



# The Winter Storm Severity Index (WSSI) “Suite of Products”

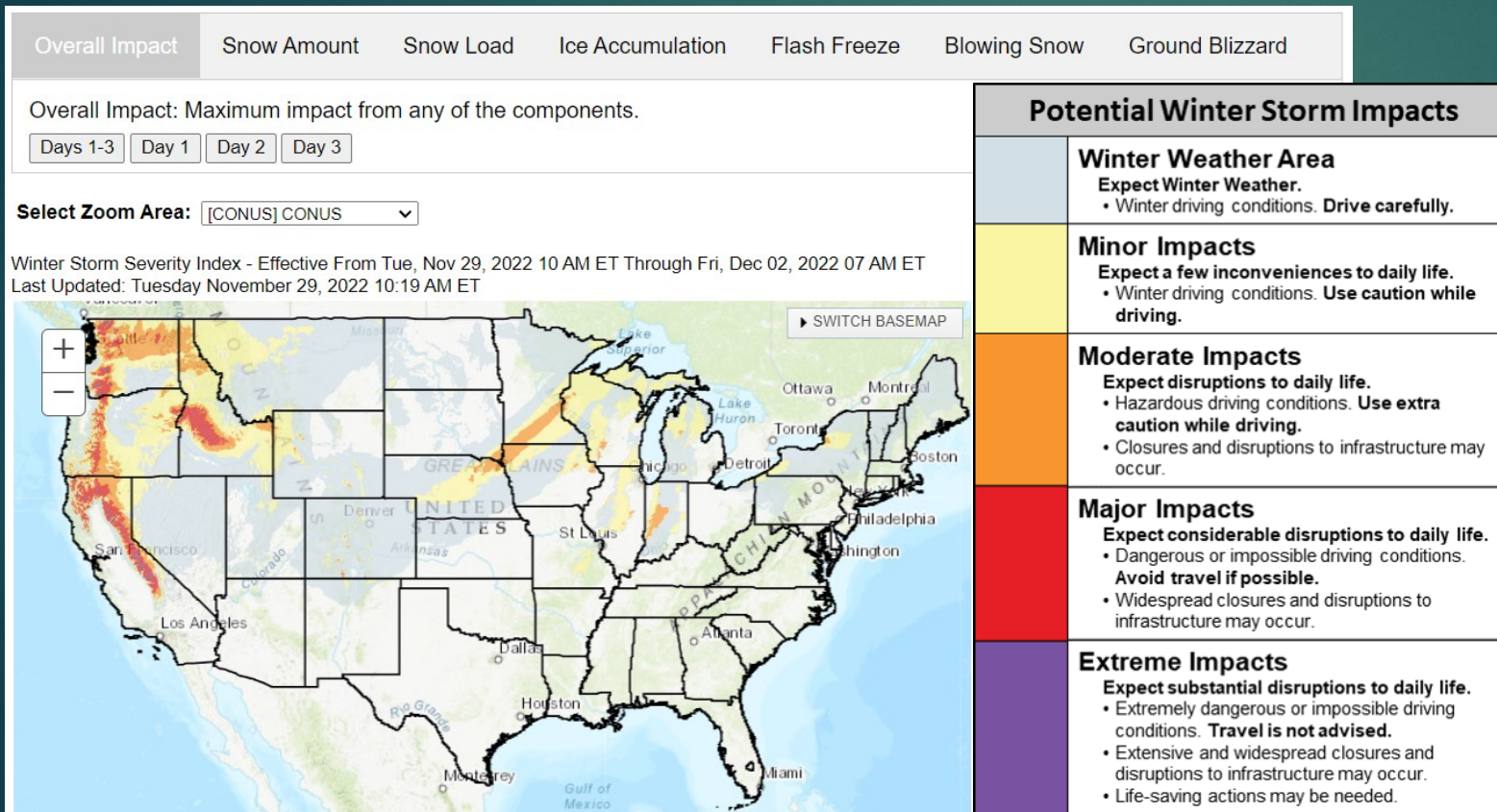
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DR. KIRSTIN HARNOS – WPC

JAMES NELSON – WPC

DR. JOSHUA KASTMAN – FORMERLY WPC

# The Winter Storm Severity Index (WSSI)



- ▶ Operational NWS forecast product
- ▶ Uses GIS to combine forecast information with climatological and non-meteorological data to communicate the spatial distribution and severity of anticipated societal impacts
- ▶ Separates impacts into components to address different meteorological hazards

# Timeline of WSSI

**2013:**  
WSSI first  
conceptualized  
at Burlington, VT  
WFO (BTV)

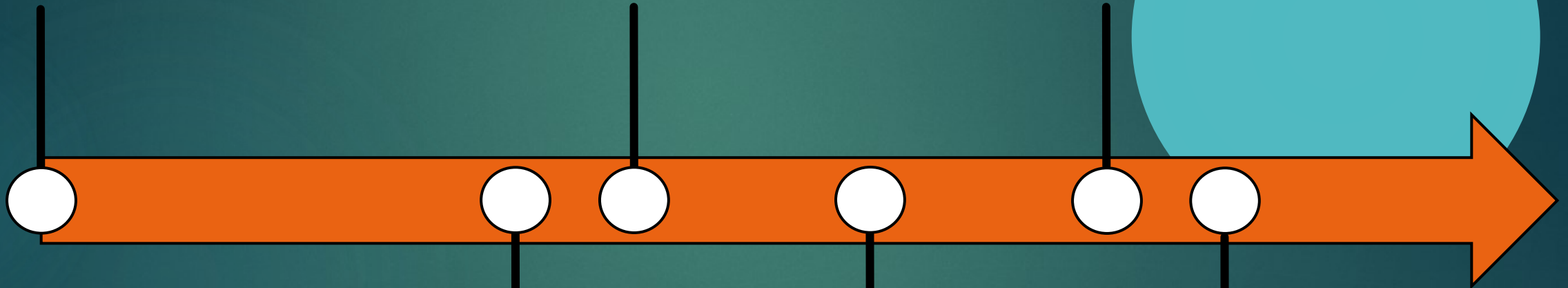
**2018:**  
WSSI becomes  
Experimental

**2022:**  
WSSI-P  
becomes  
Experimental

**2017:**  
BTV shares the  
WSSI code with  
WPC

**2020:**  
WSSI becomes  
Operational

**2023:**  
WSSI-P  
becomes  
Operational



# The WSSI “Suite of Products”

- ▶ Deterministic WSSI (operational)
  - ▶ National Digital Forecast Database (NDFD) based
  - ▶ Days 1-3 in 24h breakouts, and a 3-day summary
  - ▶ High-glance summary of the potential societal impacts based on official NWS forecasts
- ▶ Probabilistic WSSI (WSSI-P; operational)
  - ▶ WPC Super Ensemble based
  - ▶ Days 1-7 in 24h rolling breakouts
  - ▶ Deeper dive into the probabilities and potential for societal impacts
- ▶ Hourly WSSI (WSSI-H; internal prototype in development)
  - ▶ High-Resolution Rapid Refresh (HRRR) based
  - ▶ Hours 1-48 (for synoptic runs) in hourly breakouts
  - ▶ High spatial and temporal resolution of impact forecasts in the short-term, designed to aid in travel decisions and awareness

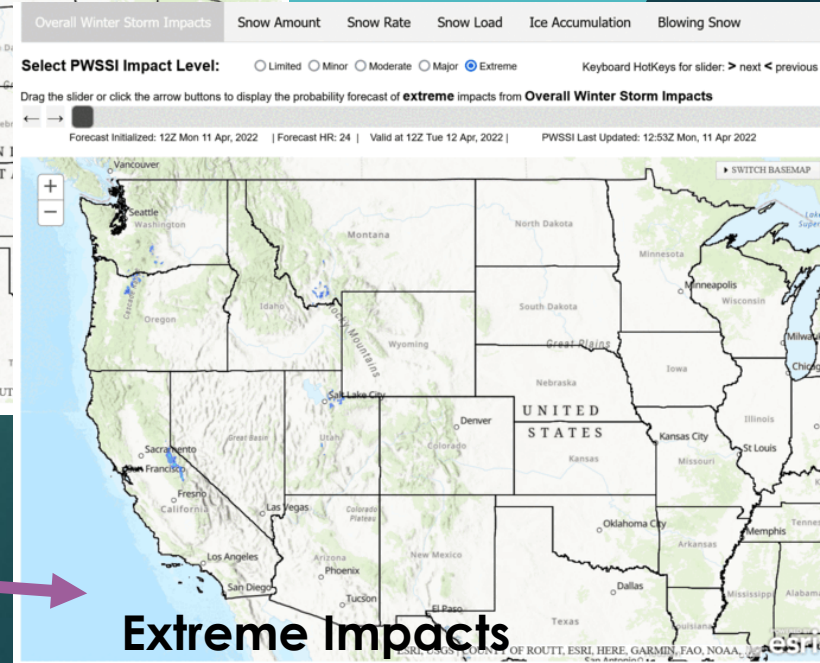
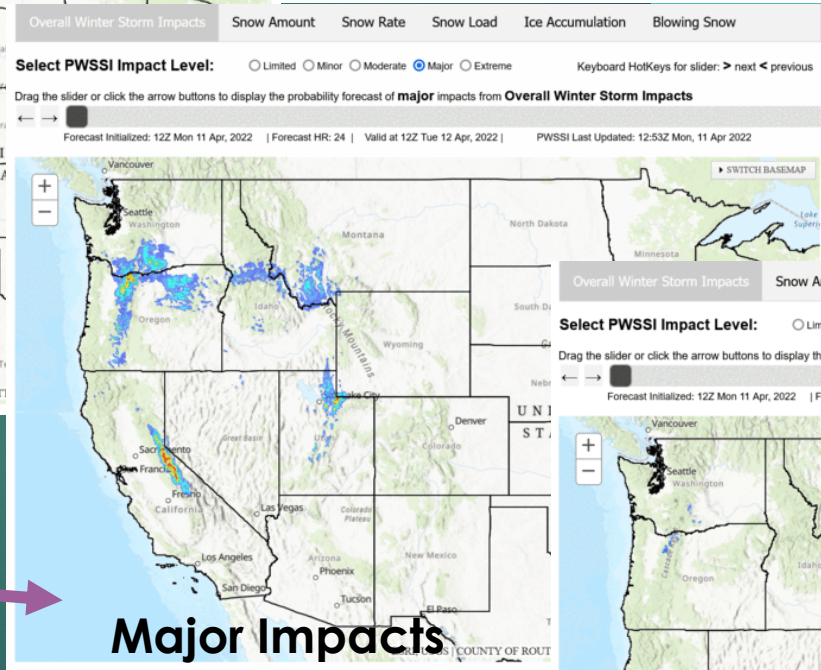
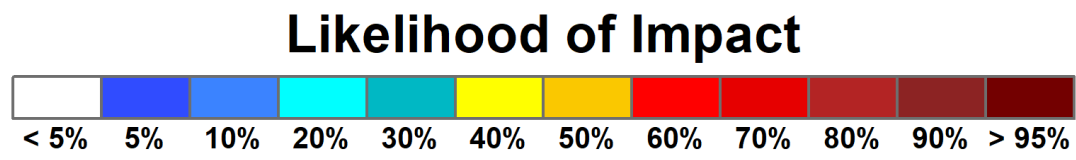
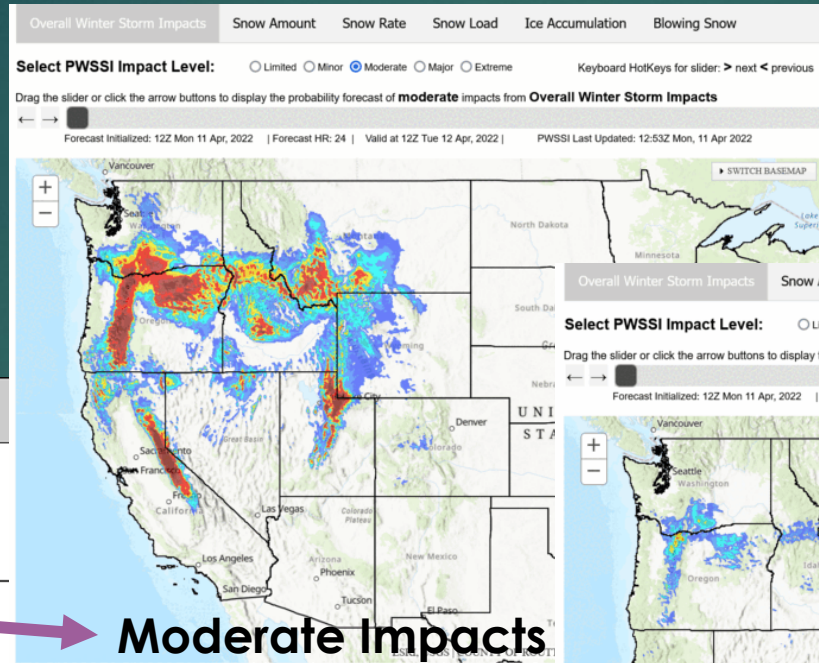


# WSSI Product Workflow

- ▶ Days 7 → 3
  - ▶ Only WSSI-P is available
  - ▶ “Keep an eye out” for potential impacts from winter storms
- ▶ Days 3 → 1
  - ▶ WSSI as a quick-glance for impending impacts
  - ▶ WSSI-P as a deep-dive into impact probabilities
  - ▶ WSSI-H as the event is unfolding (now – 48 h)



# WSSI-P Example – April 2022 Blizzard



## Potential Winter Storm Impacts

### Minor Impacts

Expect a few inconveniences to daily life.

- Winter driving conditions. **Use caution while driving.**

### Moderate Impacts

Expect disruptions to daily life.

- Hazardous driving conditions. **Use extra caution while driving.**
- Closures and disruptions to infrastructure may occur.

### Major Impacts

Expect considerable disruptions to daily life.

- Dangerous or impossible driving conditions. **Avoid travel if possible.**
- Widespread closures and disruptions to infrastructure may occur.

### Extreme Impacts

Expect substantial disruptions to daily life.

- Extremely dangerous or impossible driving conditions. **Travel is not advised.**
- Extensive and widespread closures and disruptions to infrastructure may occur.
- Life-saving actions may be needed.

Moderate Impacts

Major Impacts

Extreme Impacts

# Examples: Deterministic WSSI

## National Center (WPC)

## Local WFO

## Partners

**NWS Weather Prediction Center**  
@NWSWPC

⚠️❄️ A winter storm will bring heavy snow to parts of Colorado later today through Sunday morning. Our Winter Storm Severity Index indicates that Denver and some of the higher peaks of the Rockies may see Major impacts from this event. Avoid travel in these areas if possible!

**Oct 28 - 29 Winter Storm**

**Impacts**

Minor Moderate Major Extreme

⚠️ Avoid travel if possible

**Hazards**

- Heavy snow falling at rates up to 1-2"/hr
- Expected snowfall totals 6-12" in the plains, higher amounts in the mountains

**Timing**

- Heaviest snow Saturday night into Sunday morning

Winter Storm Severity Index  
Valid through Sunday October 29th

NATIONAL WEATHER SERVICE  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION  
WEATHER PREDICTION CENTER

ISSUED: Sat, Oct 28, 2023 10:45 AM MDT

1:13 PM · Oct 28, 2023 · 21.7K Views

**NWS Las Vegas**  
@NWSVegas

Another round of gusty winds & winter weather are on tap through Tue AM; but this will only be a preview of what's to come as the bulk of the system will move through on Wednesday.

The graphic shows the Winter Storm Severity Index thru Thursday AM.

#NVwx #CAwx #AZwx

**WINTER WEATHER**

Winter Storm Severity Index | through Thursday AM

**Hazardous Travel Conditions This Week**

**Check Road Conditions Before You Go!**

Nevada - [nvroads.com](http://nvroads.com)

California - [quickmap.dot.ca.gov](http://quickmap.dot.ca.gov)

Arizona - [az511.com](http://az511.com)

NATIONAL WEATHER SERVICE  
WEATHER.GOV/LASVEGAS

4:00 PM - Monday, February 27, 2023

6:40 PM · Feb 27, 2023 · 7,114 Views

**CHP Truckee**  
@CHP\_Truckee

HERE IT COMES!! 🚧 If you are planning to risk traveling over Donner Summit the next couple days expect dangerous travel conditions!! Expect long delays, high winds, zero visibility, and road closures... TRAVEL IS HIGHLY DISCOURAGED!!

(2/27/23 8:15am)

**Dangerous Snow Impacts**  
Today, February 27, 2023 - Tuesday, February 28, 2023

**Winter Weather Area**

Minor Impact  
Moderate Impact  
Major Impact  
Extreme Impact

Expect substantial disruptions to daily life

- Extremely dangerous or impossible driving conditions. Travel is not advised
- Extensive and widespread closures and disruption to infrastructure may occur
- Life-saving actions may be needed

**Impacted Highways**

80 5 50 36 89 49 88 4 108 162 299

NATIONAL WEATHER SERVICE - Sacramento, CA  
weather.gov/sac  
Updated: Monday, February 27, 2023

11:26 AM · Feb 27, 2023 · 46.5K Views

# Examples: Probabilistic WSSI (WSSI-P) National Center (WPC)



NWS Weather Prediction Center

@NWSWPC

## Midwest Blizzard to Prolonged Lake Effect Event Update

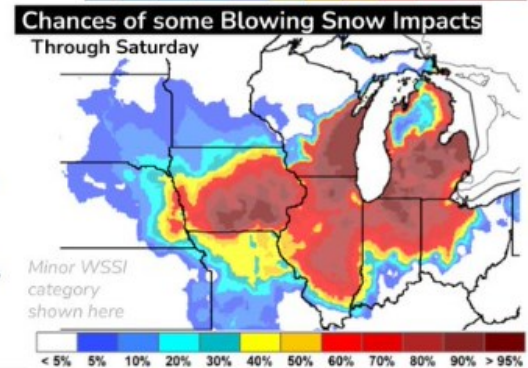


### Key Messages for Jan 11-14 Major Winter Storm

Updated Jan 12, 2024  
4:00 AM CST

An intense storm will spread a variety of significant impacts over much of the eastern half of U.S.

- Conditions Deteriorate Rapidly Today in Midwest**  
 Heavy snow will continue to spread across the Upper Midwest today. Snowfall rates of 1 to locally 2 inches per hour will lead to hazardous travel conditions over much of the region.
- Blizzard Conditions Likely with Strong Winds**  
 Winds will increase through tonight in the Midwest and Great Lakes as the storm system rapidly strengthens. Blizzard conditions are likely, particularly in exposed areas. Travel will become dangerous to impossible with whiteout conditions. Power outages are possible.
- Lake Effect Snow Persists This Weekend**  
 While the larger snow area will diminish on Saturday, the arrival of colder air will generate heavy snow downwind of the Great Lakes this weekend into midweek. Whiteout conditions in the lake effect snow bands are expected.
- Flooding and Severe Storms in the South and East**  
 Severe storms will be possible in the South today and damaging gusts may occur outside of thunderstorms. Heavy rain in the Mid-Atlantic and Northeast Friday night and Saturday will lead to renewed rises on rivers and streams and possible flooding. Moderate to isolated major coastal flooding is likely in the Mid-Atlantic and Northeast Saturday, with significant impacts.



National Oceanic and Atmospheric Administration  
U.S. Department of Commerce

For more information go to:  
[www.wpc.ncep.noaa.gov](http://www.wpc.ncep.noaa.gov) and [www.weather.gov](http://www.weather.gov)

Weather Prediction Center  
College Park, MD

5:33 AM · Jan 12, 2024 · 26K Views

## Local WFO



NWS Omaha

@NWSOmaha

It's going to snow.  
Plows will be out.



### Snow and Travel Impacts Monday/Tuesday

January 4, 2024  
3:10 PM

#### Key Messages

- Strong winter storm system will bring snow and travel impacts to much of the area Monday into Tuesday.
- Biggest impacts most likely to be in southeast Nebraska and southwest Iowa.
- Questions remain on strength of system and exact location of heaviest band of snow.

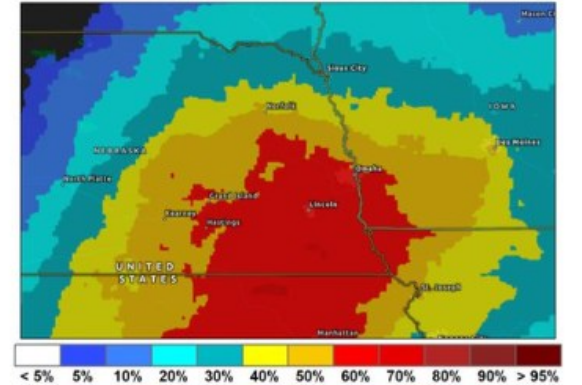
#### Important Forecast Changes

- Confidence increasing that impactful snow will fall in eastern Nebraska and/or western Iowa.

#### Overall Forecast Confidence



#### Probability of At Least Minor Travel Impacts Monday



Minor Travel Impacts:  
Winter driving conditions, expect a few inconveniences to daily life.



National Oceanic and Atmospheric Administration  
U.S. Department of Commerce

National Weather Service  
Omaha/Valley, NE

5:18 PM · Jan 4, 2024 · 74.5K Views



# WSSI Components

- ▶ Snow Amount (all products)
  - ▶ Impacts due to the accumulation of snowfall
    - ▶ Does not include any snowfall prior to initialization
- ▶ Snow Rate (WSSI-P and WSSI-H)
  - ▶ Impacts due to the rate of snowfall
    - ▶ Baked into the Snow Amount component for WSSI
- ▶ Ice Accumulation (all products)
  - ▶ Impacts due to ice accretion
    - ▶ Does not include any accumulations prior to initialization
    - ▶ Accumulations are killed off after 24 h for WSSI and WSSI-P



# WSSI Components

- ▶ Ground Blizzard (WSSI)
  - ▶ Impacts due to the resuspension of previously fallen snow
    - ▶ Uses NOHRSC to identify areas of prior snowfall
- ▶ Blowing Snow (all products)
  - ▶ Impacts due to blowing and/or drifting of falling snow
- ▶ Flash Freeze (all products)
  - ▶ Impacts due to the freezing of liquid precipitation and/or snowmelt
    - ▶ Snowmelt is brand new!



# What are Impacts??

- ▶ Anything that disrupts daily life
  - ▶ School or business closures/delays
  - ▶ Traffic disruptions (Delays, closures, crashes, speed restrictions, vehicle bans)
  - ▶ Utility disruptions (Power or internet outages)
- ▶ Damage to vegetation or infrastructure
  - ▶ Downed trees and/or power lines
  - ▶ Damaged foliage and vegetation
  - ▶ Structural collapses
  - ▶ Frozen or burst water pipes\*
- ▶ Health-related issues
  - ▶ Cardiovascular issues from shoveling heavy snow
  - ▶ Hypothermia or other cold-weather risks\*

\*Not accounted for yet!

# What are Impacts??

- ▶ Mitigation efforts are *also* considered impacts!
  - ▶ Staying home and *avoiding travel* is an impact
    - ▶ Travel plans altered due to the weather
    - ▶ Reduced mobility for discretionary travel
- ▶ Quantifying all of these impacts is challenging...
  - ▶ Impacts are holistic; cannot just examine one aspect or data source
    - ▶ Example: Crash data has limitations (e.g., closed roads have no crashes!)
  - ▶ More on this later...



# Improvements from Social Science Engagements

## Old Definitions and Colors

- ▶ Focus on the impacts to life and property, and disruptions to daily

Potential Winter Storm Impacts	
	<b>No Impacts</b> Impacts not expected.
	<b>Limited Impacts</b> Rarely a direct threat to life and property. Typically results in little inconveniences.
	<b>Minor Impacts</b> Rarely a direct threat to life and property. Typically results in an inconvenience to daily life.
	<b>Moderate Impacts</b> Often threatening to life and property, some damage unavoidable. Typically results in disruptions to daily life.
	<b>Major Impacts</b> Extensive property damage likely, life saving actions needed. Will likely result in major disruptions to daily life.
	<b>Extreme Impacts</b> Extensive and widespread severe property damage, life saving actions will be needed. Results in extreme disruptions to daily life.



Potential Winter Storm Impacts	
	<b>Winter Weather Area</b> <b>Expect Winter Weather.</b> • Winter driving conditions. <b>Drive carefully.</b>
	<b>Minor Impacts</b> <b>Expect a few inconveniences to daily life.</b> • Winter driving conditions. <b>Use caution while driving.</b>
	<b>Moderate Impacts</b> <b>Expect disruptions to daily life.</b> • Hazardous driving conditions. <b>Use extra caution while driving.</b> • Closures and disruptions to infrastructure may occur.
	<b>Major Impacts</b> <b>Expect considerable disruptions to daily life.</b> • Dangerous or impossible driving conditions. <b>Avoid travel if possible.</b> • Widespread closures and disruptions to infrastructure may occur.
	<b>Extreme Impacts</b> <b>Expect substantial disruptions to daily life.</b> • Extremely dangerous or impossible driving conditions. <b>Travel is not advised.</b> • Extensive and widespread closures and disruptions to infrastructure may occur. • Life-saving actions may be needed.

## New Definitions and Colors

- ▶ Improved and color-blind friendly colors
- ▶ Primary emphasis on the disruption to daily life
- ▶ Emphasis on transportation and driving conditions
- ▶ Inclusion of potential closures and disruption to infrastructure
  - ▶ e.g., roads, businesses, schools, utility lines, delivery services
- ▶ Removal of “Limited Impacts”
  - ▶ Replaced with “Winter Weather Area”: Winter conditions are expected to occur, but not disrupt daily life

# Color Blindness Testing

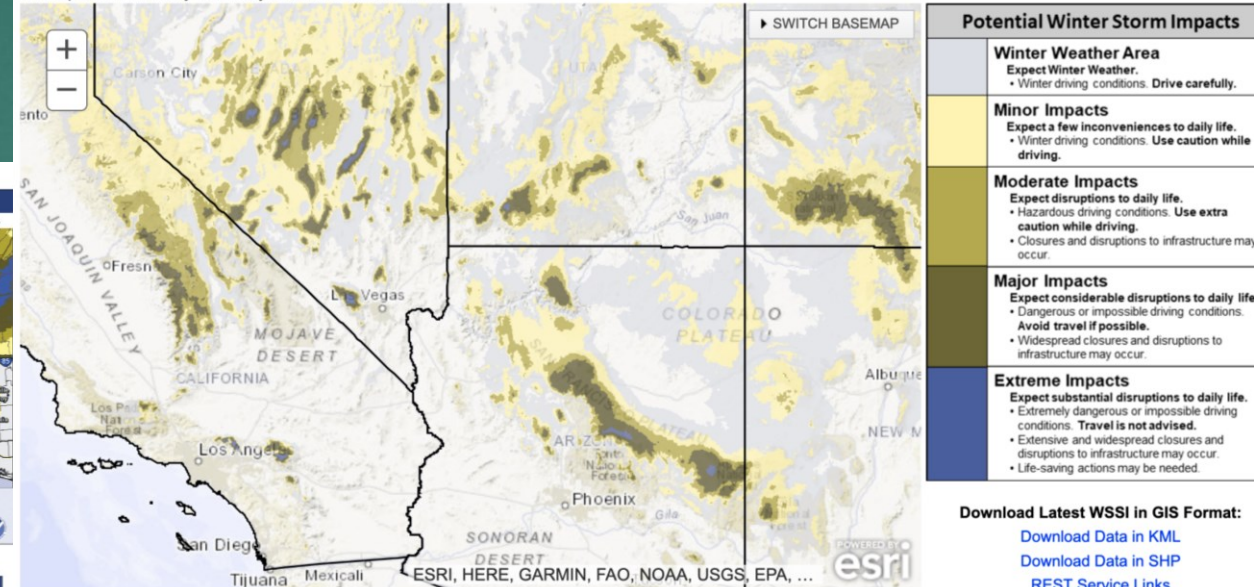
Overall Impact   Snow Amount   Snow Load   Ice Accumulation   Flash Freeze   Blowing Snow   Ground Blizzard

Overall Impact: Maximum impact from any of the components.

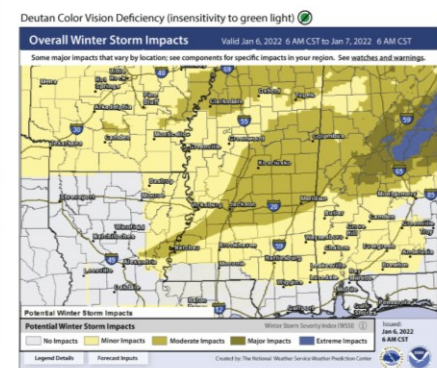
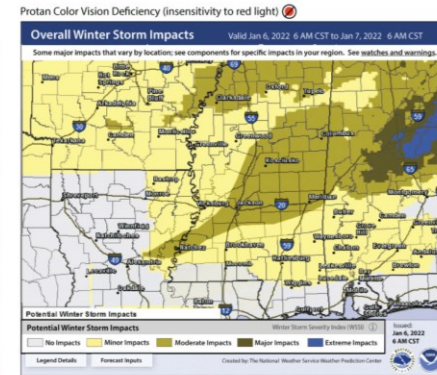
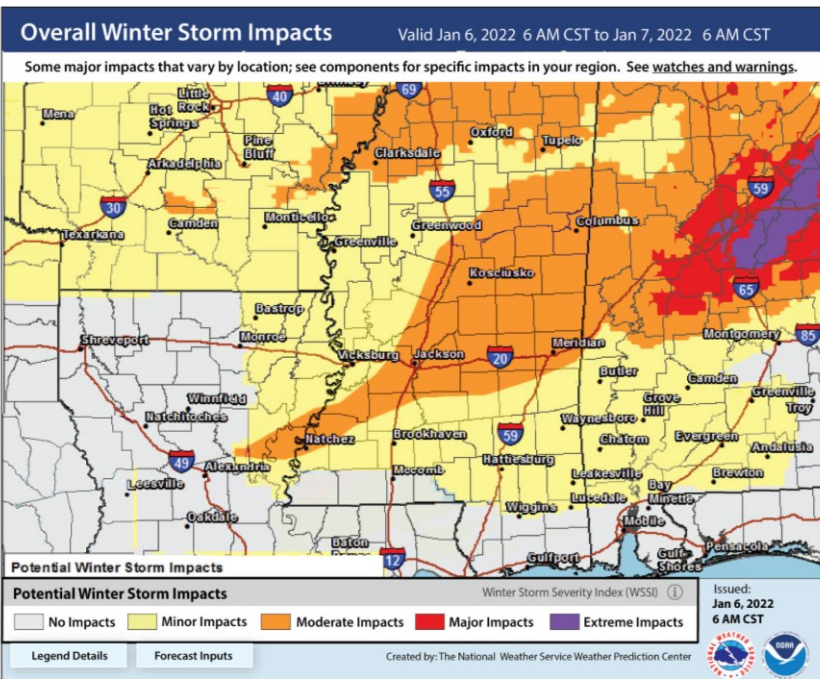
Days 1-3   Day 1   Day 2   Day 3

Select Zoom Area: [CONUS] CONUS   [Print Map](#)

Winter Storm Severity Index - Effective From Mon, Feb 05, 2024 04 PM ET Through Thu, Feb 08, 2024 01 PM ET  
 Last Updated: Monday February 05, 2024 04:28 PM ET

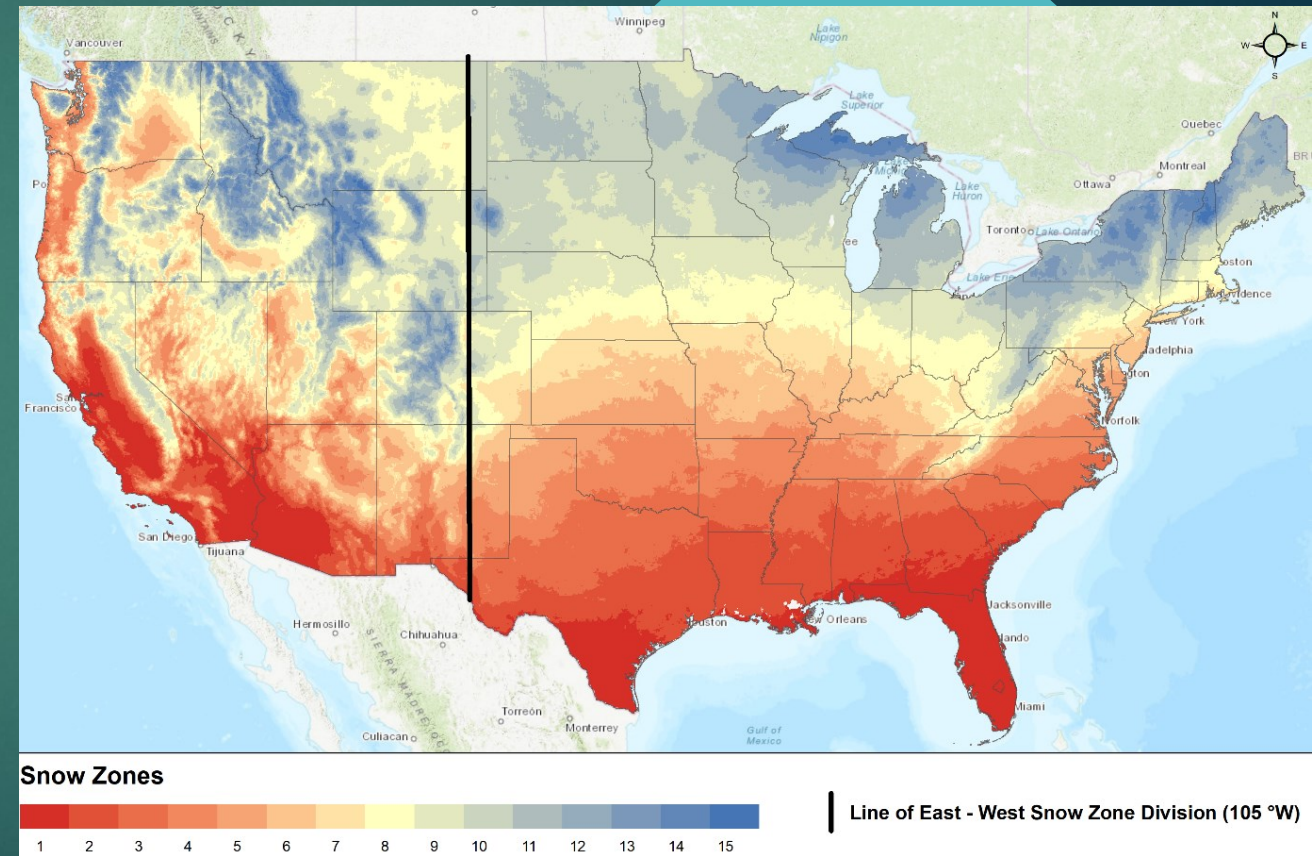


Revised WSSI - Overall Winter Storm Impacts Round 2



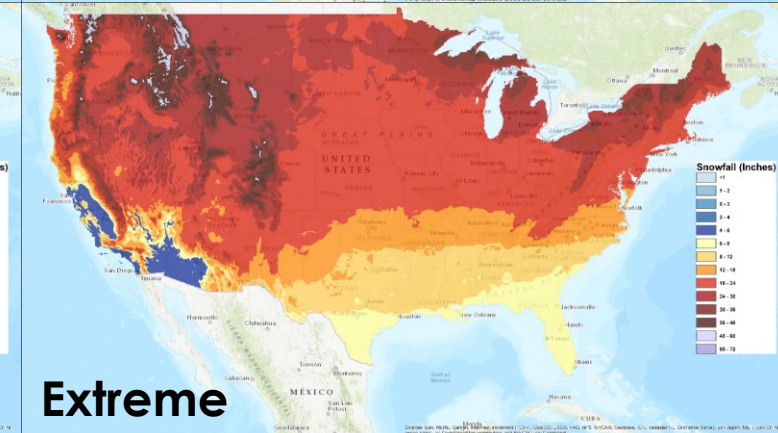
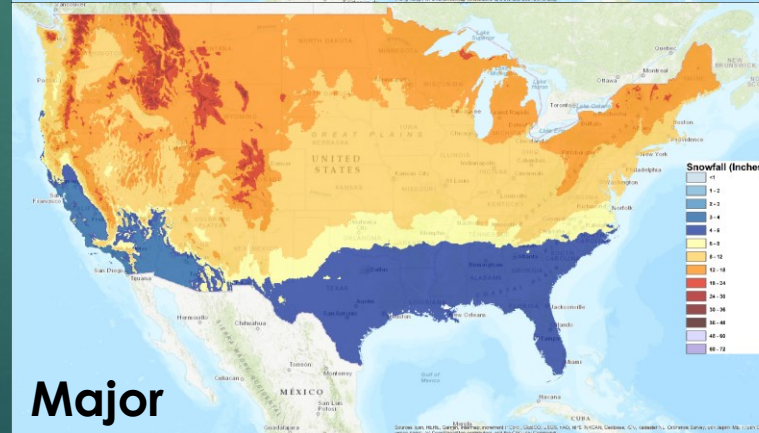
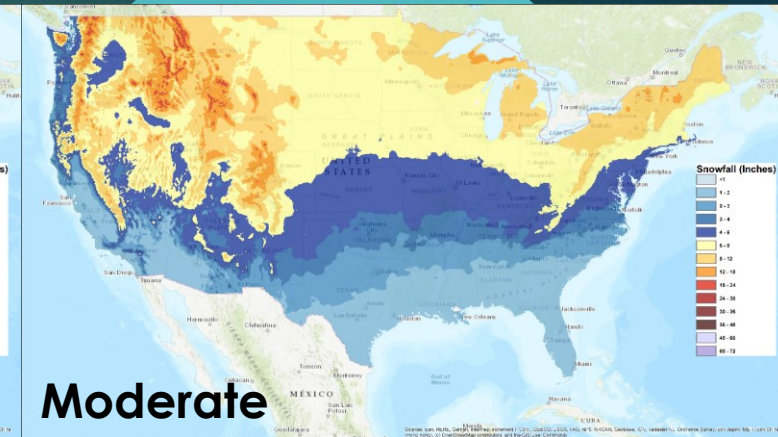
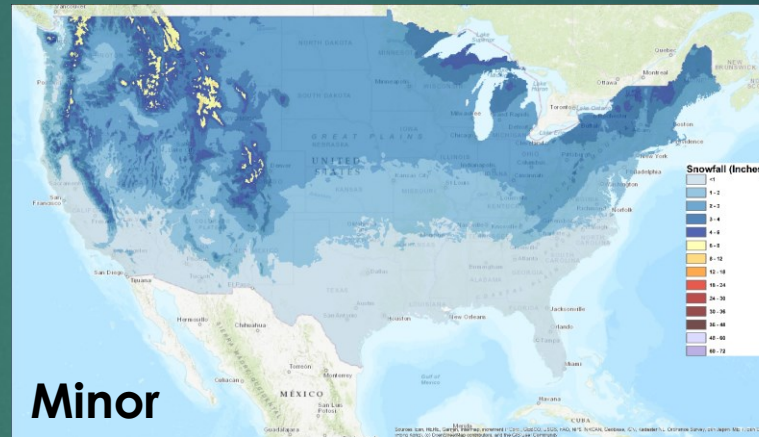
# Improved WSSI Snow Amount Climatology

- ▶ Recently updated for the 2022-2023 winter season
- ▶ Used 2-day GHCN observed snowfall data
- ▶ Grouped stations by annual average 2-day snowfall frequency (“Snow Zones”)



# Improved WSSI Snow Amount Climatology

- ▶ Impact levels based on average statistics performed on stations within each snow zone
  - ▶ **Minor:**  $0.75 \times$  (mean  $- 1 \sigma$  of the annual 85<sup>th</sup> percentile snowfall)
  - ▶ **Moderate:** mean  $- 0.25 \sigma$  of the annual 99<sup>th</sup> percentile snowfall
  - ▶ **Major:** mean  $+ 1 \sigma$  of the annual 99<sup>th</sup> percentile snowfall
  - ▶ **Extreme:** 99<sup>th</sup> percentile  $+ 1 \sigma$  of the annual *maximum* snowfall



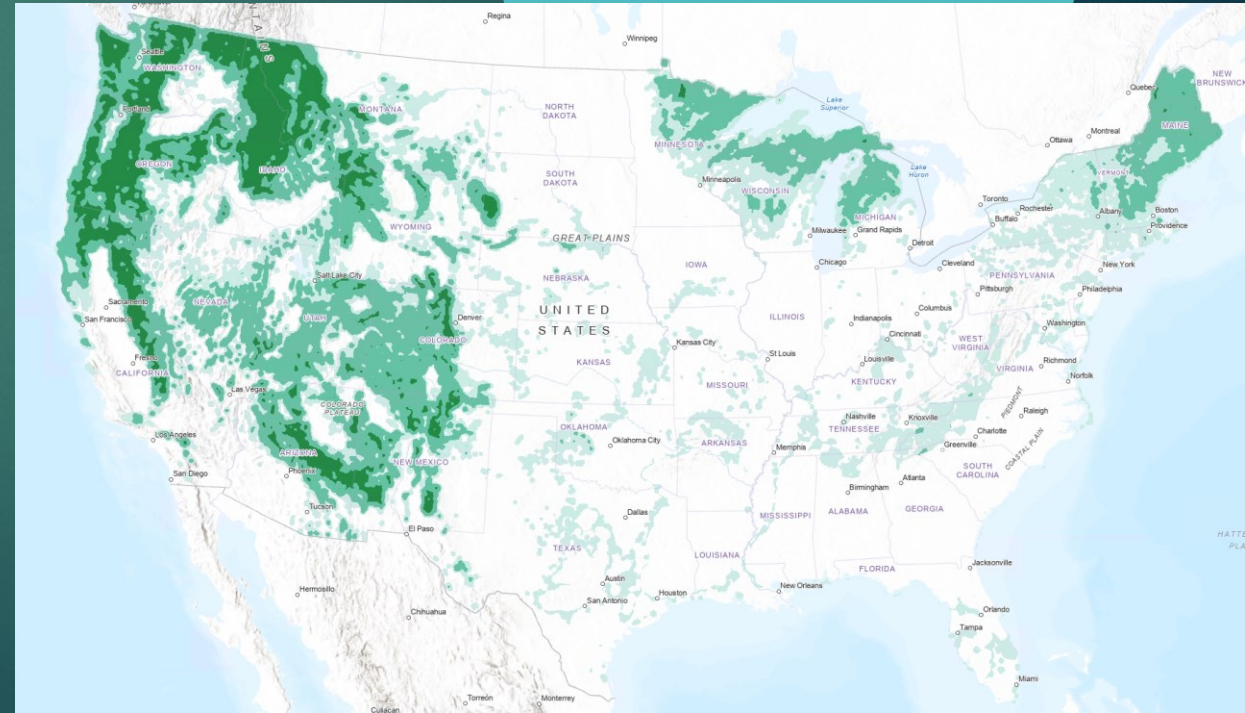


# Improved Snow Load Algorithms

- ▶ Improved handling of tree types
  - ▶ Coniferous forest density replaces tree type data
    - ▶ Higher coniferous tree density reduces snow load impacts
      - ▶ Coniferous trees can handle snow loading better!
      - ▶ Up to a 60% reduction of snow loading
  - ▶ Removes the pock-marking effect on output

## Coniferous forest density

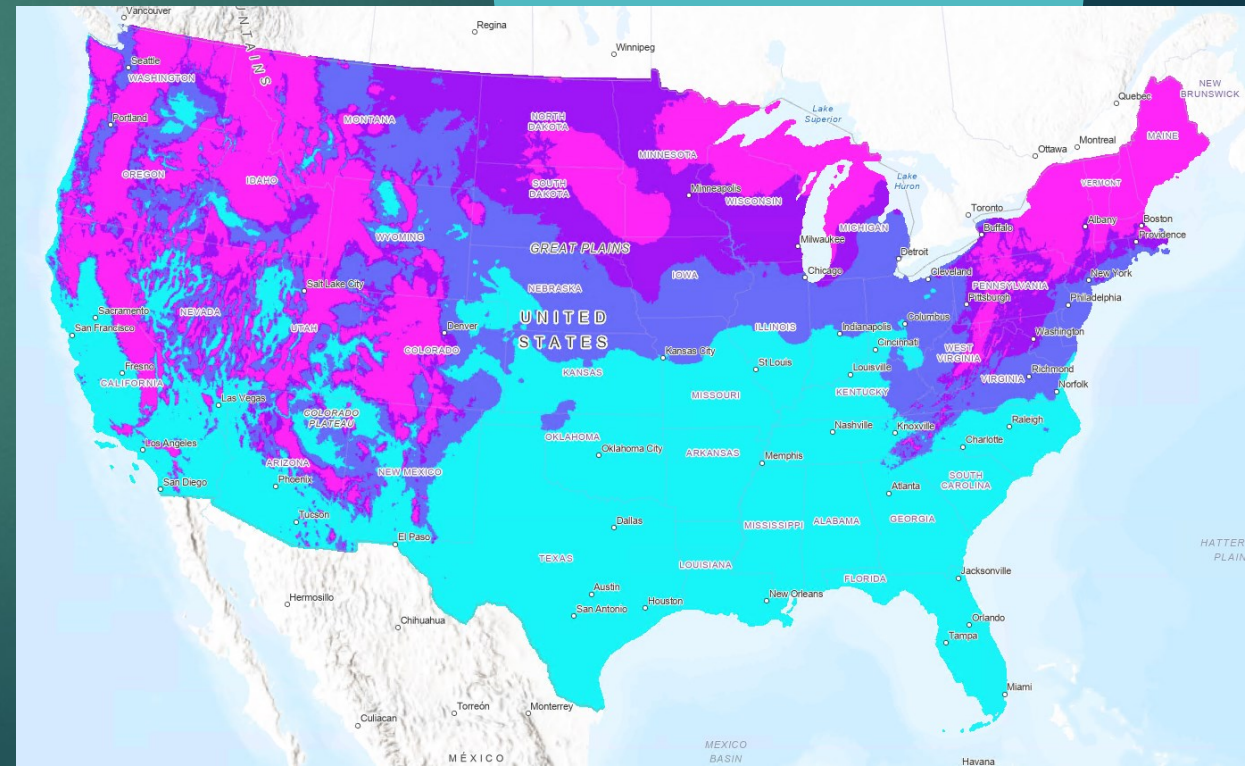
Darker green = Denser coniferous forest  
(Soft pines removed)



# Improved Snow Load Algorithms

- ▶ Obtained American Society of Civil Engineers (ASCE) data
  - ▶ 50-year mean recurrence interval (MRI) of snow load data
  - ▶ Use these to factor in exposure / resiliency to wet, heavy snow
    - ▶ Impacts adjusted accordingly (e.g., slightly lower impacts for higher snow load data)
    - ▶ Similar to adjusting snow amount thresholds based on climatology

## Snow Load Adjustments



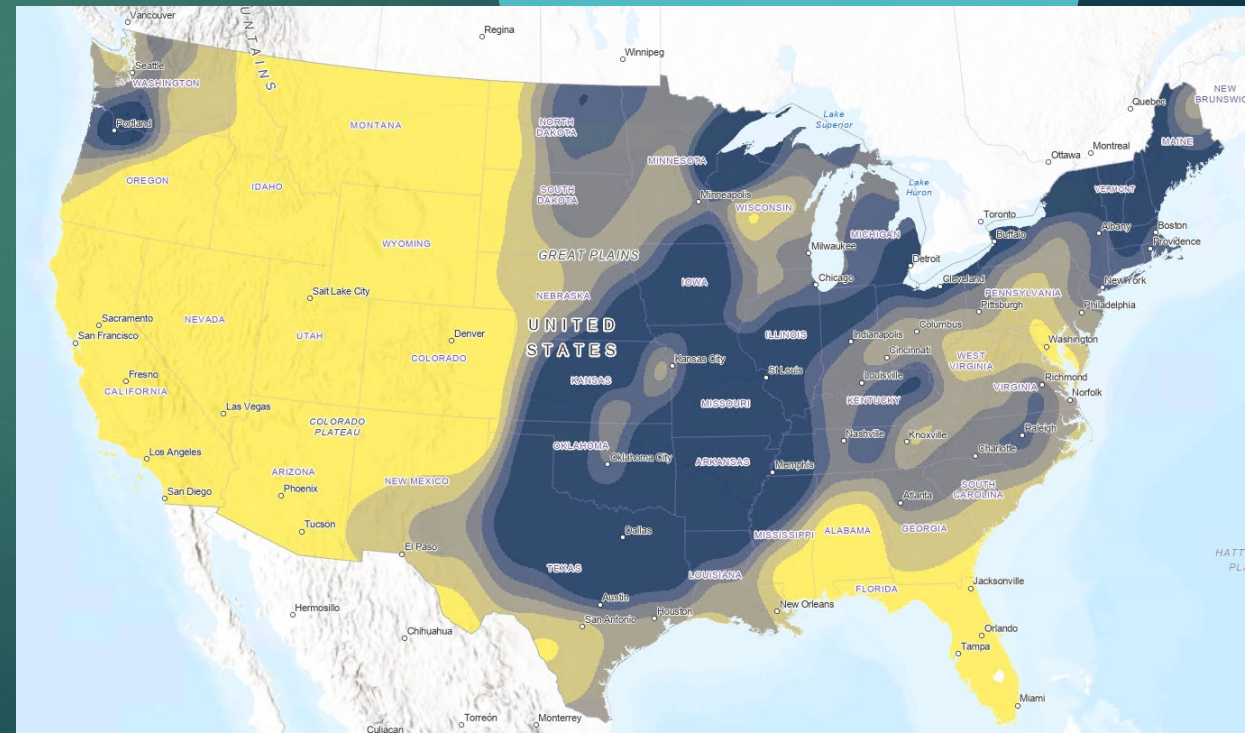
Pink = Higher exposure/resiliency (higher thresholds)  
Cyan = Lower exposure/resiliency (lower thresholds)

# Improved Ice Accumulation Algorithms

- ▶ 250-year MRI data for ice accumulation (from ASCE)
  - ▶ Use to factor in exposure / resiliency to ice
    - ▶ Higher impacts for areas with lower values
- ▶ Complete overhaul of the algorithms
  - ▶ Barjenbruch and Sanders ice + wind methodology
- ▶ Adjusted thresholds
  - ▶ Minor and Moderate to capture transportation impacts
  - ▶ Major and Extreme reserved for power line and tree limb impacts

Blue = Higher exposure/resiliency (higher thresholds)  
Yellow = Lower exposure/resiliency (lower thresholds)

## Snow Load Adjustments



# Improved Blowing Snow Algorithms

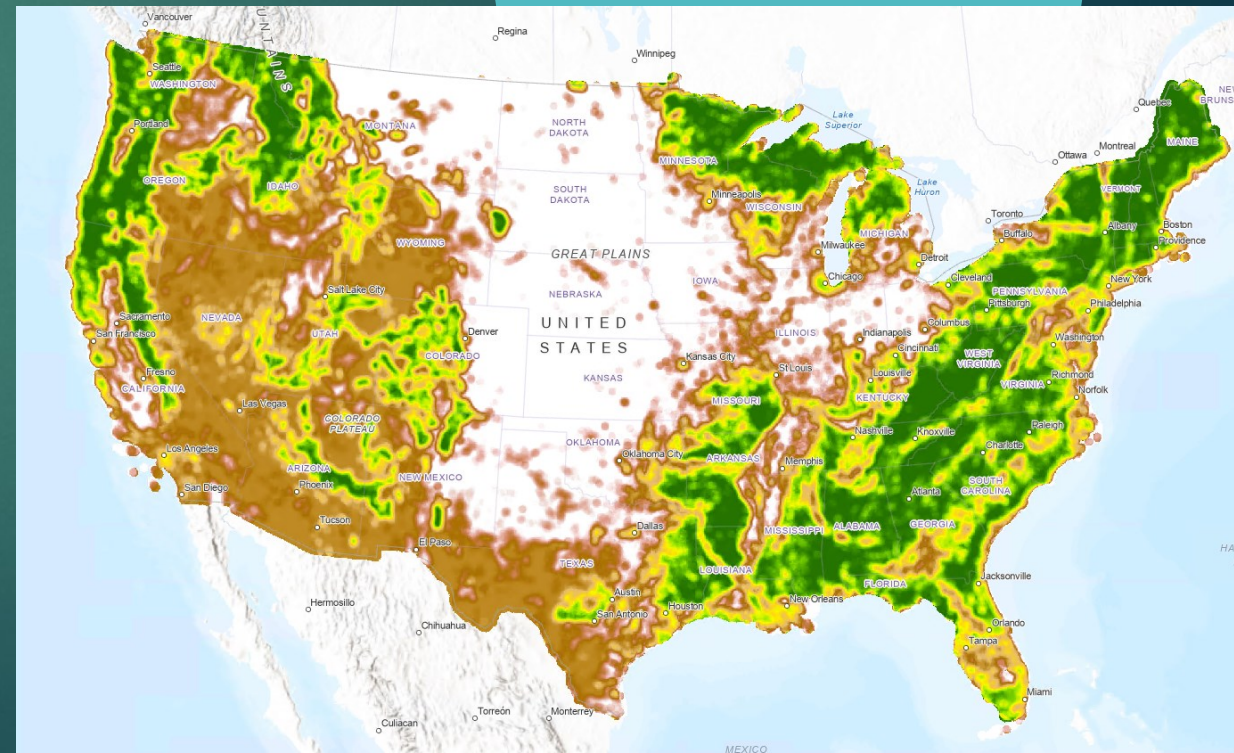
- ▶ Smoothed the land use data layer
  - ▶ Removes pock-marking effect on output
  - ▶ Maximum wind speed reductions decreased from 90% to 50%
    - ▶ Forested and urban areas were too “shielded” from impacts

## ▶ Complete overhaul of the algorithms

- ▶ Estimate visibility in blowing snow
- ▶ Impacts based on visibility estimates
  - ▶ Moderate impacts for  $\leq 1/4$  mi visibility
  - ▶ Major and Extreme reserved for longer durations of low visibility (e.g.,  $>12$  and  $>24$  h)
    - ▶ Again worked with the northern plains SOOs!  
Highlighted the need for including *duration*

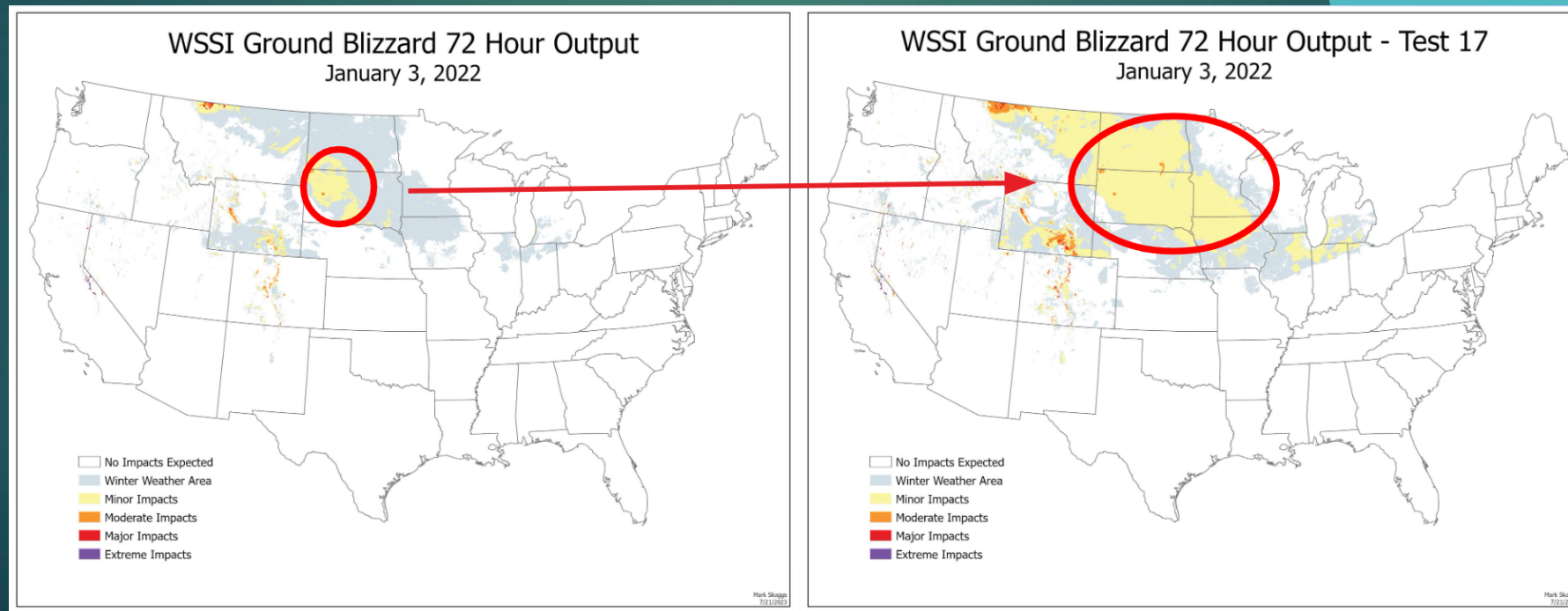
White = No Wind Speed Reduction  
Dark Green = 50% Wind Speed Reduction

## New Land Use Factor



# Improved Ground Blizzard Algorithms

- ▶ Request from northern plains SOOs to improve the GB component
- ▶ Worked with the group and a summer intern to tweak the algorithms
- ▶ Improved Land Use Factor also included



# Verifying WSSI with mPING

- ▶ Worked with the NSSL mPING development team to introduce a Winter Weather Impacts category of *tangible* impacts in Dec 2022

- ▶ Damages

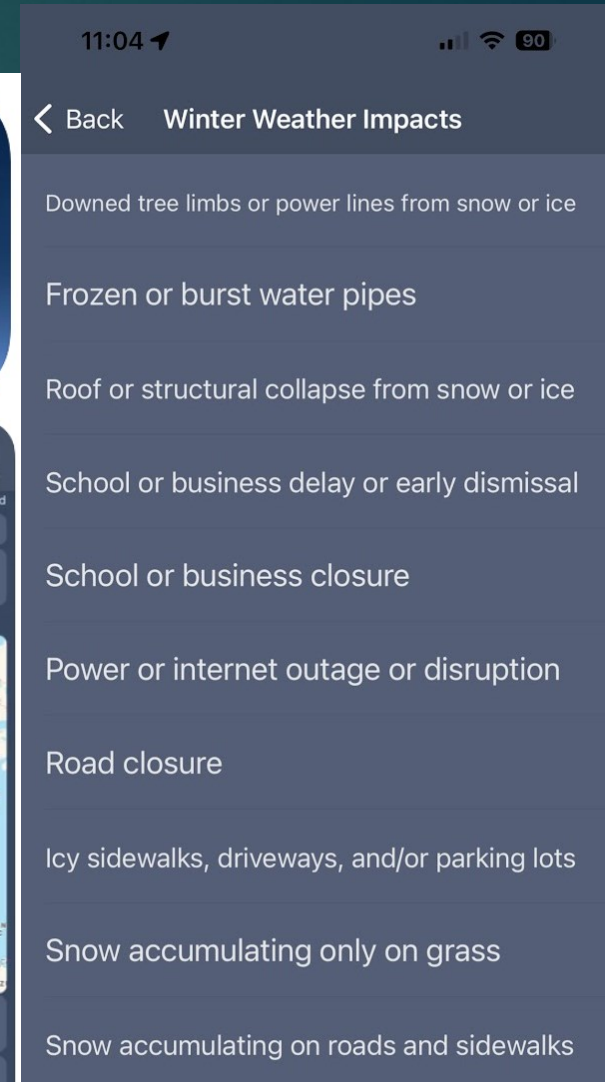
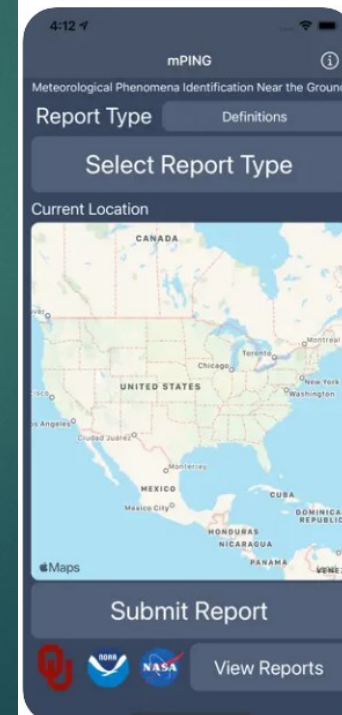
- ▶ Downed tree limbs or power lines from snow or ice
- ▶ Frozen or burst water pipes
- ▶ Roof or structural collapse from snow or ice

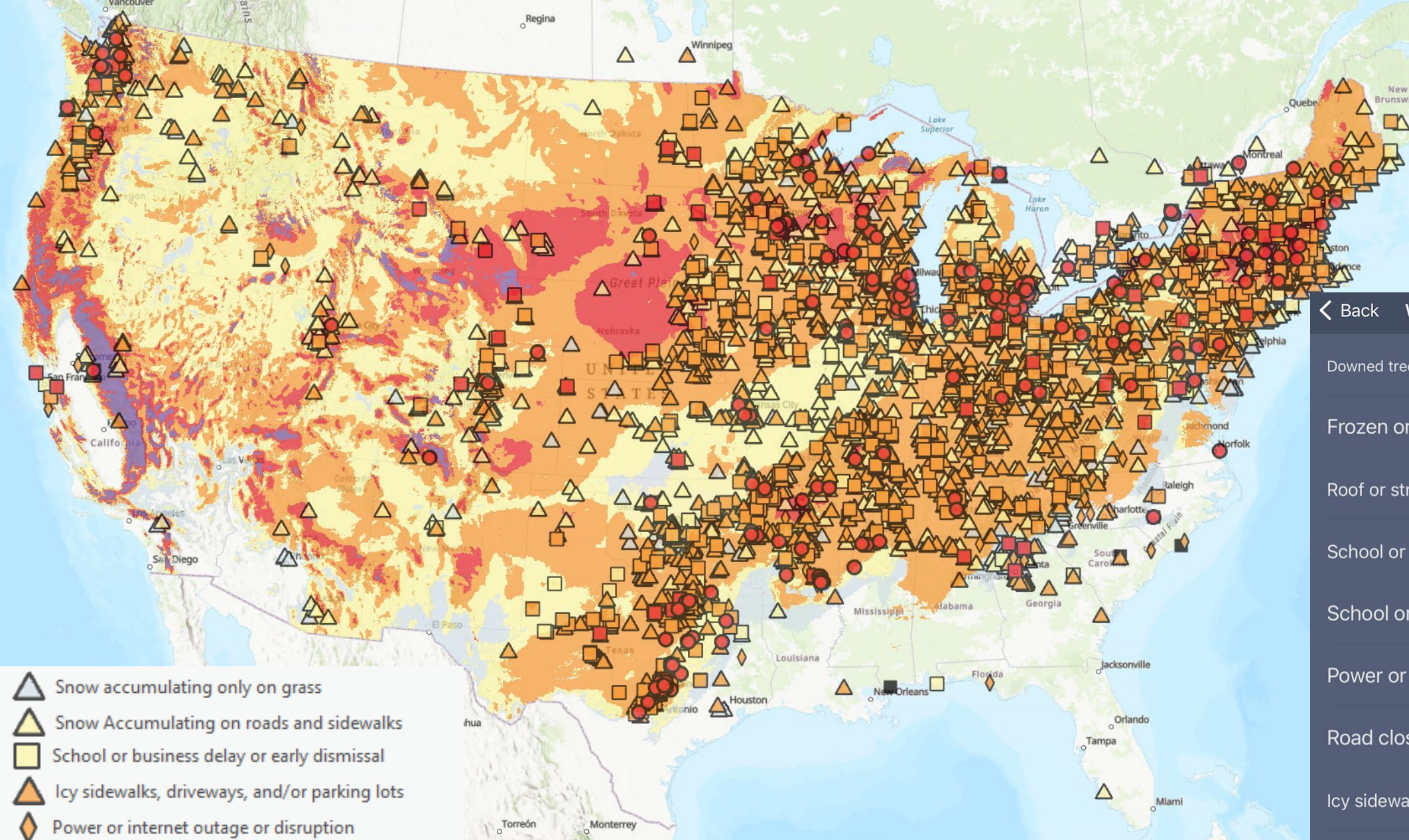
- ▶ Infrastructural Disruptions

- ▶ School or business delay or early dismissal
- ▶ School or business closure
- ▶ Power or internet outage or disruption
- ▶ Road closure

- ▶ Surface Conditions

- ▶ Icy sidewalks, driveways, and/or parking
- ▶ Snow accumulating only on grass
- ▶ Snow accumulating on roads and sidewalks





# 2022 – 2023 Winter Season Max WSSI and all Winter Impact mPING Reports

[← Back](#) Winter Weather Impacts

- Downed tree limbs or power lines from snow or ice
- Frozen or burst water pipes
- Roof or structural collapse from snow or ice
- School or business delay or early dismissal
- School or business closure
- Power or internet outage or disruption
- Road closure
- Icy sidewalks, driveways, and/or parking lots
- Snow accumulating only on grass
- Snow accumulating on roads and sidewalks

# Prototype WSSI-H

- ▶ Formerly known as WSSI Travel
- ▶ Currently NWS internal on the WWD internal site
- ▶ Current components
  - ▶ Snow Rate
  - ▶ Liquid Rate (rain and/or freezing rain)
  - ▶ Snow Amount
  - ▶ Ice Accumulation
  - ▶ Blowing Snow





# Non-Meteorological Factors

- ▶ Just like the algorithms for the other WSSI products, WSSI-H has non-meteorological factors that are used to adjust impacts
  - ▶ Impacts adjusted anywhere from a 10% reduction to a 25% increase
- ▶ Climatological factoring for snow amount
- ▶ Disruption Factors -- All components
  - ▶ Based on ambient weather and parameterized *untreated* road conditions
  - ▶ Account for how “disruptive” the driving conditions are to traffic flow
- ▶ Time-of-Day Factors – Precipitation rate components only
  - ▶ Address how time of day *typically* influences crash risk and severity

# WSSI-H Snow Rate Impact Ranges\*

	Low End	–	High End
3.0"/h:	Major	–	Extreme
2.0"/h:	Moderate	–	Major
1.0"/h:	Minor	–	Moderate
0.5"/h:	No Impacts	–	Minor

\*Actual impact levels based on the non-meteorological factors (e.g., a lower impact for overnight hours)

# WSSI-H Blowing Snow Component

- ▶ Algorithms estimate the visibility at driver eye level (~1.2 m)



## Approximate Visibility Thresholds:

$\leq 1/32$  mi: **Extreme**

$\leq 1/16$  mi: **Major**

$\leq 1/4$  mi: **Moderate** ← Warning Criteria!

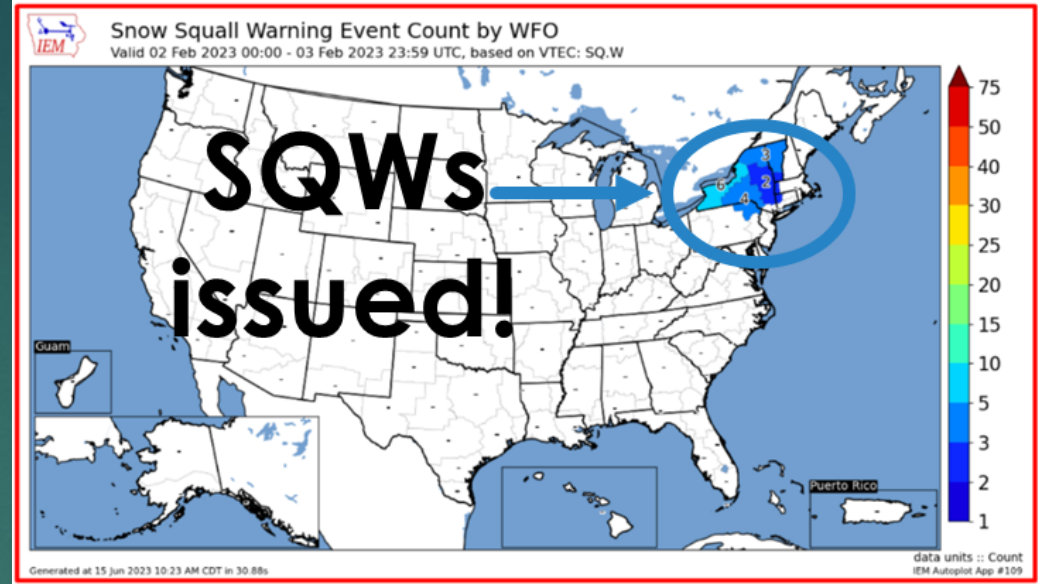
$\leq 1/2$  mi: **Minor**

$< 1$  mi: **Adverse Weather Area**

# WSSI-H BLSN for Snow Squalls???

- ▶ Internal testing shows WSSI-H can help to highlight the threat of snow
  - ▶ Output could be used to help target potential snow squall areas and timing

- ▶ Streaky-ness due to hourly HRRR data
  - ▶ Picking up on fast-moving squall-like hazards
- ▶ WSSI-H BLSN highlights same area as KM



## Key Messages for Northeast Snow Squalls

Updated Feb 2, 2023  
12:00 PM EST

A strong Arctic cold front will bring the threat of snow squalls and bitterly cold wind chills

- A strong Arctic front will race across the Great Lakes today and then push through the Northeast tonight.
- Snow squalls will accompany the Arctic front, causing heavy bursts of snow and gusty winds. Sudden whiteout conditions within snow squalls will create very dangerous driving conditions, particularly on highways.
- In the front's wake, some heavy lake effect snow bands will be possible downwind of the Great Lakes.
- A combination of bitterly cold temperatures and gusty winds will lead to dangerous cold wind chills in the Northeast from Friday into Saturday. Wind chills in northern New England are likely to fall well below minus 30 degrees in many locations, which the area has not experienced for decades.
- Limit time outside and dress in layers as frostbite and hypothermia can occur in a matter of minutes.

Snow Squalls This Afternoon & Tonight

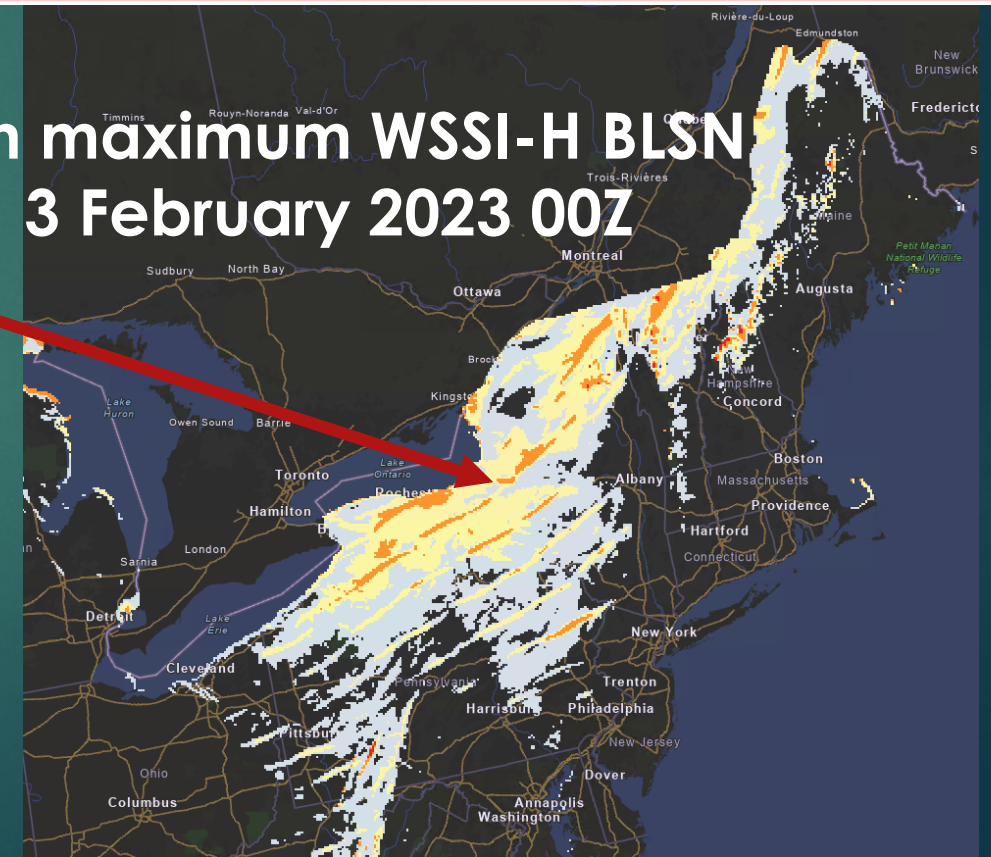
Coldest Wind Chills Friday to Saturday

National Oceanic and Atmospheric Administration  
U.S. Department of Commerce

For more information go to:  
[www.wpc.ncep.noaa.gov](http://www.wpc.ncep.noaa.gov) and [www.weather.gov](http://www.weather.gov)

Weather Prediction Center  
College Park, MD

48h maximum WSSI-H BLSN  
3 February 2023 00Z

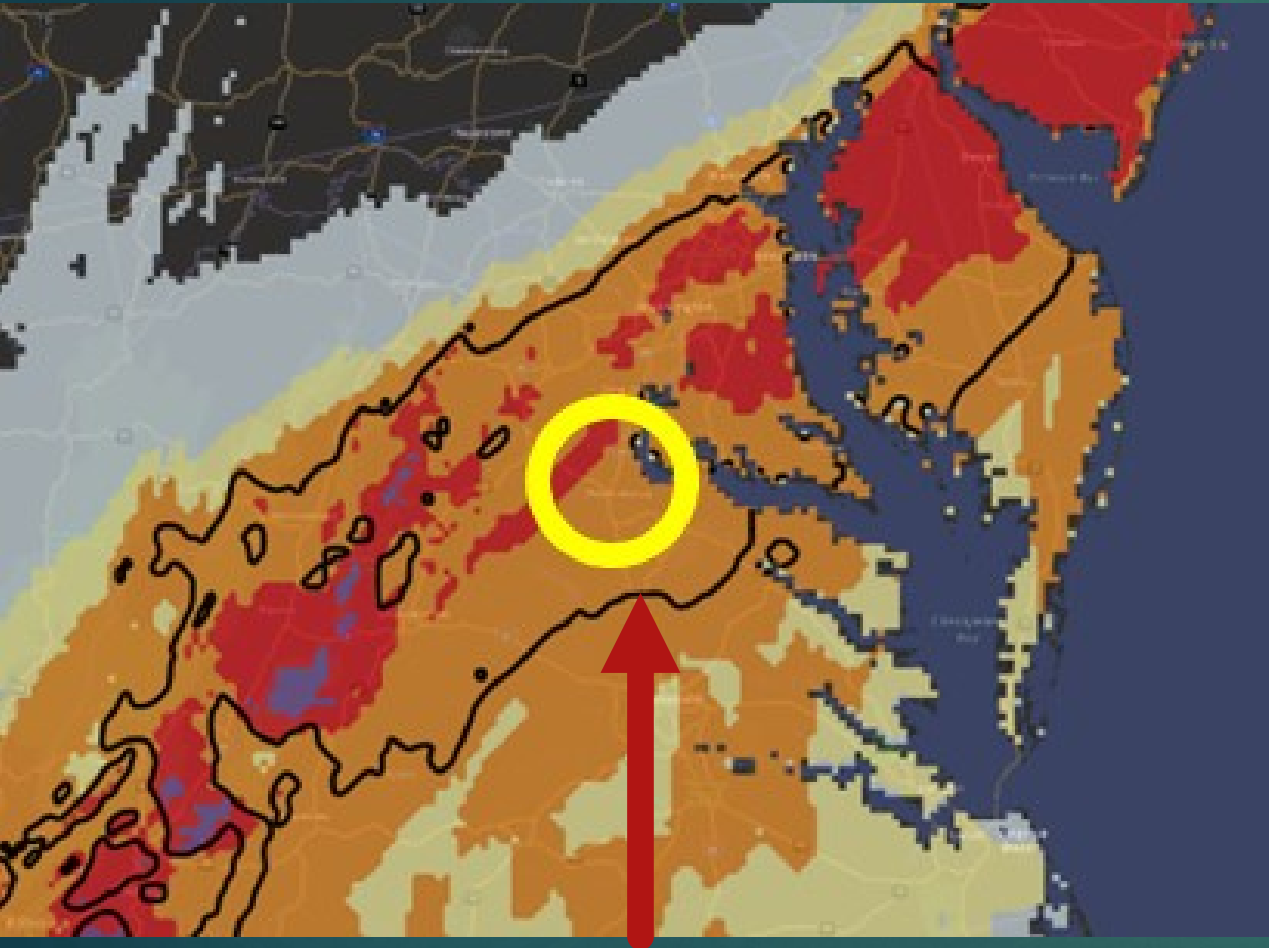


# Added Capabilities from Hourly Output: Duration of Impacts

- ▶ Long-duration events can have prolonged or cascading impacts
  - ▶ Recovery efforts may not begin until after weather has subsided
  - ▶ Potential inability to “keep up” with ongoing hazards
    - ▶ e.g., plows inundated by accumulations, more calls than first responders can manage
- ▶ Extended periods of hazardous weather can become life-threatening
  - ▶ e.g., stranded motorists from closures

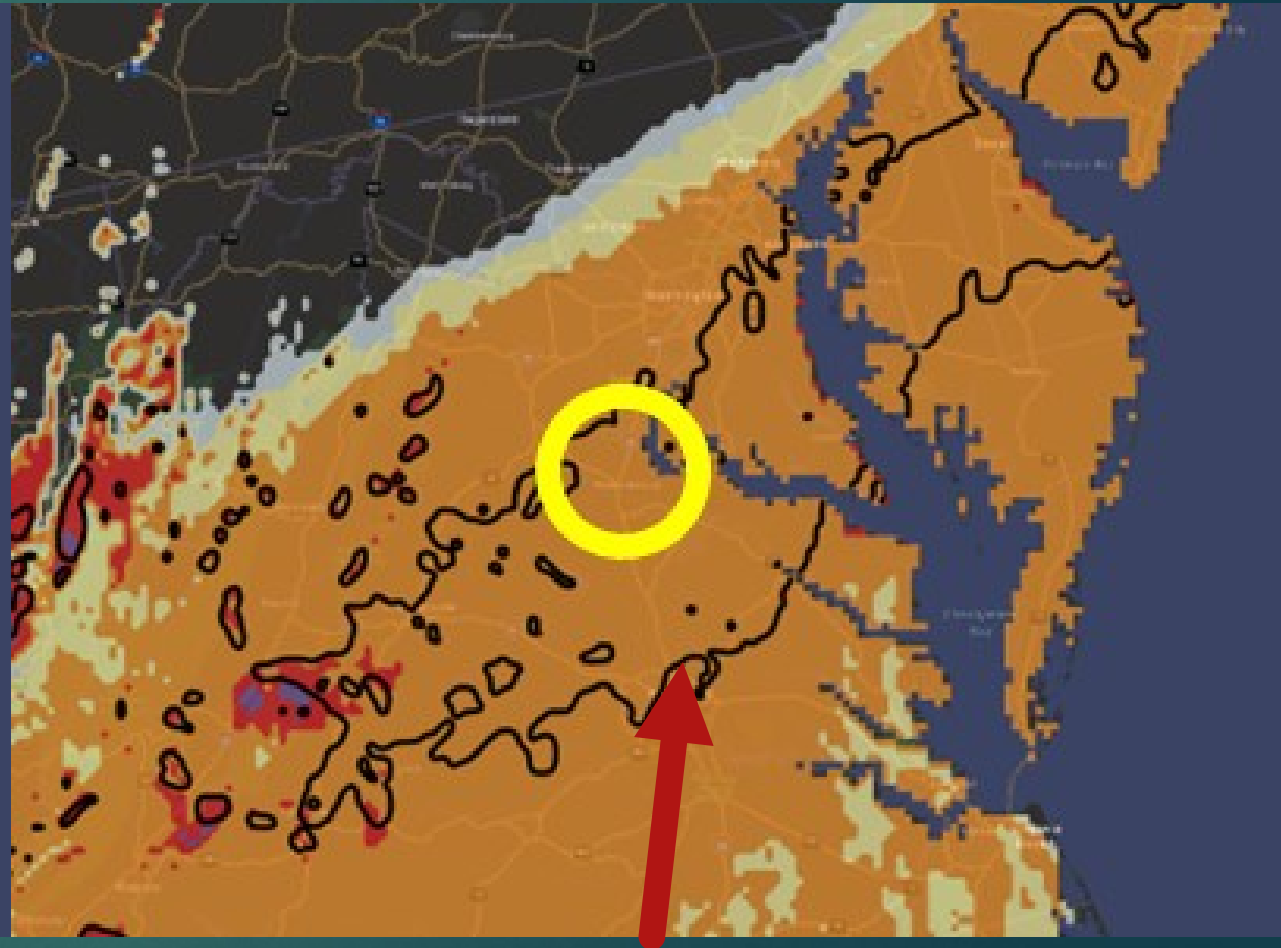
# 48h maximum WSSI-H Output – 3 January 2022 06Z

## Snow Rate



4+ consecutive hours of Moderate Impacts

## Blowing Snow

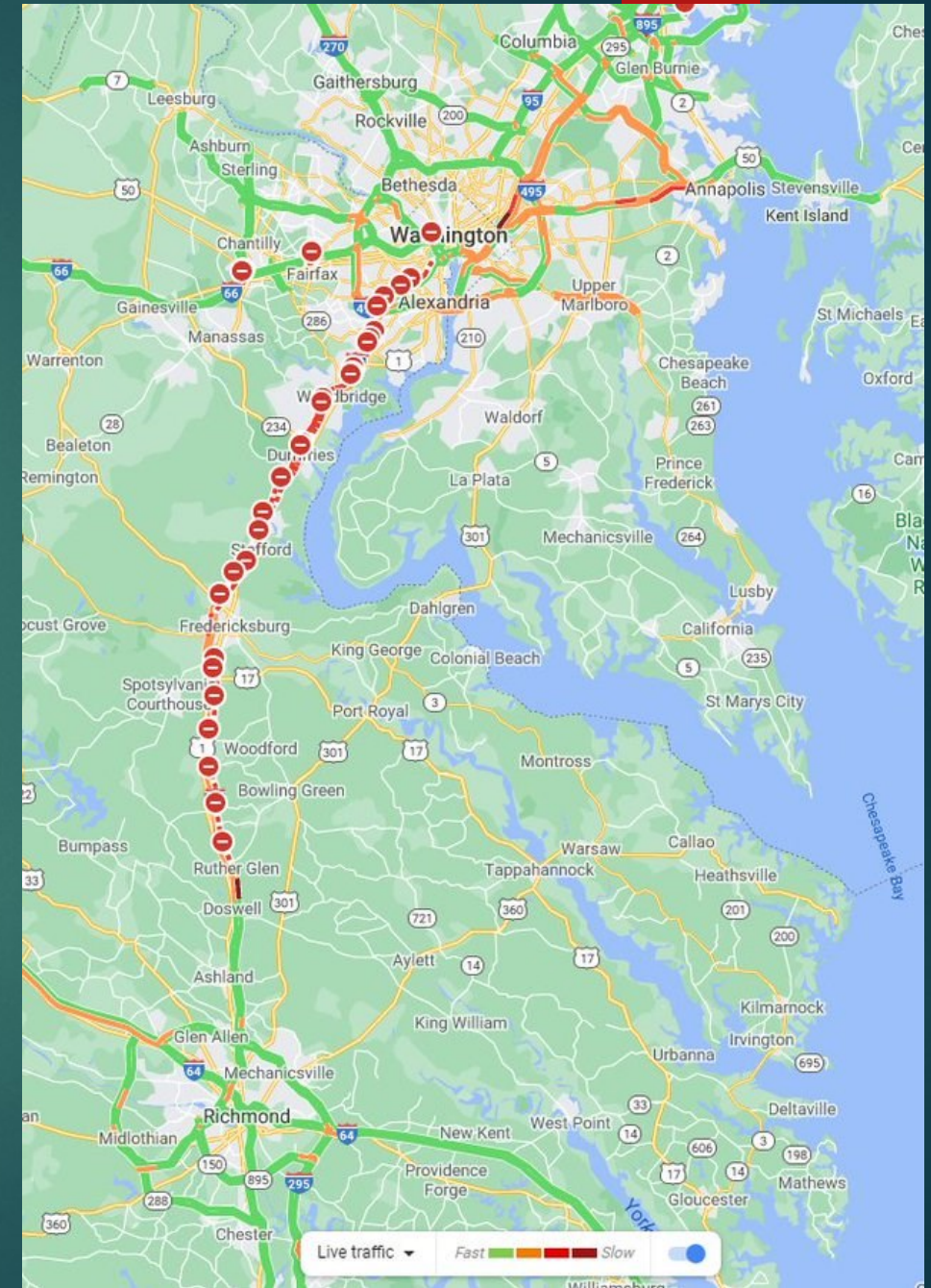


6+ consecutive hours of Moderate Impacts

**In Virginia, hundreds of people were stranded in their cars with little food and water for hours when I-95 closed due to snow.**



**This image provided by the Virginia department of Transportation shows a closed section of Interstate 95 near Fredericksburg, Va. Monday Jan. 3, 2022.** Virginia Department of Transportation via AP





# The Future of WSSI

- ▶ WSSI for Alaska!
- ▶ Cold weather impacts
  - ▶ Stand-alone component or product
- ▶ Additional non-meteorological factors and improvements
  - ▶ e.g., first snowfall, population density, holiday travel
- ▶ Web-based improvements and additional capabilities
- ▶ Additional verification
- ▶ Hourly Probabilistic WSSI (WSSI-HP??)



# Help us Improve WSSI!

- ▶ Forecasters

- ▶ Let us know how WSSI is performing!
- ▶ Work with us to figure out solutions/improvements

- ▶ Researchers

- ▶ Help us bring great research into operations!
- ▶ Have a great idea? Work with us to pursue future funding opportunities

- ▶ Connect with us!

- ▶ Dana Tobin [dana.tobin@noaa.gov](mailto:dana.tobin@noaa.gov)
- ▶ Kirstin Harnos [kirstin.harnos@noaa.gov](mailto:kirstin.harnos@noaa.gov)
- ▶ Jim Nelson [james.a.nelson@noaa.gov](mailto:james.a.nelson@noaa.gov)

