THE APRIL 2019 BLIZZARD IMPACTS TO THE WIND INDUSTRY
WHITE PAPER

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BACKGROUND

On April 10th and 11th a historic blizzard swept across the Northern Plains states with the most significant impact being felt in the Dakotas, Minnesota and Nebraska. Heavy, wet snow was accompanied by winds of 40 to 50 mph causing a significant impact on transportation and the agricultural industry. Snow totals exceeding 12 inches stretched from Wyoming to Wisconsin. (Fig. 1) The wind industry from Nebraska and the Dakotas to locations east into Minnesota also felt a major impact from the storm. Ice accumulation to turbine blades caused a significant reduction in power production and in some cases caused wind turbines to be shut down. In extreme cases blade integrity was compromised and then on the back end of the event, ice throw become a major problem as the heavy, ice missiles were cut loose. In this paper we'll review the storm which led to the historic event and review forecasts to see how well they performed. We'll then explore what industry professionals could have gleaned from these forecasts in advance of the event to mitigate the impact.

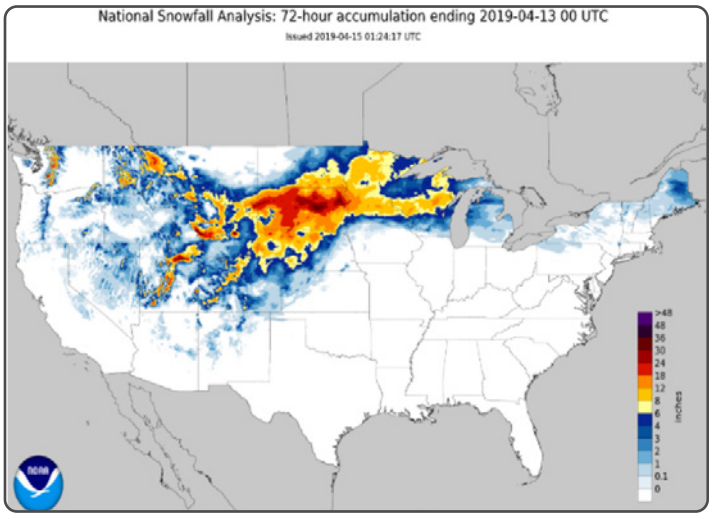

Fig. 1 The National Weather Service
https://www.weather.gov/abr/April112019BlizzardSummary

TYPES OF ICING AND THE IMPACT

Before diving into the details of the blizzard let's review the causes and types of icing to turbine blades. Freezing rain or freezing fog are the two most common forms of ice accumulation and the most widely communicated through standard weather forecast sources. In particular, freezing rain events receive a lot of attention because of their ability to turn all highways into a "skating rink" and thus impacting the entire population. While snow can have a significant impact on roads, with caution and the right vehicle, navigation can still occur. That's in contrast with a thin film of ice that can send any vehicle, even a snowplow, sliding off the highway.

Another form of ice accretion, although rarer, is from a heavy, wet snow event. These events are made up of partially melted ice crystals. For a comparison, think of the ICEE or Slushy you may buy at a convenience store. The consistency of those favorite summertime drinks can be compared to that of heavy, wet snow. You've witnessed this slushy impact when driving, after you see a large snowflake hit the windshield and it leaves that slush before being swept away by the wiper blades. Translate that observation to other objects such as power poles, trees, and even a wind turbine blade, but without the aid of a windshield wiper! Snowflakes strike an object and quickly the next snowflake piles on top leaving more slush and this process continues as the wet, heavy, sticky snow accumulates. Imagine this wind driven, heavy wet snow striking turbine blades. The adhesion rate is strong and the accumulation of what is essentially a slushy ice mixture will freeze on blades with temperatures at or below freezing. Prolonged intense events can easily bring an inch or more of ice accumulation leading to these problems:

- Up to 20% annual energy production loss
- Increased component fatigue from load
- Safety risk due to ice shedding

ANALYSIS OF WEATHER PATTERNS AND FORECASTS FOR THE APRIL 2019 BLIZZARD

In beginning our analysis of the April 2019 blizzard, the surface map in (Fig. 2) shows the stage was set for a significant spring storm to explode over the central plains. Notice in Kansas temperatures where in the 70s and low 80s, while in Minnesota temperatures where in the 30s and it was snowing. A low-pressure system was forming on the Nebraska-Kansas border that would eventually strengthen and then move very little over a 24-hour period.

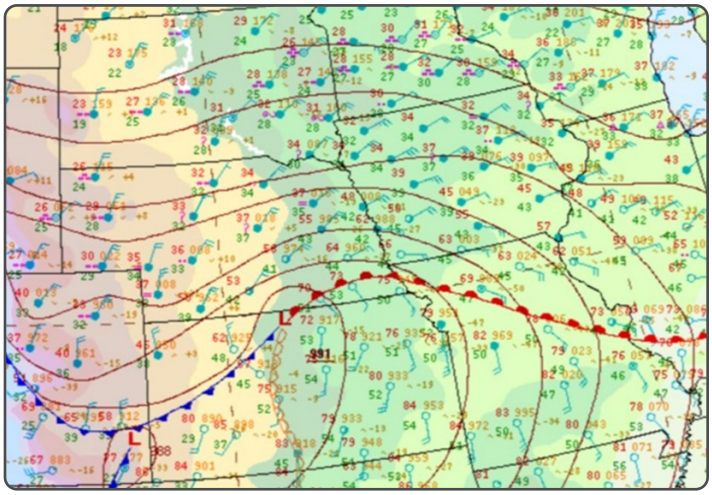

Fig. 2 www.wpc.ncep.noaa.gov, Surface Analysis Archives

Moving forward 24 hours, (Fig. 3) you can see the low-pressure system has only moved about 200 miles, just to the north of Omaha, Nebraska. Heavy, wet snow is falling in the Dakotas and Minnesota accompanied at times by thunder and lightning. Snow rates during those times reached 1-2 inches per hour. It's important to note that in the areas hit hardest, southern Minnesota and eastern South Dakota, temperatures were in the upper 20s to near 30. This is a critical temperature range where ice crystals partially melt and stick to each other producing the large, heavy, wet snowflakes.

By 7 am the morning of April 12th (Fig. 4) the low-pressure system has moved slowly northeast to the Minnesota-Iowa border and heavy, wet snow continues to fall in eastern South Dakota and southern Minnesota. However, the thundersnow and lightning has subsided, and the event is beginning to wind down. During the 48-hour event, over an inch of ice had accumulated on some turbine blades causing a significant impact to operations.

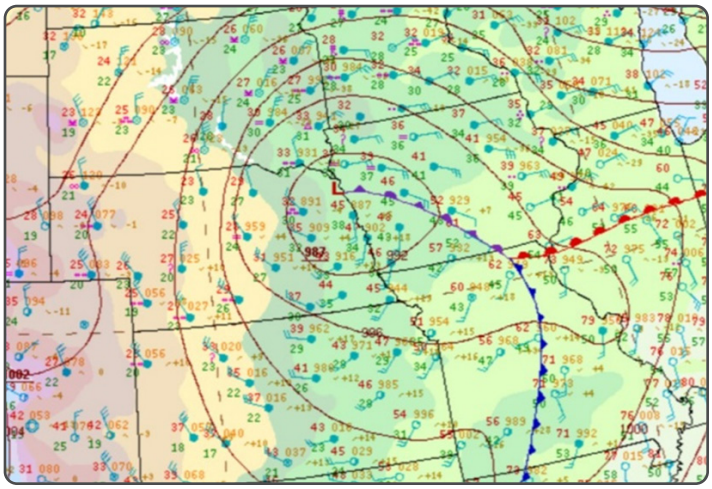

Fig. 3 www.wpc.ncep.noaa.gov, Surface Analysis Archives

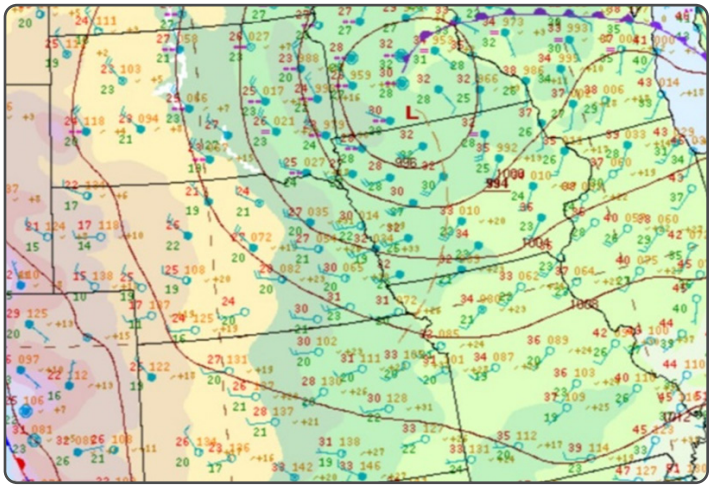

Fig. 4 www.wpc.ncep.noaa.gov, Surface Analysis Archives

In reviewing weather forecasts for the event, 24 hours prior to the start of the winter storm on the morning of April 9th, all forecast sources agreed there would be a major winter storm. Heavy snow was likely, accompanied by strong winds gusting over 40 mph. A blizzard was expected. However, what about forecasts 3 and 4 days before the event occurred? Knowing 72 hours in advance that heavy wet snow and ice accumulation was very possible, and winds would gust over 40 mph would certainly be important to wind farm operators.

Detailed forecast data from standard sources were not available for this retrospective look, however a review of an internal forecast data base from Indji Systems shows that at 6 pm on April 7th a significant

event was expected. The forecast for a location near several wind farms in southwest Minnesota is shown below, (Fig 5) with temperature forecasts, snow totals and ice accumulation areas highlighted. From 5 pm on April 10th until 9 am on April 11th over 9 inches of snow was forecast for this location and .20 inches of ice accumulation. For the entire event, 21 inches of snow was forecast and .45 inches of ice. In summary, nearly 72 hours before the event started owner/operators using this forecast would have received plenty of advance notice that a major icing event was headed their way.

Start Date (local)	Valid Date (local)	Temperature Max	Precipitation Rate Max	Wind Gust Speed	Ice Thickness
4/7/2019 6:00:00 PM	4/10/2019 5:00:00 PM	34.1	0.31	31	0
4/7/2019 6:00:00 PM	4/10/2019 6:00:00 PM	34.7	0.31	32	0
4/7/2019 6:00:00 PM	4/10/2019 7:00:00 PM	34.5	0.35	33	0
4/7/2019 6:00:00 PM	4/10/2019 8:00:00 PM	34	0.42	34	0
4/7/2019 6:00:00 PM	4/10/2019 9:00:00 PM	33.9	0.44	32	0
4/7/2019 6:00:00 PM	4/10/2019 10:00:00 PM	34.8	0.44	32	0
4/7/2019 6:00:00 PM	4/10/2019 11:00:00 PM	35	0.4	34	0
4/7/2019 6:00:00 PM	4/11/2019 12:00:00 AM	34.6	0.39	36	0
4/7/2019 6:00:00 PM	4/11/2019 1:00:00 AM	34.1	0.43	37	0
4/7/2019 6:00:00 PM	4/11/2019 2:00:00 AM	32.9	0.54	37	0
4/7/2019 6:00:00 PM	4/11/2019 3:00:00 AM	32.3	0.56	39	0
4/7/2019 6:00:00 PM	4/11/2019 4:00:00 AM	32	0.59	39	0.0375
4/7/2019 6:00:00 PM	4/11/2019 5:00:00 AM	31.8	0.63	40	0.0398
4/7/2019 6:00:00 PM	4/11/2019 6:00:00 AM	32.1	0.63	42	0.0395
4/7/2019 6:00:00 PM	4/11/2019 7:00:00 AM	32	0.68	43	0.0425
4/7/2019 6:00:00 PM	4/11/2019 8:00:00 AM	32.1	0.83	44	0.0464
4/7/2019 6:00:00 PM	4/11/2019 9:00:00 AM	32.2	0.88	45	0

Fig. 5 Indji Systems forecast database from April 7th, 2019

REVIEW OF STORM SNOW TOTALS

This historic event caused winds to gust as high as 107 mph in Colorado and dumped 30 inches of snow in parts of South Dakota. It closed interstates and extended the record run of school snow-days in many areas. It had a truly crippling effect on transportation and commerce in general for 48 to 72 hours. As witnessed by the storm total snowfall map below, (Fig. 6) the impact on the wind industry was significant in Minnesota, South Dakota and Nebraska.

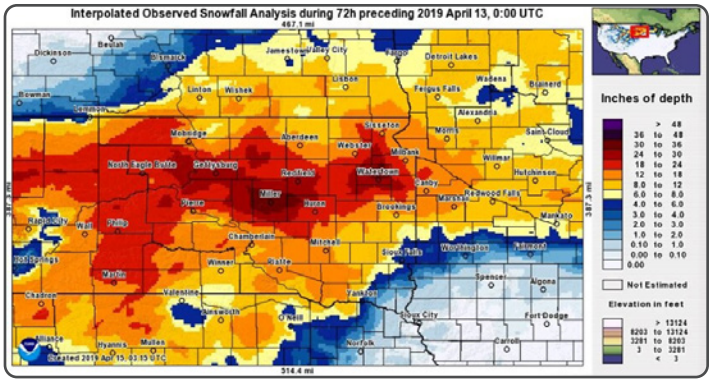

Fig. 6 https://www.weather.gov/abr/April112019BlizzardSummary

POST STORM IMPACTS

The impacts summarized herein show the blizzard's impact to the wind industry as the event unfolded. But what about residual impacts in the wake of the storm? The morning of April 13th dawned cold but sunny and by afternoon temperatures warmed into the mid to upper 30s across the hardest hit areas. The combination of temperatures above freezing and high solar insolation from the sun led to melting of the ice on the turbine blades creating a concern for wind farm owner/operators as those conditions cause ice shedding and ice throw. Interviews with industry employees confirmed that ice shedding was a significant problem on the 13th and 14th of April. Situations like this are a good example of why it can be equally important to pay attention to the post event weather to ensure a safe return to normal working conditions.

CONCLUSIONS

Heavy, wet snow events are not common but seem to be occurring with increasing frequency as climate change impacts grow. These events can result in a rapid ice accumulation and due to the nature of these storms they are often accompanied by strong winds. The combination of rapid ice build-up and strong winds is not a kind one to a wind turbine, and wind farm owner/operators should be taking extra time to analyze forecasts when these events are possible. Reliance on smart phone apps and free websites are likely not sufficient to drill into the details of an ice and snow accumulation forecast and commercial providers are better positioned to deliver detailed, accurate forecasts and advance alerts of potential ice events. Owner/operators are also reminded to pay attention to post storm weather if ice has built up on their turbines. Restarting wind turbines at the wrong time can lead to ice shedding and ice throw concerns resulting in unsafe conditions.

REFERENCES

NWS Aberdeen, SD. Summary of the April 10-12, 2019 Blizzard and Heavy snow; Weather Prediction Center Surface Analysis Page, www.wpc.ncep.noaa.gov

Indji Sytems Surface Weather Forecast, April 7th, 2019.