Communicating Winter Weather Using Uncertainty-Driven and Probabilistic Graphics

Jacob Morse

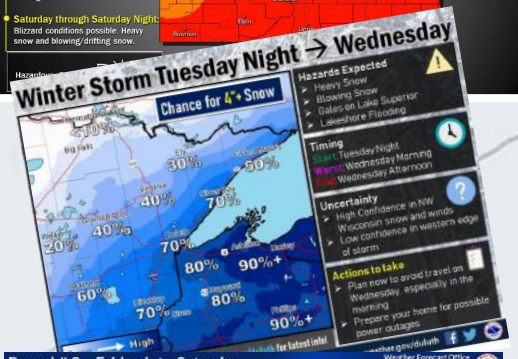
NOAA Hollings Scholarship

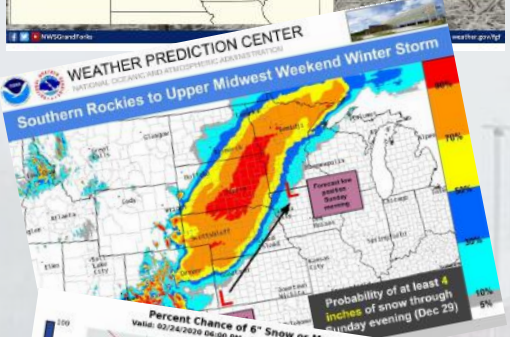
Penn State Schreyer Honors College Thesis

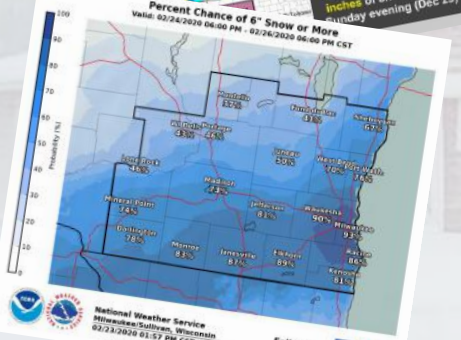
NWS Presentation – January 20, 2022

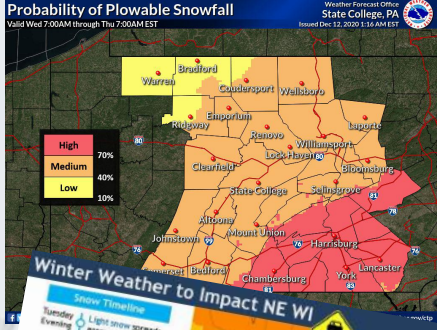
KFYR-TV Meteorologist (Bismarck, ND)
Penn State Meteorology Alumnus (‘21)
Research started at NWS Bismarck with Chauncy Schultz

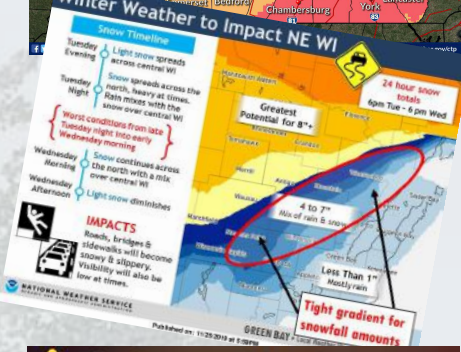
<u>See thesis for full details on this research project and its findings:</u>
jacobmorsewx.weebly.com/research

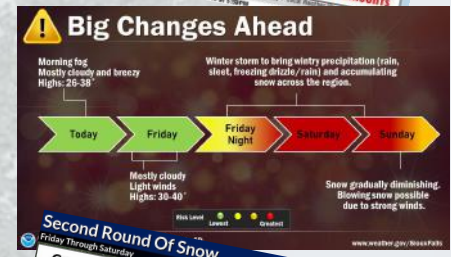










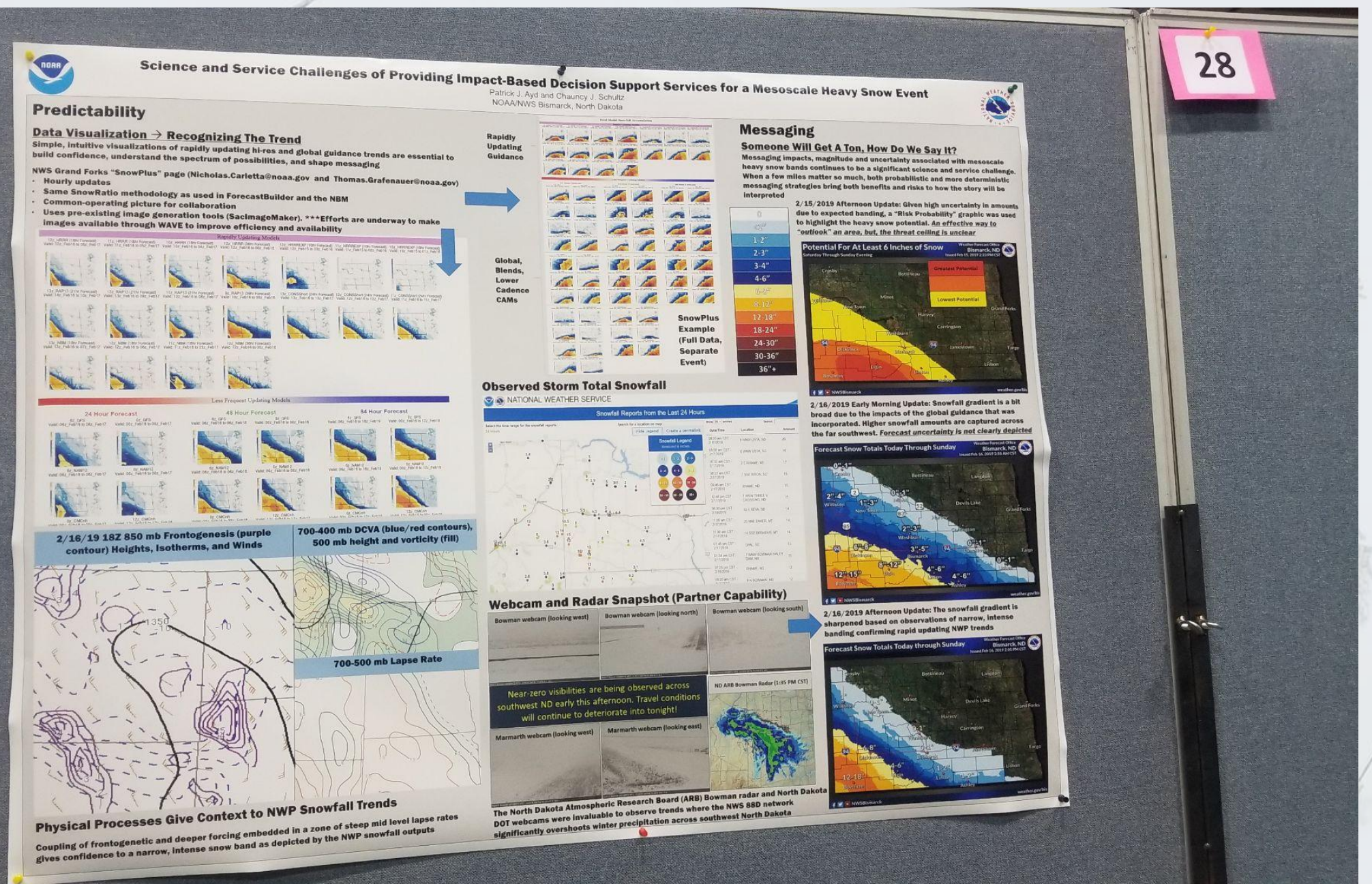


ROAD MAP FOR PRESENTATION

1. Past research
2. ***Discussion***
3. Intro to my research
4. Part 1: Long Range Forecast Graphics
5. ***Discussion***
6. Part 2: Risk Probability Graphics
7. ***Discussion***
8. Part 3: Uncertainty with Snow Maps
9. ***Discussion***
10. Bonus Results/Takeaways
11. ***Discussion & Final Questions***

2019 NWA Conference

How it all began…



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. It is very important to tailor probabilistic information to different audiences' needs. Forecasters should frame messages and forecasts that contain probabilistic information in a way that the end user can easily interpret (Connelly and Knuth 1998; Fundel et. al 2019).

3. 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).
   - "Likely" can be interpreted as anywhere from 50% to 90%; "Possible" has a bi-modal distribution at 5% and 55%
   - Categorical expressions are interpreted differently depending on the context. "Slight chance" gastric disturbances vs. "slight chance" of skin cancer. Much less probability assumed for one versus the other.

4. Communicating probabilistic information in the form of visualizations is an effective way for groups of people who are less numerate or who may have difficulty with numeric probabilities (Johnson and Slovic 1995, Gerst et. al 2020, Okan et. al 2015).

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

Susan Joslyn's

Decision Making with Uncertainty Lab

Department of Psychology, University of Washington

Study 1: Does general public need uncertainty forecasts?

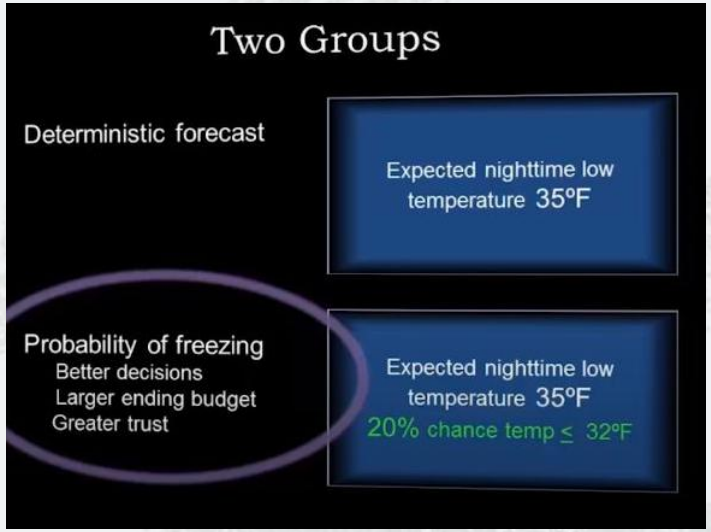
Survey: 1,340 residents of Pacific Northwest

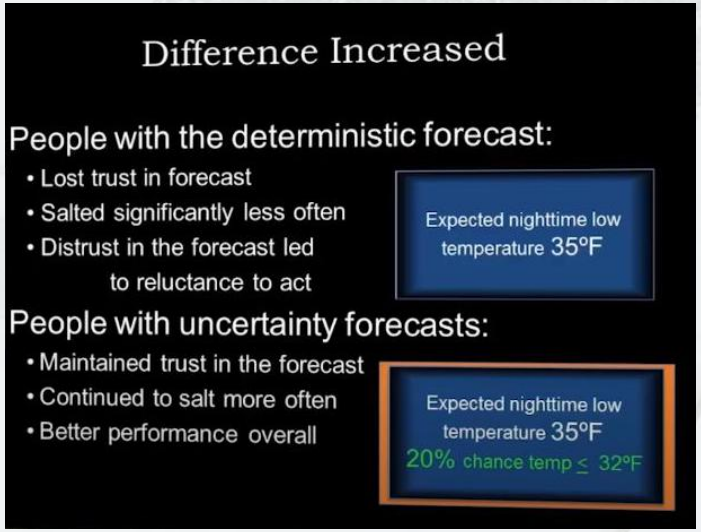
At what probability would you take precautionary action for X?_____

Study 2: Can people understand uncertainty forecasts?

Threshold probability:

- Probability for users threshold for action
  20% chance temp ≤ 32°F
- Best kind of uncertainty forecast





Website: https://depts.washington.edu/forecast/

One of her presentations: https://www.youtube.com/watch?v=SfXIt40StpA

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

Joe Ripberger
Andrew Bell
Carol Silva
Hank Jenkins-Smith

NATIONAL INSTITUTE for RISK and RESILIENCE
The UNIVERSITY of OKLAHOMA

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

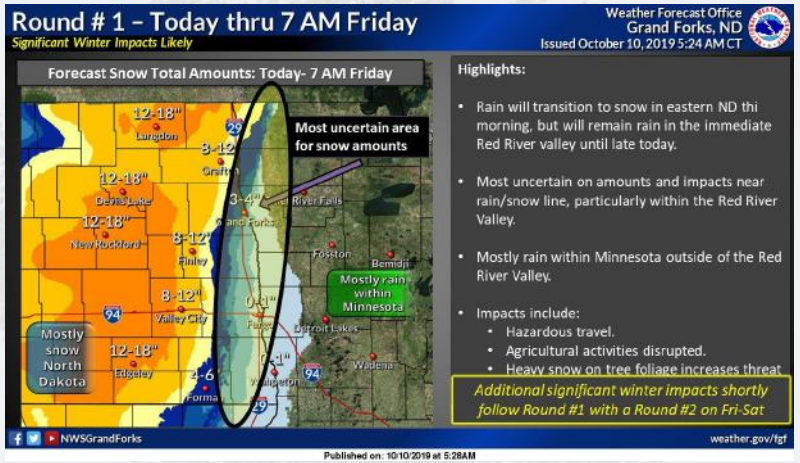
A couple of their recommendations:

- Replace: There is a chance of snow and ice this morning along I-75.
  - With: There is a *low/medium/high chance* of snow and ice this morning along I-75.
- Replace: These storms will cause heavy downpours and flooding.
  - With: There is an *extremely high (90%) chance* that these storms will cause heavy downpours and flooding.
- Replace: There is a low (15%) chance that we will see more than 10 inches of snow in the metro area tomorrow.
  - With: There is a *low (10% to 20%) chance* that we will see more than 10 inches of snow in the metro area tomorrow.
- Be aware of "directionality" when using probability information:
  - Replace: There is a high (90%) chance of sunny skies today.
  - With: There is a low (10%) chance of freezing drizzle today.
- When possible, include probability information in forecast visualizations.
  - Replace: Maps showing deterministic warning boxes/polygons.
  - With: Maps showing probabilistic information; for example: probability grids (NSSL's FACETs)

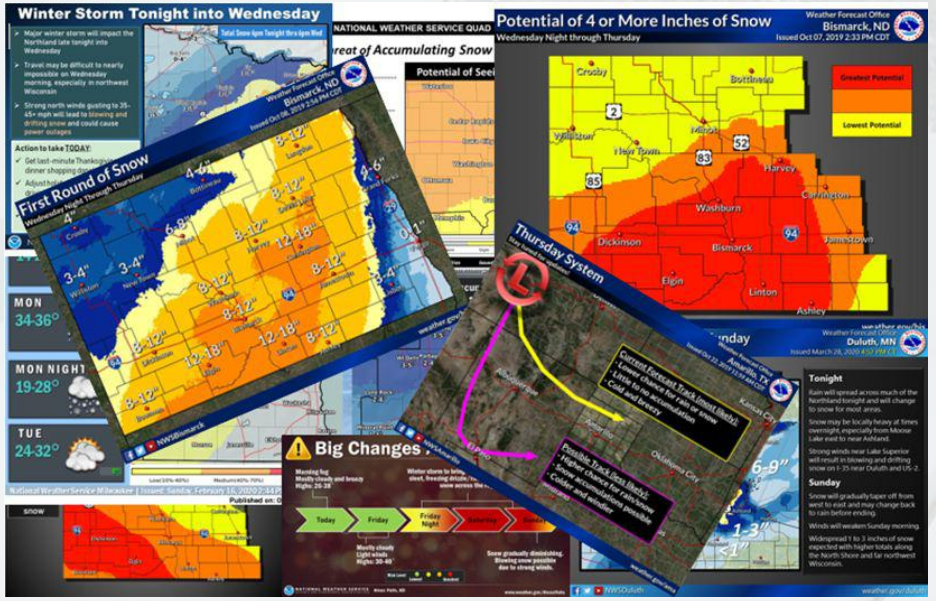
Lingering Qs: What about specifically for winter weather? What graphics are best for winter wx?

GOAL:
Identify best messaging strategies for winter storms and achieve more consistency

Days 3-7 before storm → *Days 2-3 before storm* → *Days 1-2 before storm*



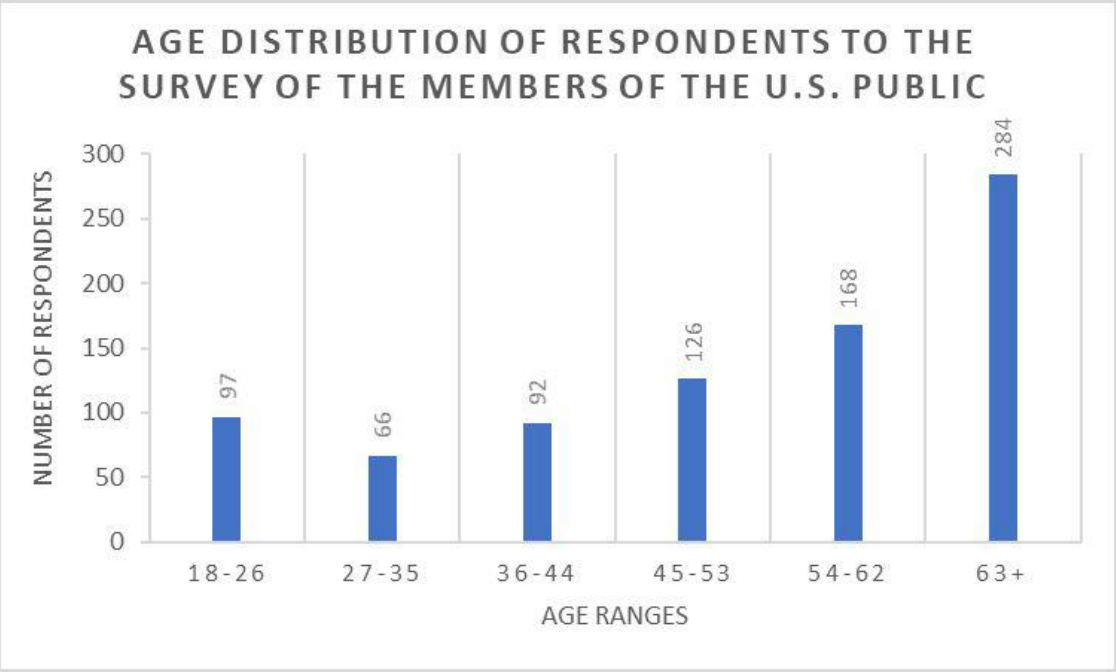
1. Gathered hundreds of NWS graphics
2. Organized and identified key differences among graphics
3. Used social media analytics to study specific storms
4. Received feedback through surveys and focus groups
   a. Survey of U.S. public *(N=833)*
   b. Survey of meteorologists *(N=40)* and non-meteorologists *(N=32)* at NWS offices



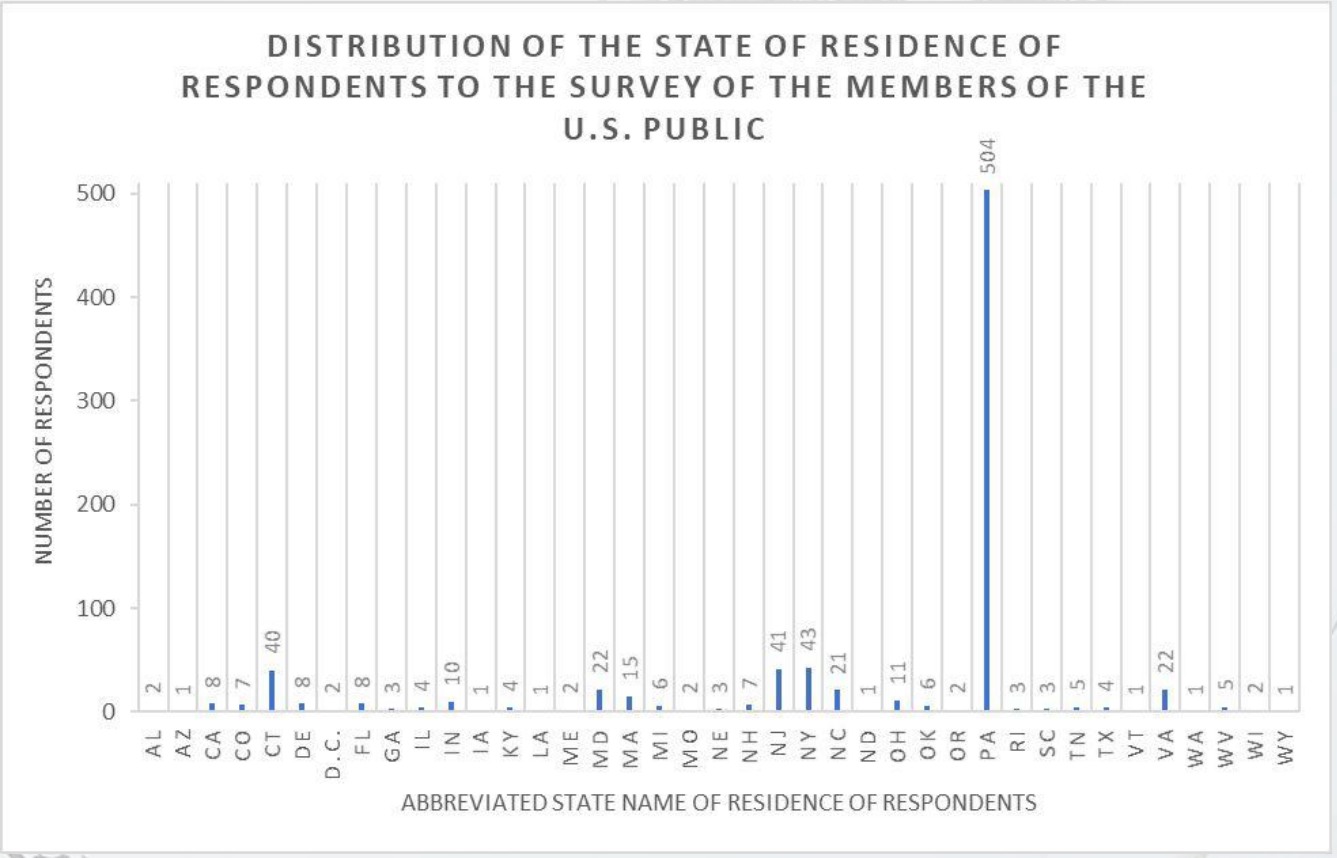
N = number of respondents for each question

Focusing on survey of U.S. public

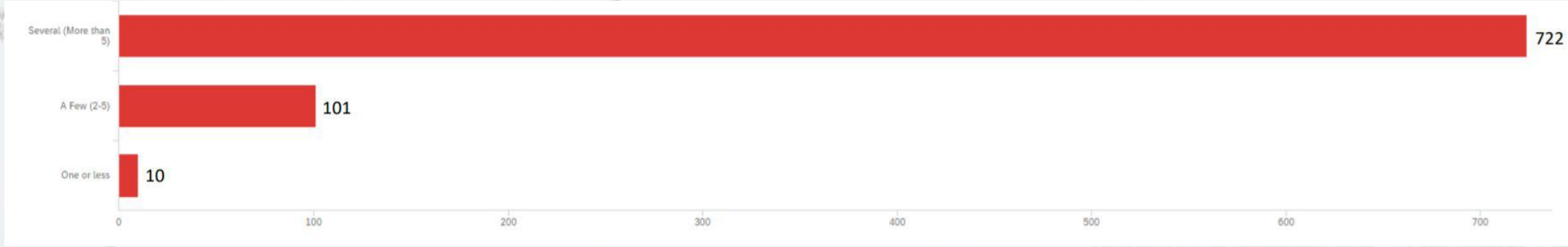
Please select your age group
(N=833)



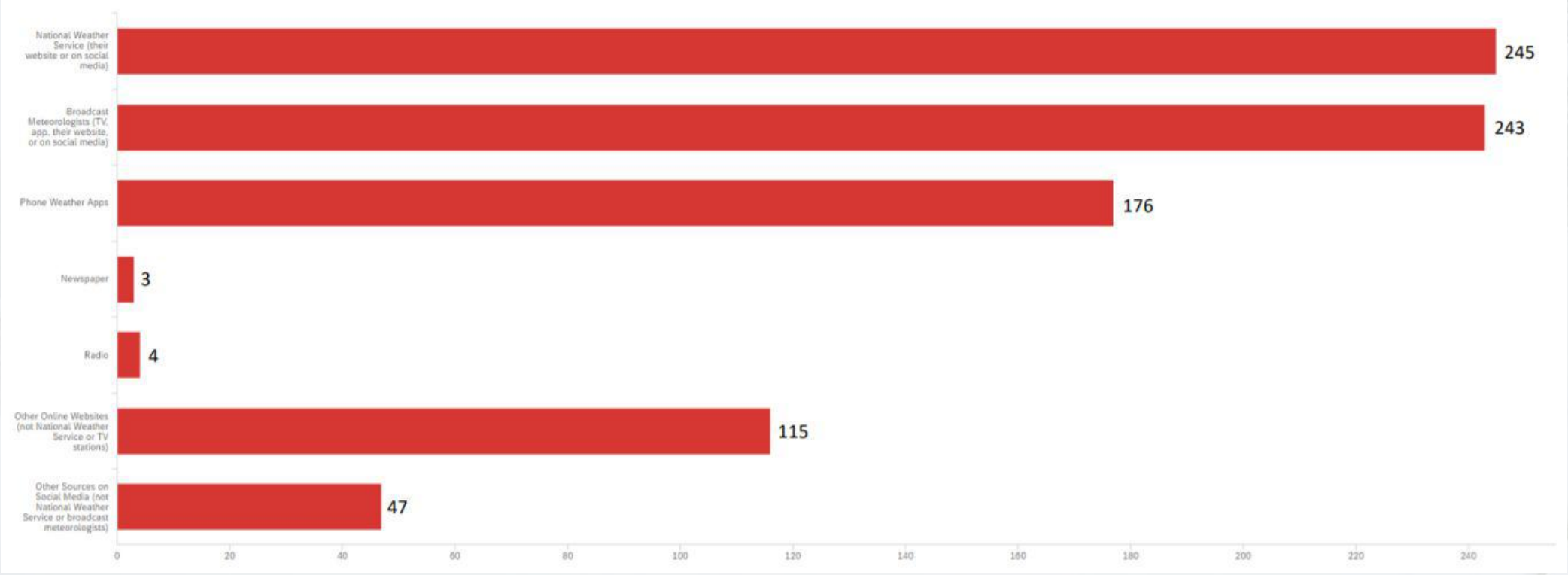
In which state do you currently reside?
(N=832)



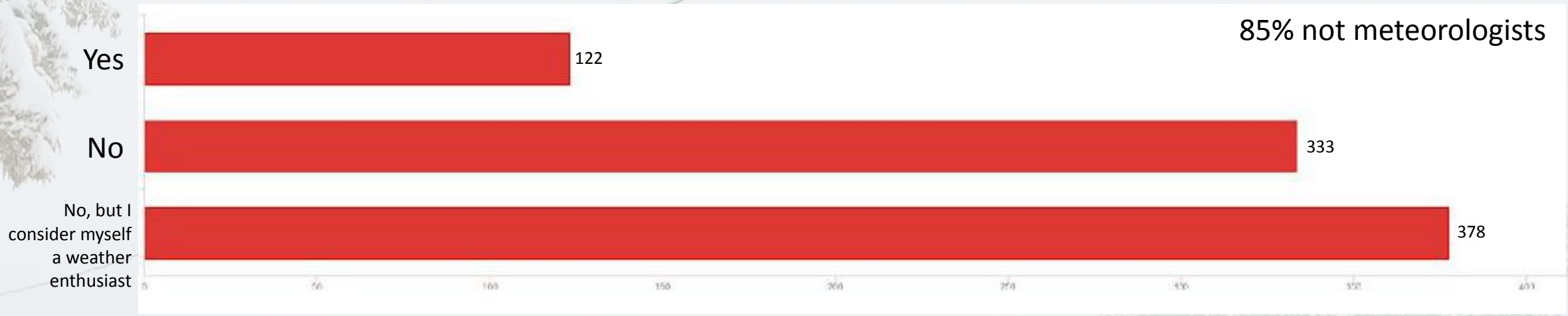
How many winter storms have you experienced within the past 10 years?
(N=833)



During the WINTER SEASON, what source of weather information do you look at most?
(N=833)



Do you have a background in meteorology? (working towards a degree, have a degree, etc.)
(N=833)



I applied filters to the survey data to determine if any possible biases occurred.

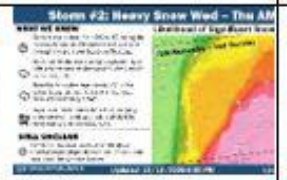
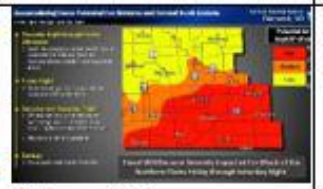
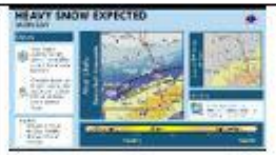
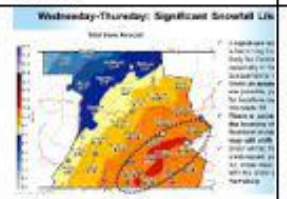
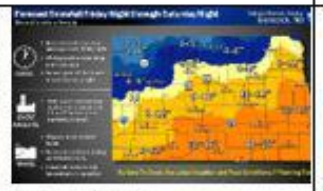
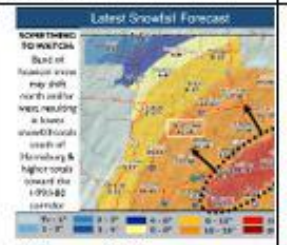
When meteorologists, PA residents, those who rely on NWS forecast info, and those not experienced with winter storms were filtered out, all the distributions of responses remained practically the same.

Format of survey of U.S. public

Four scenarios were created, and respondents were randomly placed in ONE of them by the survey software.

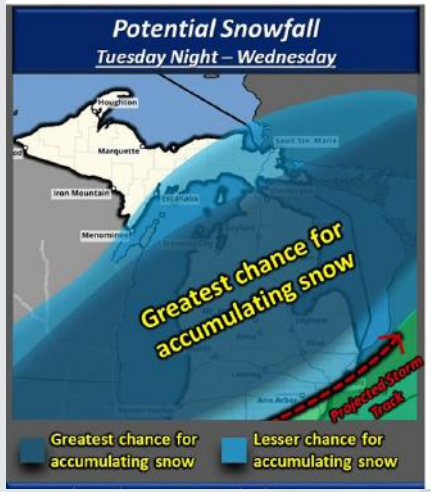
Within each scenario, a series of graphics that NWS offices used to message winter storms during the 2019-2020 or 2020-21 winter seasons were presented to respondents.

1. NWS Omaha from January 22-24, 2021 *(N=187)*
2. NWS State College from December 15-17, 2020 *(N=212)*
3. NWS Bismarck from November 24-28, 2019 *(N=221)*
4. NWS Green Bay from November 23-25, 2019 *(N=213)*

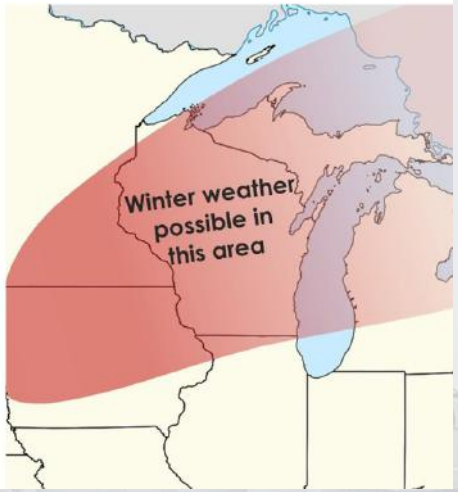
	Scenario #1 – NWS Omaha	Scenario #2 – NWS State College	Scenario #3 – NWS Bismarck	Scenario #4 – NWS Green Bay
First Graphic Presented	 (Figure 67) Posted 1/22/21 – three days before storm	 (Figure 72) Posted 12/11/20 – five days before storm	 (Figure 77) Posted 11/24/19 – five days before storm	 (Figure 81) Posted 11/23/19 – three days before storm
Second Graphic Presented	 (Figure 68) Posted 1/23/21 – two days before storm	 (Figure 73) Posted 12/13/20 – three days before storm	 (Figure 78) Posted 11/27/19 – two days before storm	 (Figure 82) Posted 11/24/19 – two days before storm
Third Graphic Presented	 (Figure 70) Posted 1/23/21 – two days before storm	 (Figure 75) Posted 12/14/20 – two days before storm	 (Figure 80) Posted 11/28/19 – one day before storm	 (Figure 83) Posted 11/24/19 – two days before storm
Fouth Graphic Presented	 (Figure 71) Posted 1/24/21 – one day before storm	 (Figure 76) Posted 12/15/20 – one day before storm		 (Figure 85) Posted 11/25/19 – one day before storm

LONG RANGE:
Identified four common graphic types used at this lead time

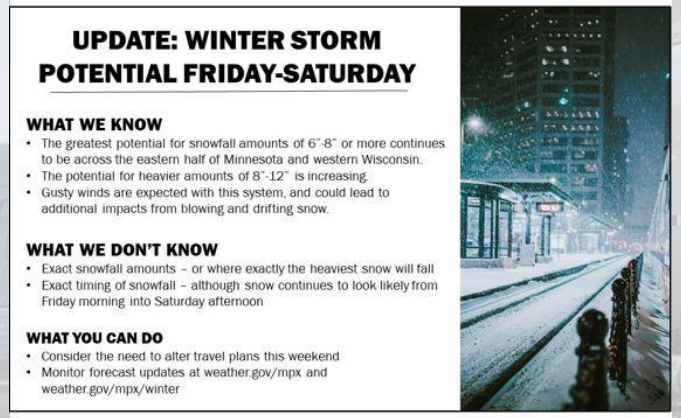
EXAMPLE 1



EXAMPLE 2



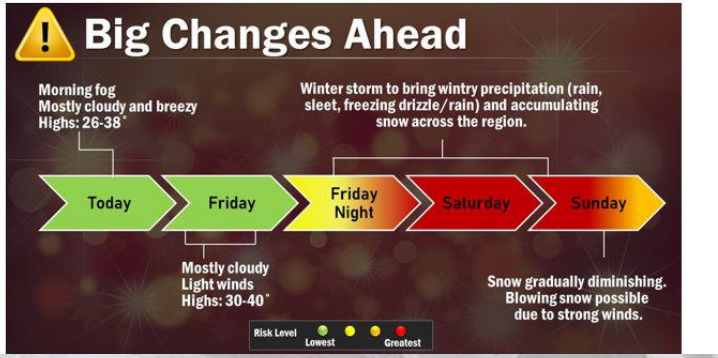
EXAMPLE 1



EXAMPLE 2

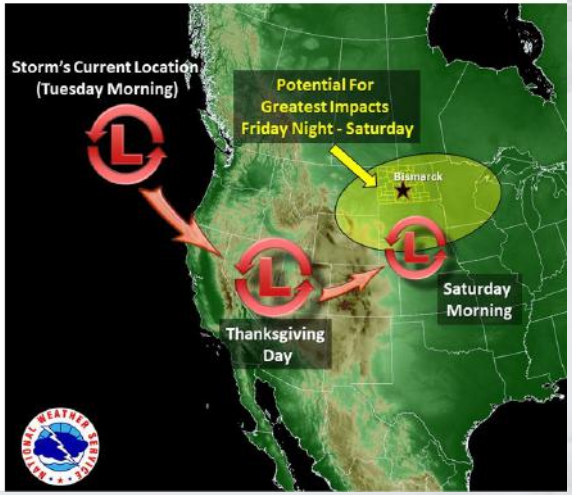
EXAMPLE 1

EXAMPLE 2



EXAMPLE 1

EXAMPLE 2

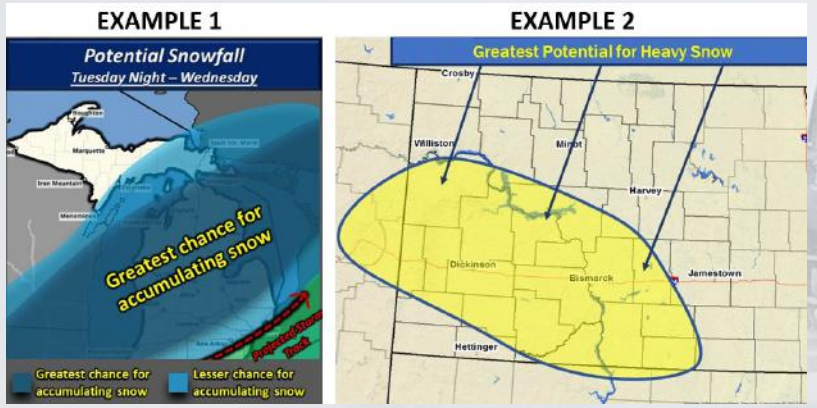


Key Takeaway #1

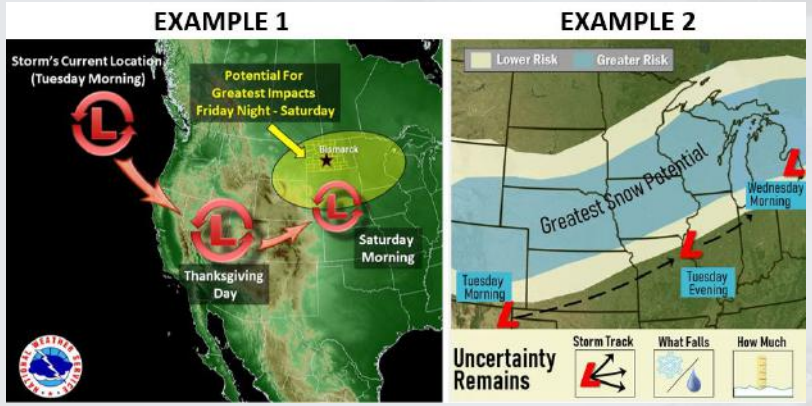
Map-based graphics for long-range messaging

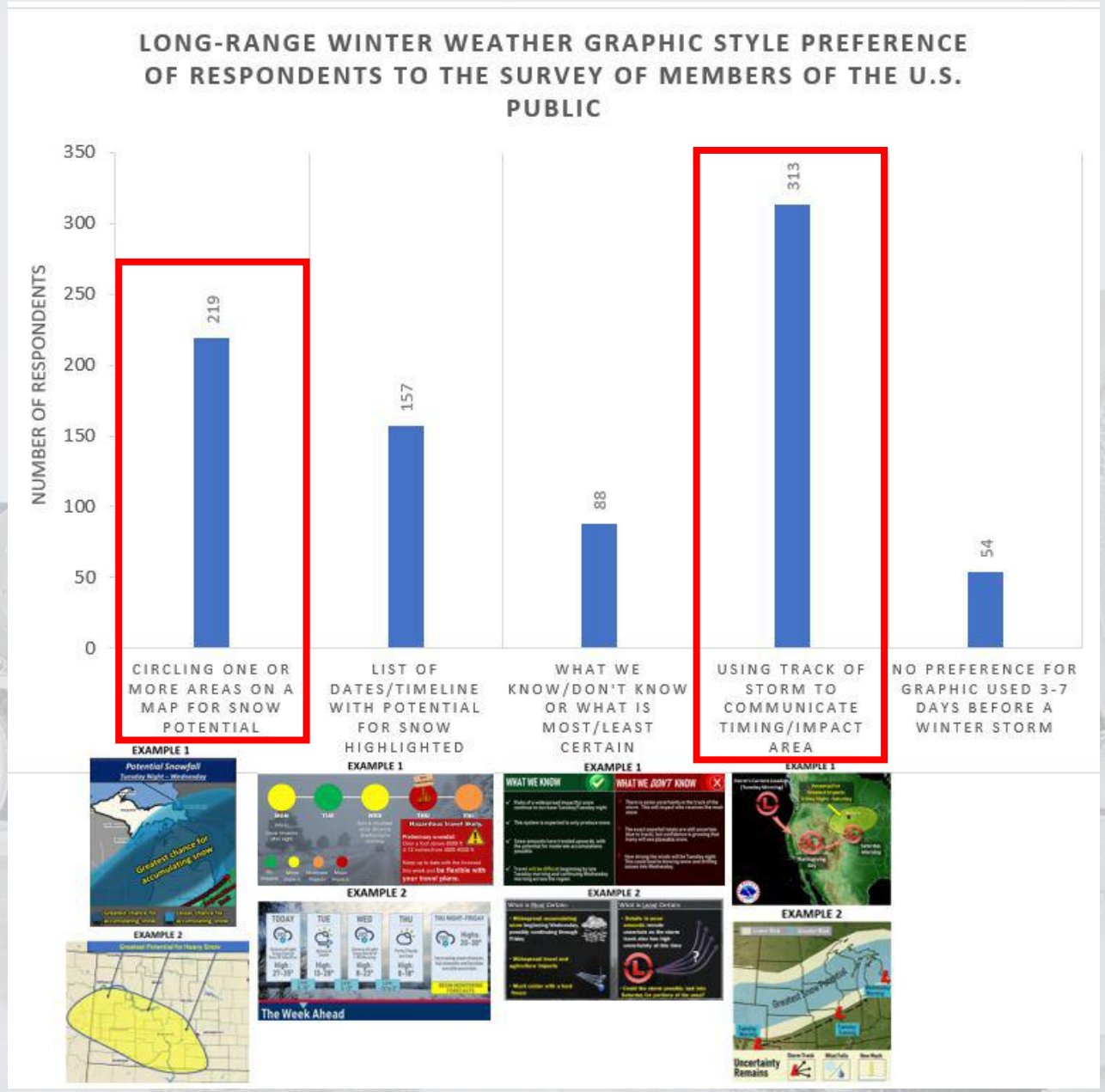
1. Circling one or more areas on a map for snowfall potential
2. Using the track of the storm to communicate the timing and impact area

(1)



(2)

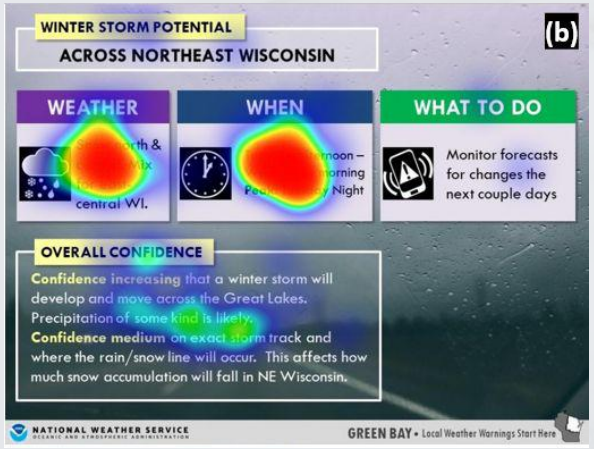


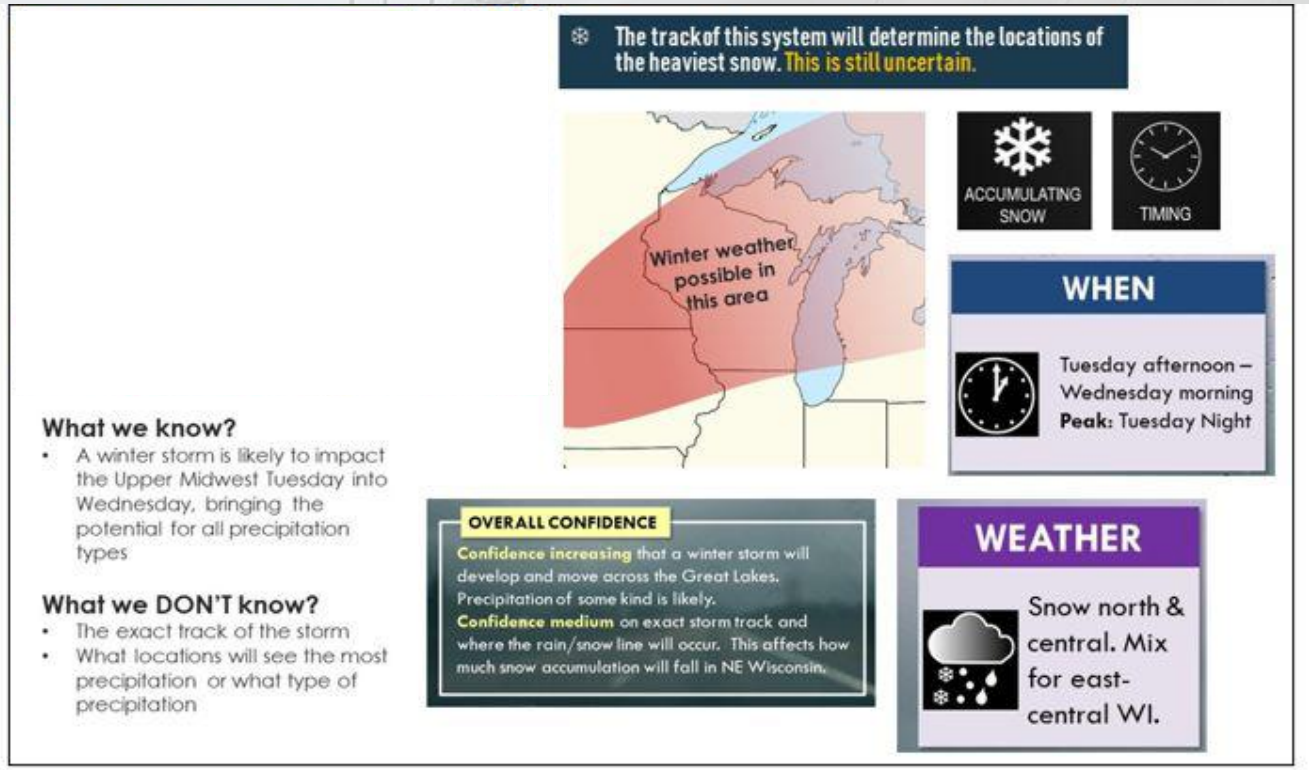


Results were consistent with survey of NWS meteorologists and non-meteorologists, as well as emergency managers

Key Takeaway #2

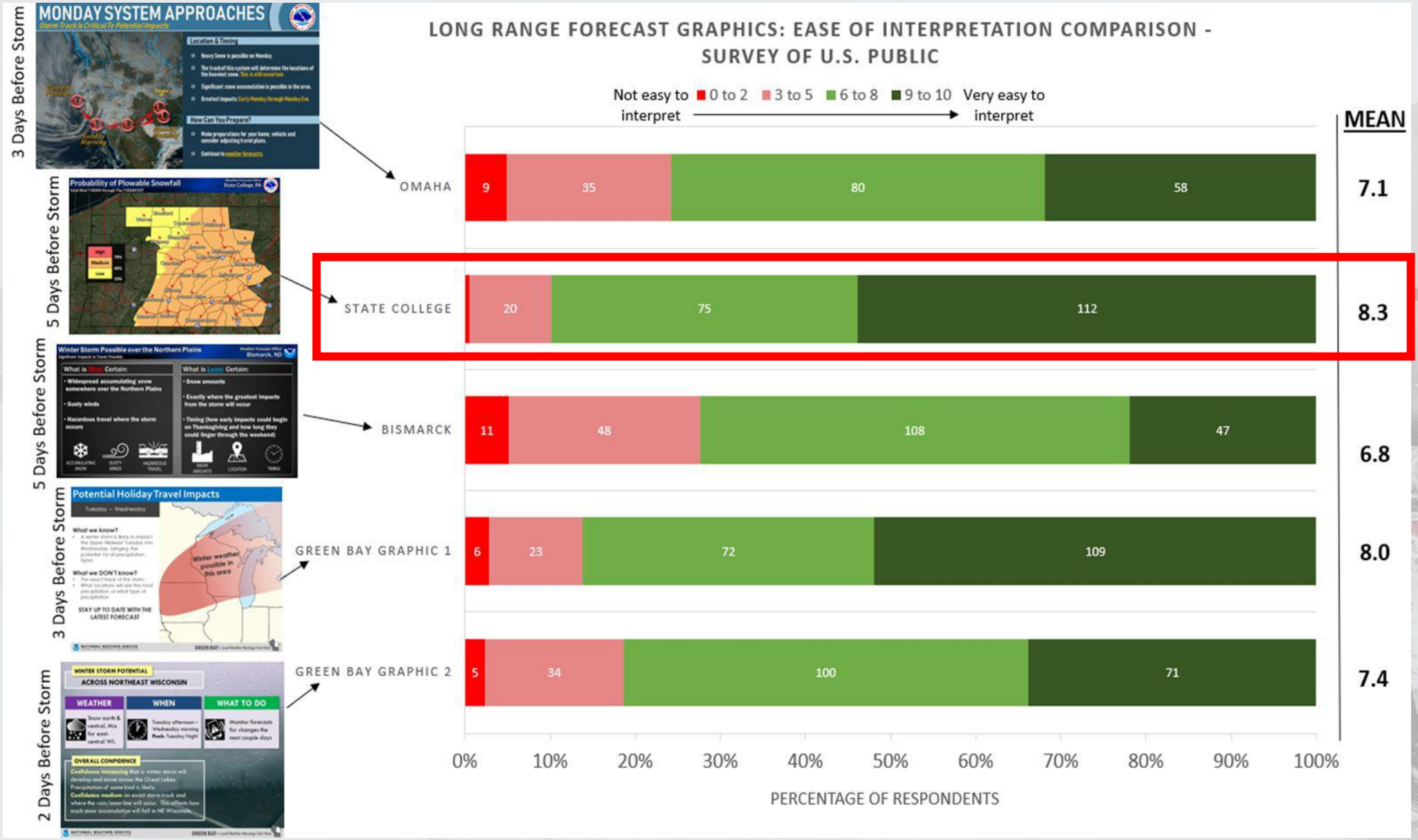
Simplistic graphics were also **preferred at longer lead times**, with not too much text on the graphics making them easier to interpret. Some text-based information communicating the uncertainty or confidence in the forecast was found to be useful to the public and should be added to these graphics alongside the maps.





Elements of long-range winter weather graphics found to be helpful and important to respondents of the survey of the U.S. public.

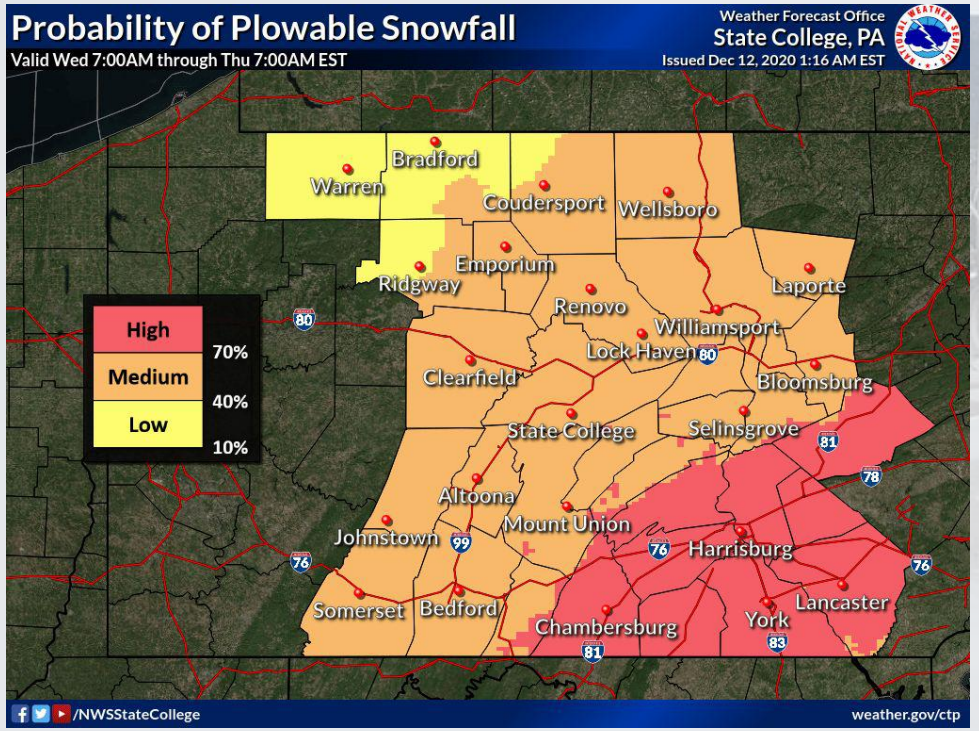
Key Takeaway #3



Key Takeaway #3 (cont.)

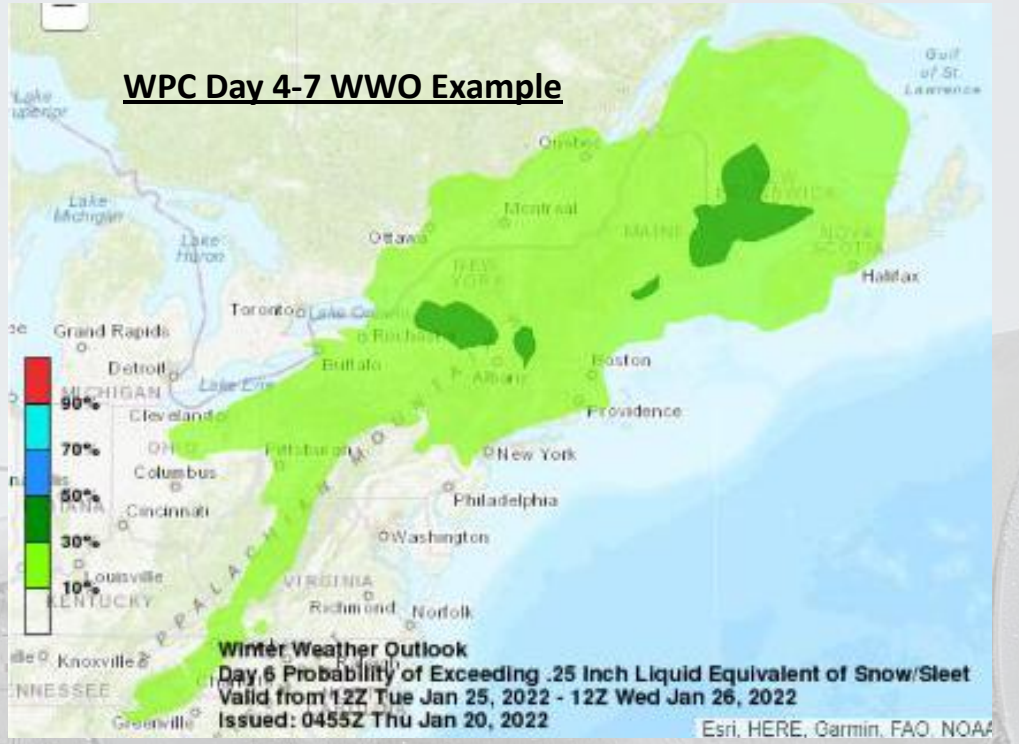
NWS State College's Probability of Plowable Snowfall Graphic

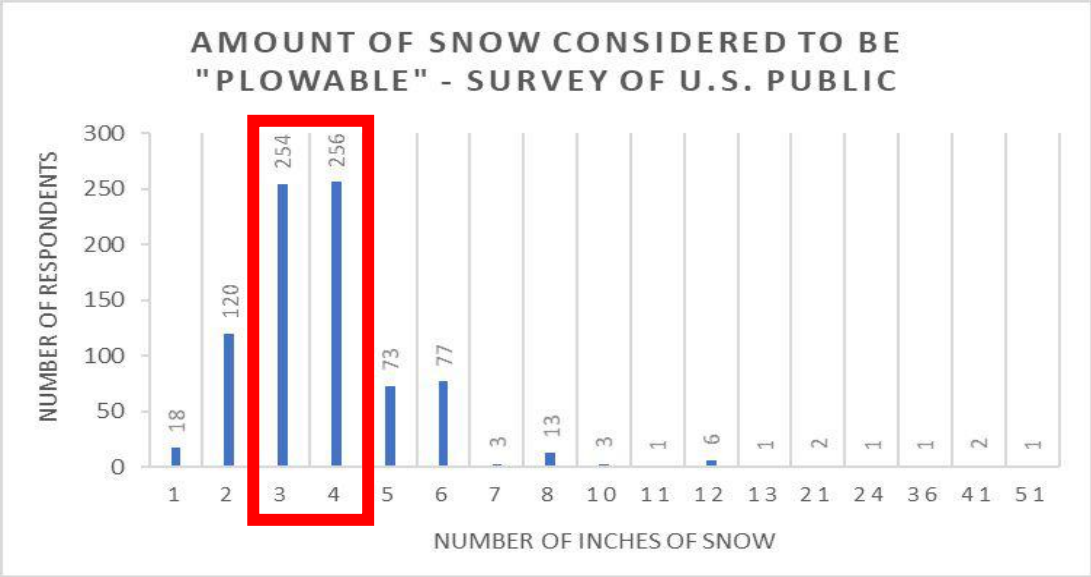
Allows WPC's probability of exceeding 0.25" of liquid equivalent of snow/sleet maps to be turned into helpful long-range weather information that is focused on the local area of the NWS office. https://www.weather.gov/ctp/wwo



Found to be ***easy to interpret and useful to the public 4-7 days before a storm.***

WPC Day 4-7 WWO Example

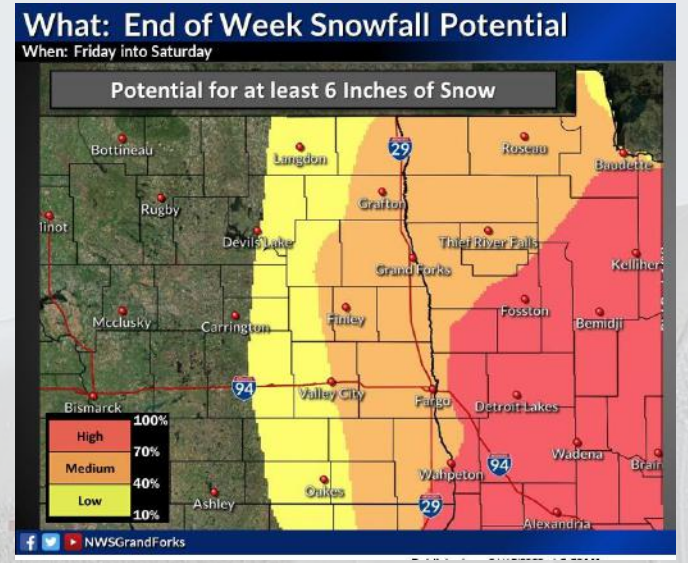




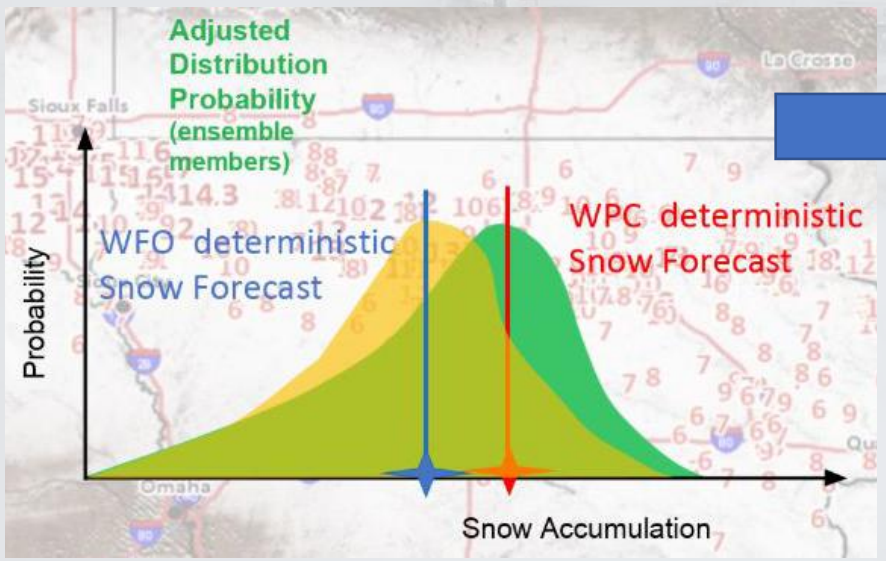
RISK PROBABILITY GRAPHICS: What's the purpose of these graphics?

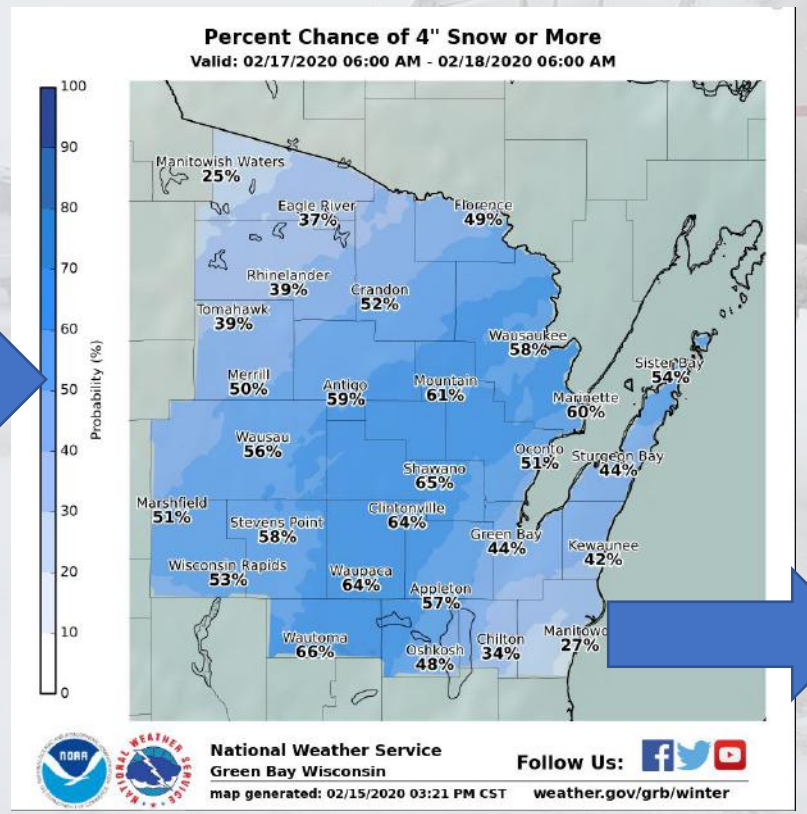
Probability of exceeding X inches of snowfall – ensemble based

- 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



Ensemble distribution is shifted based on human forecasts to get probability percentages at a specific threshold





Discrete percentages can be placed in three categories

Key Takeaway #4

Risk probability graphics were found to be understandable & helpful with decision making.

Three days before storm onset

NWS non-meteorologist survey when asked to decide about staffing for an upcoming storm based on different forecast graphics

Scenario 1

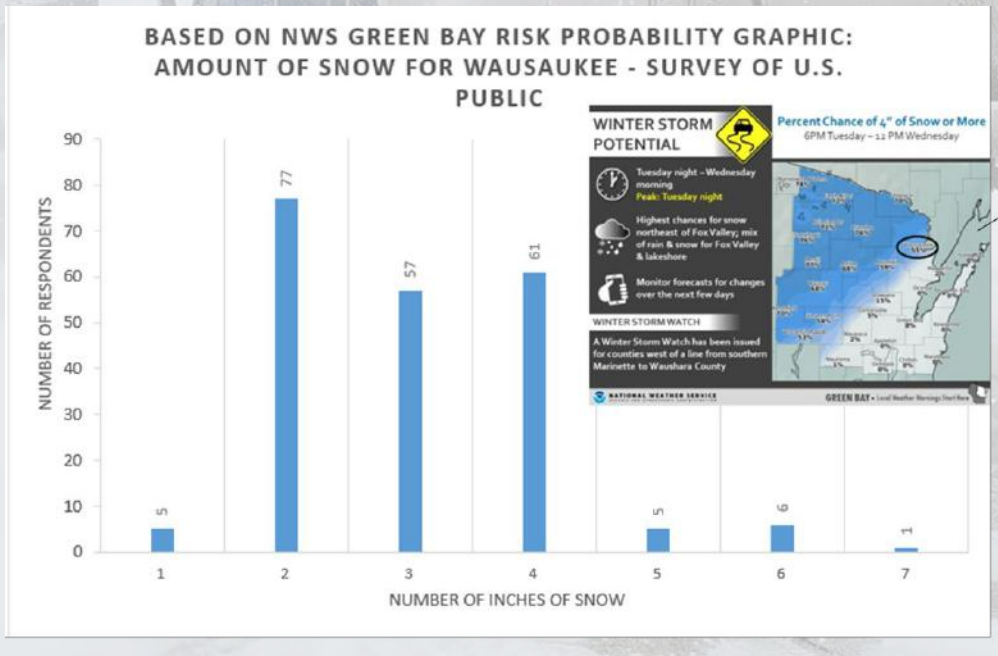
Scenario 2

Public's Interpretation of Graphic:

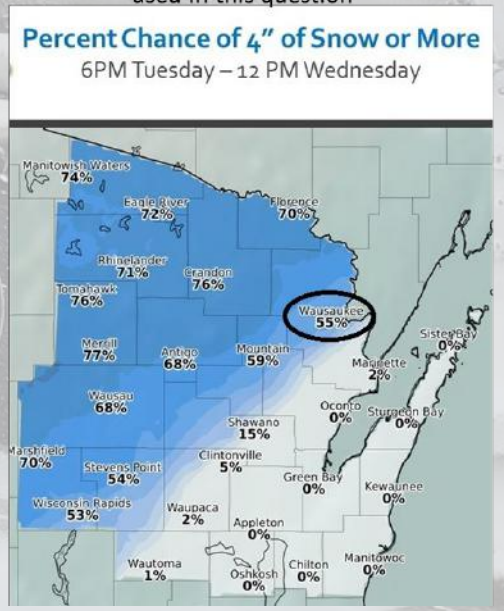
For the most part, they thought the city on the map would get **the amount of snow listed in the title of the map or a range of values lower than that.**

Remaining Question:

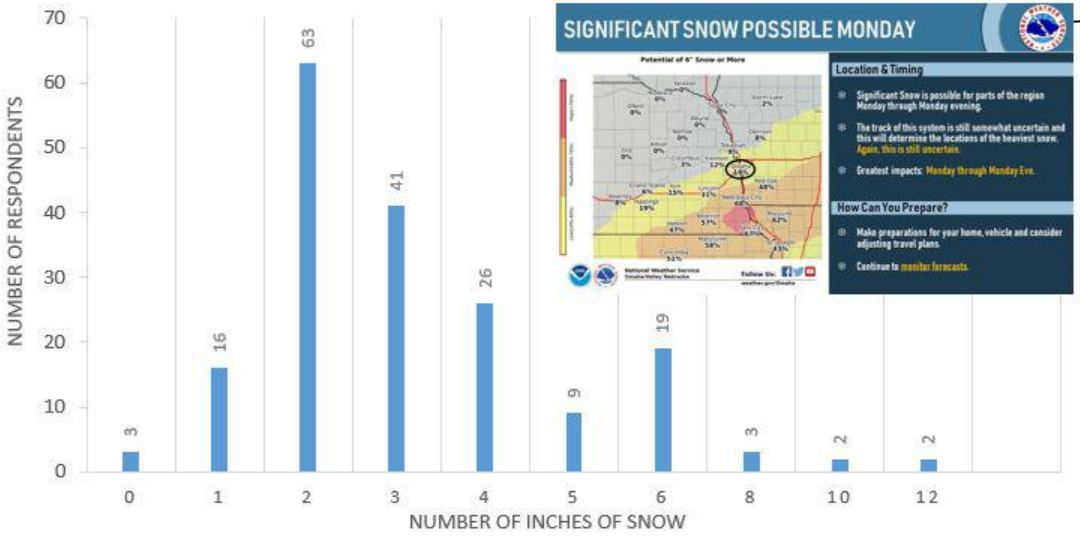
Is this the way we want people to interpret risk probability graphics?

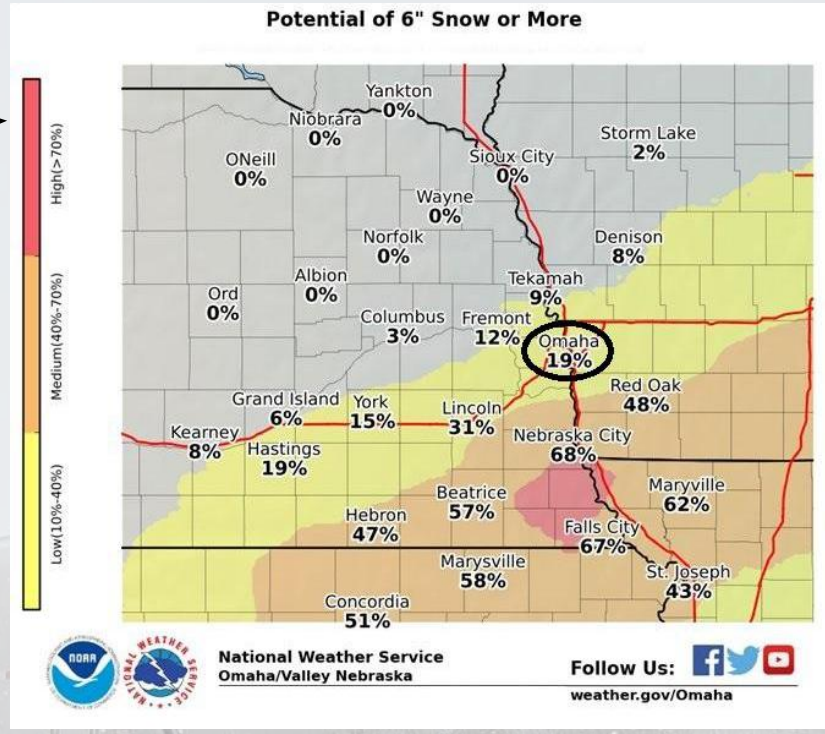


Zoomed in view of the risk probability map used in this question



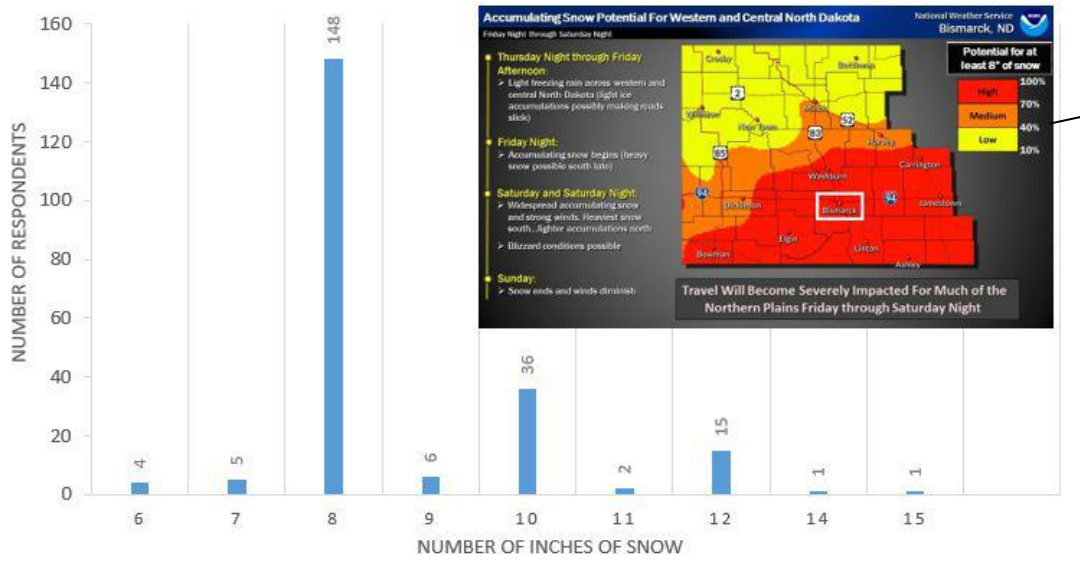
BASED ON NWS OMAHA RISK PROBABILITY GRAPHIC: AMOUNT OF SNOW FOR OMAHA - SURVEY OF U.S. PUBLIC

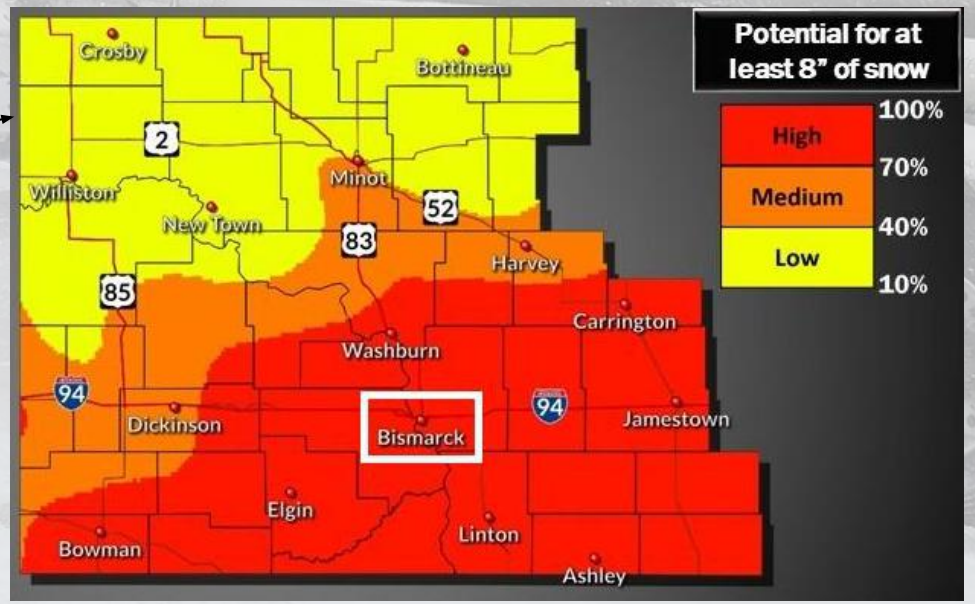




Zoomed in view of the risk probability map used in this question

BASED ON NWS BISMARCK RISK PROBABILITY GRAPHIC: AMOUNT OF SNOW FOR BISMARCK - SURVEY OF U.S. PUBLIC

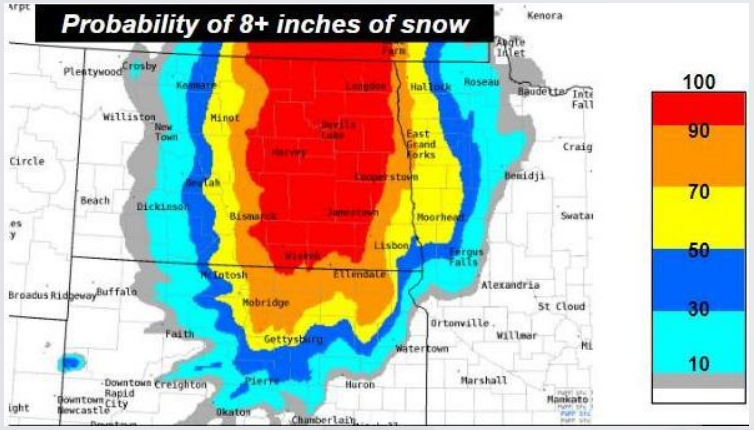


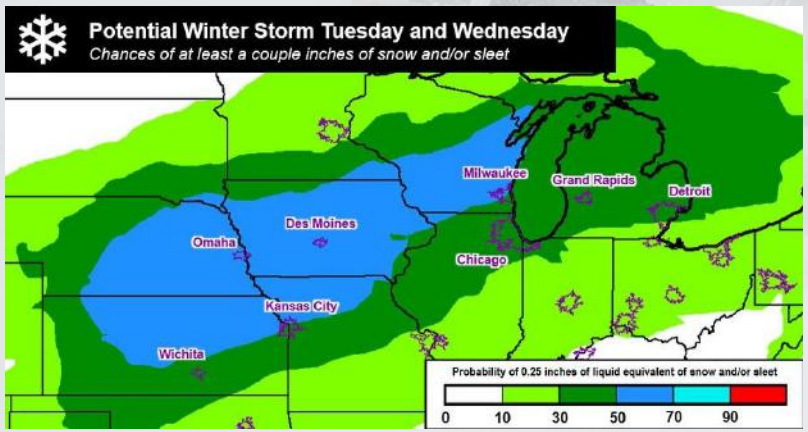


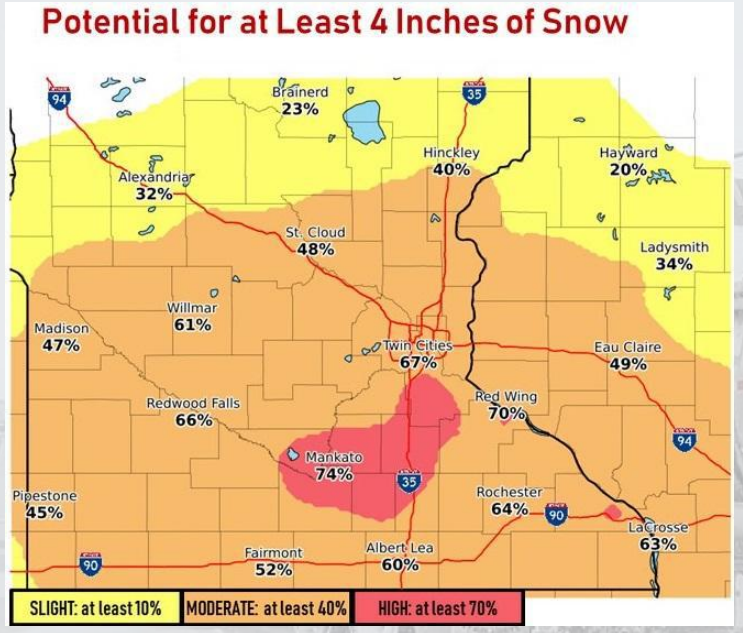
Zoomed in view of the risk probability map used in this question

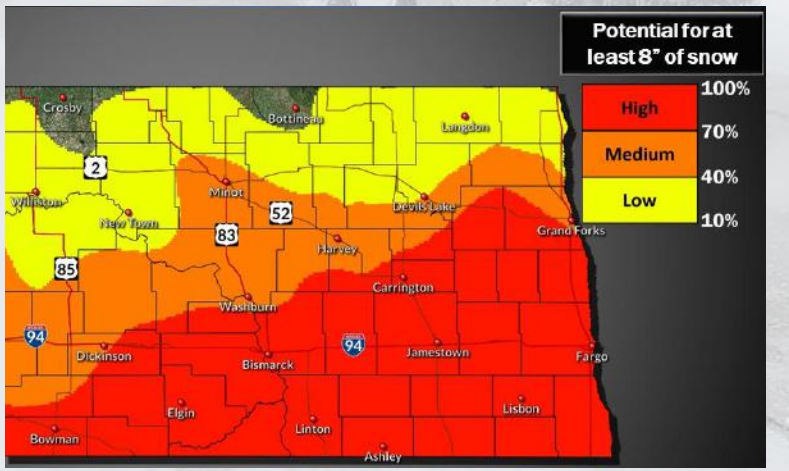
RISK PROBABILITY GRAPHICS

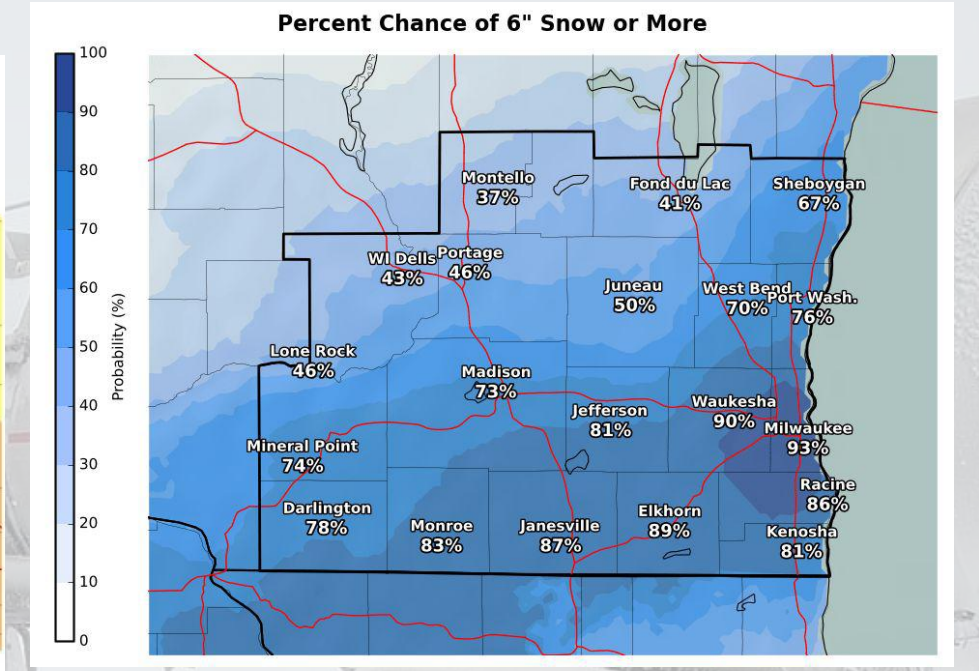
But there are many different color schemes used for these graphics:

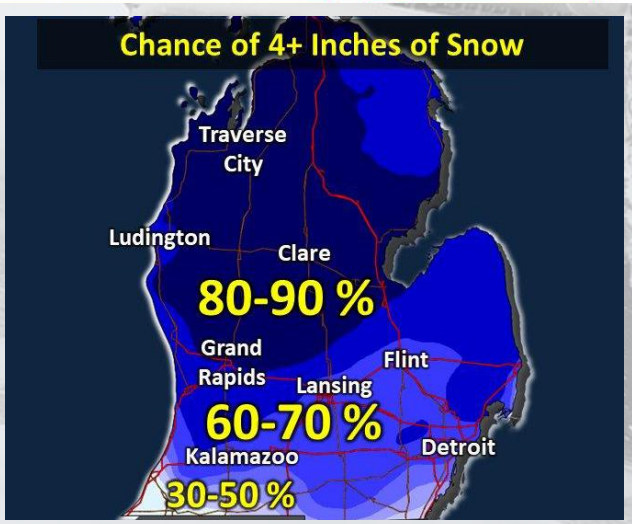










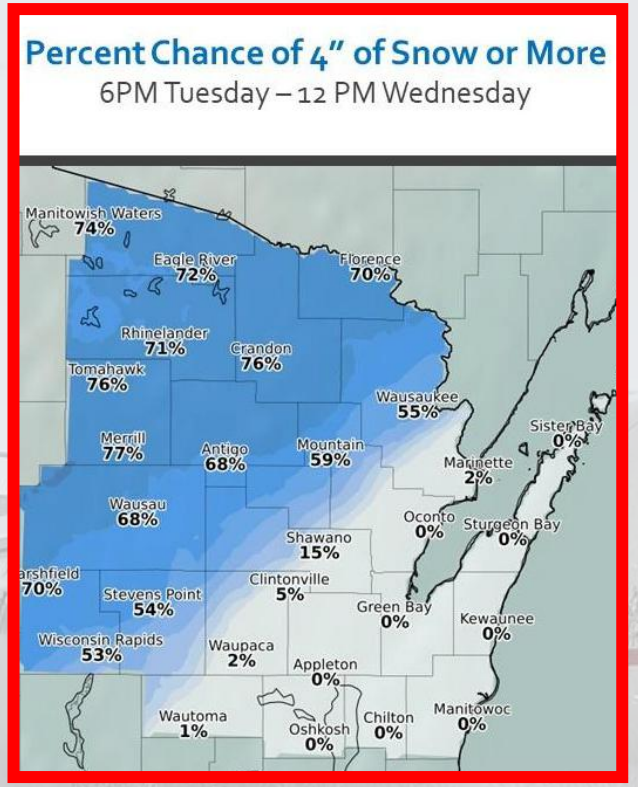


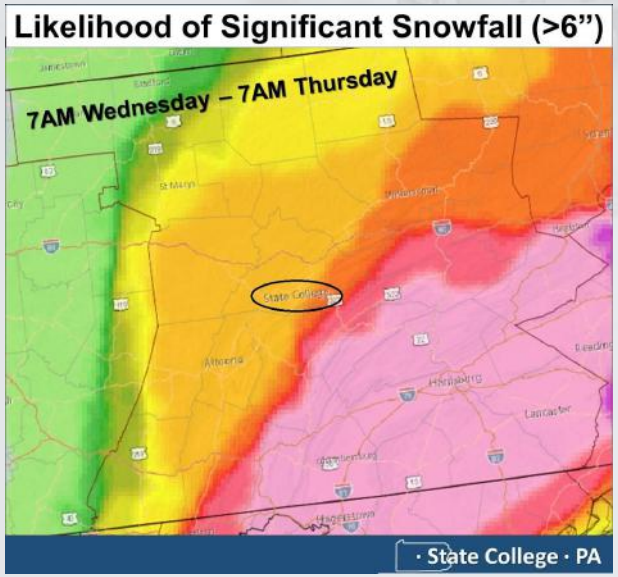
Key Takeaway #5

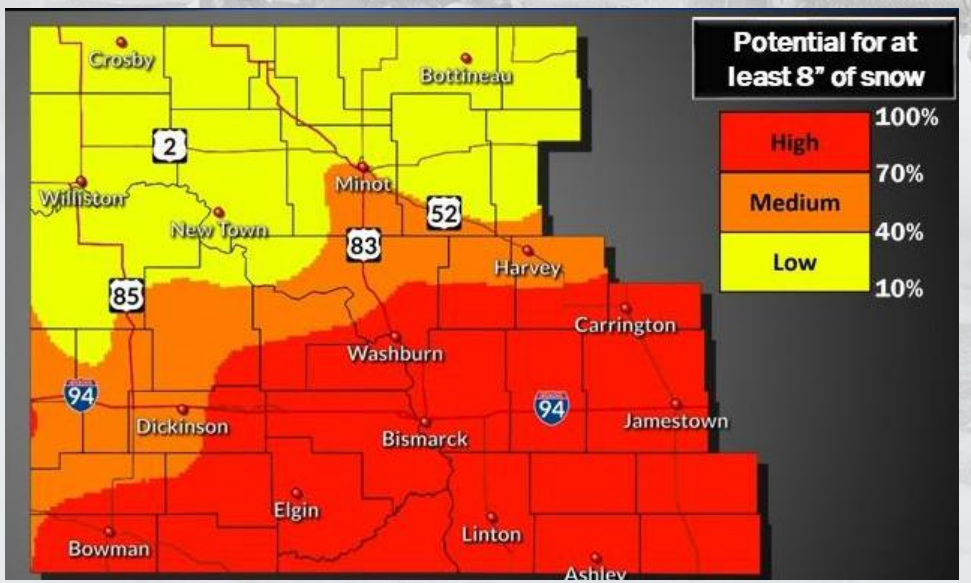
The ***blue gradient*** color scheme with probability percentages plotted at each location was the ***most preferred.***

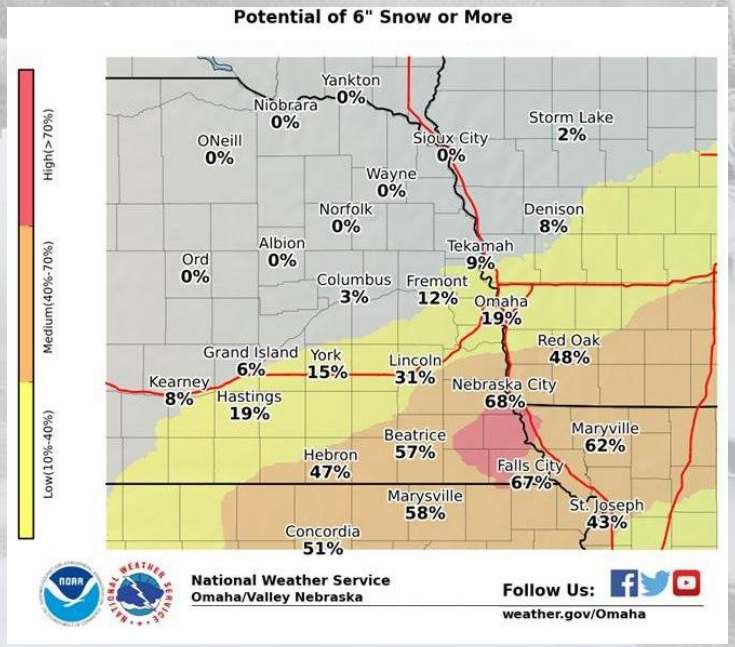
Easiest to interpret and the best communicator of the uncertainty present in the forecast based on the survey of the U.S. public.

Past research that suggests numerical expressions of uncertainty should be prioritized over purely categorical statements as numerical expressions of uncertainty are interpreted more consistently
(Budescu et. al 1988, Jaffe-Katz et. al 1989).

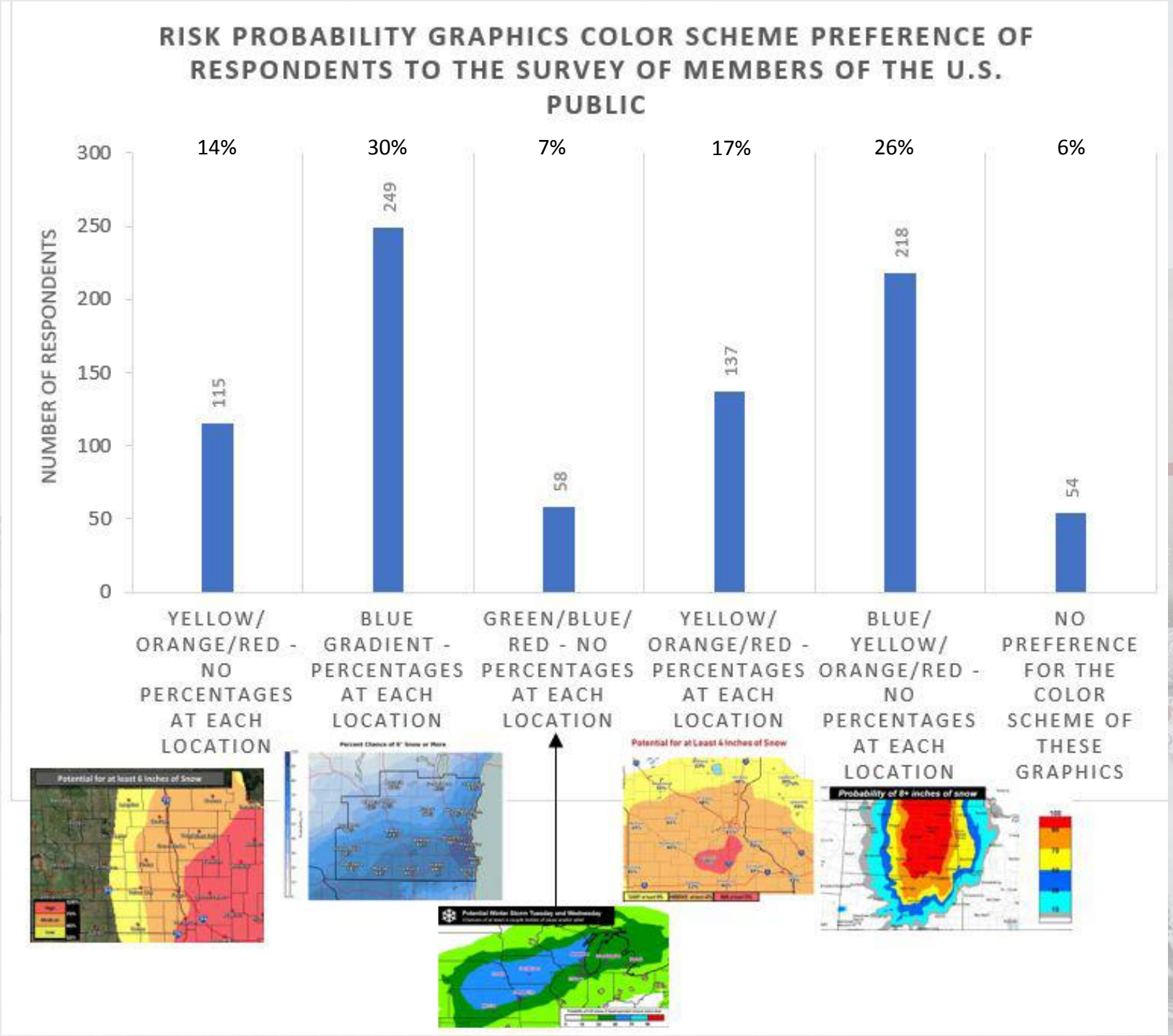


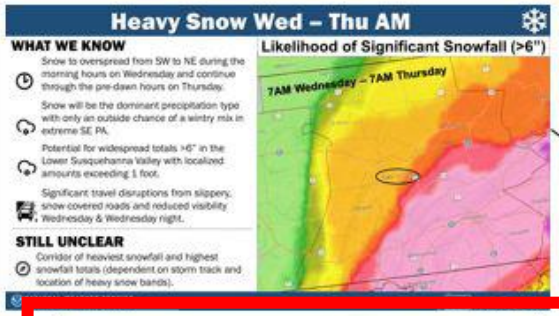


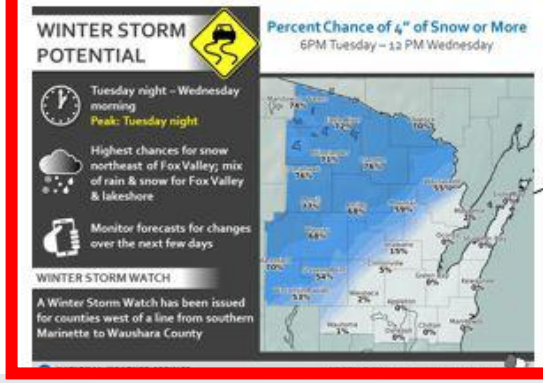




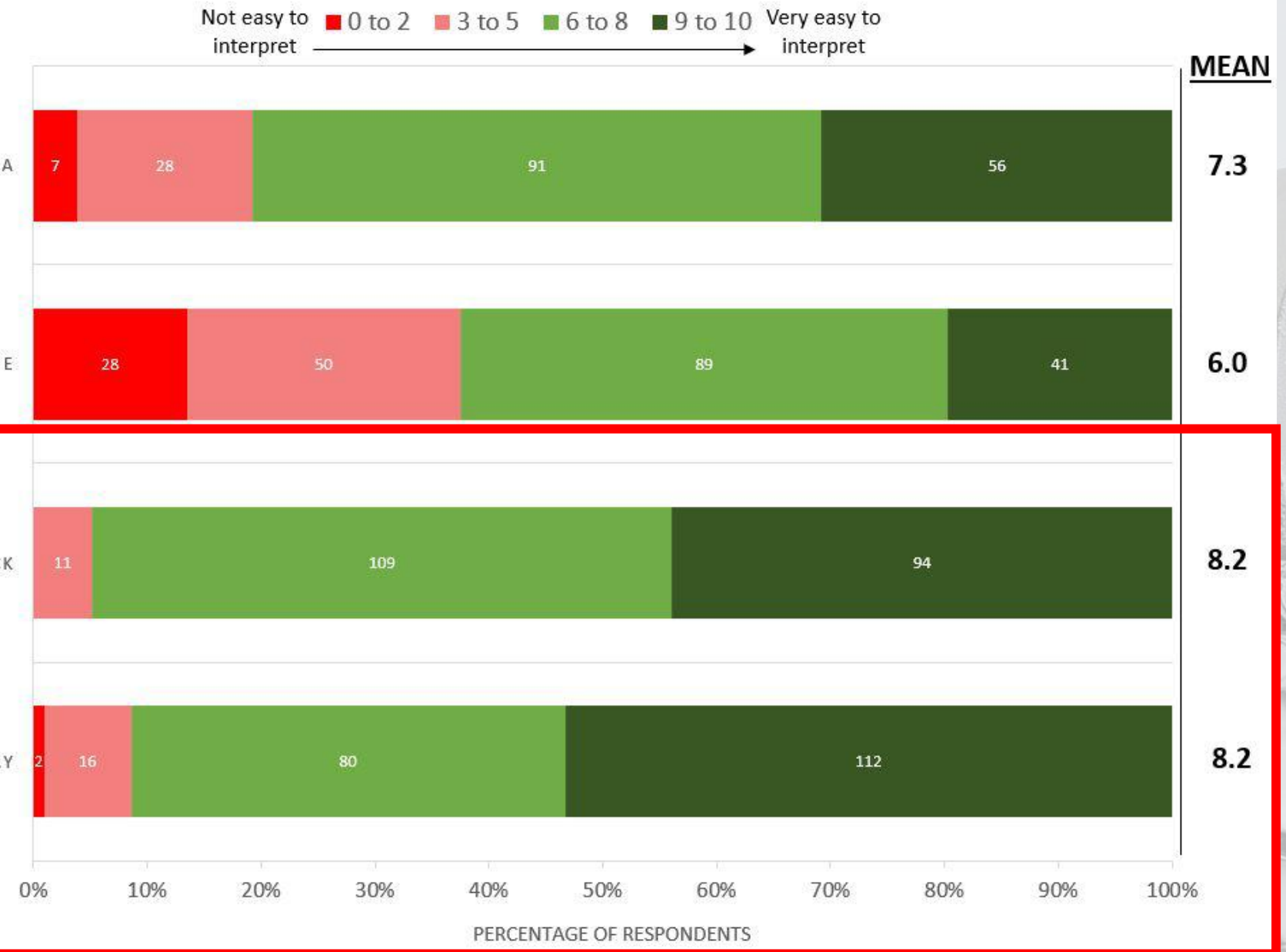
There are many different color schemes used in graphics to communicate the **probability of snowfall from a winter storm exceeding a specified amount.** Which **color scheme** do you think is the BEST?

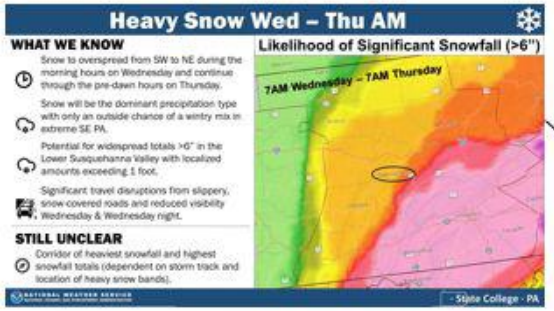




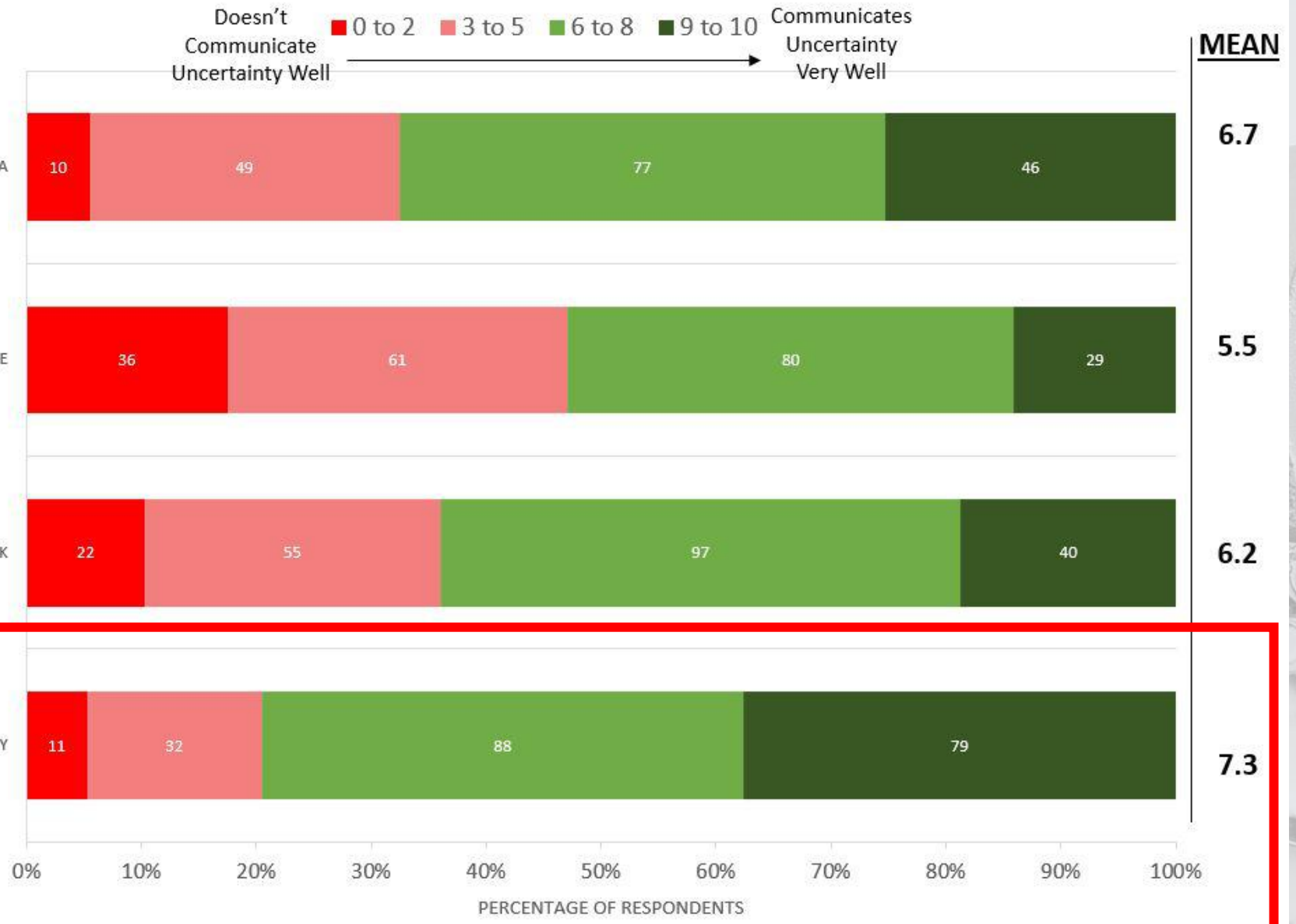


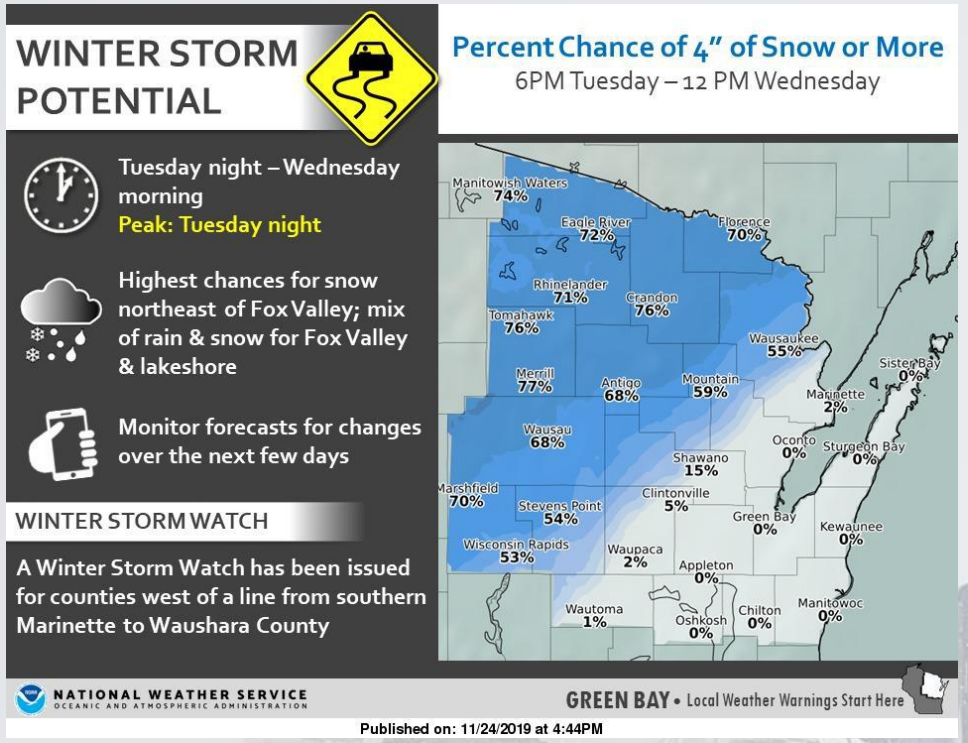
RISK PROBABILITY GRAPHICS: EASE OF INTERPRETATION COMPARISON





RISK PROBABILITY GRAPHICS: COMMUNICATION OF UNCERTAINTY COMPARISON - SURVEY OF U.S. PUBLIC

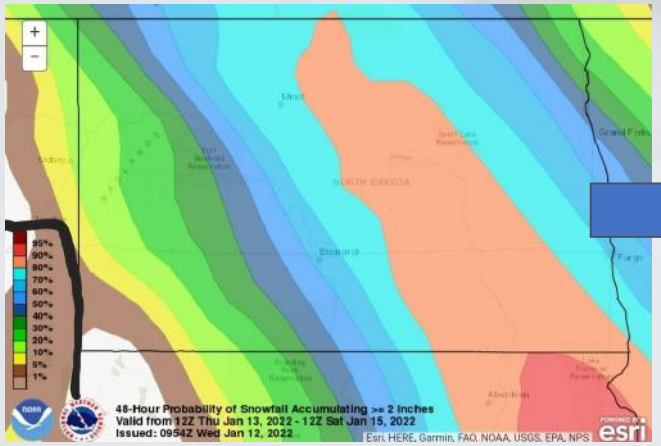


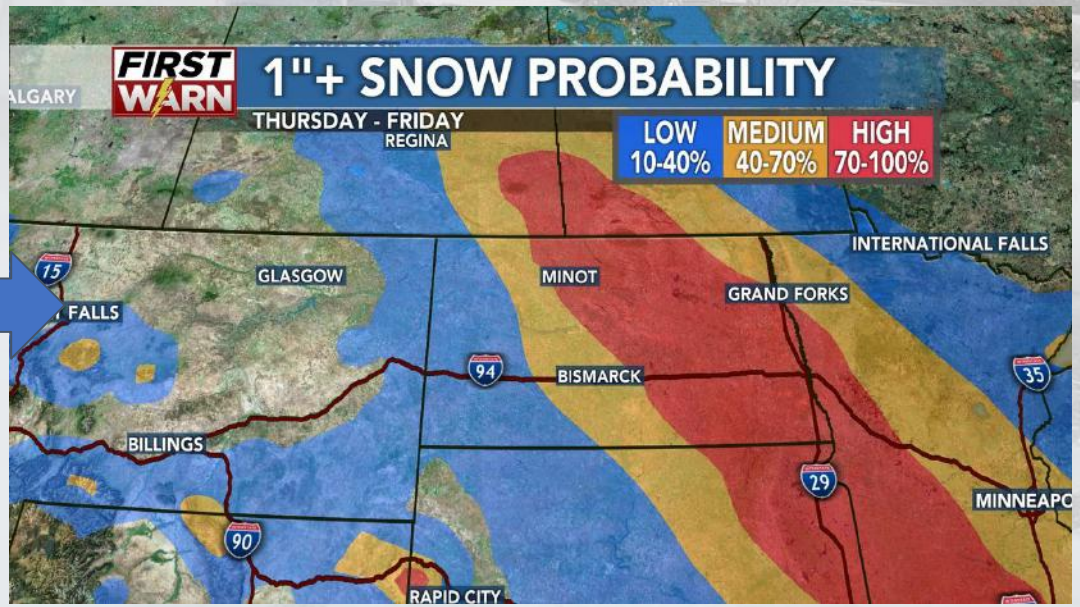


Some people found the probability percentages plotted at each location on this color scheme helpful for them to interpret the forecast.

A possible suggestion would be to round the percentages at each location to the nearest 5% or 10% so they're not so exact and down to the 1% – easier to interpret?

If probability percentages are not included as plotted locations on the risk probability map, ***these percentages should at least be included on the legend of the graphic so that the risk probability graphic is not completely devoid of numerical expressions of uncertainty.***





Risk Prob graphics at KFYR

Based on KML downloads from WPC

Went with blue as 10-40% contour for better contrast (yellow & orange were too similar with how the KML files work in MAX graphics - transparency issues)

Open to KML download of Risk Prob from individual NWS office

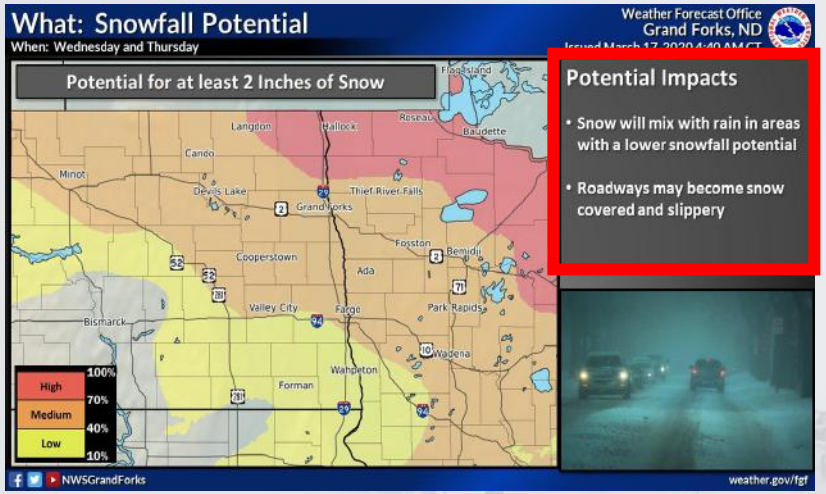
Key Takeaway #6

The red/orange/yellow color scheme for risk probability graphics was the preferred options for meteorologists that were surveyed in the Central Region, most likely due to their familiarity with it.

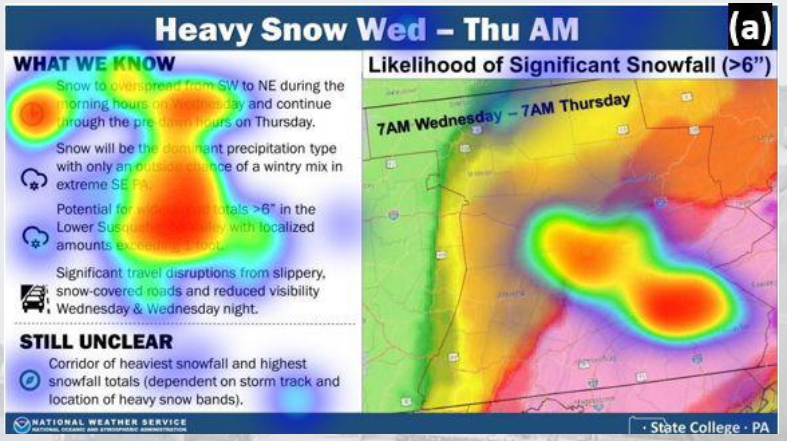
Q1 – Risk Probability Color Scheme Preference	Three-tiered (red, orange, yellow)	Blue shadings	Brown, Yellow, Green, Blue, Red	Grey, Blue, Yellow, Orange, Red (WPC Scale)	No preference for color scale
	21	**6**	**7**	**6**	**2**

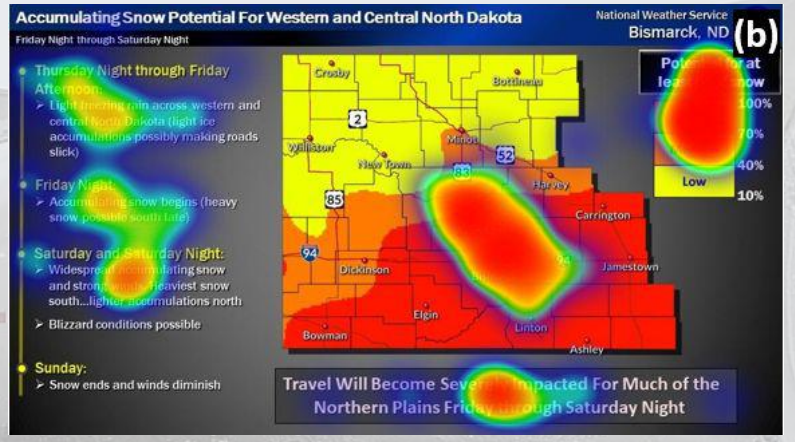
Key Takeaway #7

Risk probability graphics should overall be kept simple, but some **brief, additional text should be added**

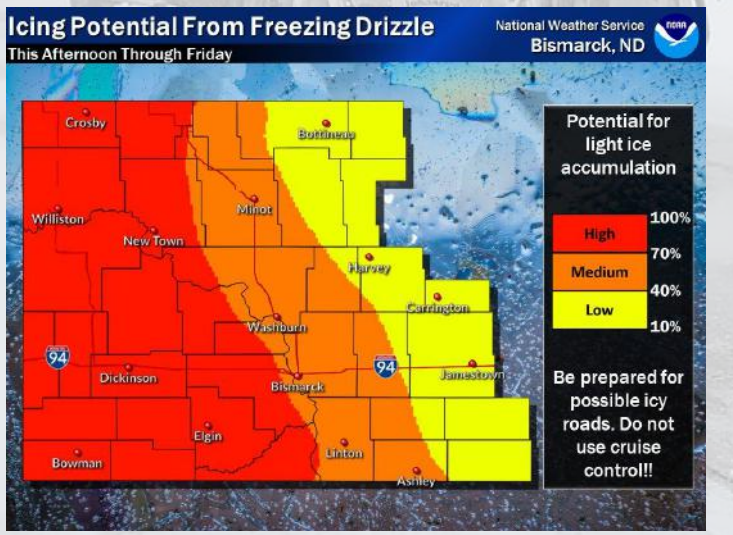


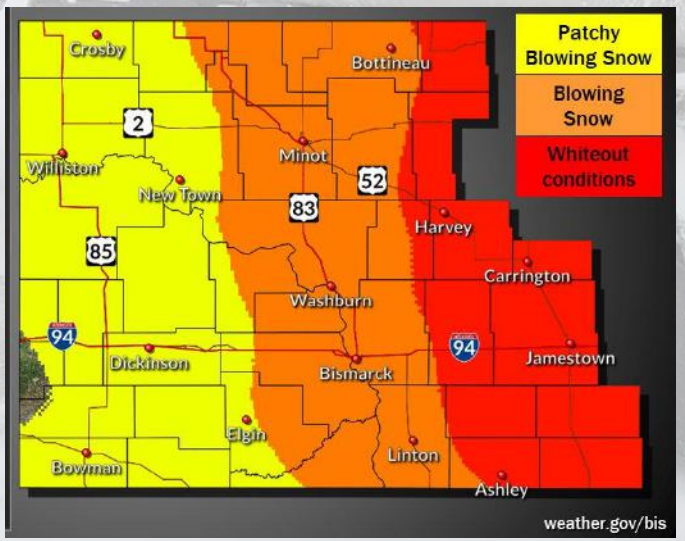
Heat map question results – shows that some people find the text on the graphic important and helpful (see full thesis for more analysis)





Using risk probability graphics to communicate other hazards, such as for icing/freezing rain potential, was also shown to be something that NWS meteorologists would want to do.



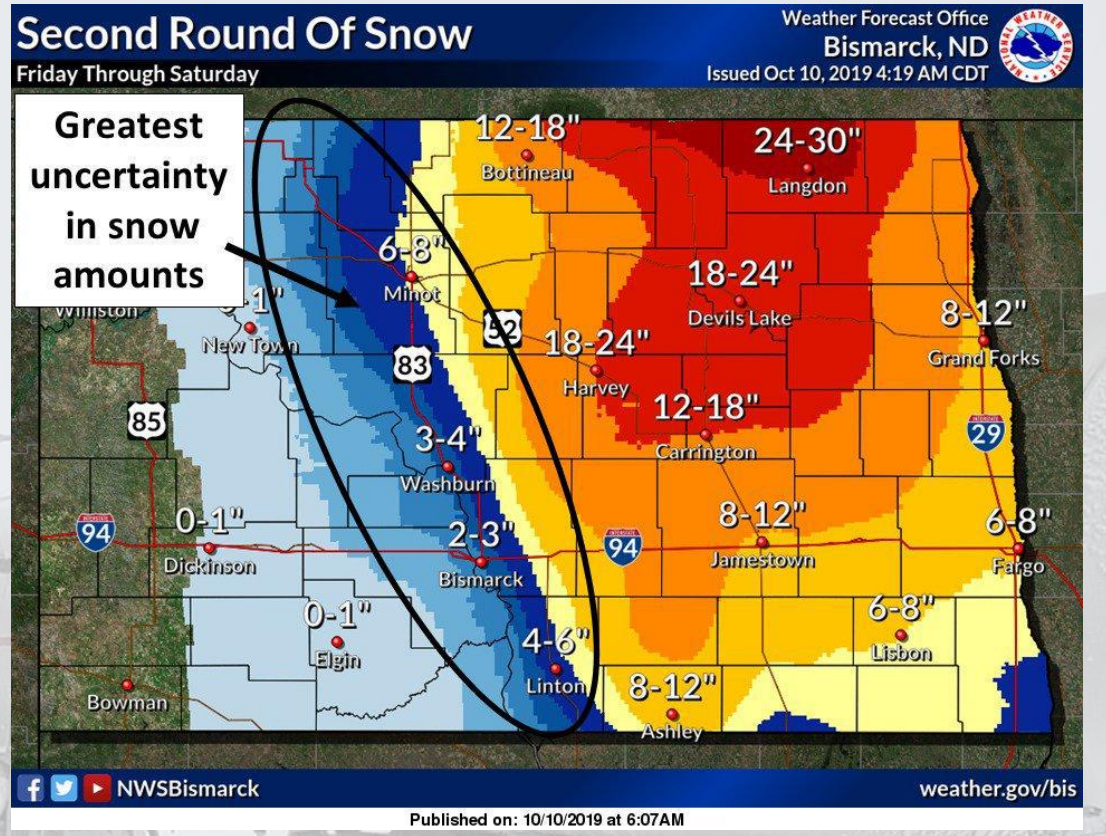


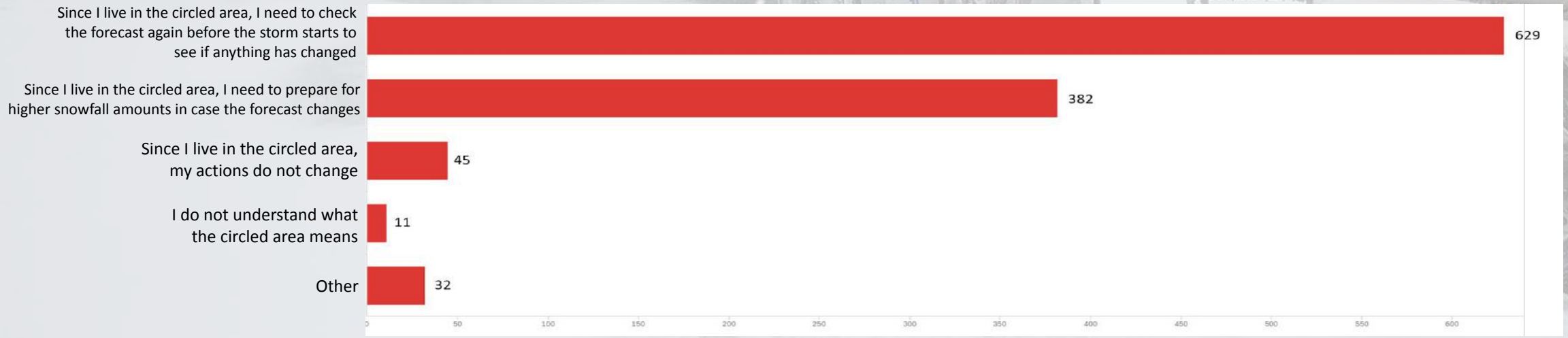
SNOW MAPS: Circling areas of uncertainty

Key Takeaway #8

<u>Circling areas of uncertainty on snowfall forecast maps was liked by all and should be done by NWS offices and others in the weather enterprise when it is necessary.</u>

Overall majority would check back for forecast updates if they lived in the circled area of uncertainty to see if anything had changed.





SNOW MAPS: Circling areas of uncertainty

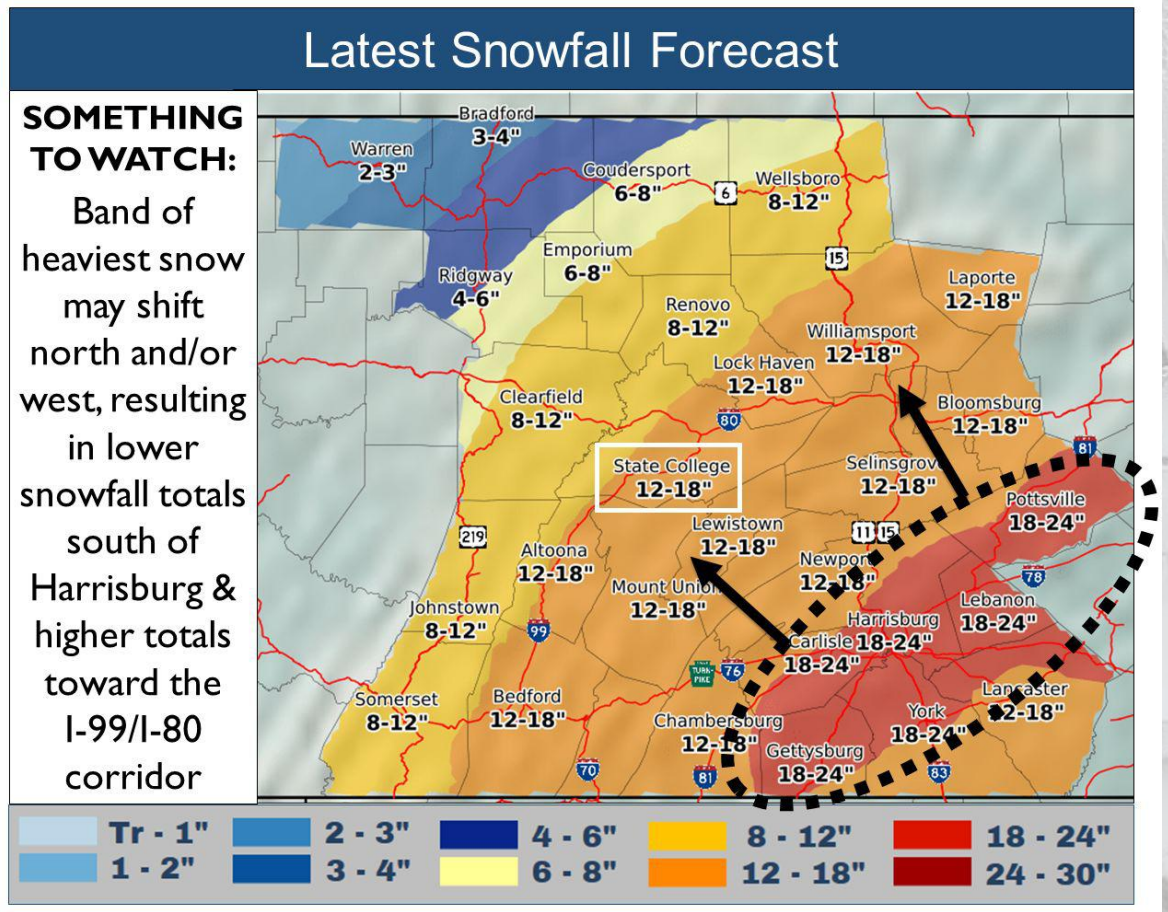
Results were consistent with NWS non-meteorologists that were surveyed

Q27 – How Do You Interpret Circled Area of Uncertainty on Snow Maps If You Live Within It (select all that apply)	Check the forecast again before the storm starts to see if anything has changed	Prepare for higher snowfall amounts in case the forecast changes	Actions do not change compared to if I lived in an area that was not circled	I do not understand what the circled area means
	22	16	2	1

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.

Greatest uncertainty in snow amounts ✓

Tight gradient for snowfall amounts ✗

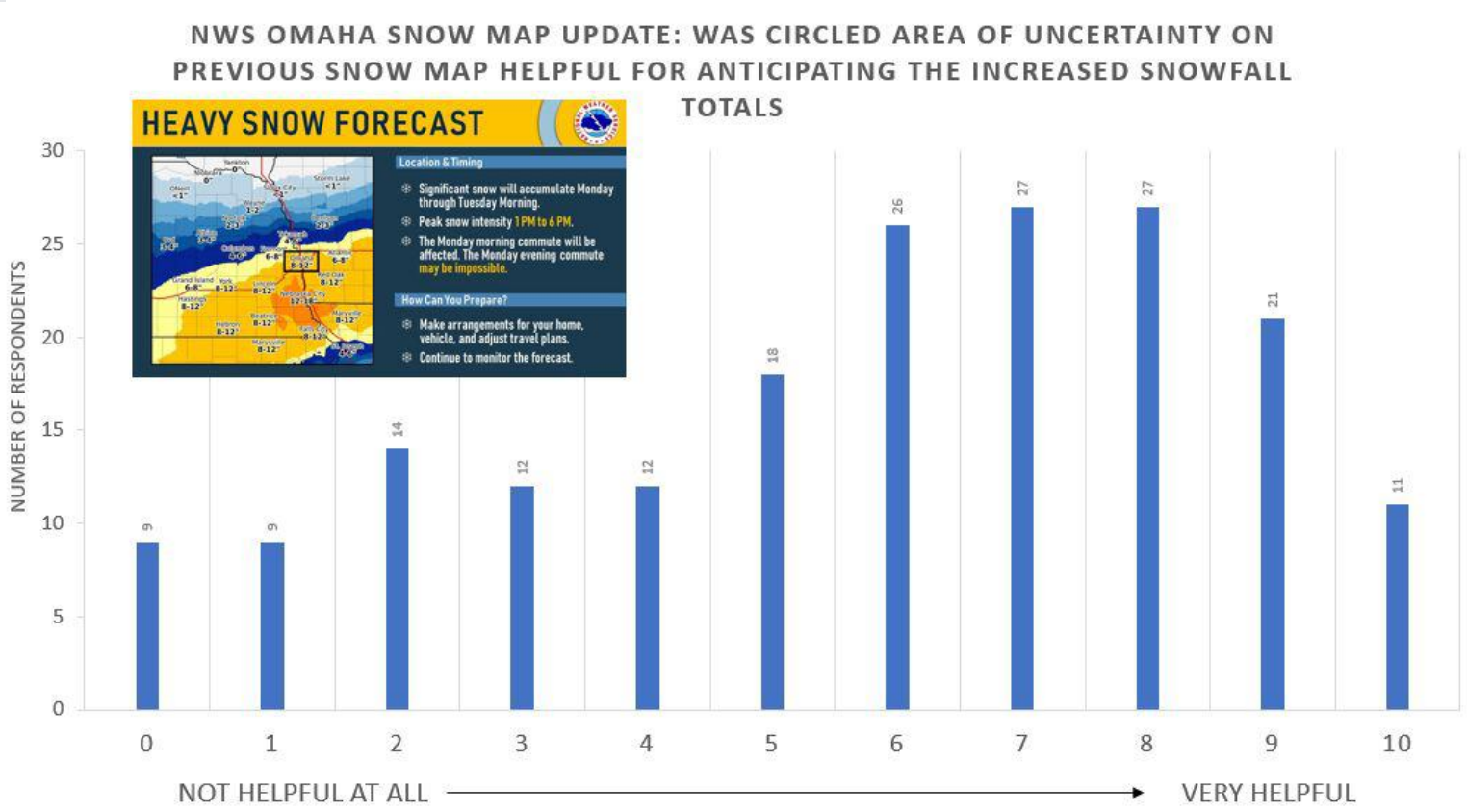


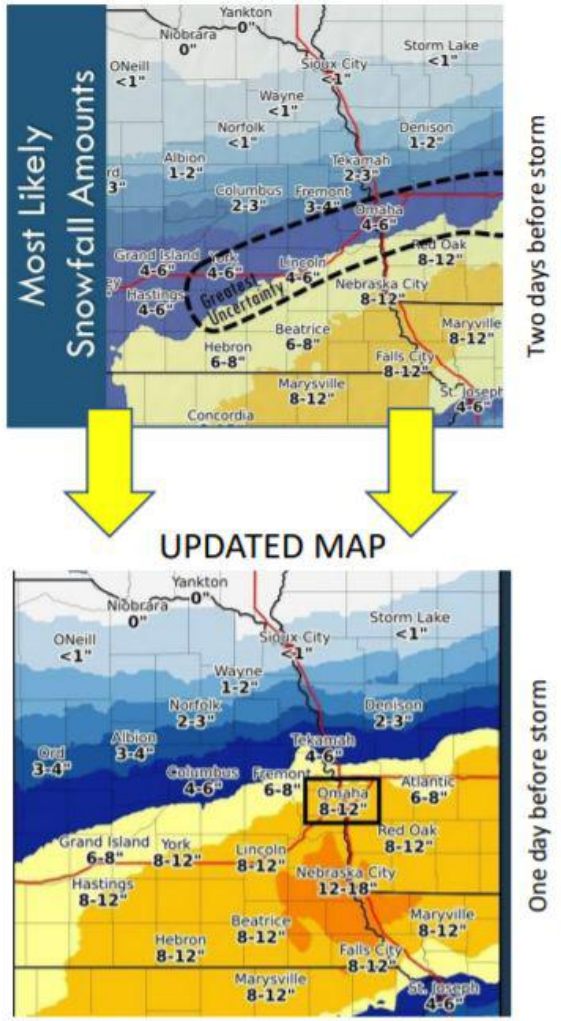
SNOW MAPS: Circling areas of uncertainty

Suppose you live in Omaha (in the black box on the graphic above). Did the circled area of uncertainty on the previous graphic help you anticipate the increased snow totals predicted for Omaha on this updated map?

Not helpful at all — It was very helpful

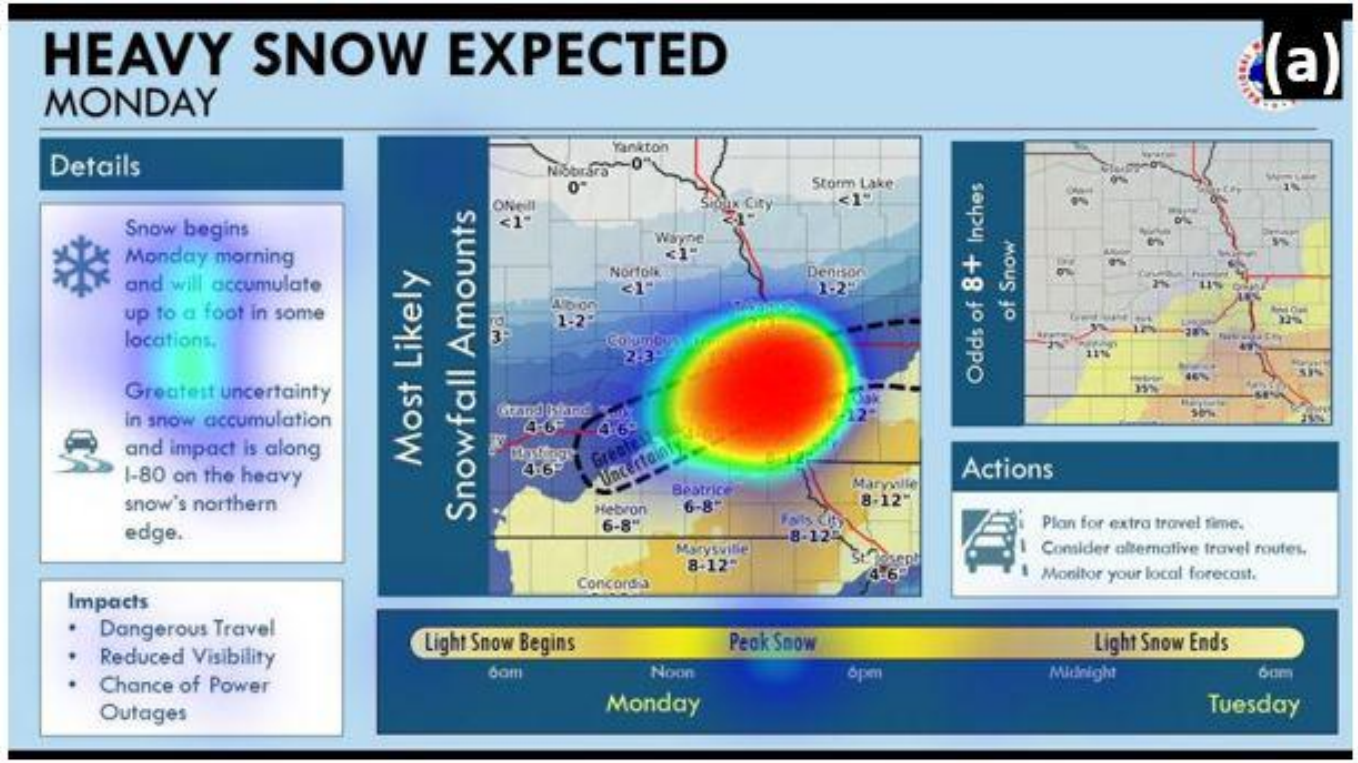
0 1 2 3 4 5 6 7 8 9 10

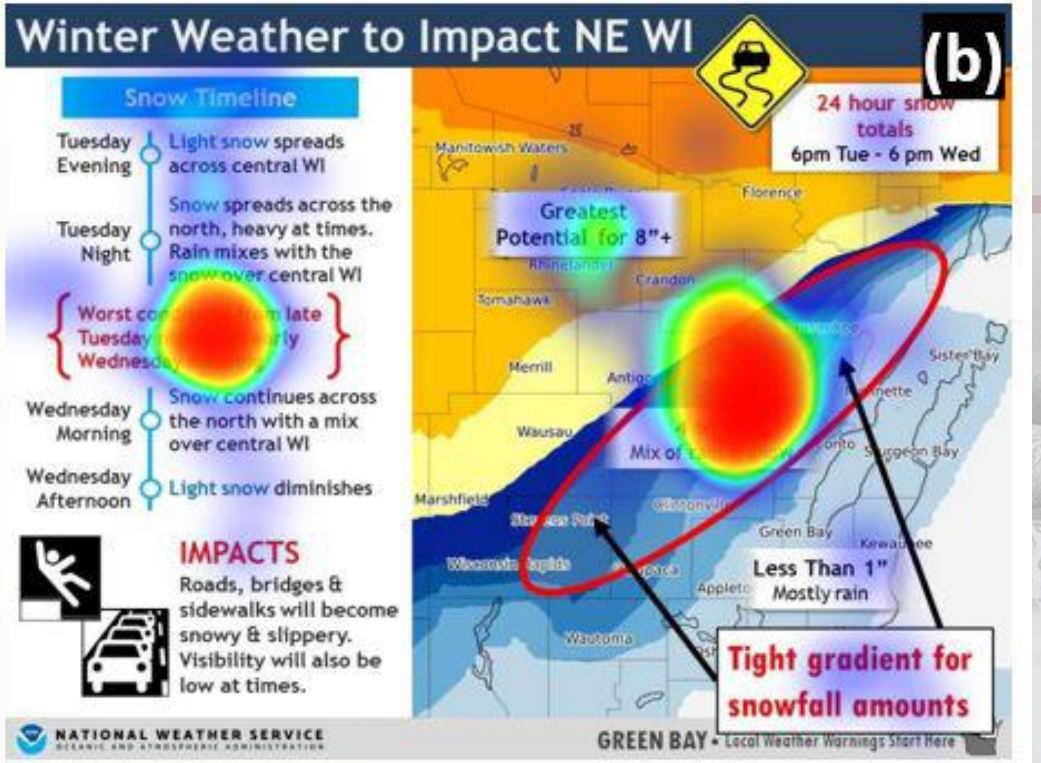




SNOW MAPS: Circling areas of uncertainty

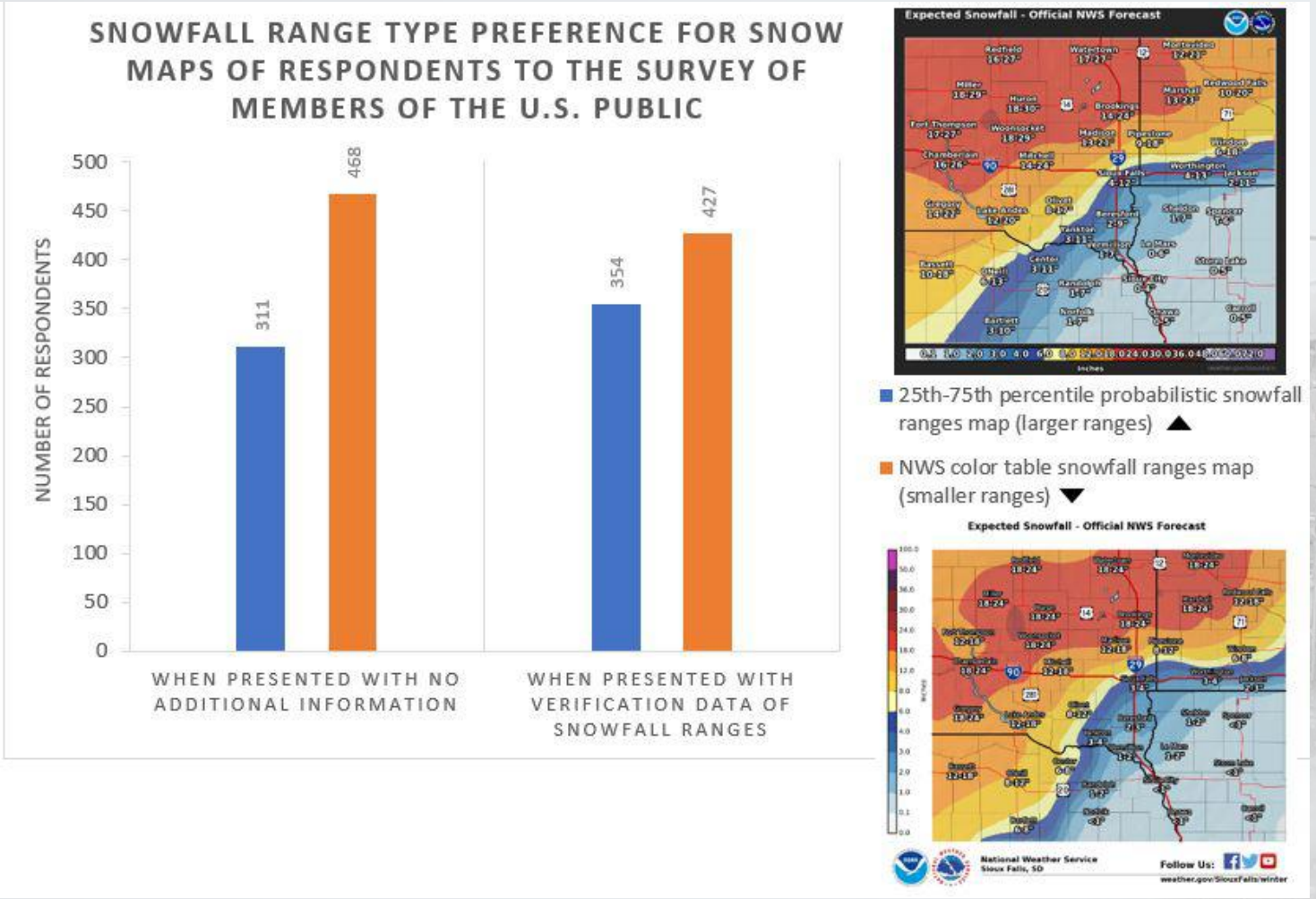
More heat map question results – because they're super cool :)

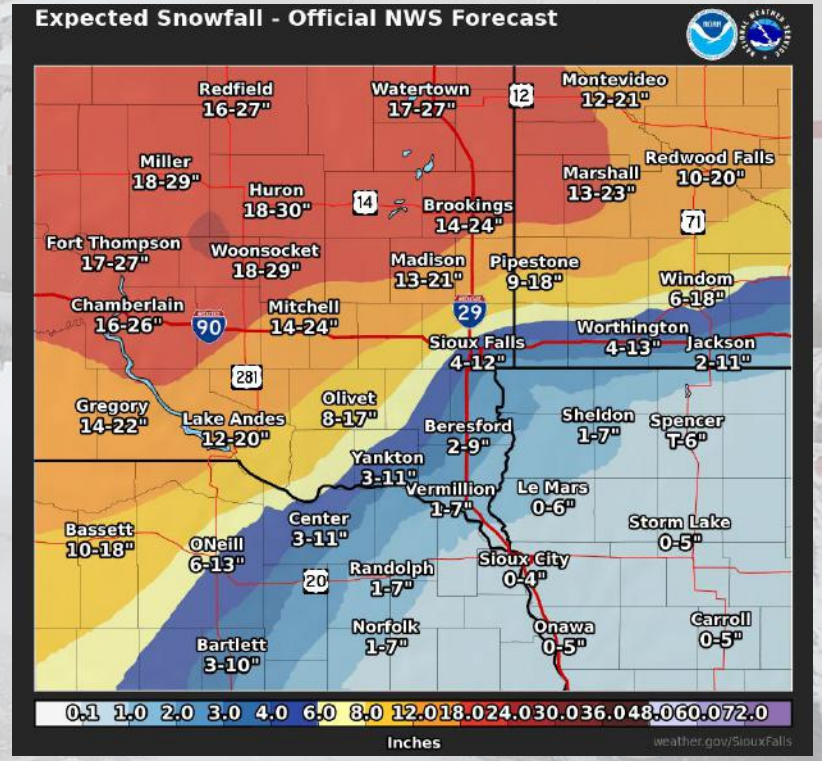




Probabilistic snowfall ranges are a viable alternative to the standard NWS color table snowfall ranges.

But very large ranges can be created, so ***use caution*** when choosing what snowfall range option to use.





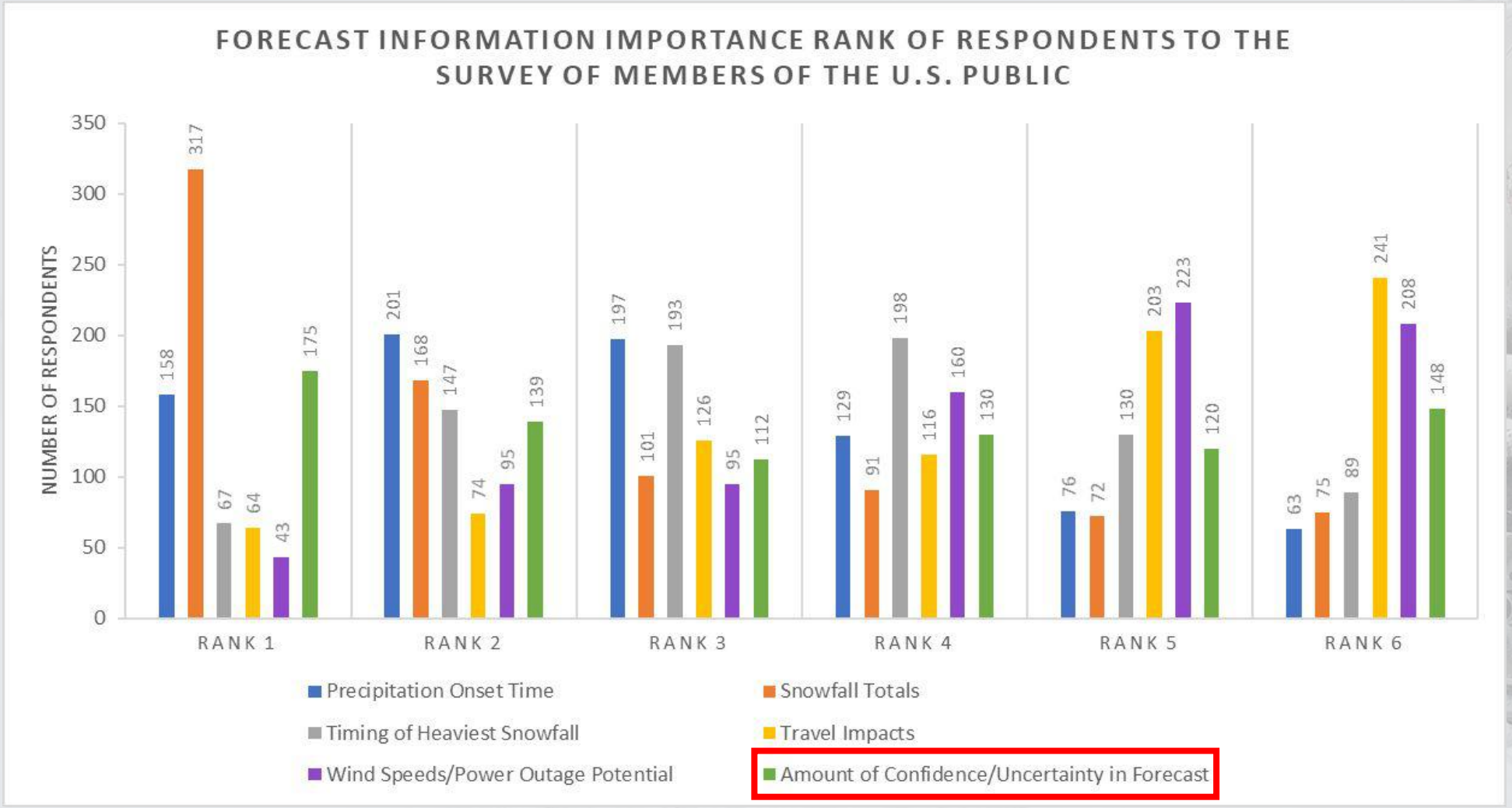
NOTE: an extreme example of snowfall spreads was selected for the probabilistic snowfall map used in this question.

Verification stats from Phil Schumacher (SOO Sioux Falls):

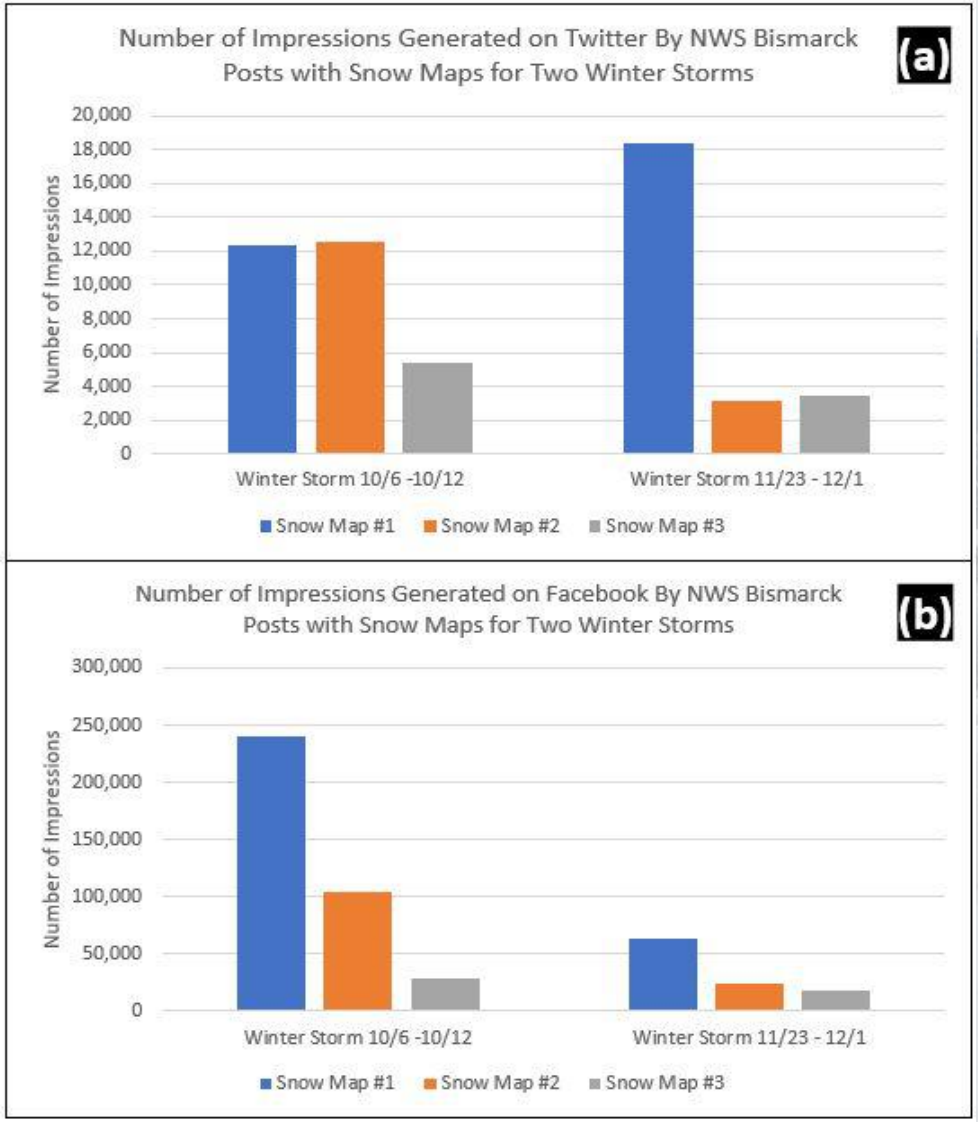
Studies have shown that using the **larger snowfall ranges** results in the actual snowfall amount verifying within that range **50% of the time**.The **smaller snowfall ranges** result in the actual snowfall amount verifying within that range **30% of the time**.

Key Takeaway #10

Members of the public ***<u>want to see information about how confident or uncertain a forecast is.</u>***

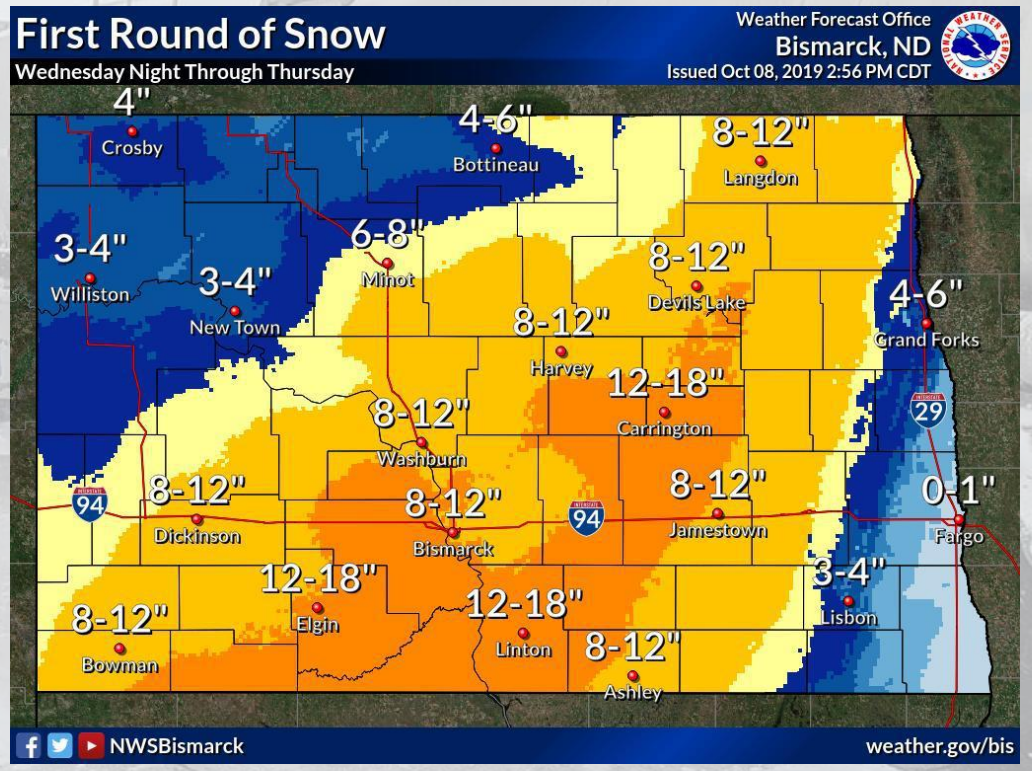


Bonus Takeaway!



<u>Very preliminary social media research:</u>

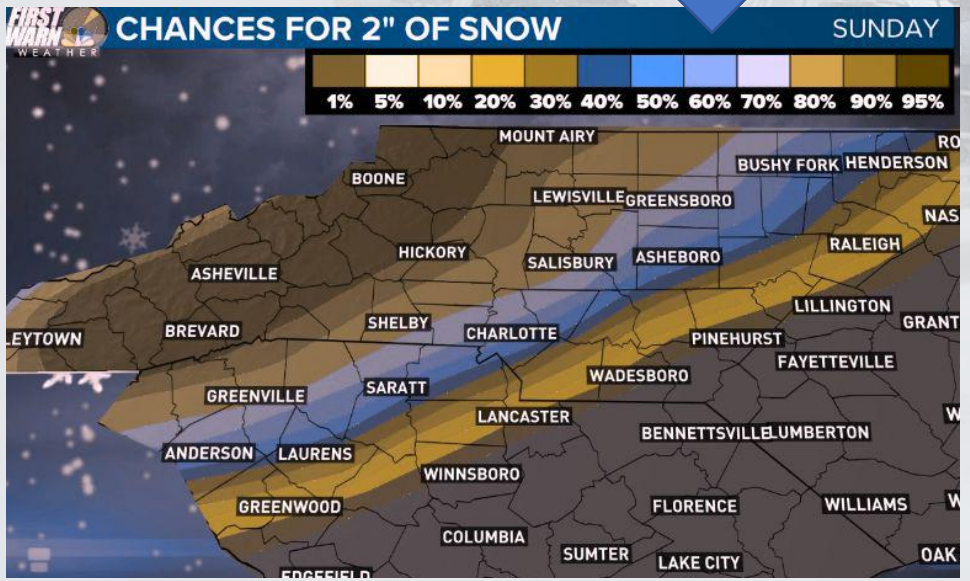
When looking just a snow maps, the first iteration that's posted gets more impressions than the subsequent ones

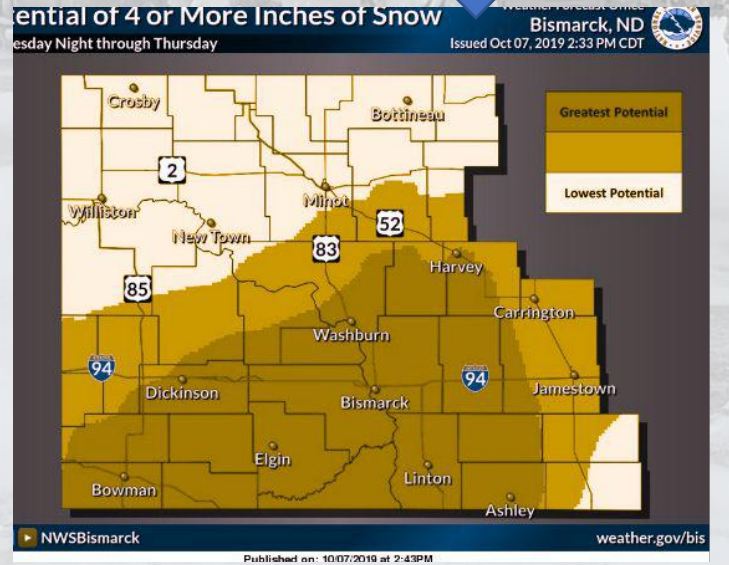


Another Bonus Takeaway!

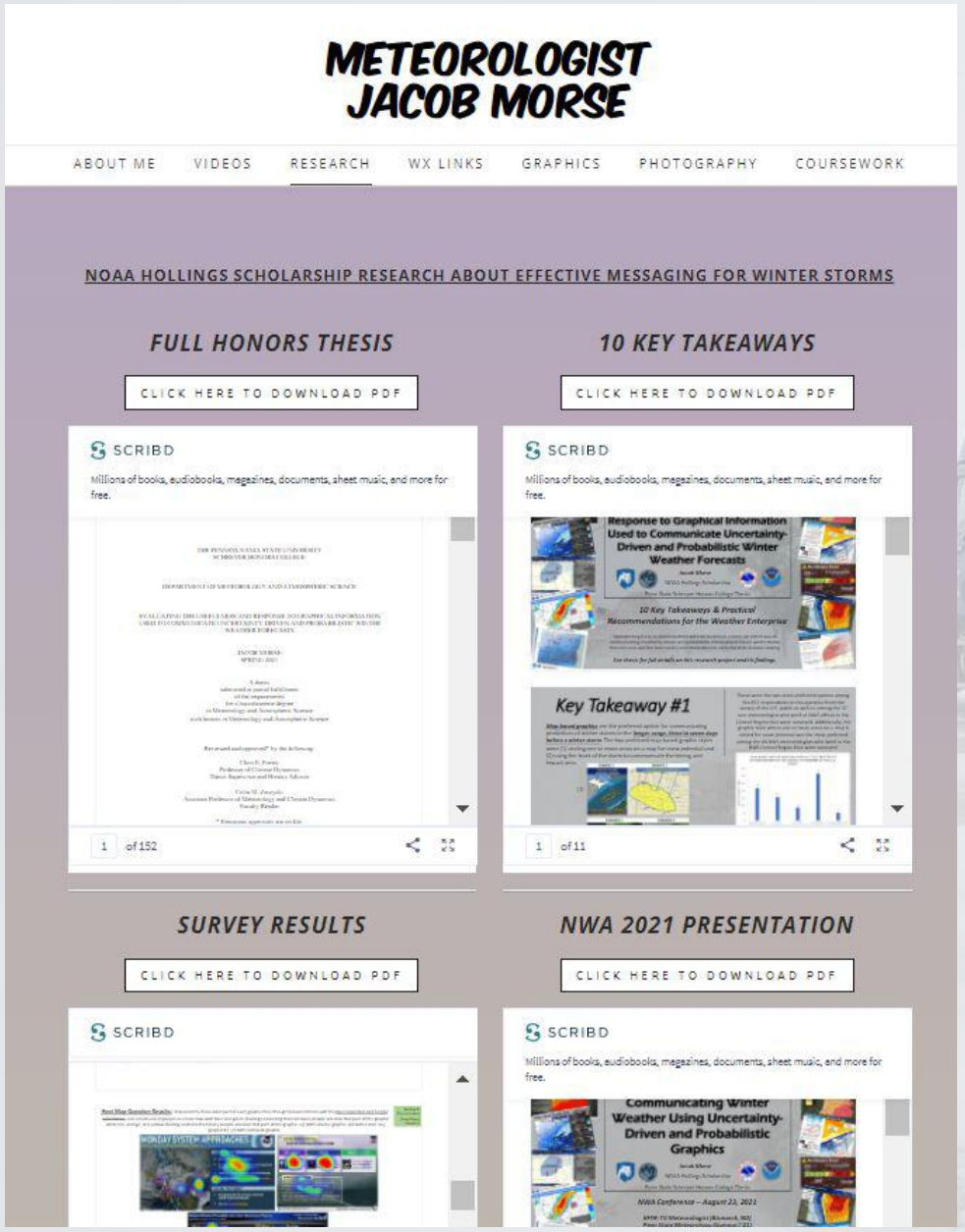
What about those that are color blind?

https://www.color-blindness.com/coblis-color-blindness-simulator/
Green-Blind/Deuteranopia lens





jacobmorsewx.weebly.com/research



<u>TAKE-HOME MESSAGE:</u> We need to be more comfortable talking about uncertainty and probabilistic information. People want to hear about this and find it helpful for decision-making.

Messaging for partners can/should be different than messaging for the public, but my research supports that ***<u>probabilistic information</u>*** is helpful for ***<u>the public when communicated correctly</u>***

THANK YOU!

<u>Reach out to me with questions:</u>

Twitter: @JacobMorseWX

Email: <u>jmorse879@gmail.com</u>