

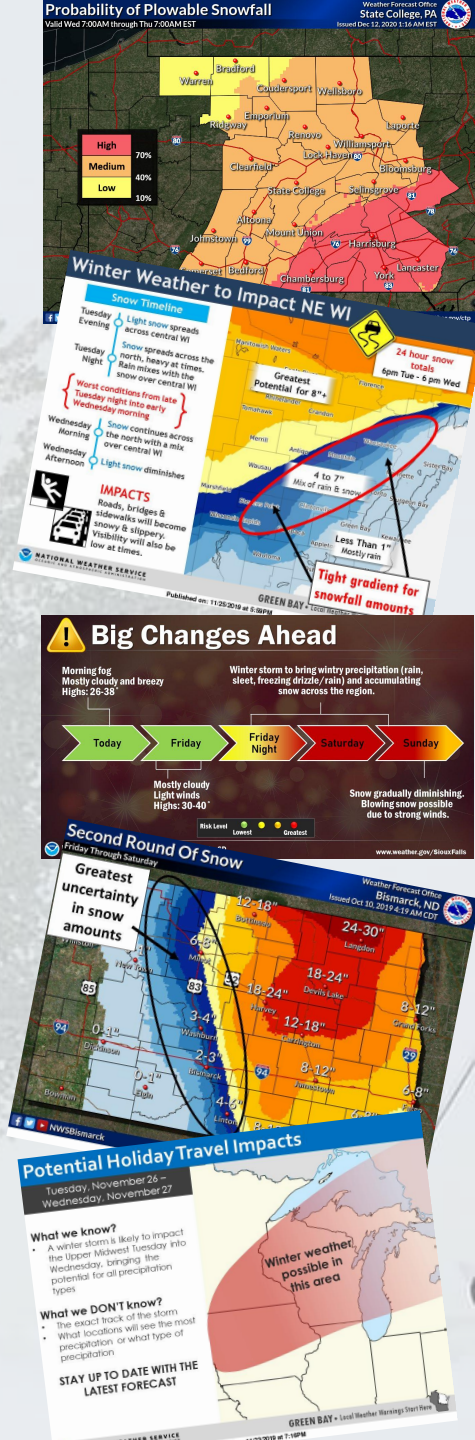
Communicating Winter Weather Using Uncertainty-Driven and Probabilistic Graphics

Jacob Morse
NOAA Hollings Scholarship

Penn State Schreyer Honors College Thesis

NWA Conference – August 21, 2022
KFYR-TV Meteorologist (Bismarck, ND)
Penn State Meteorology Alumnus ('21)
Research started at NWS Bismarck with Chauncy Schultz

See thesis for full details on this research project and its findings:
jacobmorsewx.weebly.com/research



Probabilistic information can be helpful, even for the public (*past research*)

1. People make **better decisions**, have **higher trust** in information, and display a **greater understanding** of forecast information when they are shown a **probabilistic** forecast instead of a deterministic one. (Ash et al. 2014; Bolton and Katok 2018; Joslyn and Demnitz 2019; Joslyn et al. 2007; LeClerc and Joslyn 2012; Marimo et al. 2015; Roulston and Kaplan 2009; Roulston et al. 2006; Joslyn and Grounds 2015)
2. Probabilistic information is **most effective** when displayed with **numbers**, as categorical expressions of uncertainty have been shown to be vague and open to interpretation among **USERS**. (Windschitl and Wells 1996)
 - Categorical expressions are interpreted differently depending on the context.
 - Example: “Likely” can be interpreted as anywhere from 50% to 90%
 - **Threshold probabilities** are the **best** kind of uncertainty forecasts (ex.: 20% chance temp < 32°).
Probability for **users threshold for action**.

Risk and Uncertainty Communication Using Probabilistic Information: A Systematic Review and Assessment of Existing Research

Joe Ripberger
Andrew Bell
Carol Silva
Hank Jenkins-Smith



EXCELLENT summary of state of uncertainty communication:
<https://crcm.shinyapps.io/probcom/>



A couple of their recommendations:

- Include **numeric translations** next to words/phrases that indicate probability information.
 - Example: Thunderstorms are possible (30% chance) this evening.
- Use **numeric point estimates** if available and appropriate. (Example: The forecast is rapidly evolving, but there is a 15% chance that we will see more than 10 inches of snow in the metro area tomorrow morning.)
 - If they are not, use **numeric probability ranges or predictive intervals** to emphasize uncertainty. (Example: ...there is a 50% chance that we will see 6 to 14 inches of snow in the metro area...)

Lingering Qs: What about specifically for winter weather? What graphics are best for winter wx?

Received feedback through surveys and focus groups

- Survey of U.S. public (N=833)
- Survey of meteorologists (N=40) and non-meteorologists (N=32) at NWS offices

Put survey respondents in scenarios for upcoming winter storms with graphics that were used by various NWS offices

MONDAY SYSTEM APPROACHES

Storm Track is Critical To Potential Impacts

Location & Timing

- Heavy Snow is possible on Monday.
- The track of this system will determine the locations of the heaviest snow. *This is still uncertain.*
- Significant snow accumulation is possible in the area.
- Greatest impacts: **Early Monday through Monday Eve.**

How Can You Prepare?

- Make preparations for your home, vehicle and consider adjusting travel plans.
- Continue to **monitor forecasts.**

Issued 10/22/2011 2:27 PM

SIGNIFICANT SNOW POSSIBLE MONDAY

Location & Timing

- Significant Snow is possible for parts of the region Monday through Monday evening.
- The track of this system is still somewhat uncertain and this will determine the locations of the heaviest snow. *Again, this is still uncertain.*
- Greatest impacts: **Monday through Monday Eve.**

How Can You Prepare?

- Make preparations for your home, vehicle and consider adjusting travel plans.
- Continue to **monitor forecasts.**

Issued 10/22/2011 4:18 AM

HEAVY SNOW EXPECTED MONDAY

Details

- Snow begins Monday morning and will accumulate up to a foot in some locations.
- Greatest uncertainty in snow accumulation and impact is along I-80 on the heavy snow's northern edge.

Impacts

- Dangerous Travel
- Reduced Visibility
- Chance of Power Outages

Most Likely Snowfall Amounts

Light Snow Begins 6am Monday **Peak Snow** 6pm Monday **Light Snow Ends** 6am Tuesday

Actions

- Plan for extra travel time.
- Consider alternative travel routes.
- Monitor your local forecast.

HEAVY SNOW FORECAST

Location & Timing

- Significant snow will accumulate Monday through Tuesday Morning.
- Peak snow intensity **1 PM to 6 PM.**
- The Monday morning commute will be affected. The Monday evening commute **may be impossible.**

How Can You Prepare?

- Make arrangements for your home, vehicle, and adjust travel plans.
- Continue to monitor the forecast.

Potential Holiday Travel Impacts

Tuesday – Wednesday

What we know?

- A winter storm is likely to impact the Upper Midwest Tuesday into Wednesday, bringing the potential for all precipitation types.

What we DON'T know?

- The exact track of the storm
- What locations will see the most precipitation or what type of precipitation.

STAY UP TO DATE WITH THE LATEST FORECAST

Issued 10/22/2011 10:00 AM

WINTER STORM POTENTIAL ACROSS NORTHEAST WISCONSIN

WEATHER	WHEN	WHAT TO DO
Snow north & central. Mix for east-central WI.	Tuesday afternoon – Wednesday morning Peak: Tuesday Night	Monitor forecasts for changes the next couple days

OVERALL CONFIDENCE

Confidence increasing that a winter storm will develop and move across the Great Lakes. Precipitation of some kind is likely. Confidence medium on exact storm track and where the rain/snow line will occur. This affects how much snow accumulation will fall in NE Wisconsin.

WINTER STORM POTENTIAL

Percent Chance of 4" of Snow or More
6PM Tuesday – 12 PM Wednesday

WINTER STORM WATCH

A Winter Storm Watch has been issued for counties west of a line from southern Marinette to Waushara County.

Winter Weather to Impact NE WI

Snow Timeline

- Tuesday Evening: Light snow spreads across central WI.
- Tuesday Night: Snow spreads across the north, heavy at times. Rain mixes with the snow over central WI.
- Wednesday Morning: Snow continues across the north with a mix over central WI.
- Wednesday Afternoon: Light snow diminishes.

Impacts

- Roads, bridges & sidewalks will become snowy & slippery. Visibility will also be low at times.

24 hour snow totals
6pm Tue – 6pm Wed

Greatest Potential for 8"+

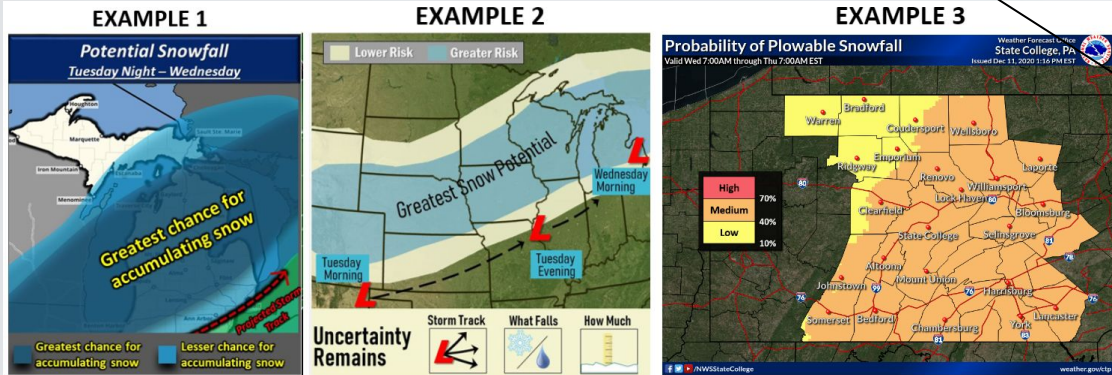
4 to 7" Mix of rain & snow

Less Than 1" Mostly rain

Tight gradient for snowfall amounts

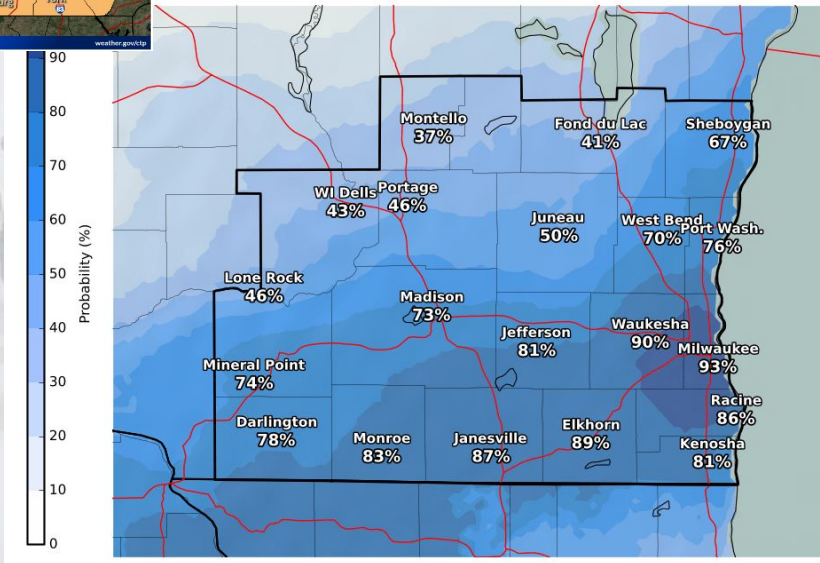
MAIN FINDING: IDEAL COMMUNICATION OF HIGH-IMPACT STORM

Days 3-7 before storm



Days 2-3 before storm

Percent Chance of 6" Snow or More

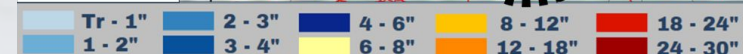
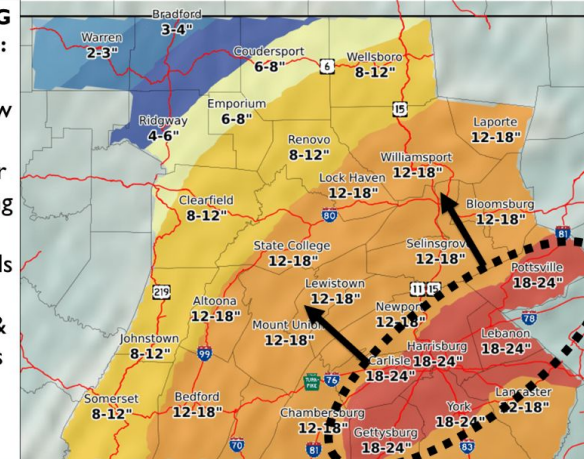


Days 1-2 before storm

Latest Snowfall Forecast

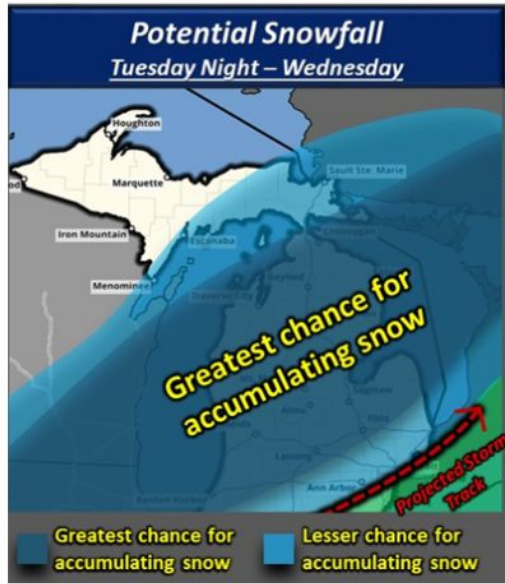
SOMETHING TO WATCH:

Band of heaviest snow may shift north and/or west, resulting in lower snowfall totals south of Harrisburg & higher totals toward the I-99/I-80 corridor



LONGER RANGE: map-based graphics are preferred

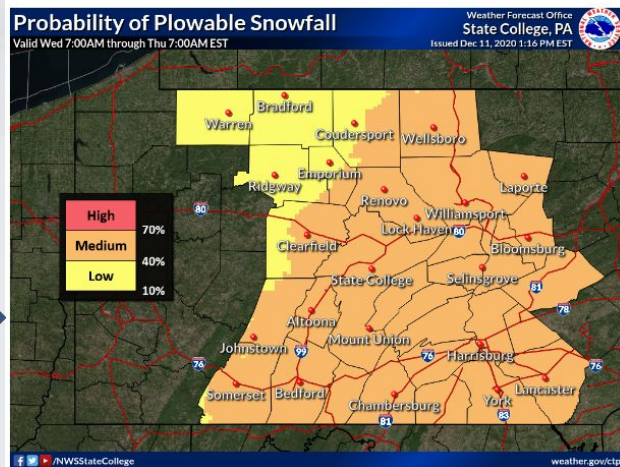
EXAMPLE 1



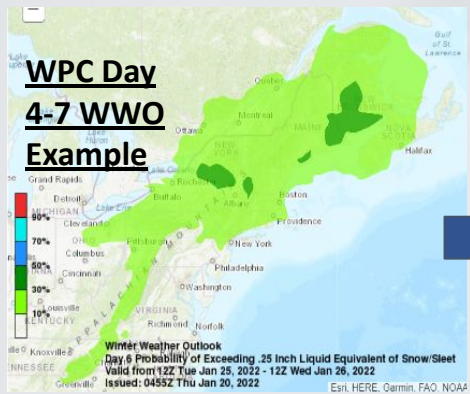
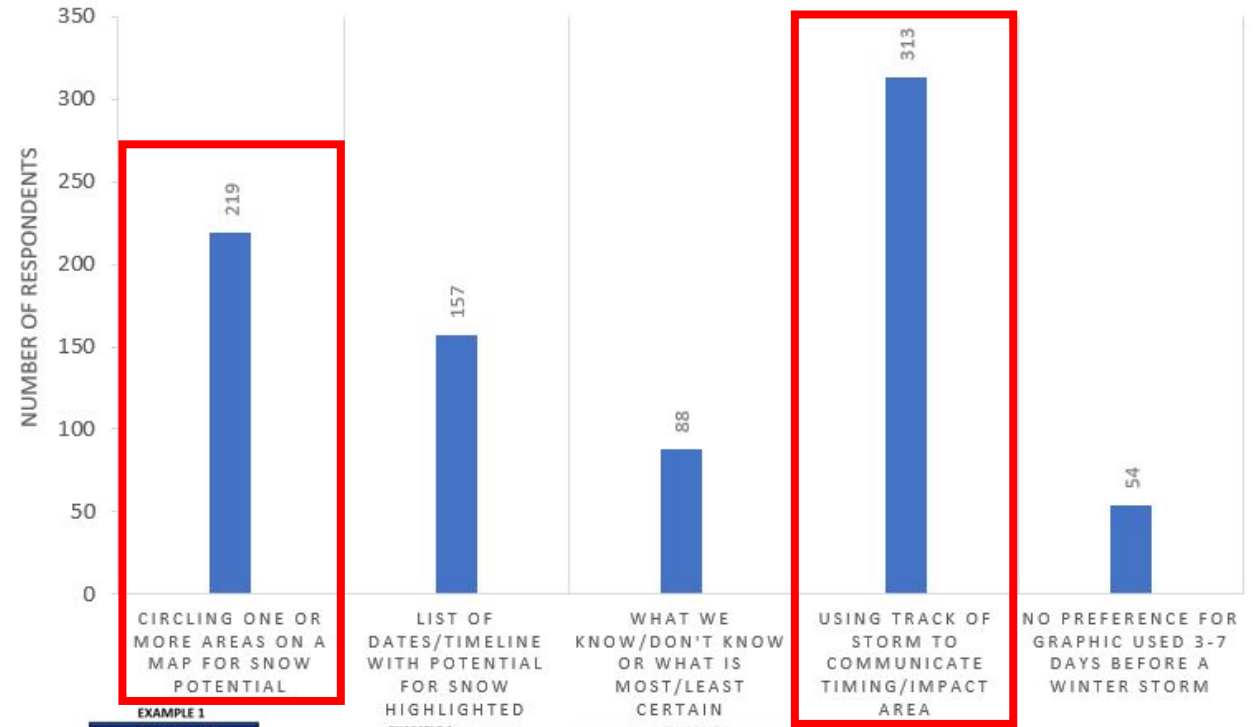
EXAMPLE 2



EXAMPLE 3

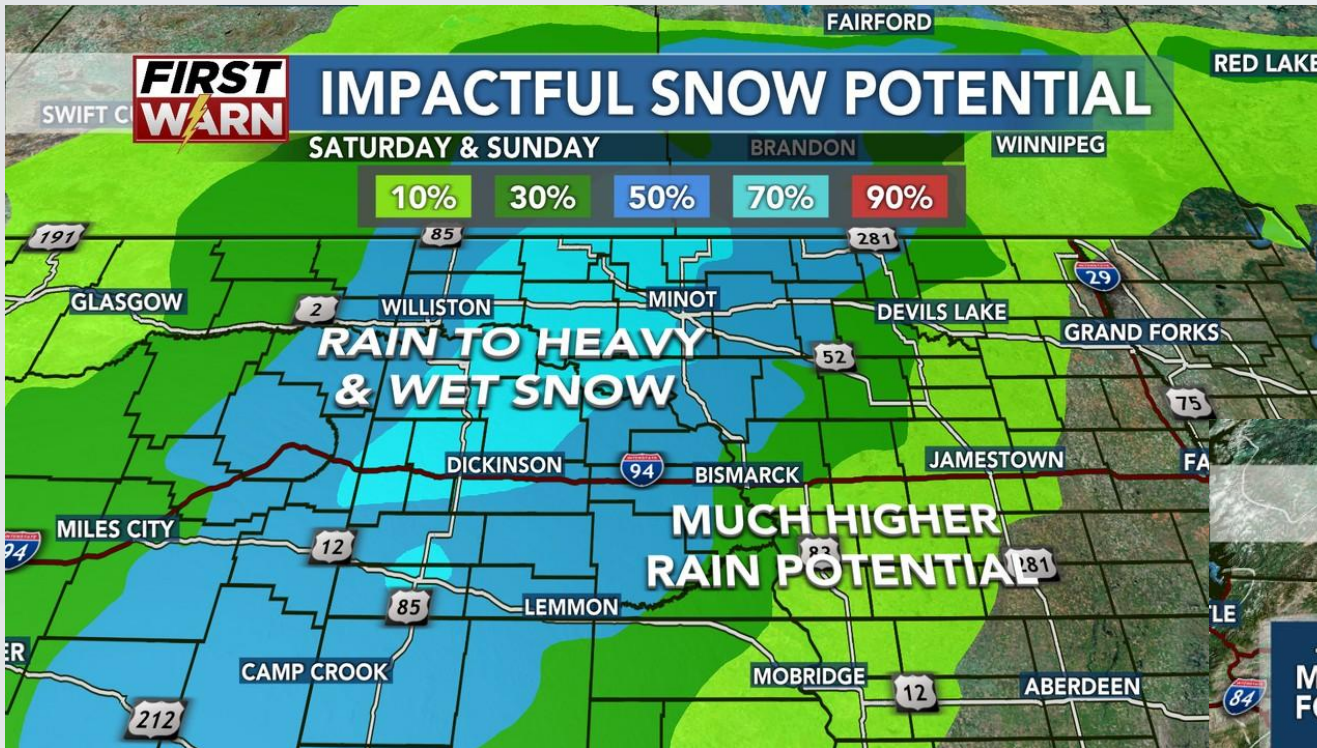


LONG-RANGE WINTER WEATHER GRAPHIC STYLE PREFERENCE OF RESPONDENTS TO THE SURVEY OF MEMBERS OF THE U.S. PUBLIC



FOR BROADCAST METS: communicate some uncertainty with maps

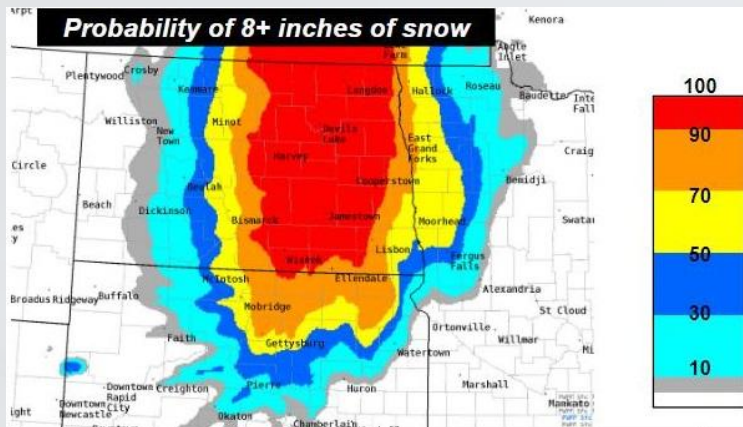
WPC Day 4-7 Winter Weather Outlook: KML download



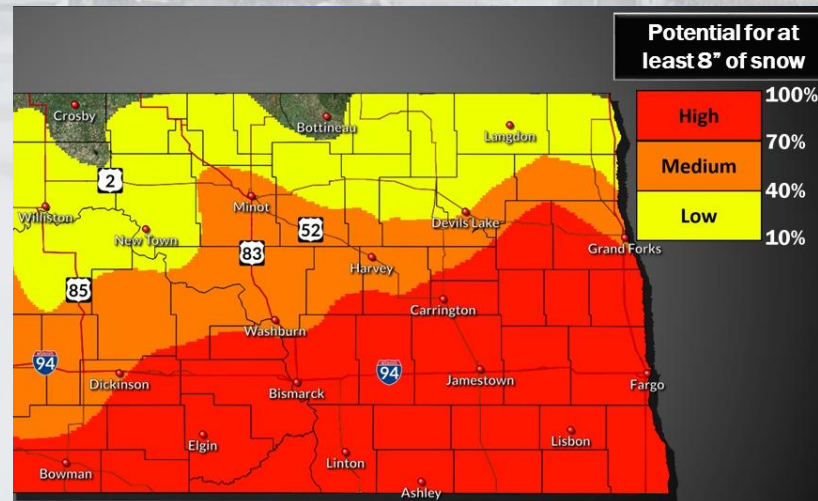
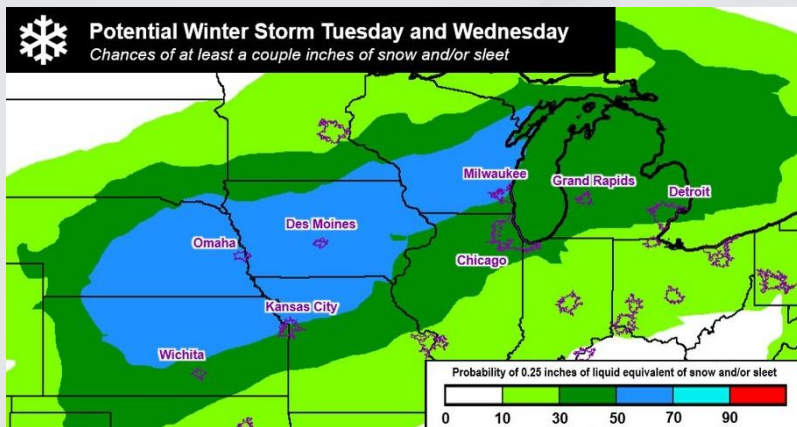
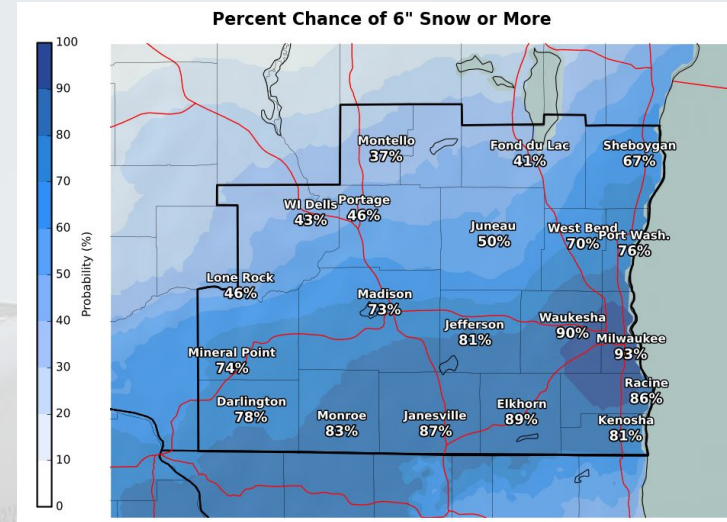
CLOSER TO STORM ONSET: probability of exceedance graphics

Probability of exceeding X inches of snowfall – ensemble based

- Used when there's too much uncertainty for snow maps to be released
- Communicates the spatial coverage *and* likelihood of the threat
- Conveys the uncertainty in the forecast and encourages user to check back for updates



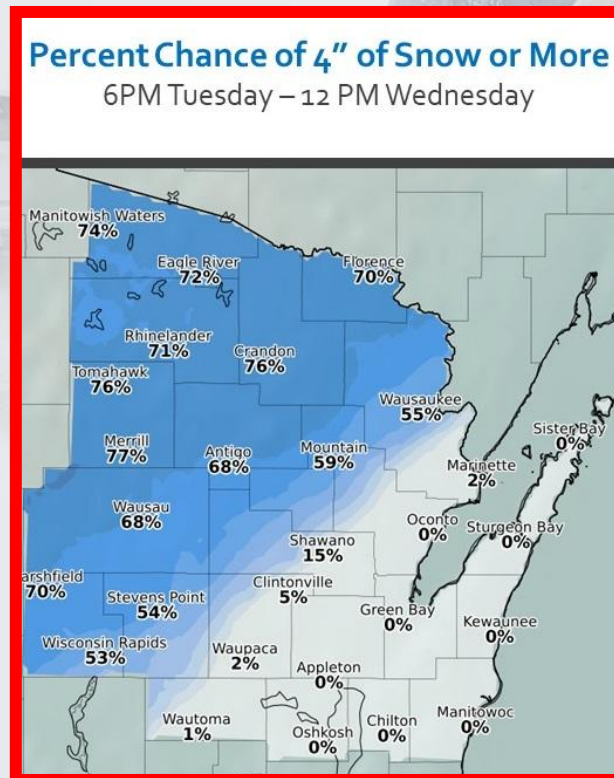
But there are many different color schemes used for these graphics:



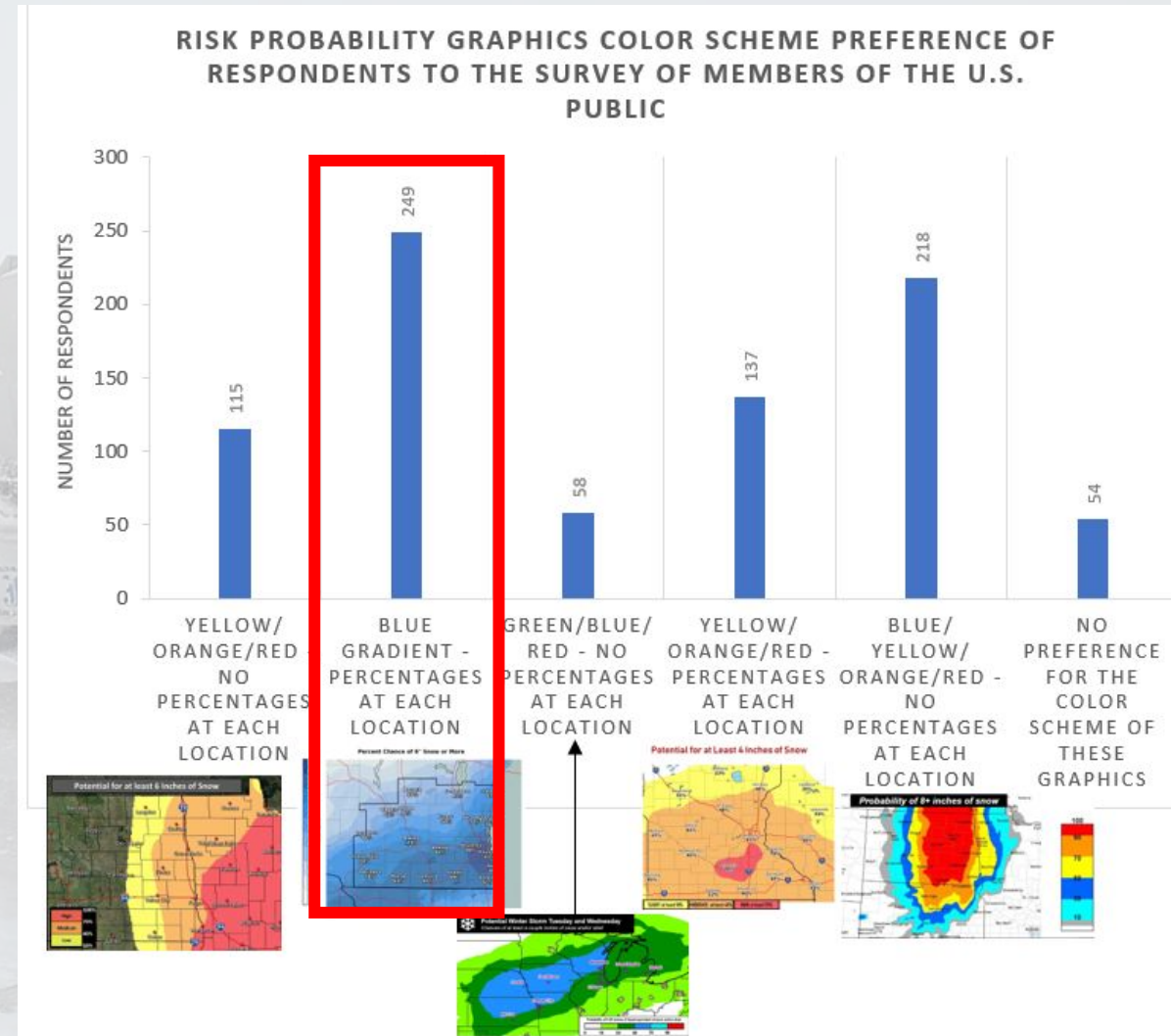
1-3 DAYS BEFORE STORM: probability of exceedance graphics

The **blue gradient** color scheme with probability percentages plotted at each location was the **most preferred**.

Easiest to interpret and the best communicator of the uncertainty present in the forecast based on the survey of the U.S. public.




Monochromatic color schemes can be helpful for those that are color blind



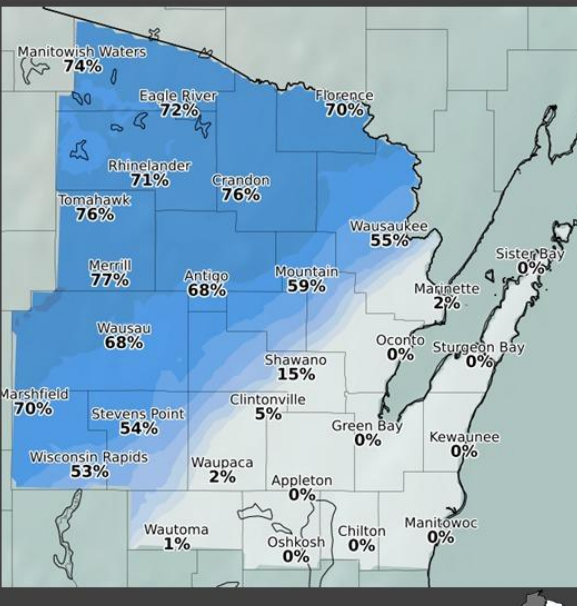
1-3 DAYS BEFORE STORM: probability of exceedance graphics

WINTER STORM POTENTIAL



6PM Tuesday – 12 PM Wednesday

Percent Chance of 4" of Snow or More



Manitowish Waters 74%
Eagle River 72%
Florence 70%
Rhineland 71%
Grandon 76%
Tomahawk 76%
Wausau 55%
Merrill 77%
Antigo 68%
Mountain 59%
Wausaukee 55%
Sister Bay 0%
Marshfield 70%
Stevens Point 54%
Clintonville 5%
Oconto 0%
Sturgeon Bay 0%
Shawano 15%
Green Bay 0%
Kewaunee 0%
Wisconsin Rapids 53%
Wautoma 1%
Waupaca 2%
Appleton 0%
Oshkosh 0%
Chilton 0%
Manitowoc 0%

WINTER STORM WATCH

A Winter Storm Watch has been issued for counties west of a line from southern Marinette to Waushara County

NATIONAL WEATHER SERVICE
OCEANIC AND ATMOSPHERIC ADMINISTRATION

GREEN BAY • Local Weather Warnings Start Here

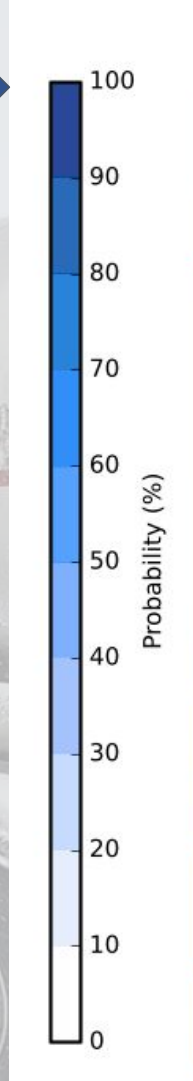
Published on: 11/24/2019 at 4:44PM

Icons: Clock (Tuesday night – Wednesday morning, Peak: Tuesday night), Cloud with snow and rain (Highest chances for snow northeast of Fox Valley; mix of rain & snow for Fox Valley & lakeshore), Smartphone (Monitor forecasts for changes over the next few days)

Probability percentages at locations were found to be helpful, but a **color scale** helps to fill in the gaps. →

A possible suggestion would be to **round the percentages** at each location to the nearest 5% or 10%.

Based on heat maps: some brief, additional text was found to be helpful (especially **timing information**). However, “monitor forecast”/“check back for updates” was found to not be very helpful/important to public.



Location & Timing

- ❄️ Heavy Snow is possible on Monday.
- ❄️ The track of this system will determine the locations of the heaviest snow. Still uncertain.
- ❄️ Significant snow accumulation is possible in the area.
- ❄️ Greatest impacts likely Monday through Monday Eve.

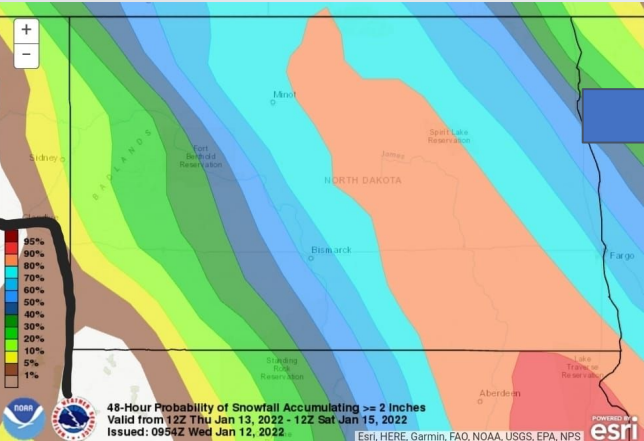
How Can You Prepare?

- ❄️ Make preparations for your home, vehicle and consider adjusting travel plans.
- ❄️ Continue to monitor forecasts.

FOR BROADCAST METS: probability of exceedance graphics

WPC 24, 48, or 72-hour probability of exceedance KML files

<https://www.wpc.ncep.noaa.gov/kml/kmlproducts.php#winx>



Override colors to combine 1-39%, 40-69%, 70-100%

KML Style

Styles Edit Icon Edit Line Edit Polygon Restore Defaults

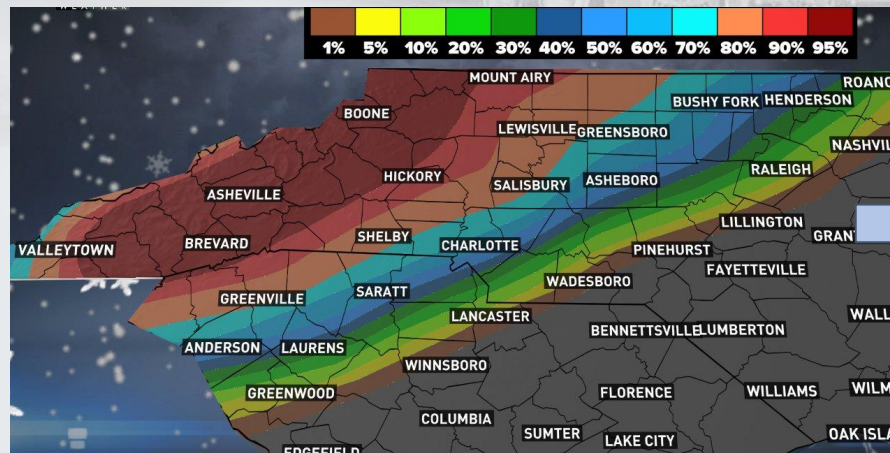
#poly_1	Overridden
#poly_5	Overridden
#poly_10	Overridden
#poly_20	Overridden
#poly_30	Overridden
#poly_40	Overridden

Three-tier is color blind friendly. Eliminates confusion with the standard rainbow color scheme.

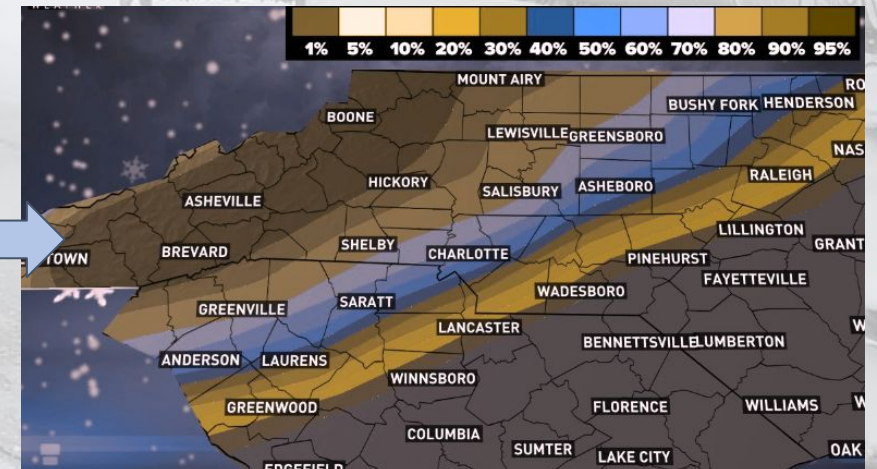
5-class RdYlBu

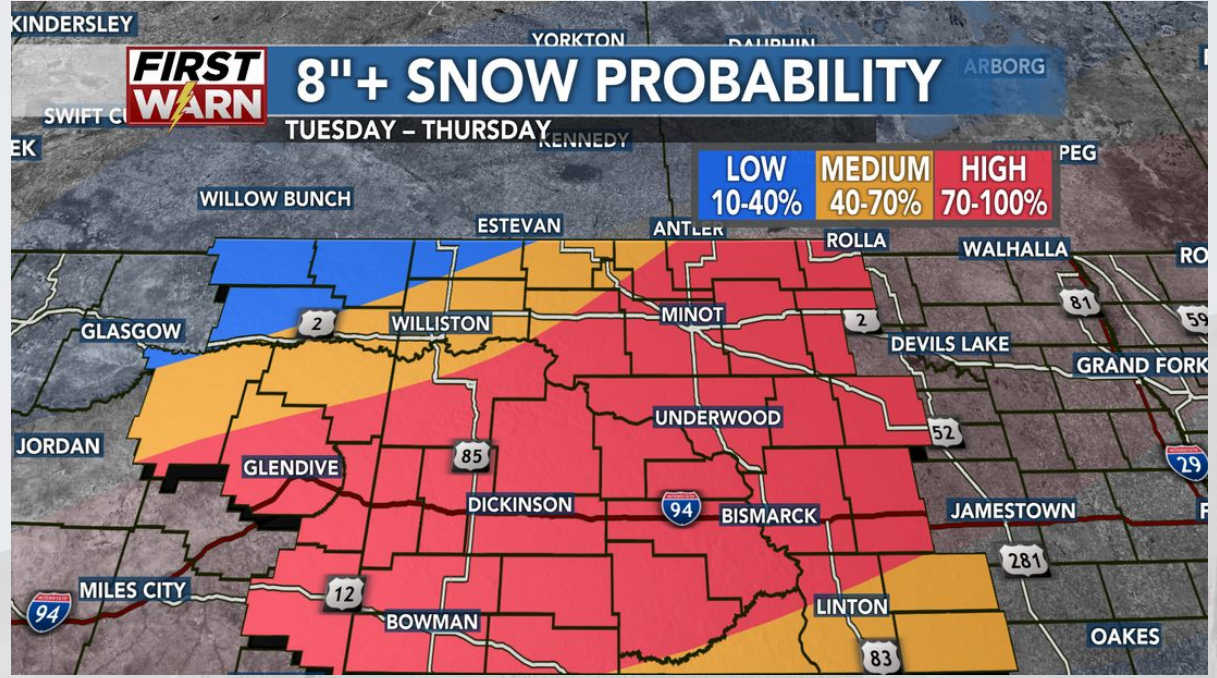
HEX

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	#fdae61
	#ffffbf
	#abd9e9
	#2c7bb6



Color blind simulator

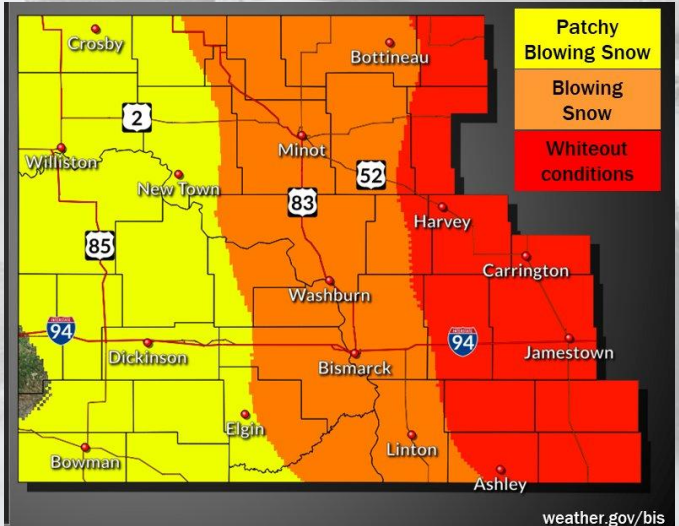
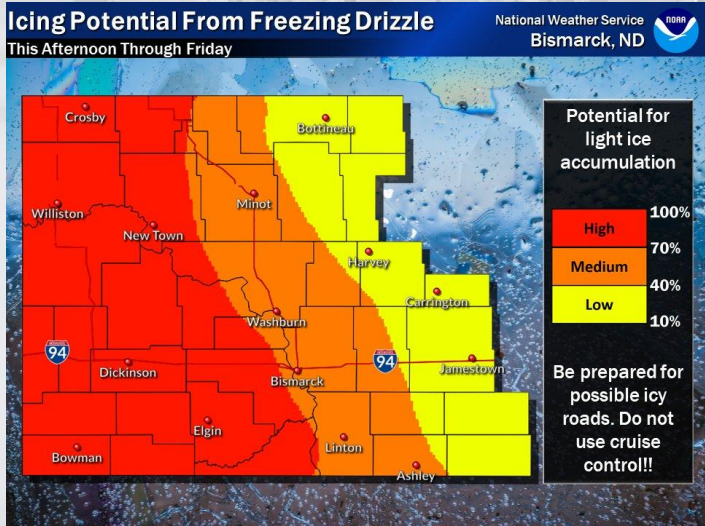




Using probability of exceedance graphics to communicate other hazards, such as for icing/freezing rain potential, was shown to be valuable.

Possible monochromatic color scheme for freezing rain: pink or purple?

Examples from WFO Bismarck

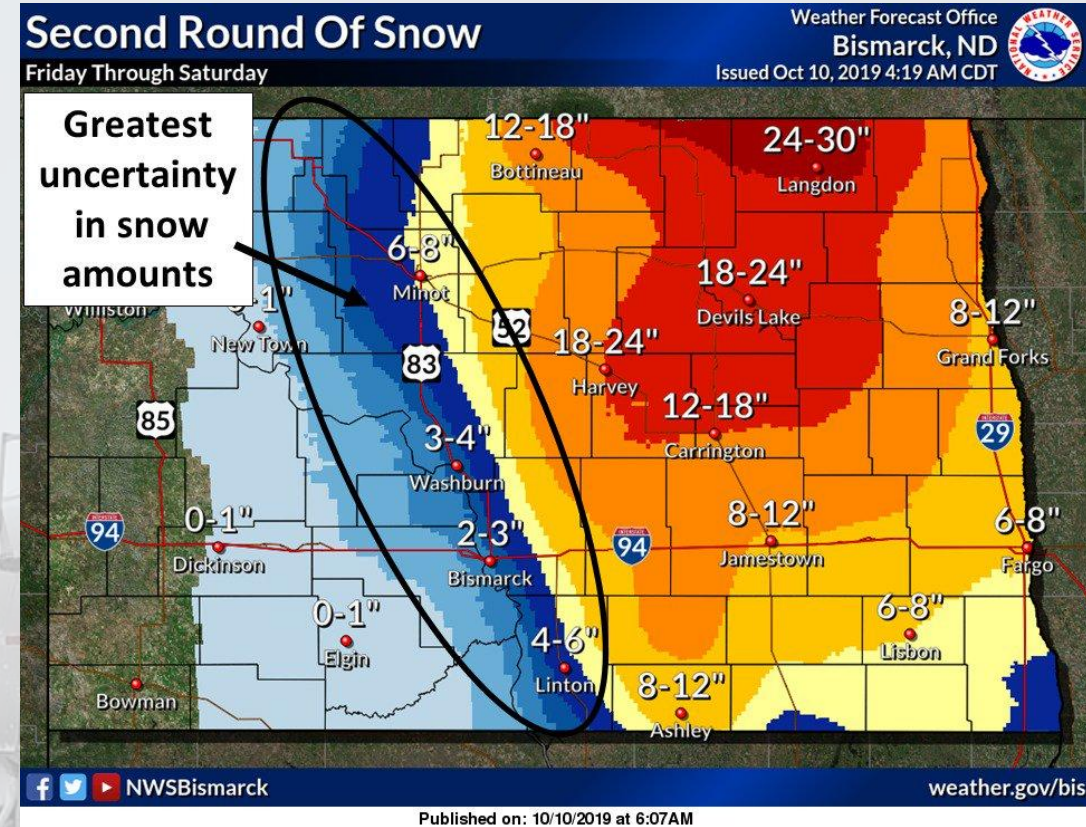
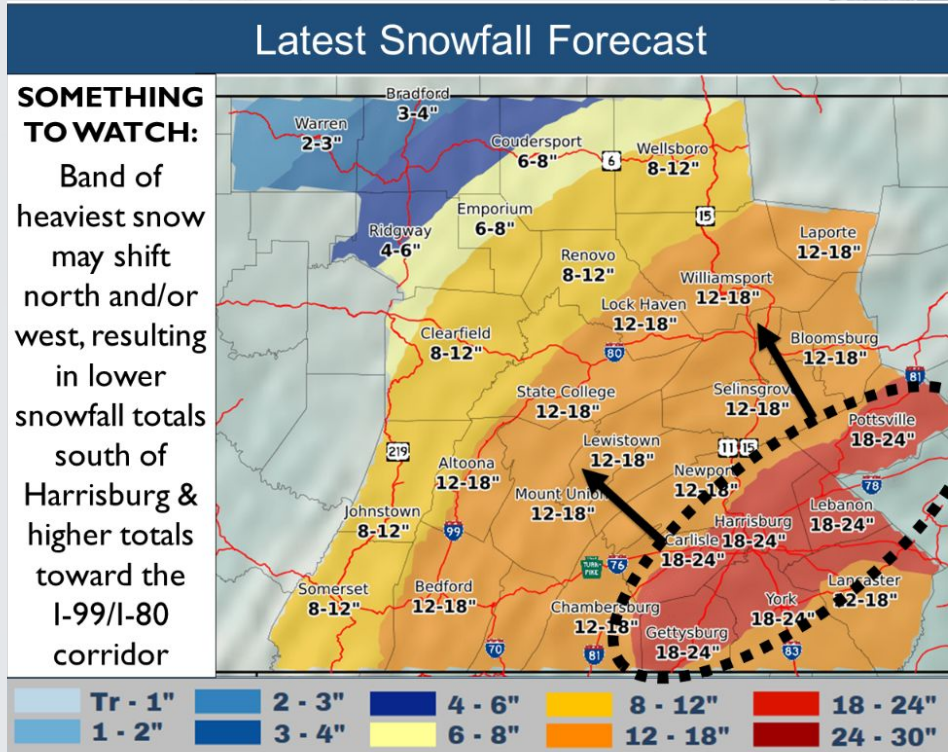


SNOW MAPS: Circling areas of uncertainty

If survey respondents were in the circled area:

75% would check back for forecast updates to see if anything had changed.

46% would prepare for higher snowfall amounts in case the forecast changed.

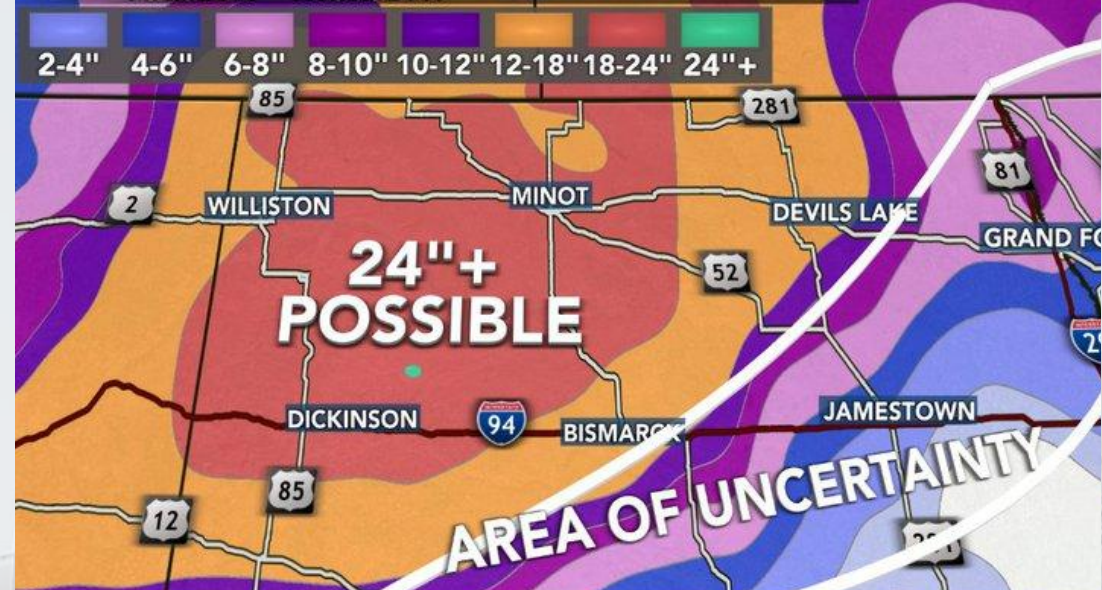


The word "uncertainty" should be used when describing this circled area and adding a ***brief statement*** on the graphic as to ***why the uncertainty exists or where the band of heaviest snow might shift*** was shown to be preferred.

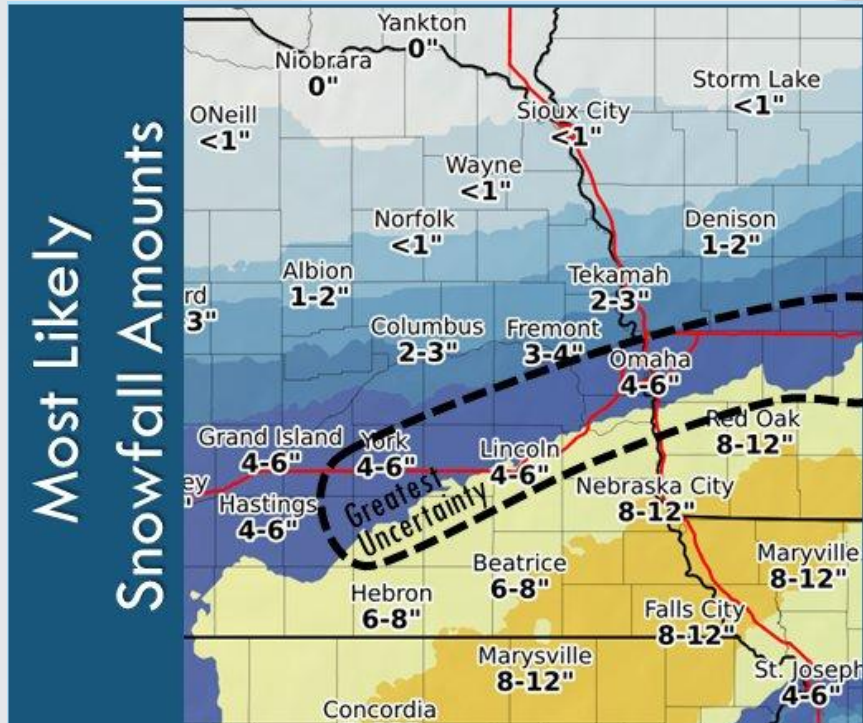
Tight gradient for snowfall amounts ❌

SNOW MAPS: Circling areas of uncertainty

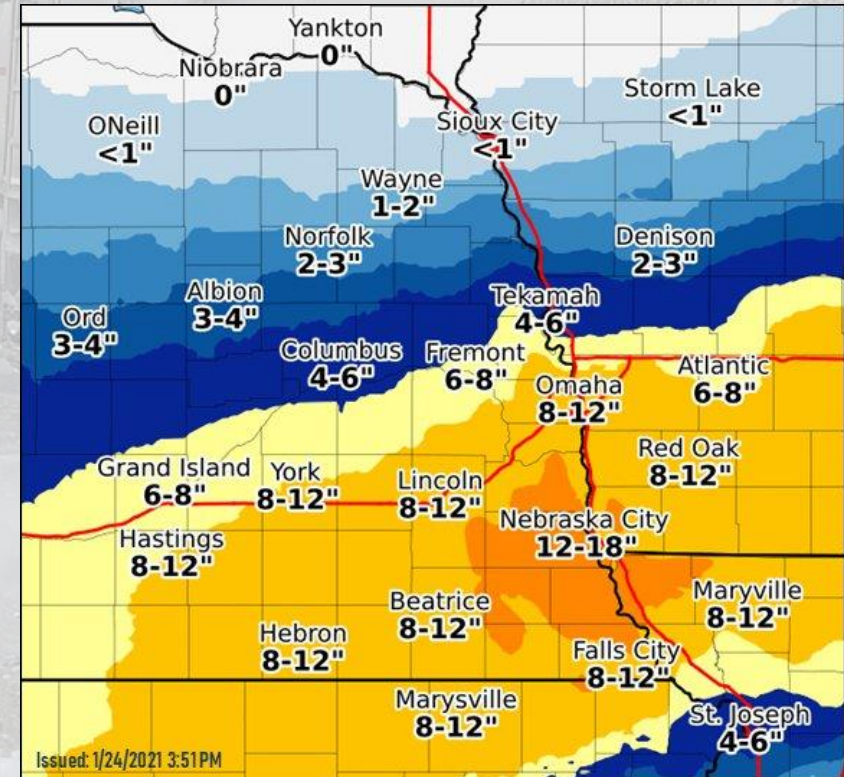
60% of respondents said the circled area was helpful for anticipating the increased snow totals in the example below.



TWO DAYS BEFORE STORM



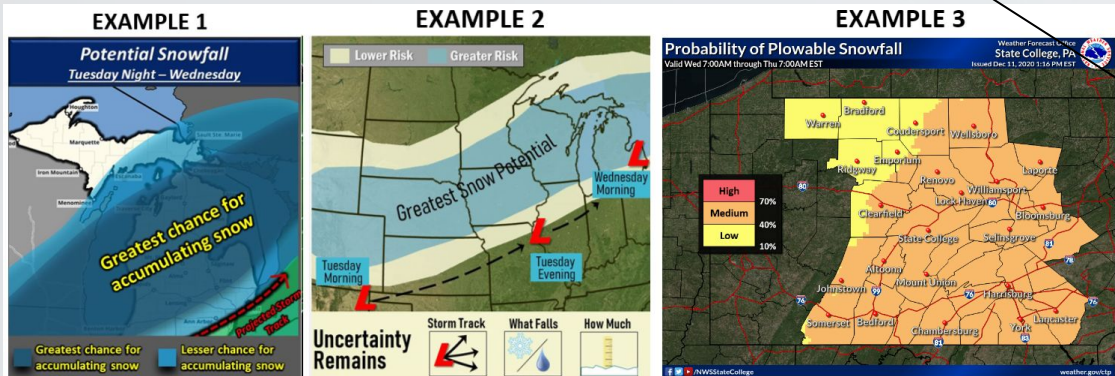
ONE DAY BEFORE STORM



Issued: 1/24/2021 3:51PM

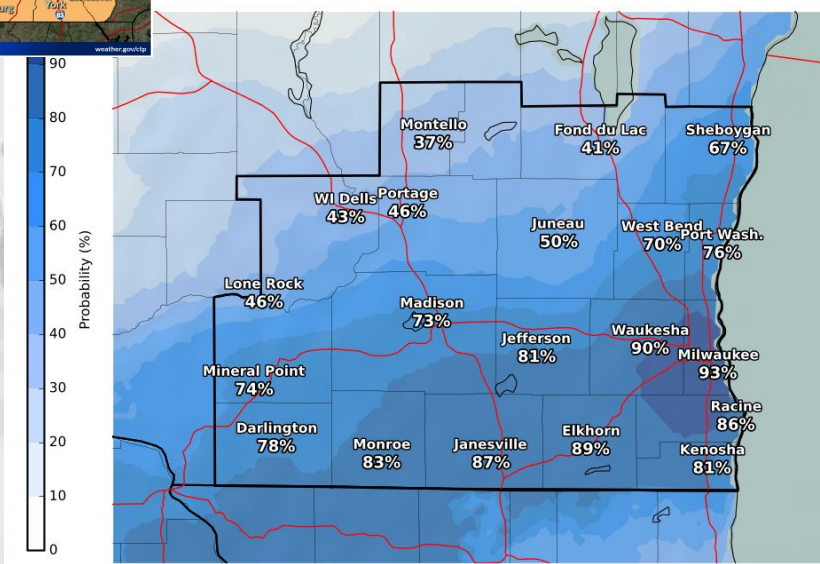
MAIN FINDING: IDEAL COMMUNICATION OF HIGH-IMPACT STORM

Days 3-7 before storm



Days 2-3 before storm

Percent Chance of 6" Snow or More

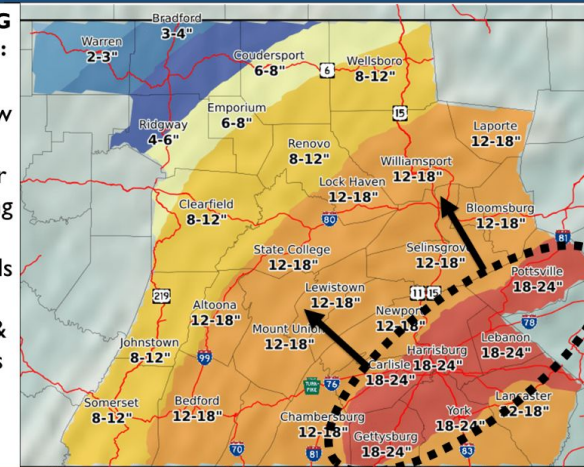


Days 1-2 before storm

Latest Snowfall Forecast

SOMETHING TO WATCH:

Band of heaviest snow may shift north and/or west, resulting in lower snowfall totals south of Harrisburg & higher totals toward the I-99/I-80 corridor



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METEOROLOGIST JACOB MORSE

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NOAA HOLLINGS SCHOLARSHIP RESEARCH ABOUT EFFECTIVE MESSAGING FOR WINTER STORMS

FULL HONORS THESIS

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TAKE-HOME MESSAGE: People want to hear about uncertainty & probabilistic information and find it helpful for decision-making *when presented correctly*. Greater *consistency* is needed across the weather enterprise with these forecast products.

THANK YOU!

Reach out to me with questions:

Twitter: [@JacobMorseWX](https://twitter.com/JacobMorseWX)

Email: jmorse879@gmail.com