as 99 percentile level meaning that the river was running higher than the current stage only 1% of the times at that point in the year. However, what stage the river would take during a given flood season depends on more than the two indicators mentioned above including snowfall in winter, rainfall before April, soil moisture, ground thaw rate and snow melt rate. However, the two conditions we have observed to-date can be taken as an early-warning sign.

Temperature

The average North Dakota temperature for the fall season (September 1 through November 30) was 77.5°F, which was 0.04°F warmer than last year, 4.9°F warmer than the 1981-2010 average fall temperature and the warmest fall since 1963. This would rank fall 2016 as the 2nd warmest fall since such records began in 1895. Figure 2 shows the departure from normal temperature distribution geographically. Based on historical records, the state average fall temperature showed an increasing trend of 0.19°F per decade since 1895. The highest and the lowest seasonal fall average temperatures for the state ranged from the highest amount of 49.1° in 1963 to the lowest amount of 32.2° in 1896. The “Historical Fall Temperature For North Dakota” time series on page 5 shows a graphical depiction of these statistics.

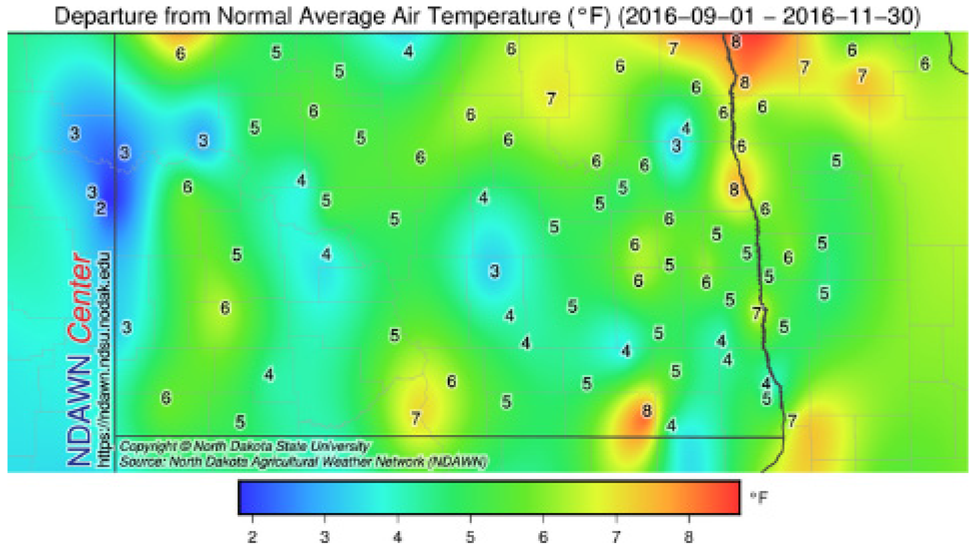

Figure 2. Temperature Departure from Normal in Fall 2016 for North Dakota (NDAWN)

Agricultural Impact: Warmer than normal conditions in the beginning of the season caused above normal seasonally accumulated growing degree days for most crops. However, heavy rains in some regions such as the Red River Valley not only caused delayed harvest but also caused crop losses for edible bean farmers. Active storms caused crop damage due to hail and high wind. The North American Land Data Assimilation System (NLDAS) total column soil moisture anomalies across the state indicate excess soil moisture in northern ND while slightly below normal in the central region and near normal soil moistures elsewhere by the end of October. By the end of the season, warm and dry conditions allowed farmers to continue finishing harvest work. Based on the USDA National Agricultural Statistics Service report on November 28, corn and sunflower seed harvested was 97% both of which were near normal.

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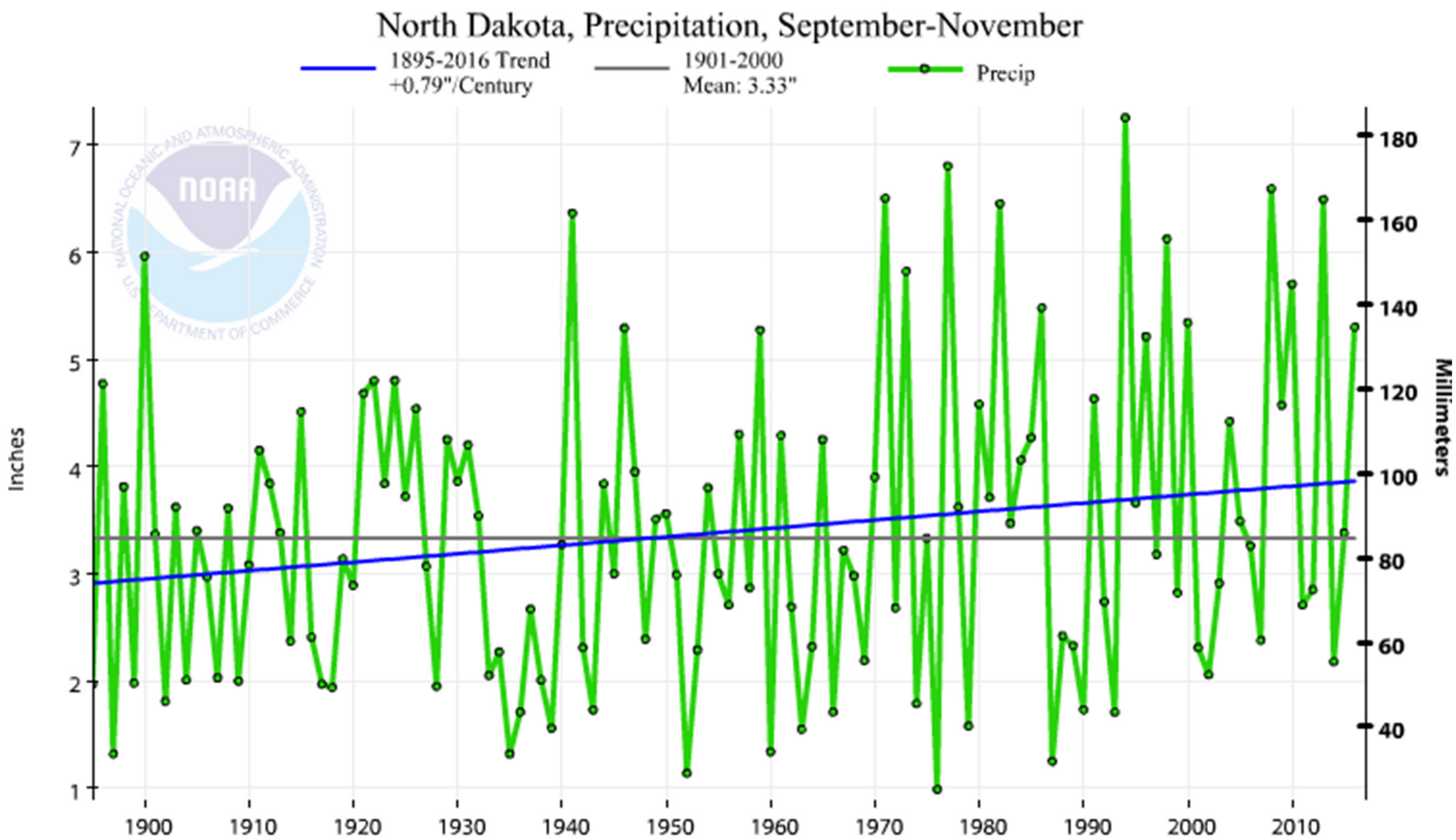
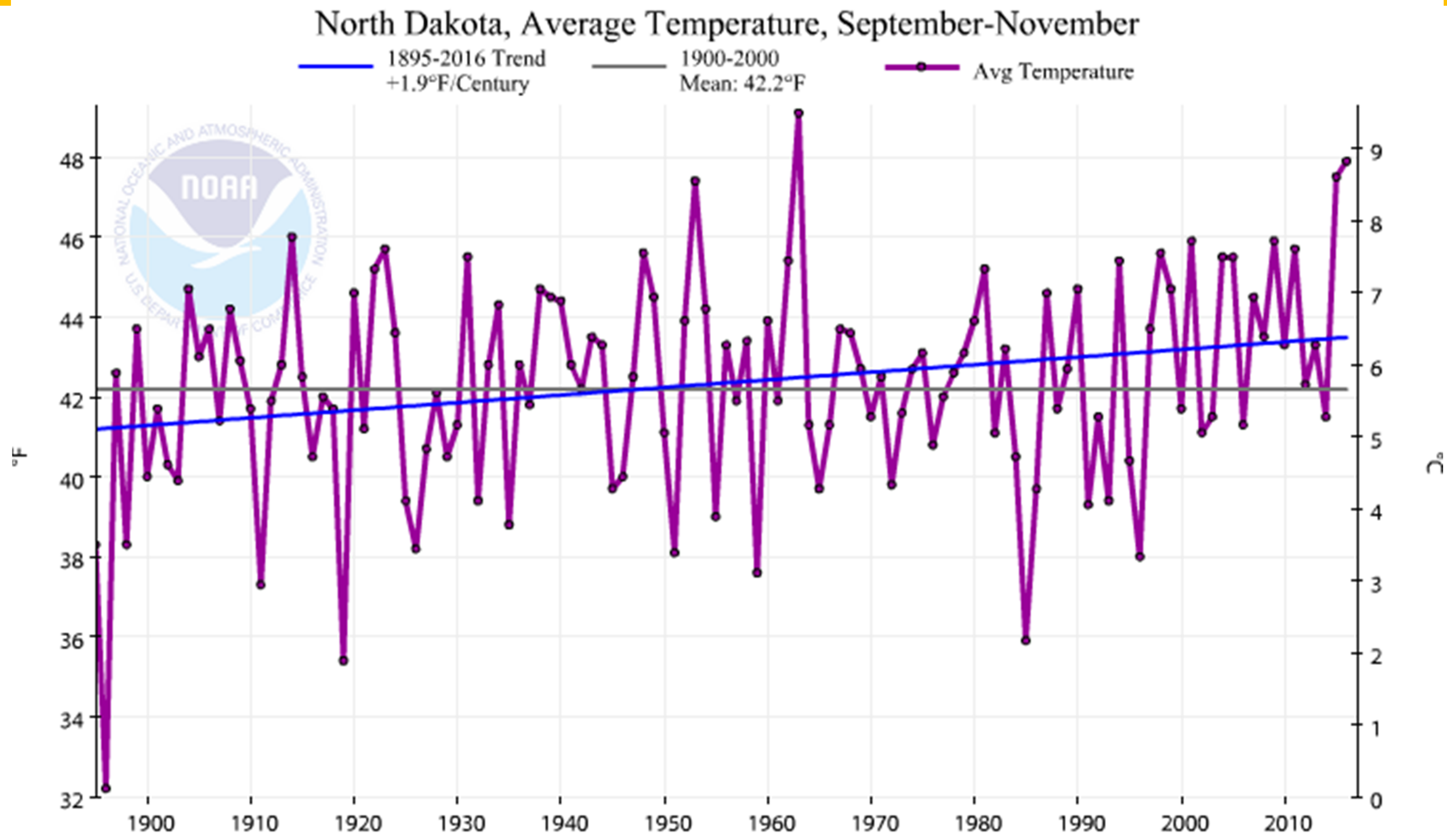
HISTORICAL FALL PRECIPITATION FOR NORTH DAKOTA



Record High Value: 7.25" in 1994
Record Low Value: 0.99" in 1976
Seasonal Trend: 0.08" per Decade

Fall 2016 Value: 5.3"
1981-2010 Average: 3.85"
Seasonal Ranking: 14th Wettest Fall
Record Length: 122 years

HISTORICAL FALL TEMPERATURE FOR NORTH DAKOTA



Record High Value: 49.1°F in 1963
Record Low Value: 32.2°F in 1896
Seasonal Trend: 0.19°F per Decade

Fall 2016 Value: 47.5°F
1981-2010 Average: 42.6°F
Seasonal Ranking: 2nd Warmest Fall
Record Length: 122 years

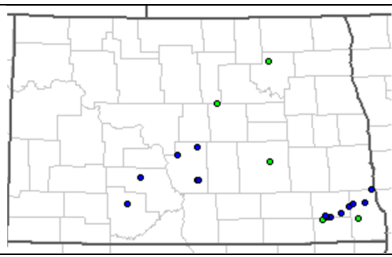
Storms & Record Events

State Tornado, Hail, and Wind Events for Fall 2016

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	6	14	**20**
October Total	0	0	0	**0**
November Total	0	0	0	**0**
3-Month Total	**0**	**6**	**14**	**20**

The graphics below shows 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).

	No Tornado/Hail/Wind	No Tornado/Hail/Wind
September 2016 North Dakota Storm Events	October 2016 North Dakota Storm Events.	November 2016 North Dakota Storm Events.

State Record Events for Fall 2016

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.	0	1	69	**70**
Highest Daily Min Temp.	19	36	66	**121**
Lowest Daily Max Temp.	0	2	0	**2**
Lowest Daily Min Temp.	0	1	0	**1**
Highest Daily Precipitation	47	25	54	**126**
Highest Daily Snowfall	0	2	25	**27**
Total	**66**	**67**	**214**	**347**

Seasonal Outlook

Winter 2016 Outlook — By R. Kupec[1]

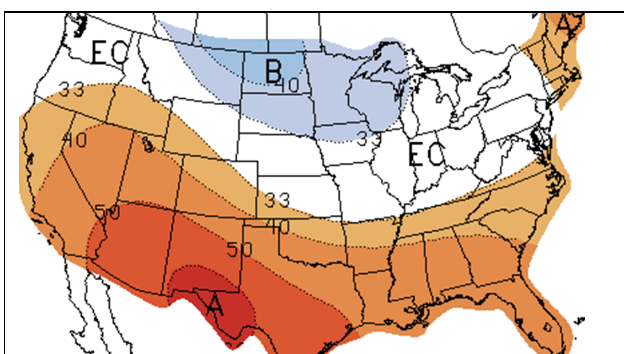
The long anticipated La Niña in the southern Pacific has finally arrived, though considerably weaker than many forecasts predicted. La Niña, the cooling of water along the equator in the Pacific Ocean, is currently barely above the neutral threshold. It is in fact so weak that we could easily see a turn back towards neutral sea surface temperatures in the region over our winter and spring months. A strong La Niña has very good indicators for winter weather in North Dakota but a weaker one is less certain. That combined with a change in sea surface temperatures in the northern Pacific and diminished sea ice in the Arctic Ocean make the winter forecast more challenging.

Much of North Dakota experienced the warmest November on record. Developing La Niñas in the fall often produce above average temperatures for the season. They also have a tendency for colder than average winters but there are some doubts as to whether that will be the case this year. An examination of the 20 warmest Novembers on record show that 3 of them were followed by warm winters, 10 were followed by average winter temperatures and 7 had colder to very cold winters after them. However this year's warm November is different in that, in many cases, it was the warmest by several degrees across the state, and it was also wetter than average. The vast majority of warm Novembers are dry.

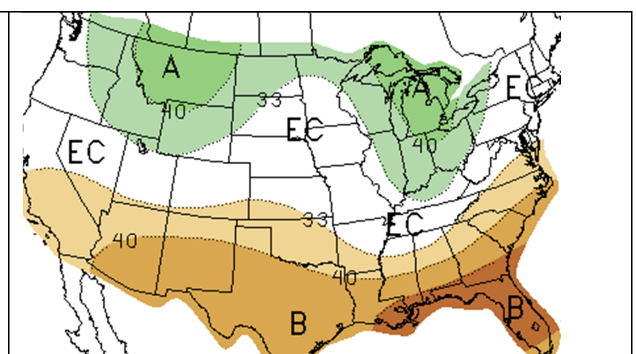
Across North Dakota, there is a significant correlation between La Niña conditions in the south Pacific and colder winter temperatures. Most locations run about 2 to 3 degrees below long-term averages. The correlation between precipitation and La Niña in the winter is not as clear. There is a tendency towards slightly more precipitations, but there is considerable variability from month to month and the amounts are not that much greater than average. The early December snowstorm has much of North Dakota on track for snow and precipitation amounts that are above average and it appears that arctic air will dominate temperatures for a large portion of the month. Despite the weak nature of the current La Niña, I would expect the winter to continue the trend of below average temperatures that is common with La Niña. Even with the early season jump on snow, I believe by the end of the winter season to see average to slightly below average precipitation. This would still be an increase over the previous two relatively snow-free winters in North Dakota.

The current Climate Prediction Center (CPC) Winter Outlook also gives the state a better than average chance of seeing below average temperatures for the season (see figure below). The CPC has a slightly different outlook on winter precipitation with nearly the entire state seeing a chance of above average precipitation; the one exception is the southeast corner which is forecasted to have an equal chance of above or below average precipitation.

The next 90-day outlook from the CPC should be available after December 15th at
http://www.cpc.ncep.noaa.gov/products/predictions/90day



December through JanuaryTemperature Outlook



December through January Precipitation Outlook

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

Hydro-Talk

A Very Long-Range Hydrological Outlook: Winter and Spring — By A. Schlag[2]

Usually, I don't have a lot to work with in formulating an opinion this early in winter on how the spring may unfold outside of our long-range climate outlooks. To add to our useful information, Table 1 provides the historical breakdown for liquid water equivalent received over our meteorological winter using the Bismarck area as a proxy for the state, even though we know the state is drier in the west and wetter in the east than Bismarck.

Table 1. Monthly Precipitation Statistics for Bismarck Area (1874 to Present) as inches of water.

Month	Average (Mean)	50th Percentile (Median)	10th Percentile	25th Percentile	75th Percentile	90th Percentile
Dec	0.51	0.40	0.11	0.24	0.70	0.95
Jan	0.46	0.38	0.09	0.23	0.68	0.89
Feb	0.46	0.36	0.13	0.22	0.57	0.87
Mar	0.86	0.70	0.25	0.39	1.16	1.61

As I am so often inclined to point out, the much used average, or statistical mean, is universally higher than the median values (the number which represents the point where half the data are above, and half the data are below). For discussion purposes, I will use the median values. Under a year where we get something equivalent to the median, the region would receive about 1.84 inches of water as snow from December through March. Note, I intentionally ignore November as its precipitation often comes in some mix of snow and rain with the snow often melting before December, and similarly I am using all of March's precipitation simply because whether it comes as snow or rain, it is generally available for creating spring runoff. What we are trying to do here with this exercise is to give ourselves a sense of what moisture is most often available come spring for the spring melt. To do so, we should also subtract some of that moisture that we know will be lost to sublimation (yes, this is a very real process in our winters). While there really is no good data I am aware of with regard to sublimation rates in ND, the loss of 0.3-0.4 inches is easily attainable, so our total of 1.84 inches of available water equivalent during a median winter is easily reduced to about 1.5 inches of water available for the spring melt. Granted, we don't generally see a lot of flood problems in a median year, but let's now look at where we already sit for this entry into winter.

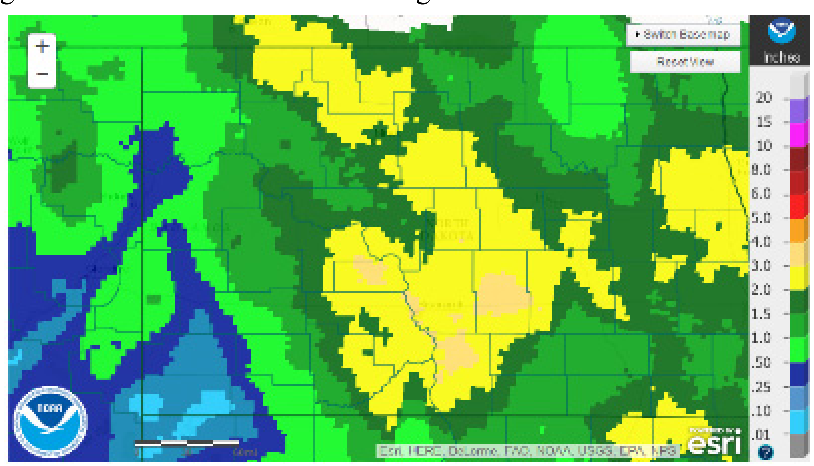


Figure 1. December 6th, 2016 map of precipitation received over the past 14 days as water equivalent.

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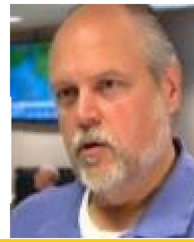
[2] The corresponding author: Allen Schlag is the Service Hydrologist at the NOAA's National Weather Service, Weather Forecast Office in Bismarck, ND. E-Mail: Allen.Schlag@noaa.gov

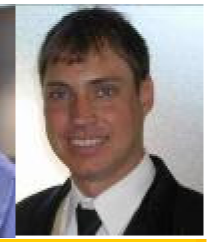
Figure 1 is a recent Advanced Hydrologic Prediction Service (AHPS) Precipitation Mapping image showing the estimated liquid equivalent received over the past 14 days. The snowfall totals for the last few days of November were impressive, especially given the overall warm and dry month of November leading up to the Nov 28-30 storm. Importantly, the snow received this late in November and early December events all fell on soils with temperatures still above freezing. Snow falling on warm ground partially melts and soaks into the soil. In general, wet soils are bad going into winter.

So here's a quick list of what we already know about the rest of winter and next spring's eventual melt:
1. Much of North Dakota already has more SWE on the ground than is normal for the end of December.
2. Soils received a fresh shot of liquid water through rain and some meltwater right before they reached sub-freezing temperatures.
3. The region is in an extended well below normal temperature regime with Dec, Jan, and Feb climate outlooks that favor a continuation of the cold and wet entry into winter.

The above are not the only factors that dictate the severity of the spring flood season, but what we already know tends to favor a more active spring flood season than we have seen over the past couple of years.

Science Bits



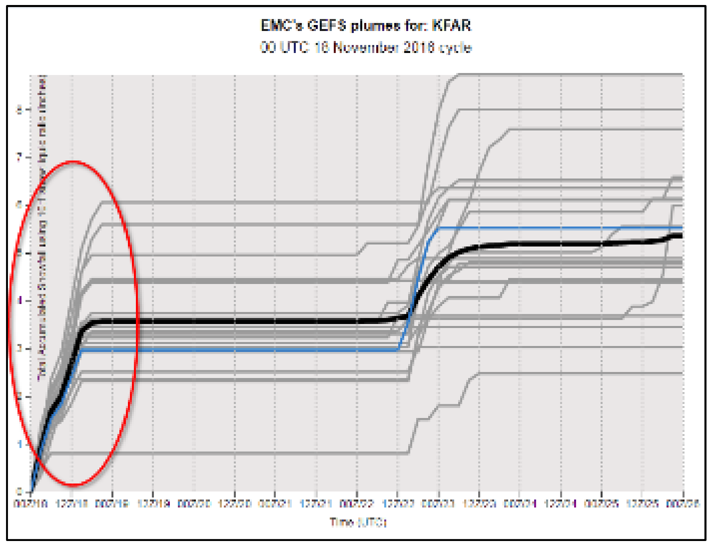


Forecasting a Northern Plains Snow Storm

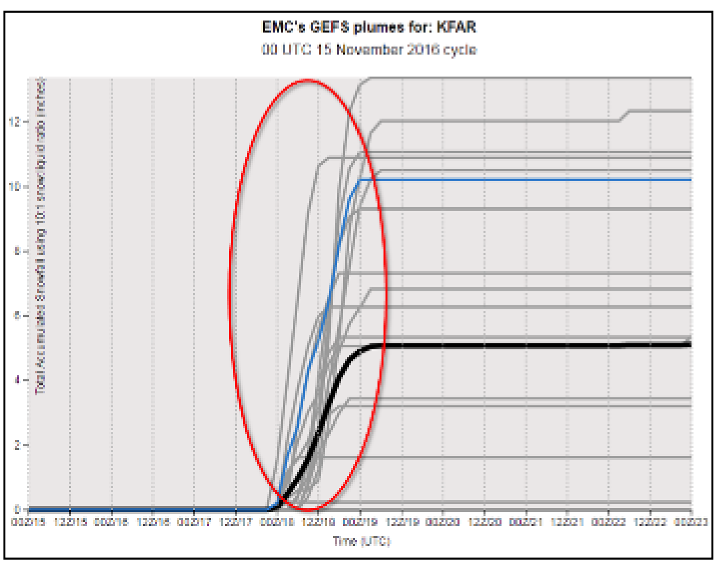
By G. Gust and T. Grafenauer[3]

Winter has come into the state of North Dakota with a bang this year, after a couple of relatively mild and overall less auspicious years. But that bang has occurred at quite different times for each sector of the state. First affected was the southeast corner (Nov. 17-18), then the central and western parts of the state (Nov. 27-28), and finally the northeast and east-central areas (Dec. 5-6). As of this writing (Dec. 12, 2016), most of the state has a decent blanket of snow, ranging from an inch to a foot deep or more.

That first storm which affected mainly the southeast corner of the state on November 17-18, spread a thick blanket of heavy, wet snow from Ellendale, across Wahpeton, and deep into the Minnesota Lakes Country. Because it was an early season storm, for us forecasters there was a fairly high degree of initial uncertainty in the projected storm's path… some 2-4 days out… and trouble determining just how much snowfall potential there really was, as compared to the risk for sleet or even heavy rains.



The Ensemble Approach: The image on the right shows the potential snowfall as expressed by one suite of weather models, for the Fargo area and covering an 8 day period, starting at 6pm CST on the 17th (00 UTC, on the 18th). The red circled area shows the potential snowfall for the next 24 hour period. Notice that the spread of the ensemble model forecasts ranges from at least 1 inch of snow to as much as 6 inches, but is most tightly clustered from 3 to 3.5 inches.



The image on the left shows how the same set of ensemble model runs from 3 days earlier, showed a much larger spread in the potential for snowfall at Fargo, ranging from zero to as much as a foot of snow. As one would expect, as one gets closer to the actual event, which began the evening of the 17th, such model guidance will usually hone in on a more viable solution.

In these examples, each model plume represents one of 21 ensemble model forecasts, from the suite of ensembles in the Global Ensemble Forecast System (GEFS), produced at the NOAA/NWS National Centers for Environmental Prediction (NCEP), Environmental Modelling Center (EMC). The thick black line represents the mean or average

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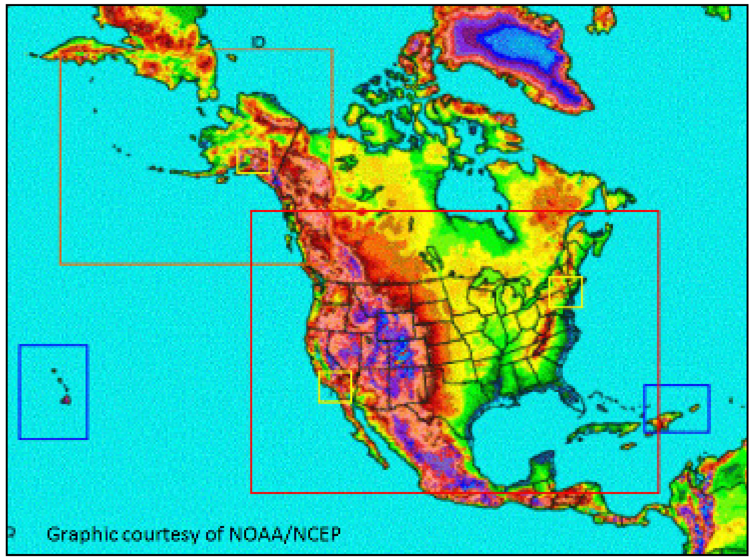
Tommy Grafenauer, Science and Operations Officer of the same office. E-Mail: thomas.grafenauer@noaa.gov .

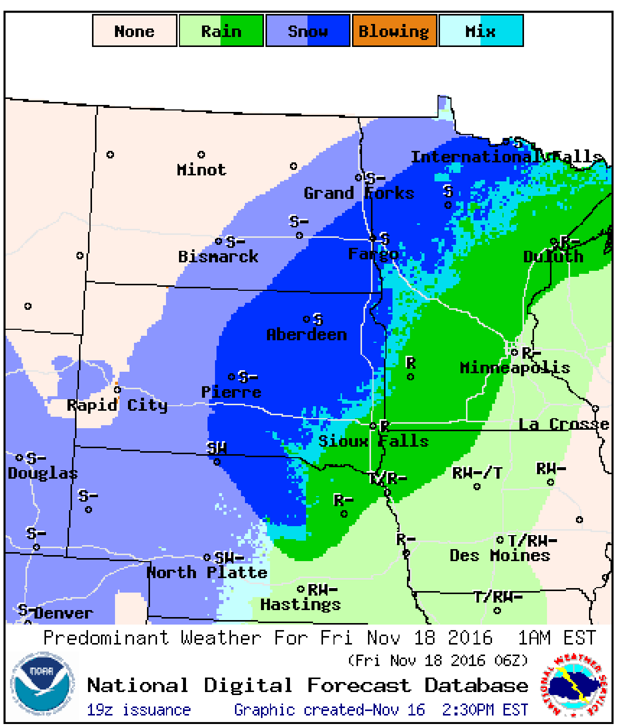
of the distribution, while the thinner blue line represents the results from the main operational model run of the Global Forecast System (**GFS**). In the GEFS, each ensemble member is one slight variant of the main operational GFS run, so that the suite of ensemble members really shows how these slight variations within the same model can skew the resulting snowfall or rainfall forecast for any one point.



The Multi-Model Approach: As NWS forecasters, we rely heavily on the GFS as our main weather modeling system, but we do have access to much more in the computer modeling world. The other main northern-hemispheric or "global" model, available to us is the model run produced at the European Center for Medium-Range Weather Forecasting (**ECMWF**)… also known as the "European". While our GFS model produces updated output out to 10-16 days and is run every 6 hours, the European provides output out to 10 days and is updated every 12 hours. In addition, the "Canadian" Global Environmental Multiscale Model, or **GEM**, and the **UKMET** provide us with a similarly long-range and larger scale look at things.

Regional Scale. On a somewhat smaller and shorter scale, there are a number of regional models which come into play. These models are typically initialized within the global domain of the GFS or European but then run over a smaller area, or nest, within that domain. Over our area, we typically use nested models like the North American Mesoscale (**NAM**) Model or the Weather Research and Forecasting (**WRF**) Model to provide higher detail.

Local Scale. There is even a set of models that are particularly well tuned for situations when deep convection, or thunderstorms, are a possibility. These Convection Allowing Models, or **CAMs**, are best at targeting narrow-banded or clustered areas of heavy precipitation, either snow or rain, and are typically used in the very near-term forecasting… something which may be occurring over the next 12 hours or less. The High-Resolution Rapid Refresh (**HRRR**) Model and its variants can provide us forecasters with township scale or smaller model resolution of potential weather phenomena at 1-hour increments, 12-24 hours in advance, with updates every hour.



Each of these models has its particular strengths and weaknesses, and as forecasters, we have to critically examine each model run to determine if these models are converging on a viable solution, or not, and which model may be performing the best for the given situation.

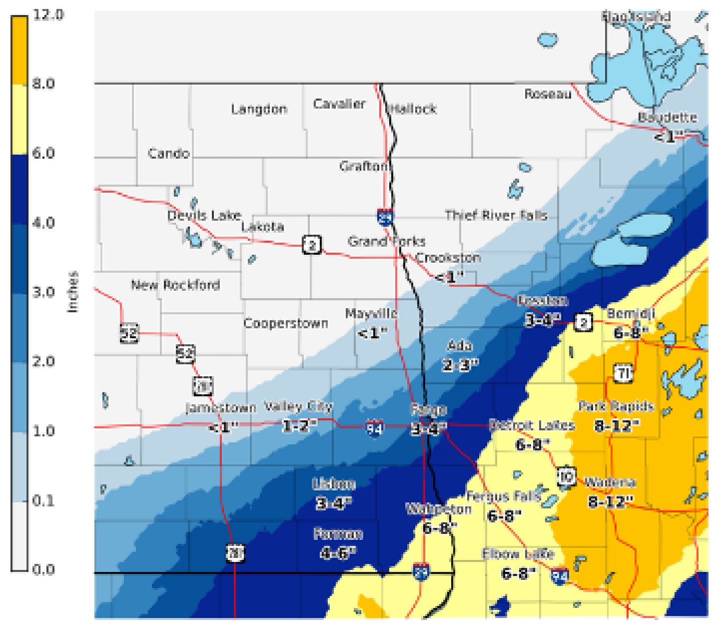
Back to forecasting heavy snow… versus sleet, or heavy rain, or nothing at all?!

The Ensemble of Ensembles Approach: The process of forecasting any heavy snow event still boils down to having highly trained and experienced forecasters at our national centers and our local forecast offices analyzing the situation, sorting through the available model guidance and collaborating on a consensus forecast which best addresses each part of the country for its particular range of impacts.

The image on the left shows part of that official NWS consensus forecast as issued early in the afternoon of Nov. 16th, and valid for a 1 hour block of time some 35 hours in the future, at midnight (CST), Thursday night, Nov. 17th, in the middle of the expected heavy snow/rain episode.

Notice that rain, mixed precipitation, and snow areas are all highly specified, hour by hour, at a 2.5 km grid scale resolution.

Forecast Total Snowfall Graphic issued at 1 pm on Nov. 17, 2016



Forecast graphics produced for later that night would show the areas of mixed precipitation and rain steadily cooling down and turning to snow, so that by Friday morning area in southeast North Dakota, and most of eastern South Dakota through central Minnesota would be under either a Blizzard Warning or a Heavy Snow Warning.

NEW - Snowfall Probabilities! Each of the models we use produces a certain type or amount of precipitation based on certain plausible conditions. Once we forecasters settle on a most likely scenario we are now able to harness this other information and produce a set of "what if" scenarios - the risk of either higher or lower amounts, based on the 70 members of this ensemble of ensembles suite. You can find out more about this Probabilistic Snowfall Experiment here:

http://www.nws.noaa.gov/com/weatherreadynation/news/160712_winter_probabilistic_snow.html

The net result was that there was a mix of sleet, changing to snow, across much of southeast North Dakota, that Thursday evening. Further, south and east there was a large area of heavy rain that moved up through central Minnesota, as far north as Bemidji. And on Friday, the (south) eastern Dakotas and (south) western Minnesota prairies had transitioned to blizzard or ground blizzard conditions, while the Minnesota Lakes lay buried in snow.

The initial Winter Storm Watch, issued early Thursday morning, had Fargo in the band for 4-8 inches of snow. However, by early that afternoon, the forecast shown above was produced, and the Fargo area was kept in an Advisory, for 2 to 5 inches of snow, while Heavy Snow and Blizzard Warnings were issued for points south and east. About as expected, Fargo measured 2.8 inches of snow, most of which melted within a couple of days, and Park Rapids MN received over a foot.

We love it when a forecast comes together!

Contacting the North Dakota State Climate Office

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

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