A December to Remember: Power Outages and Winter Storm Preparedness

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WINTRE-MIX Workshop - May 22, 2023

Vermont electric grid impacts: Dec 16: Most severe wet snow storm, Dec 23: top three wind storms (never in known history two storms so close)

dt DISASTERTECH

VERMONT ELECTRIC CO OP

vermont electric power company VELCO

GREEN MOUNTAIN POWER

Vermont Weather-Caused Power Outage Impacts (2011-2019)

Thunderstorm wind   Ice   Wet snow   Gradient wind

Total Customer Outage Hours

High

Low

0
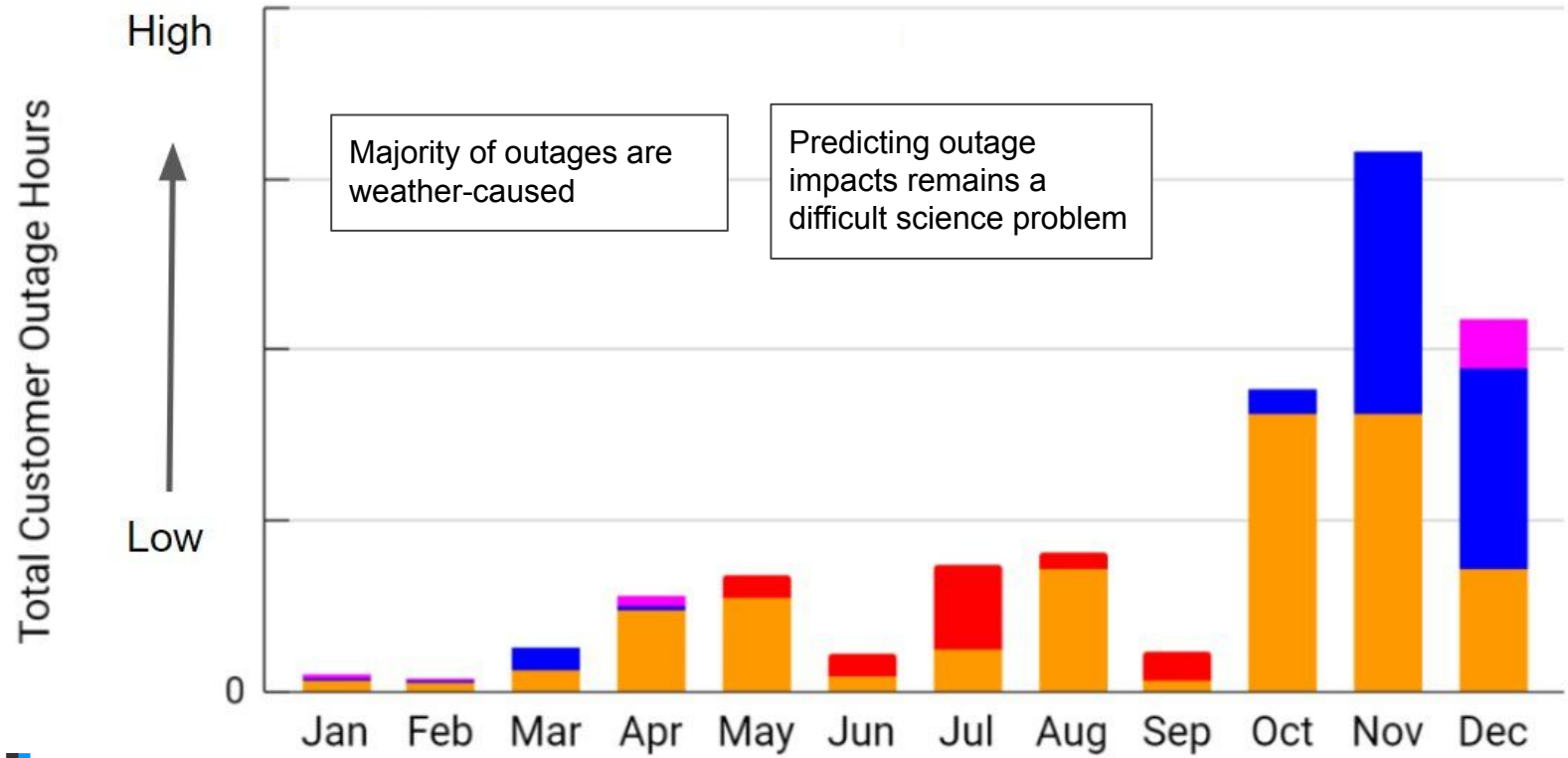
Majority of outages are weather-caused

Predicting outage impacts remains a difficult science problem

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

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Trees and Outages

County-Average Forest Cover

Percent Forested Land
- 1% - 15%
- 16% - 30%
- 31% - 40%
- 41% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 83%

Dec 23, 2023 Power System Resilience and Forest Condition

n=1450 (county aggregated over 16 states)

Low Forest Cover · High Forest Cover

Peak Customers Without Power

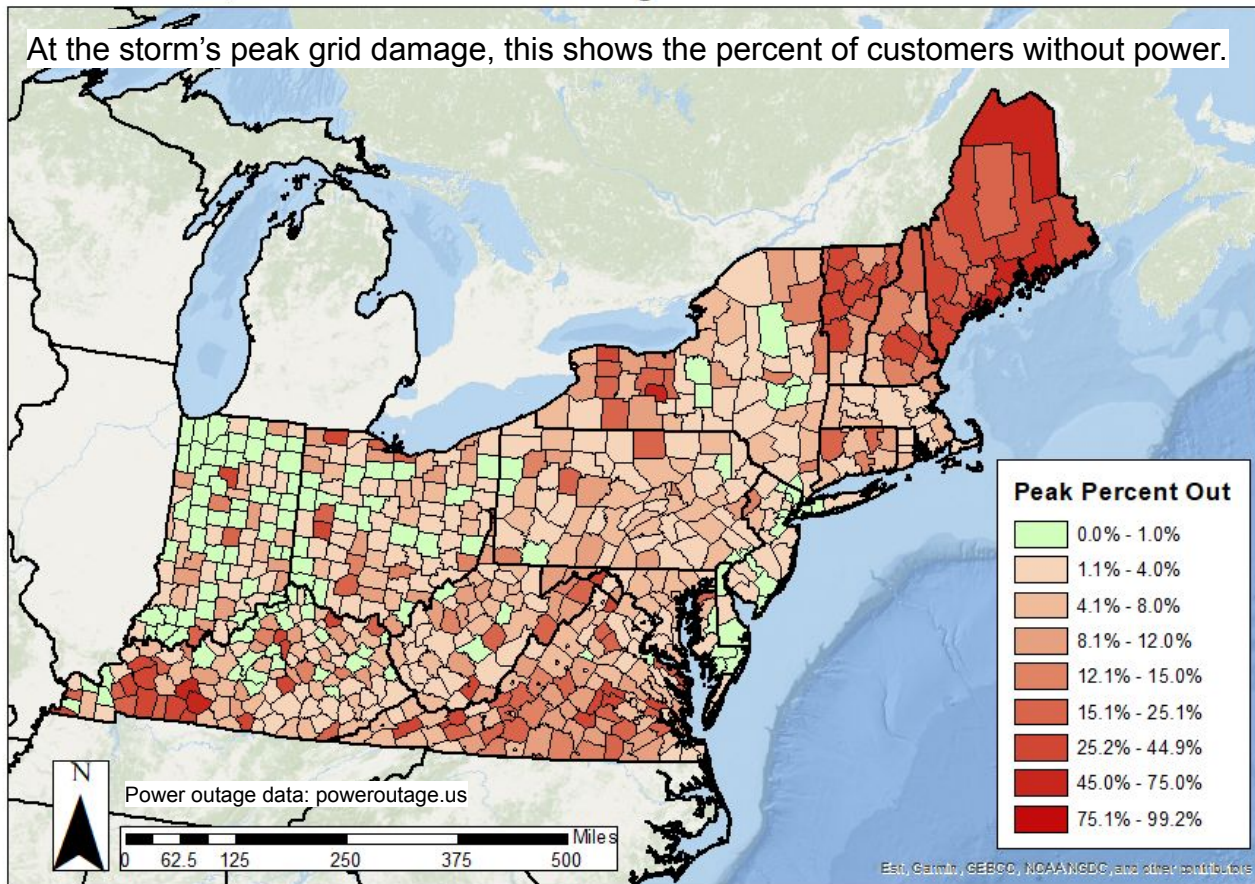|	31 to 40 mph	41 to 50 mph	51 to 60 mph
Low Forest Cover	6%	6%	10%
High Forest Cover	8%	9%	21%

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The Grinch Storm: Power Grid Impacts

- Primarily a wide-area or gradient wind event
- Similar wind performance could be used to inform what caused variability in power system fragility (good control storm over a large area)
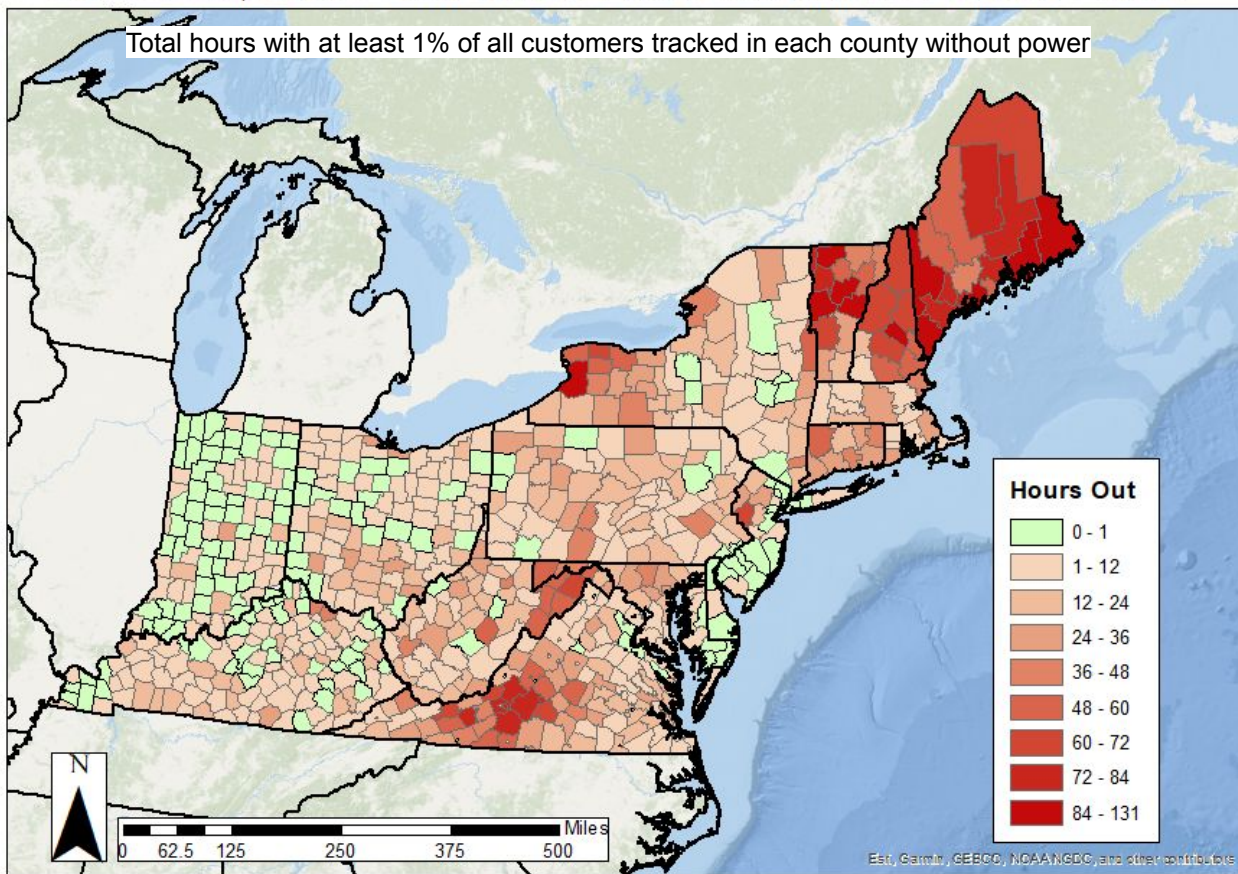- Record-breaking by strength and impacts (high winds, cold, Lake Effect snow)

Dec 23, 2022: 00Z

Dec 23, 2022: 18Z
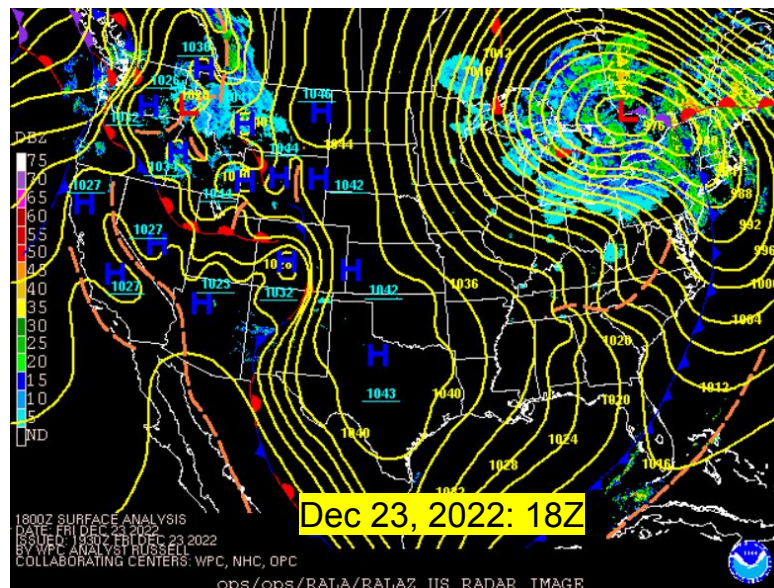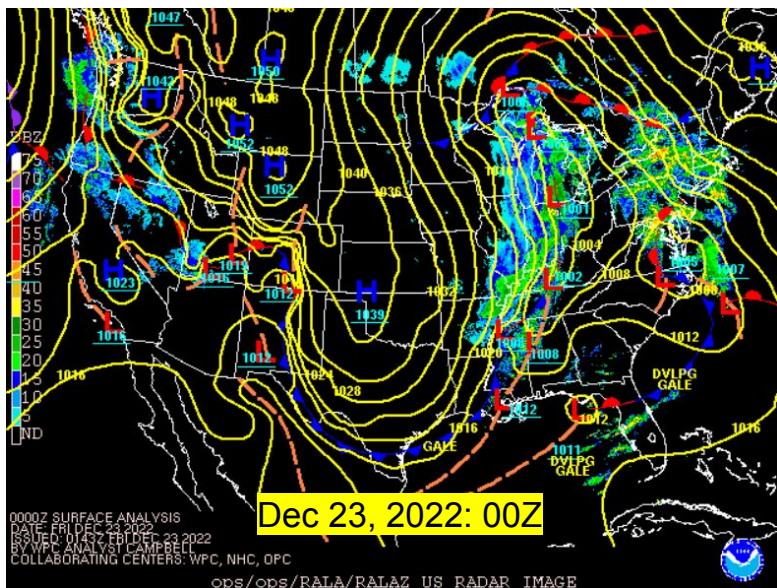
Dec 23-28, 2022: Peak Percentage of Customers Without Power

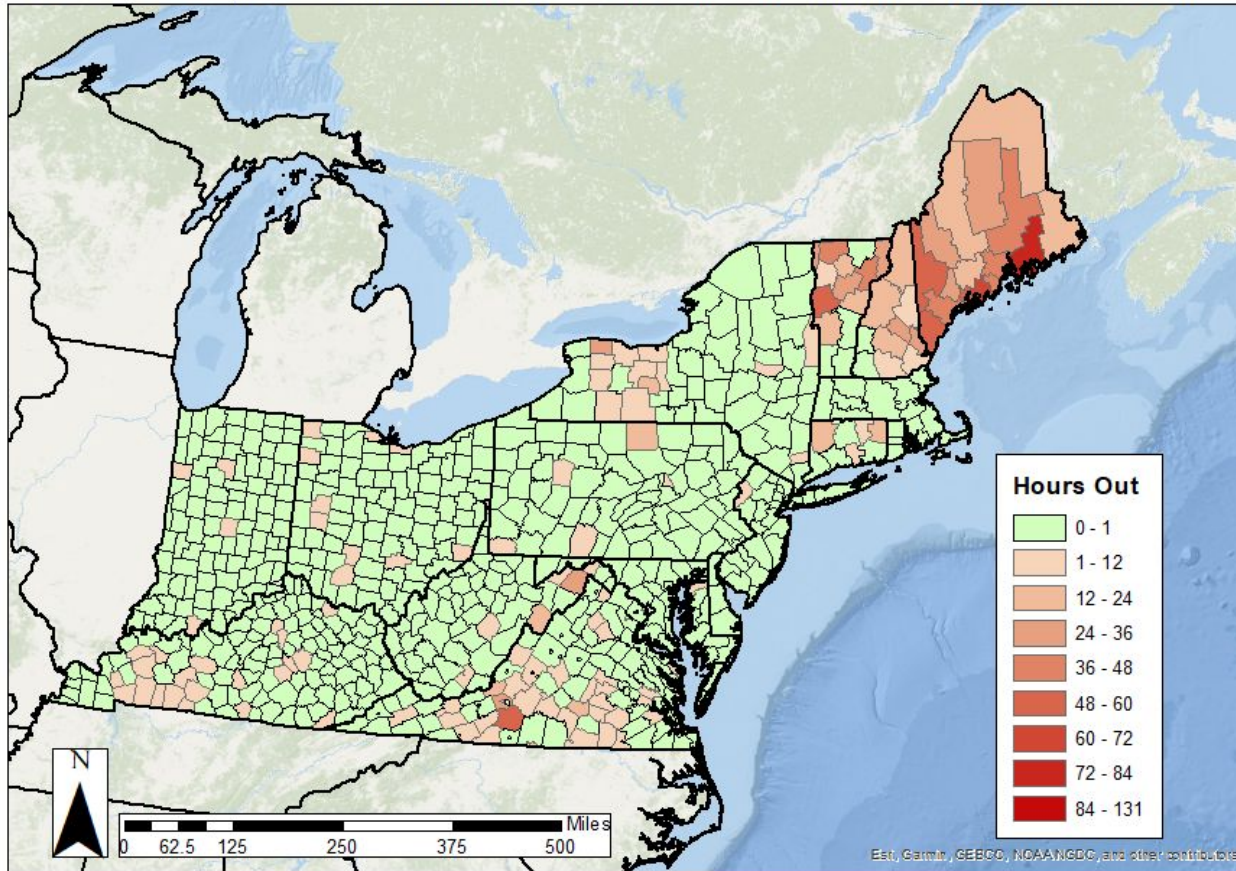At the storm's peak grid damage, this shows the percent of customers without power.

Peak Percent Out
- 0.0% - 1.0%
- 1.1% - 4.0%
- 4.1% - 8.0%
- 8.1% - 12.0%
- 12.1% - 15.0%
- 15.1% - 25.1%
- 25.2% - 44.9%
- 45.0% - 75.0%
- 75.1% - 99.2%

Power outage data: poweroutage.us

Key research goal: Understand what factors can explain this variability

Dec 23-28, 2022: Total Hours 1% of Customers Without Power

Total hours with at least 1% of all customers tracked in each county without power

Hours Out
- 0 - 1
- 1 - 12
- 12 - 24
- 24 - 36
- 36 - 48
- 48 - 60
- 60 - 72
- 72 - 84
- 84 - 131

Miles
0   62.5   125   250   375   500

Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Dec 23-28, 2022: Total Hours 10% of Customers Without Power

Hours Out

- 0 - 1
- 1 - 12
- 12 - 24
- 24 - 36
- 36 - 48
- 48 - 60
- 60 - 72
- 72 - 84
- 84 - 131

Miles
0   62.5   125   250   375   500

Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

Dec 23-28, 2022: Total Hours 25% of Customers Without Power

Hours Out
- 0 - 1
- 1 - 12
- 12 - 24
- 24 - 36
- 36 - 48
- 48 - 60
- 60 - 72
- 72 - 84
- 84 - 131
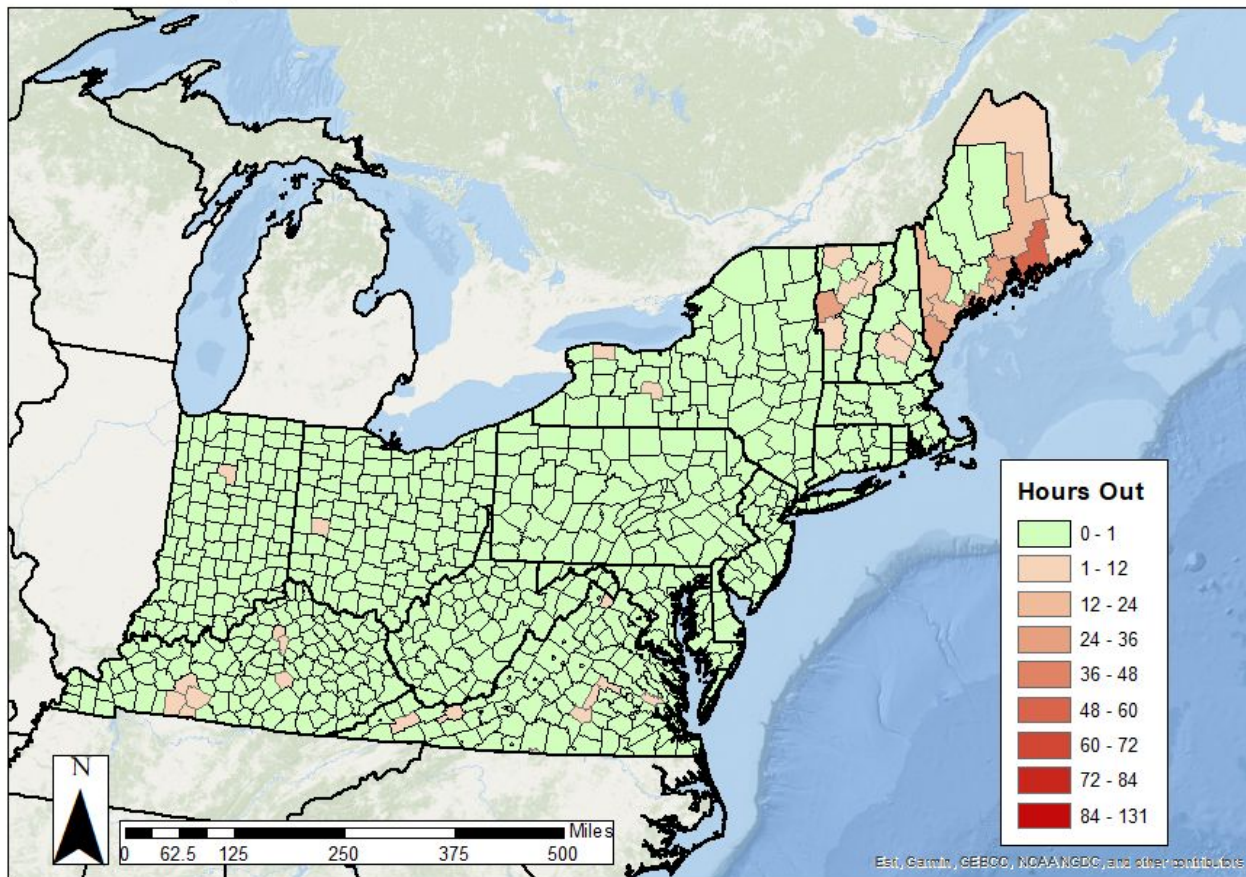
Dec 23, 2022 County-Based Fragility and Weather Stress
(n=1450)
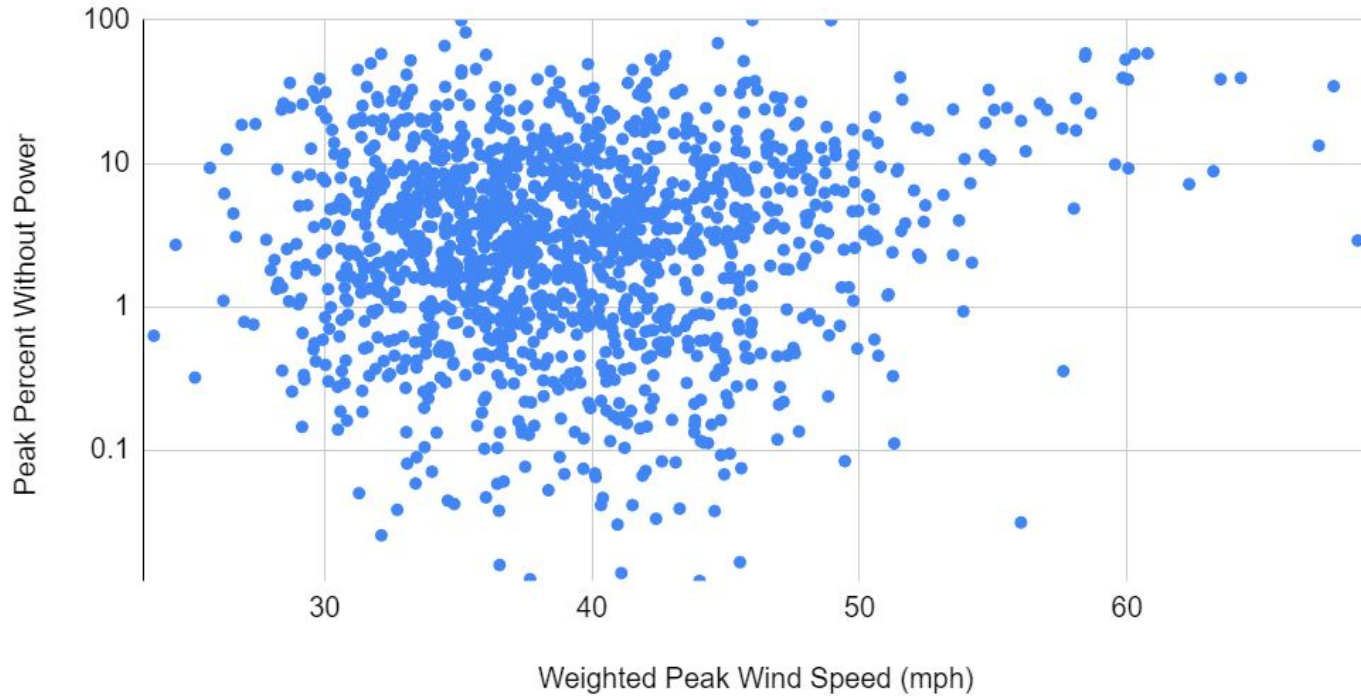
Key result: This is a non-linear problem with many variables explaining this variability.
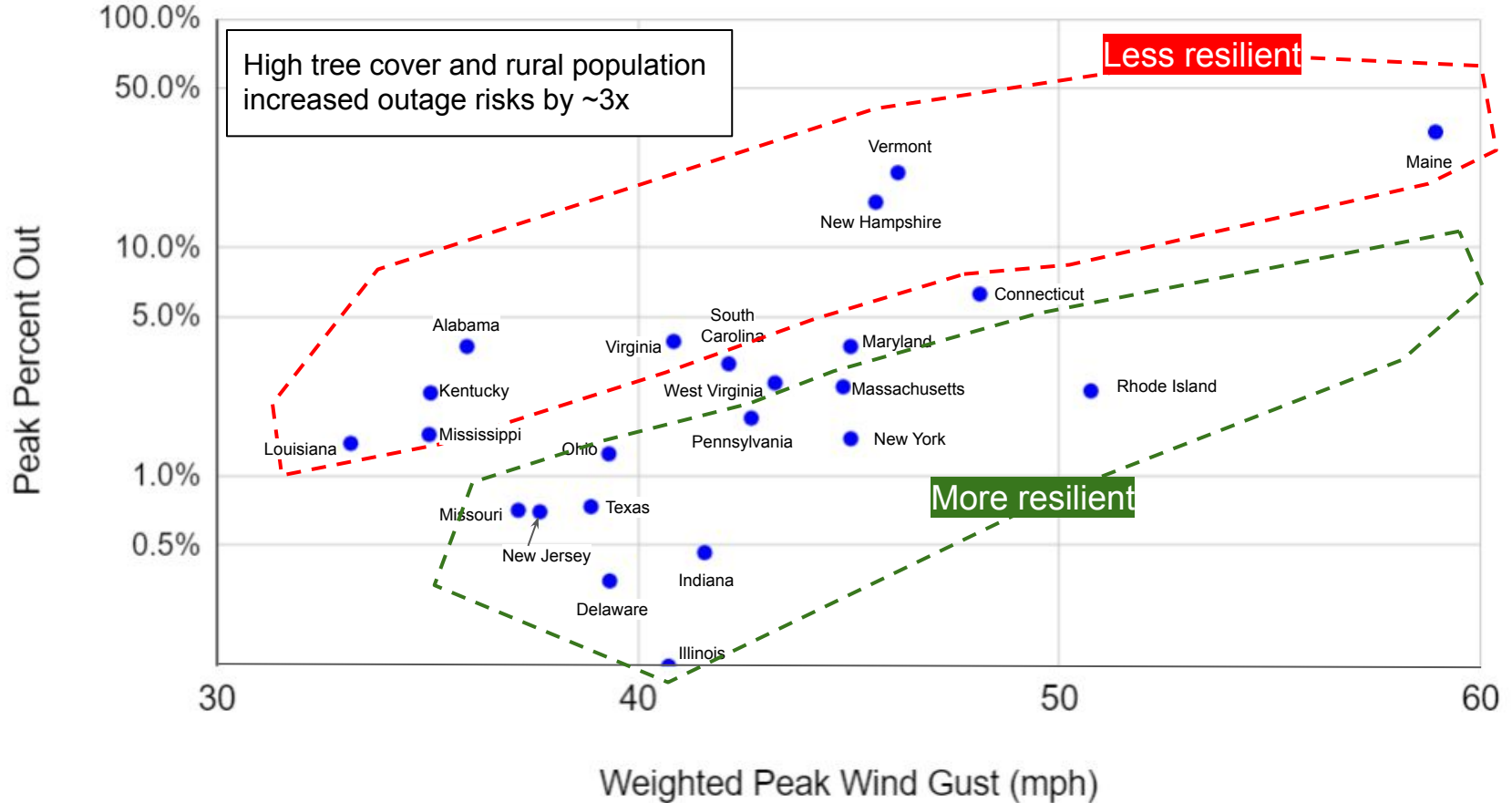
Dec 23, 2023 Power System Resilience

Percent Out at Peak ■ SAIDI

SAIDI is a standard reliability metric - in this case it's the average outage duration (hours)

n=1450 (county aggregated over 16 states)
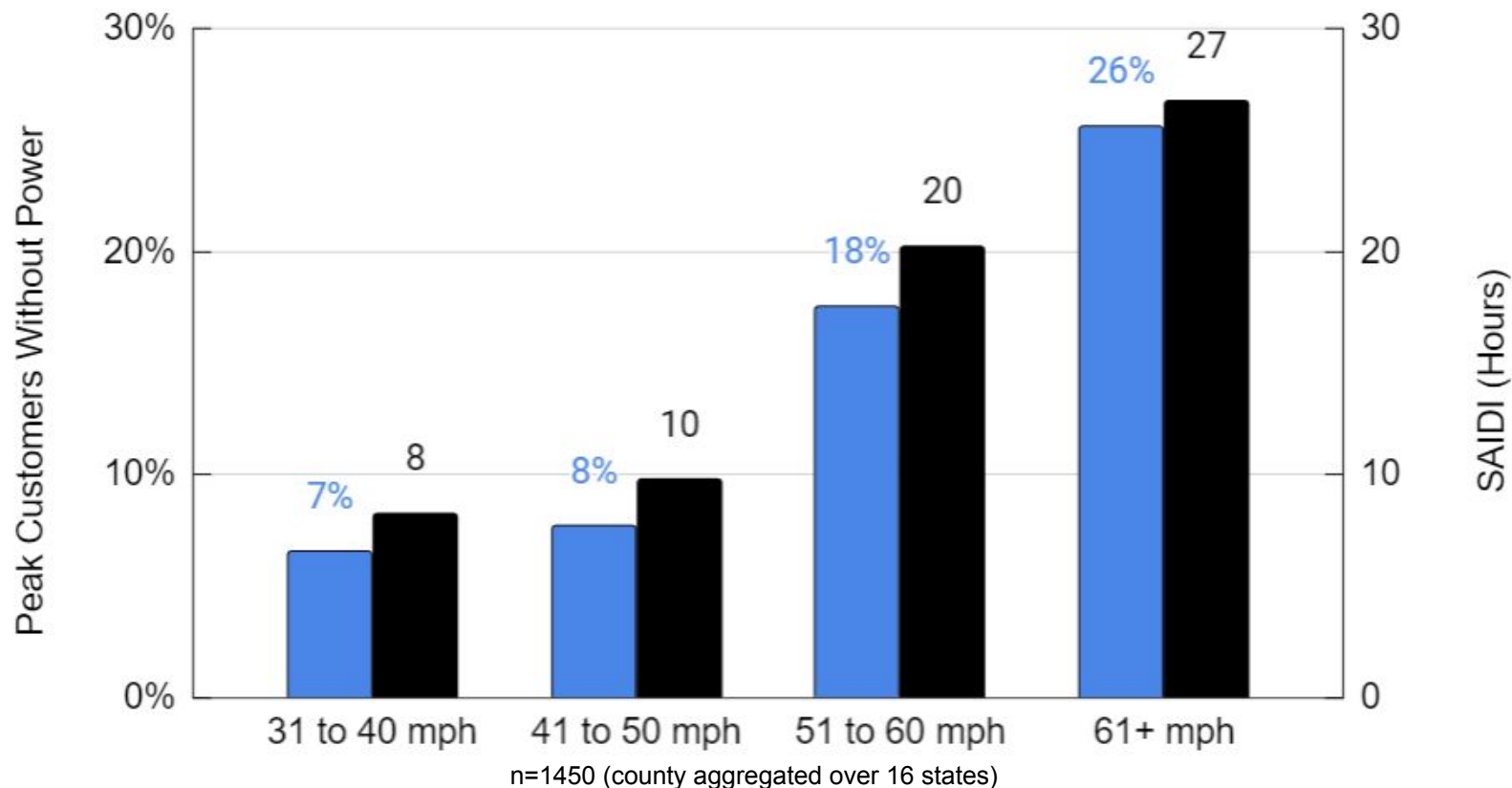
Peak Wind and Reliability Performance

High tree cover and rural population increased outage risks by ~3x

Less resilient

More resilient

Peak Percent Out

Weighted Peak Wind Gust (mph)

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Wet Snow Loading Forecast Challenges

Wet snow causes ~20% of power outages across northeast US

No standardized way to measure or predict loading on trees/lines

Predictability challenged by thermodynamic environments (melting layers, precipitation intensity)

We should stop using snow-to-liquid ratio thresholds. Our work uses a surface wet bulb temperature to identify wet snow liquid near the melting point.
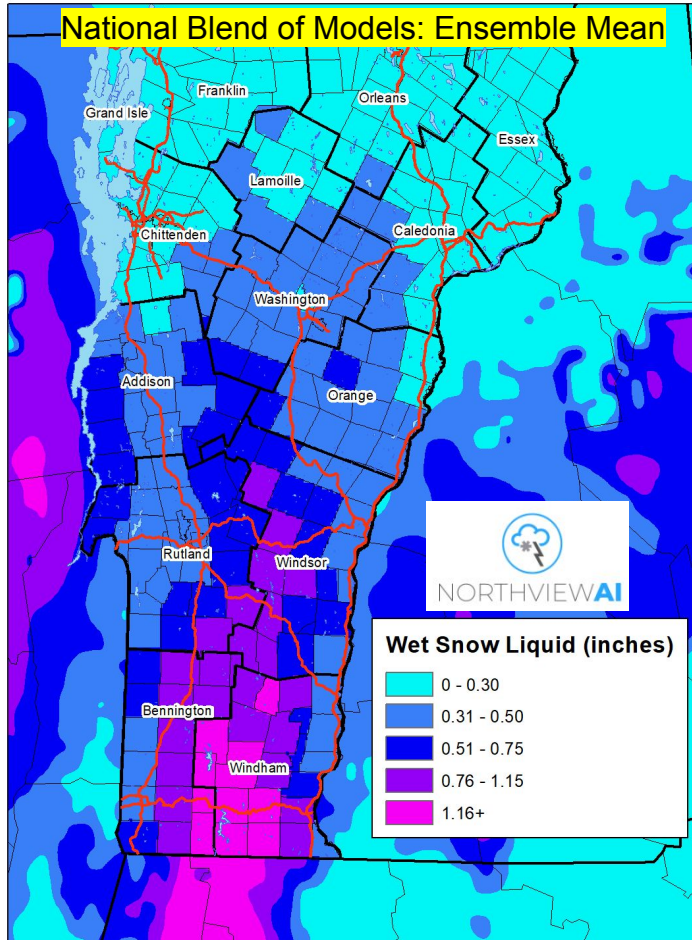
Green Mountain Power

Identifying Wet Snow

Melting Layer
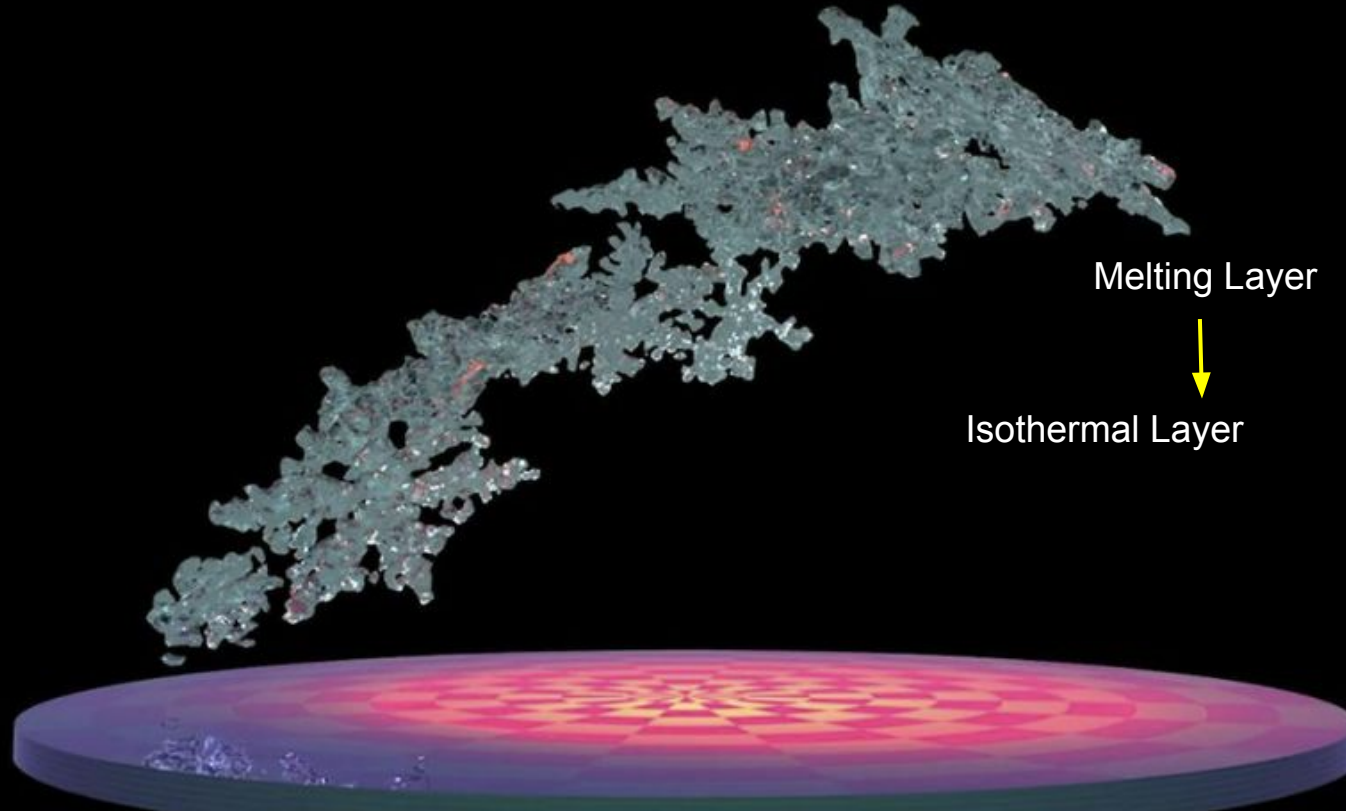
Isothermal Layer

Amplifying Risk Factors:
- High precipitation rates
- Deep isothermal layer
- Steady-state thermodynamic environment (slow-moving storm)
- Subfreezing surface temperatures

NASA melting snow: Scientists Create First-Ever 3-D Model of a Melting Snowflake - YouTube

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GMP Top Wet Snow Storms Outage Profile (2009-2023)

Nov 27-Dec 2, 2018

Dec 16-20, 2022

Dec 11-16, 2014

Wet snow was identified as the Vermont grid hazard with the highest confidence to increase in risk with warmer winter storm profiles forced by climate change.

Feb 25-Mar 1, 2010

Customers Out

Hour into Storm

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NORTHVIEW AI

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Dec 15-16, 2022 Wet Snow Liquid Forecast
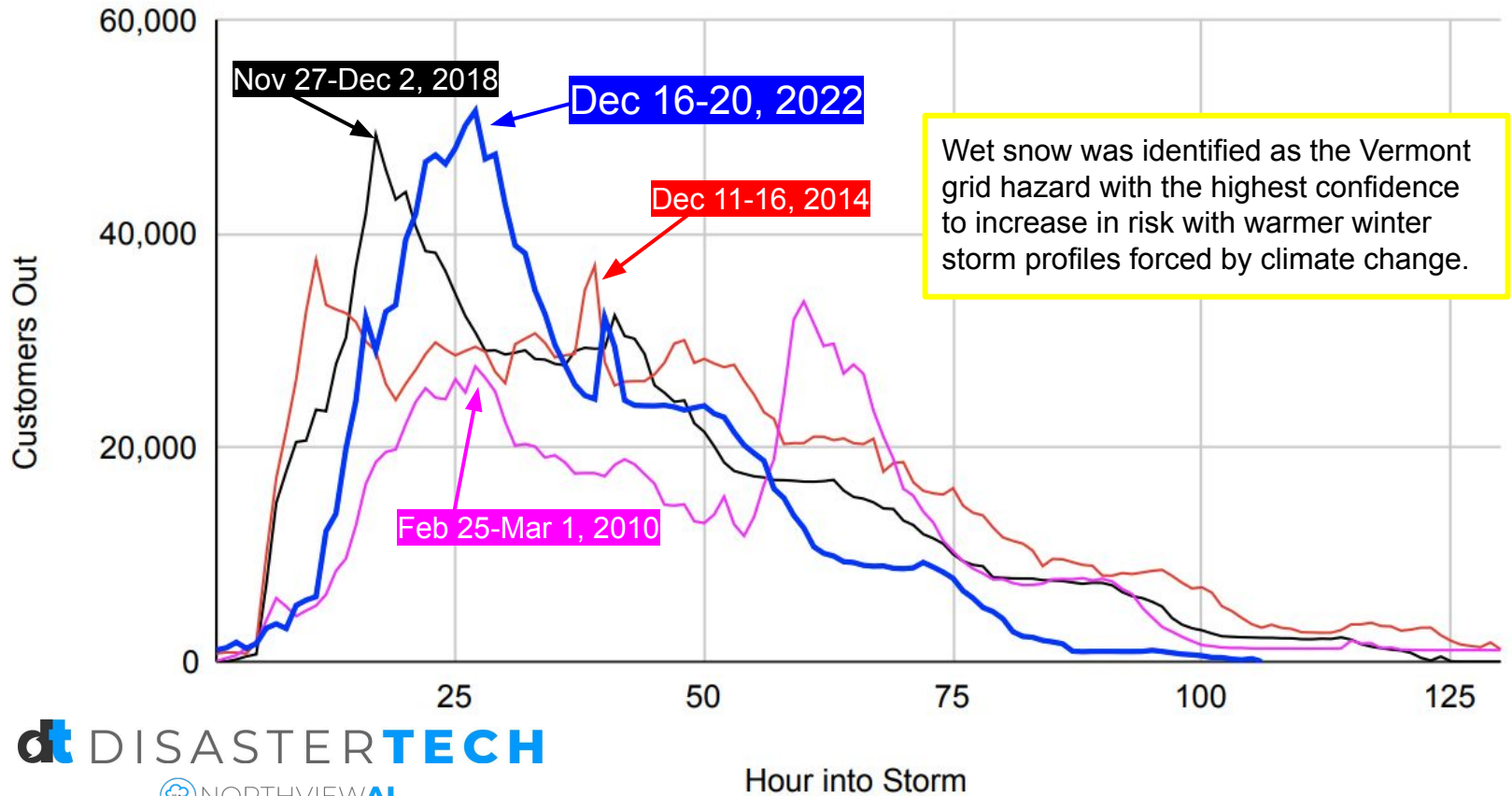
Power Outages at Storm Peak

Most severe impacts were about 30-50 miles further north than short-term forecasts

vtoutages.com
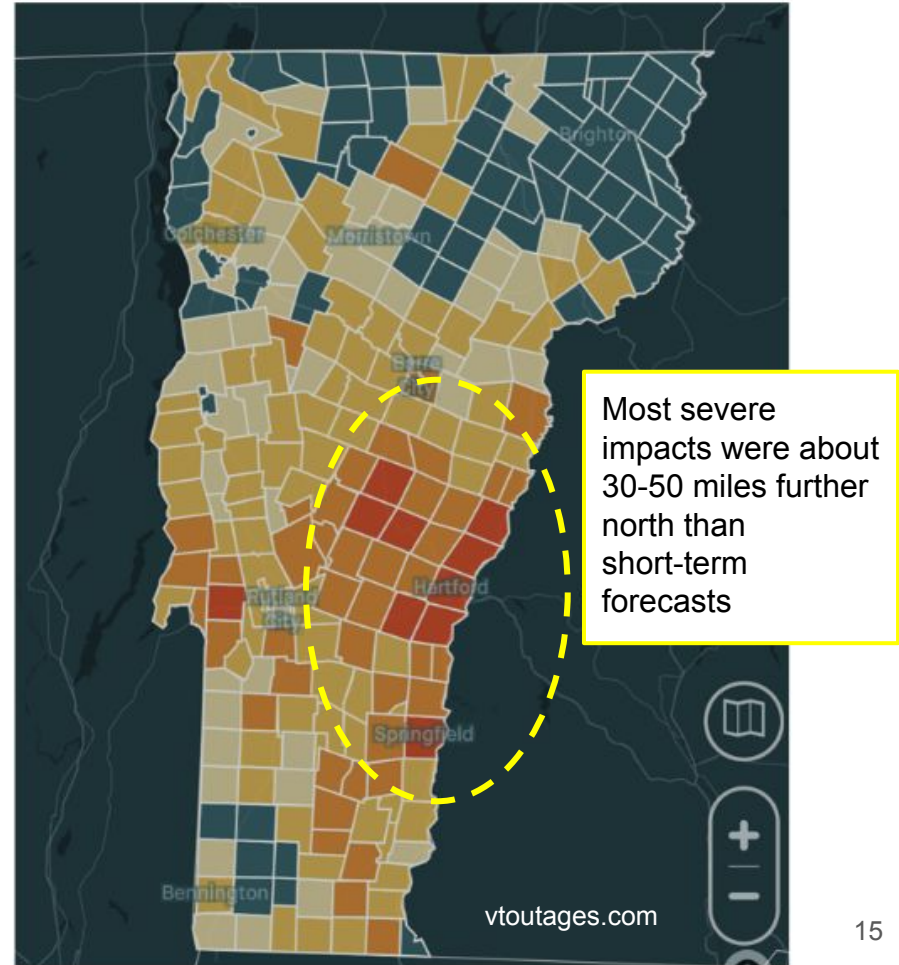
Communicating Forecast Variability

Forecast risk profile described in five scenarios.
Golden rule: communicate uncertainty with certainty.

GMP Wet Snow Outage Event Forecast for Dec 16 - 17, 2022
Data Input: National Blend of Models

Scenario	Forecast Run	Dec 13	Dec 14	Dec 15	Dec 16	Last Three Run Average
	10th Percentile	0	0	104	179	94
	25th Percentile	12	164	595	583	447
	Mean	763	928	1,547	1,655	1,376
	75th Percentile	1,499	2,117	2,411	2,244	2,257
	90th Percentile	2,825	3,718	3,994	3,349	3,687

Validation

1,963

Validation was between mean and 75th percentile. Users would rather know variability than plan on a deterministic value.

Forecast trend over time

We recommend time averaging to account for run-to-run variability.

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WSSI: Snow Loading Applications

Research Wish List

Improving citizen-science ice measurement

Standardized wet snow accretion/loading

Feb 1, 2023 TX Ice Storm - CoCoRaHS Obs

Computer vision…

Summary

Threshold-based risk for electric utility storm planning remain best practice vs. complex ML models

Compounding uncertainty with phase and amount make it very **difficult** to make well informed storm planning decisions beyond ~2 to 3 days ahead for wet snow and ice

Communicate uncertainty with **certainty**; let the forecast variability speak for itself

Human-in-the-loop provides value through articulating **story** (storm evolution) and **known** biases/insights

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