

Midwest Agrivoltaics for Resilient Communities (MARC)

Breakout session: Energy and Economic Resilience of Agrivoltaics



Institute for a
Sustainable Future



Tackle key barriers – three prongs

1. Extreme weather resilience
(ag + energy)

2. Suitability (design)

3. Acceptability (trust)

Imagine a world *not* affected by
extreme weather.
Can agrivoltaics help get us there?



Extreme weather

Dan Chavas

Energy resilience

Xiaonan Lu

Economic resilience

Juan Sesmero

Extreme weather

Dan Chavas

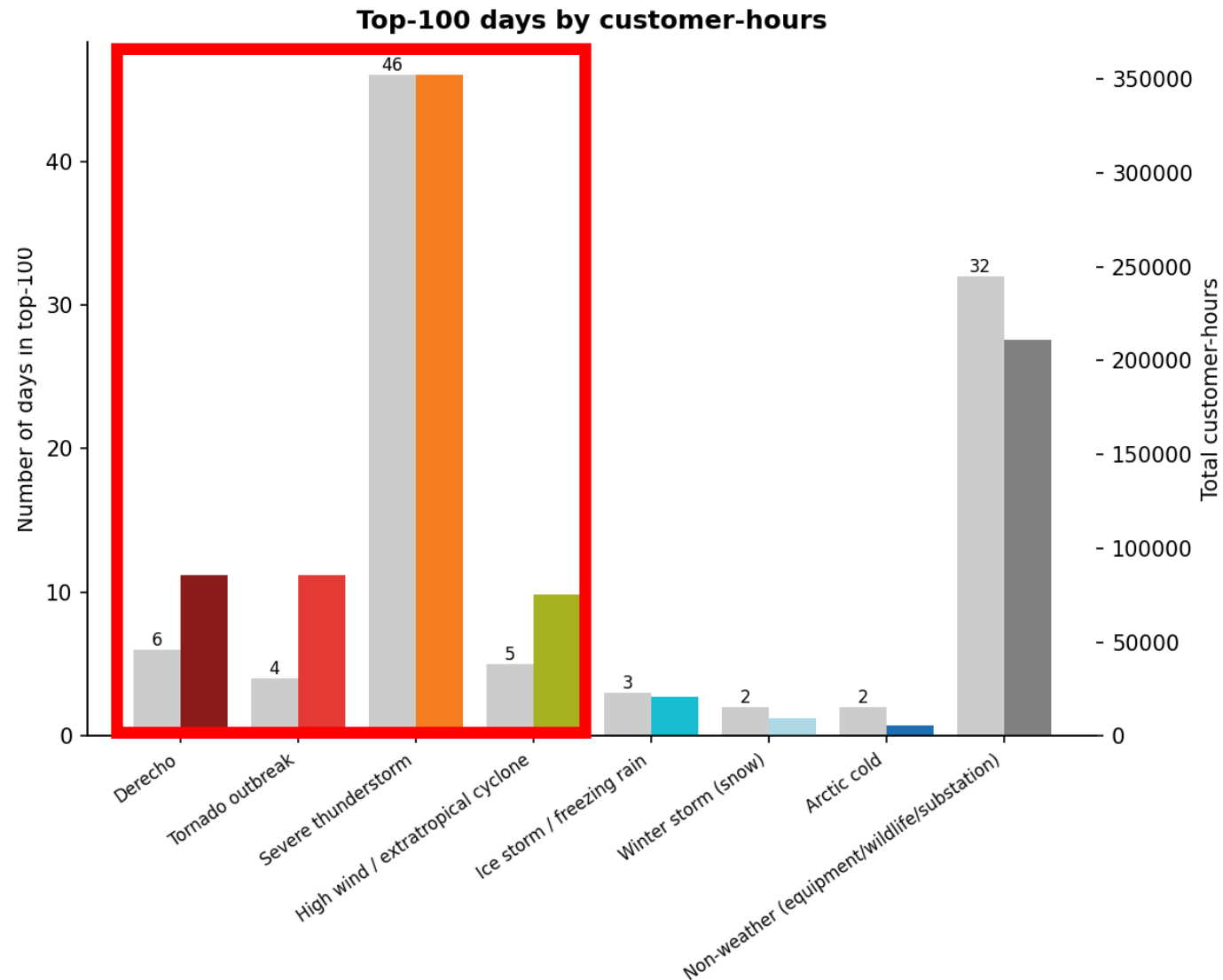
Purdue University, Earth, Atmospheric and Planetary Sciences

with Danny Brouillette and Melissa Widhalm (Midwest Regional Climate Center)



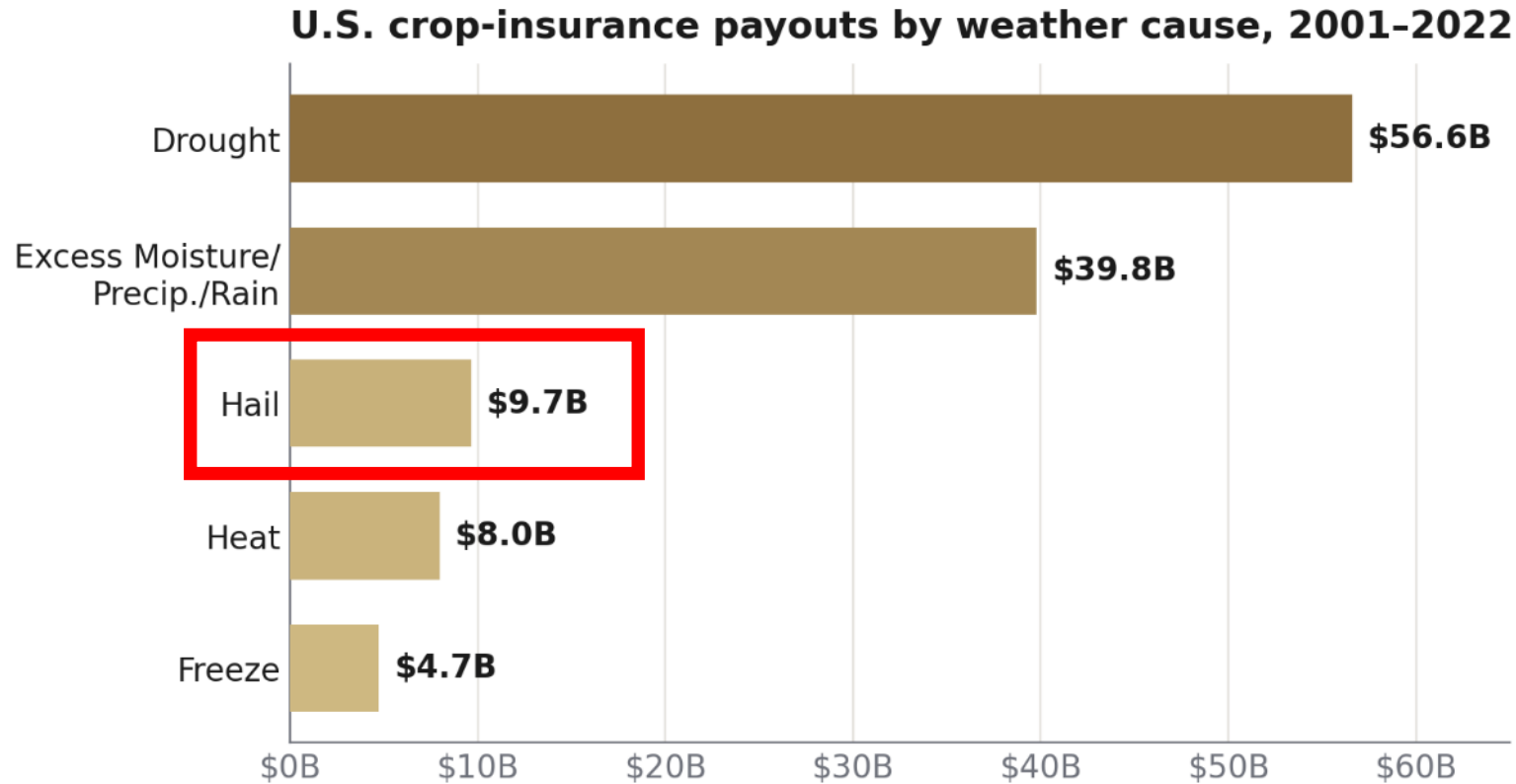


Severe wind storms
dominate!





Drought and excess moisture dominate crop losses



\$118.8B

Total weather-related crop-insurance payouts, 2001–2022 (73% of all payouts)

60%

of that total came from drought + excess moisture alone

Indiana lies in the heart of the Corn Belt, so it is directly exposed to the two dominant perils.

A new public interface for extreme weather maps and trends (development ongoing)

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A new public interface for extreme weather maps and trends (development ongoing)

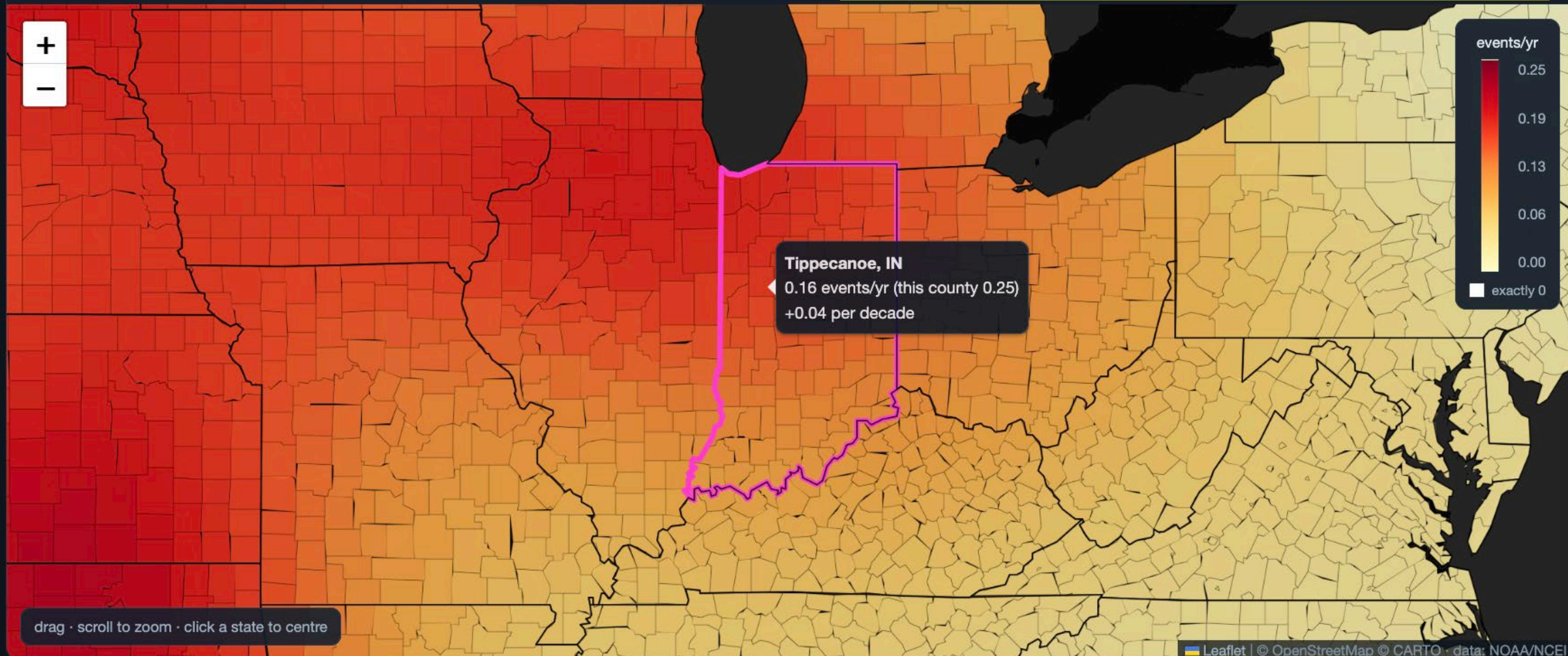
Derecho (>58 mph)

Source: Squidieri et al. (2026, BAMS)

+ NOAA Storm Prediction Center storm reports

Climatology

Mean annual derecho events per county, 2001–2024 · 2° Gaussian smoothed



A new public interface for extreme weather maps and trends (development ongoing)

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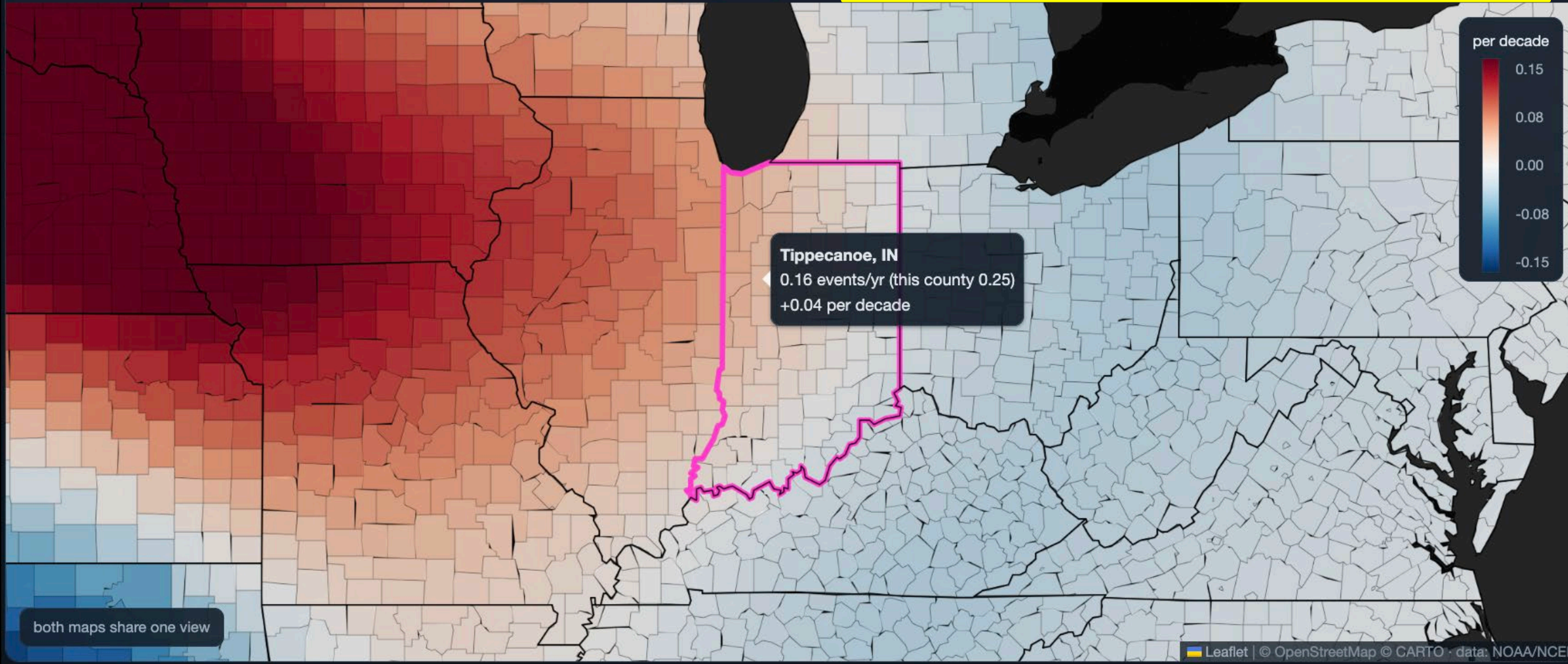
Source: Squidieri et al. (2026, BAMS)

+ NOAA Storm Prediction Center storm reports

Trend

Change per decade · outlined where $p < 0.05$ · **2° Gaussian smoothed**

Trends are inherently far noisier: focus on coherent spatial patterns, not the value in any single county.



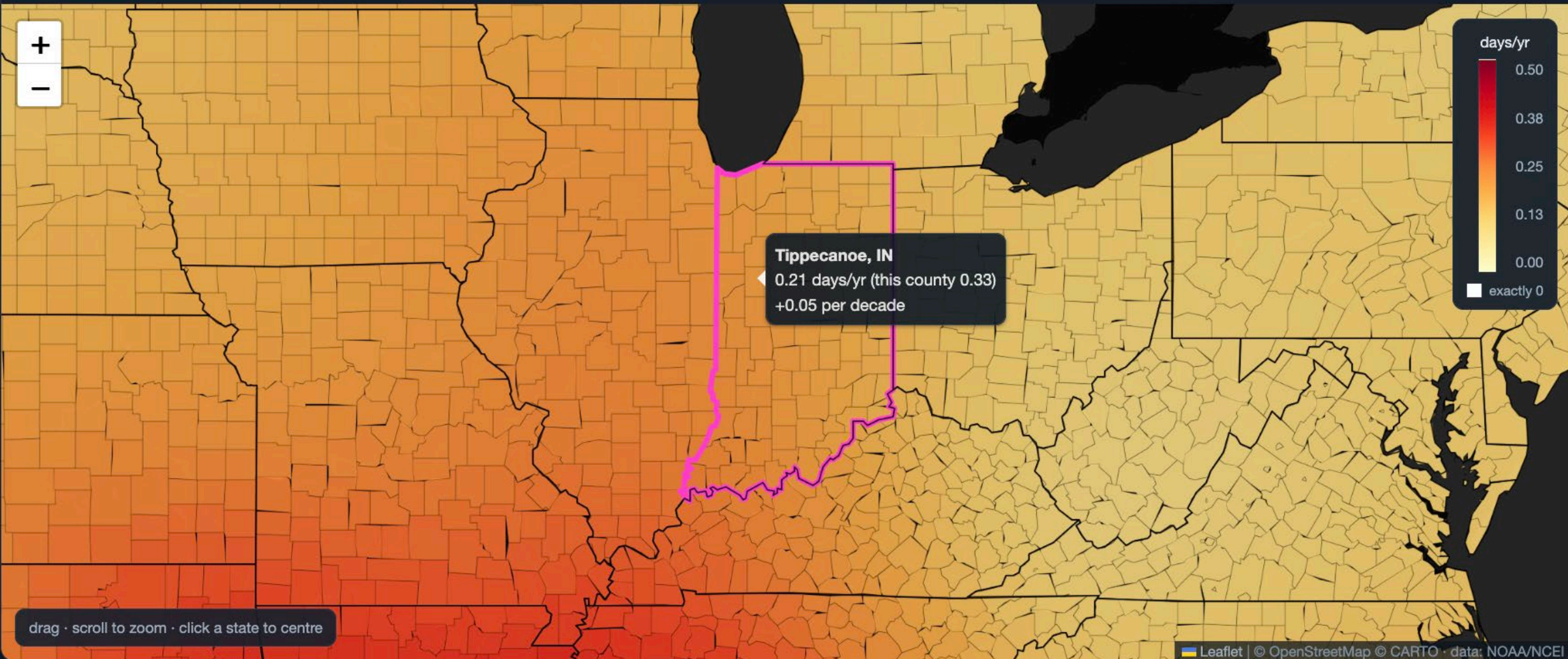
A new public interface for extreme weather maps and trends (development ongoing)

Tornado (EF1+)

Source: NOAA Storm Prediction Center storm reports

Climatology

Mean annual tornado days per county, 2001–2024 · 2° Gaussian smoothed



A new public interface for extreme weather maps and trends (development ongoing)

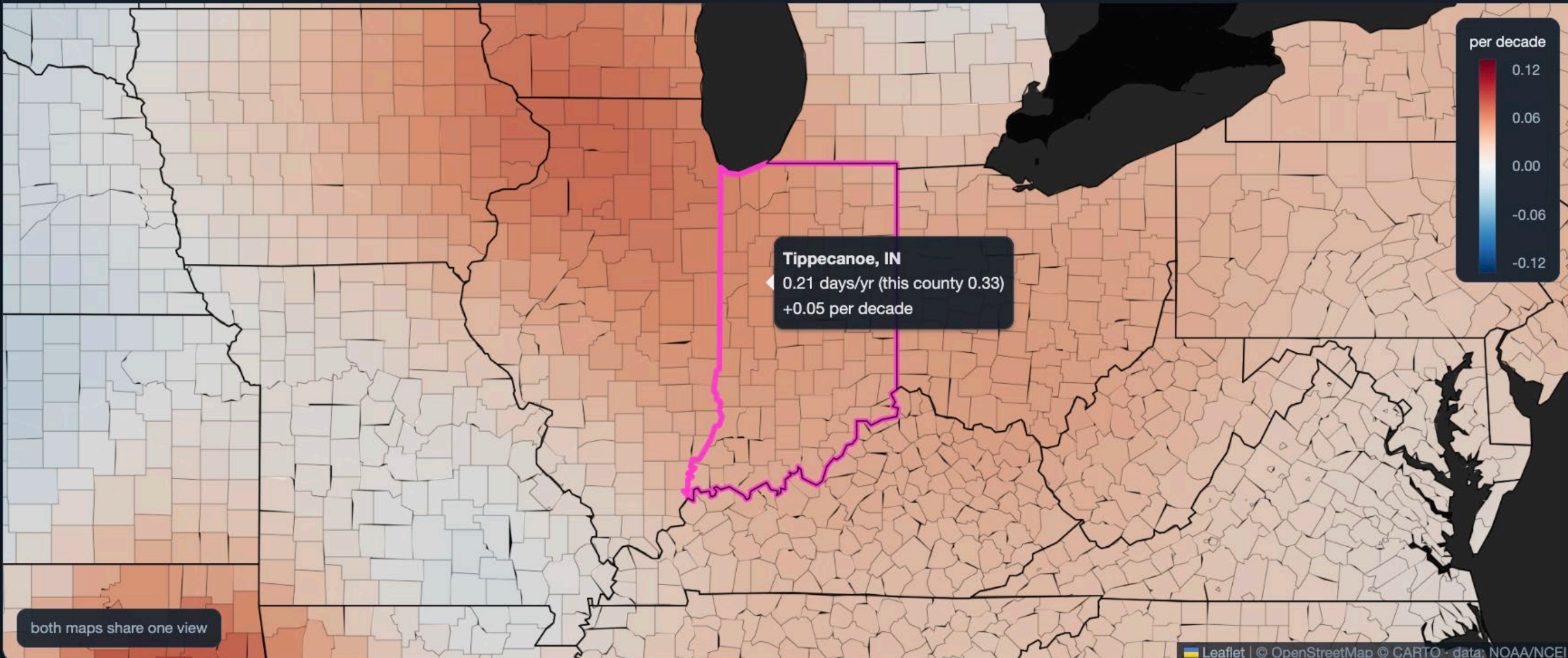
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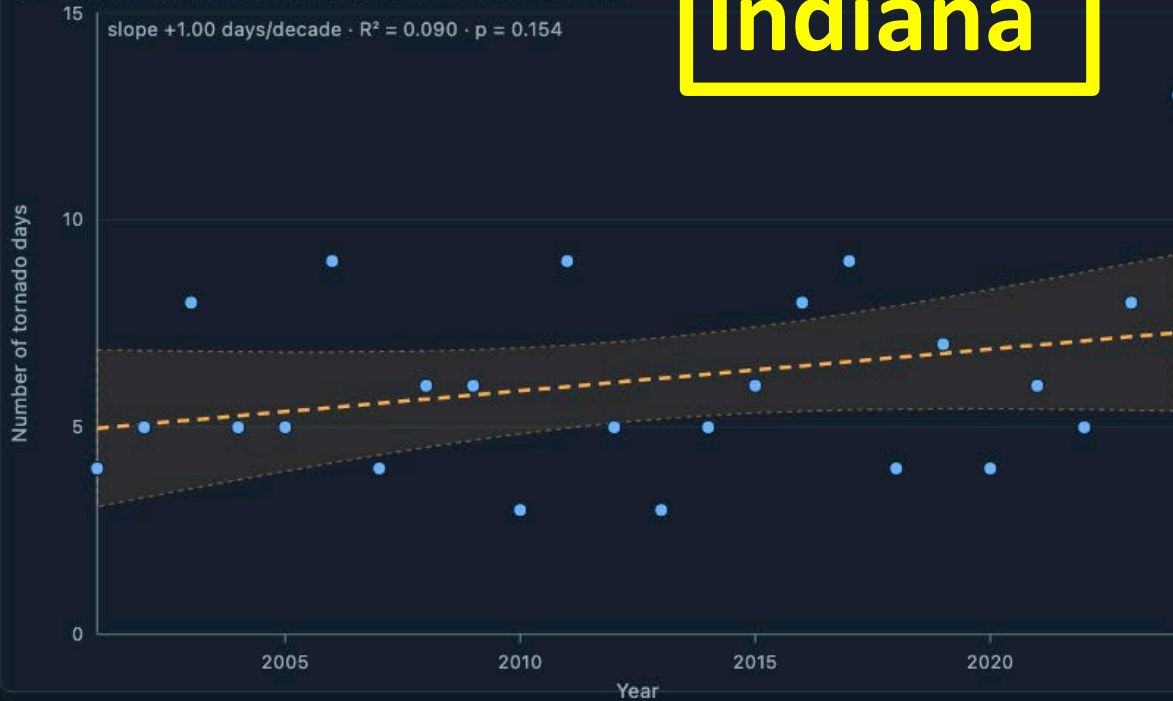
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Annual number of tornado days

2001–2024 · with least-squares trend and 95% confidence band

slope +1.00 days/decade · $R^2 = 0.090$ · $p = 0.154$

Indiana



Month by month

Days per month each year, 2001–2024 · trend with 95% band, bold R^2 = significant at $p < 0.05$



both maps share one view

A new public interface for extreme weather maps and trends

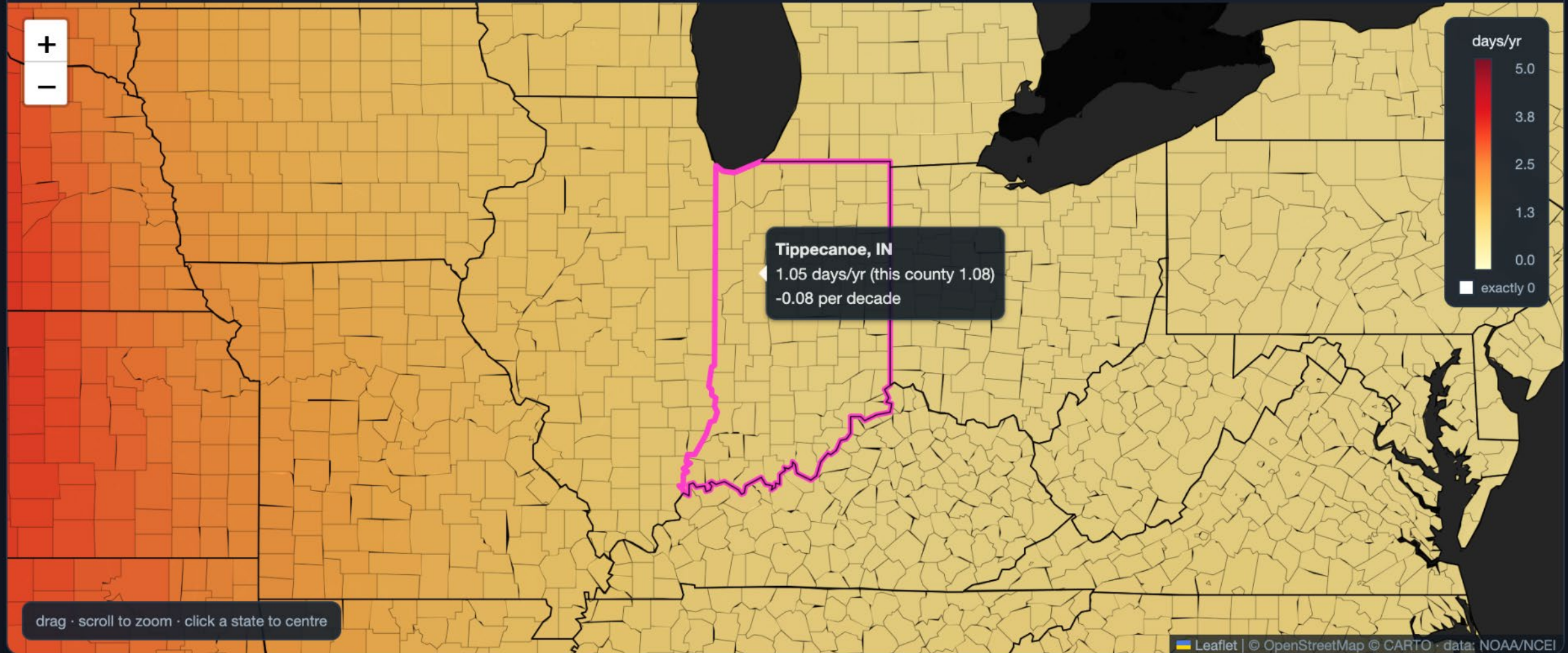
(development ongoing)

Hail (>1")

Source: NOAA Storm Prediction Center storm reports

Climatology

Mean annual hail days per county, 2001–2024 · 2° Gaussian smoothed



A new public interface for extreme weather maps and trends (development ongoing)

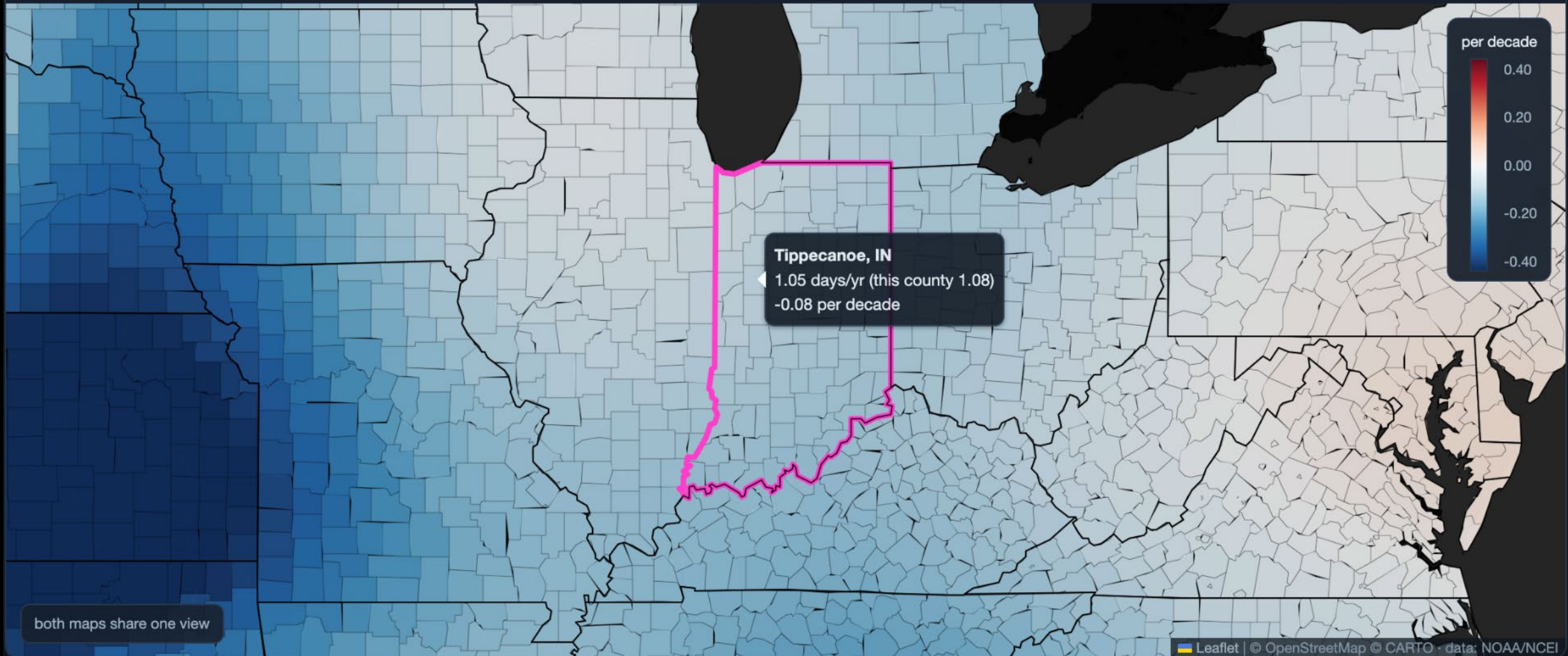
Hail (>1")

Source: NOAA Storm Prediction Center storm reports

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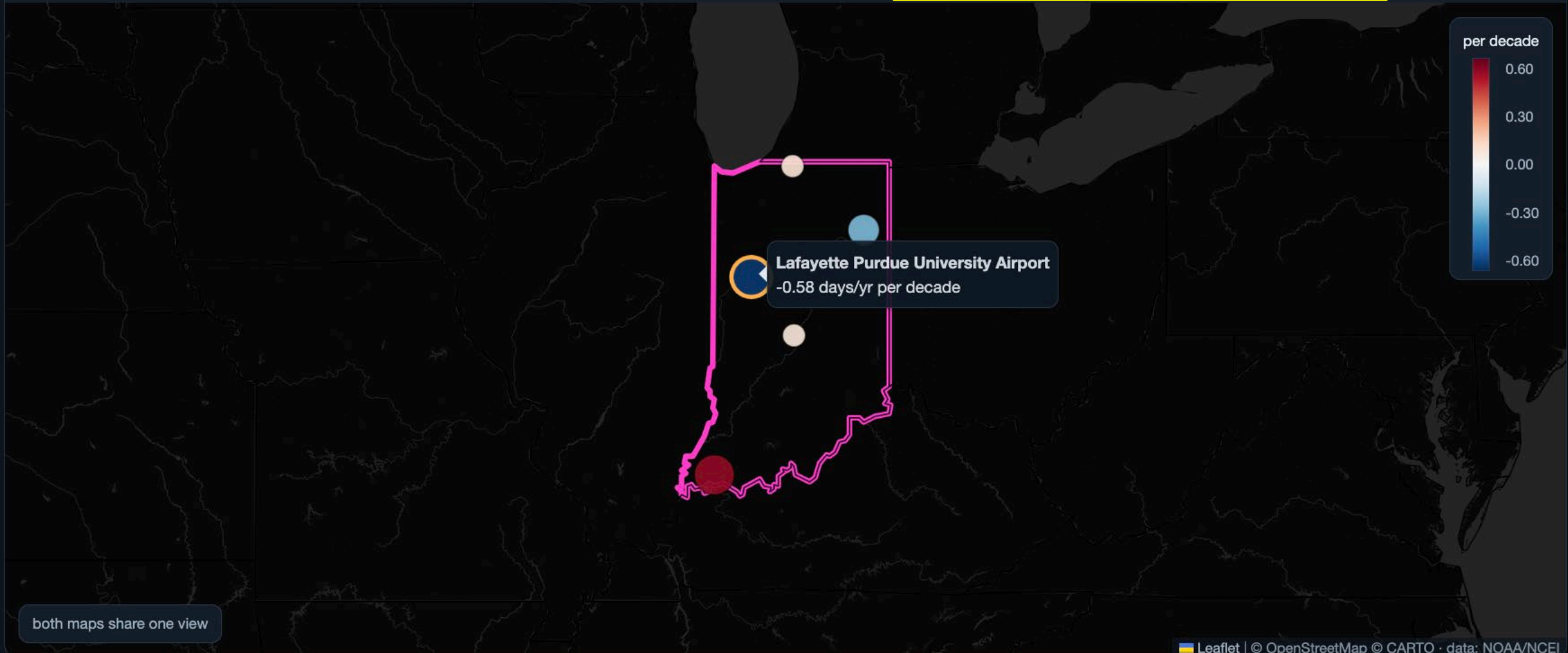
Freezing rain

Source: Del Pizzo et al. 2025
+ NOAA ISD surface station obs

Trend

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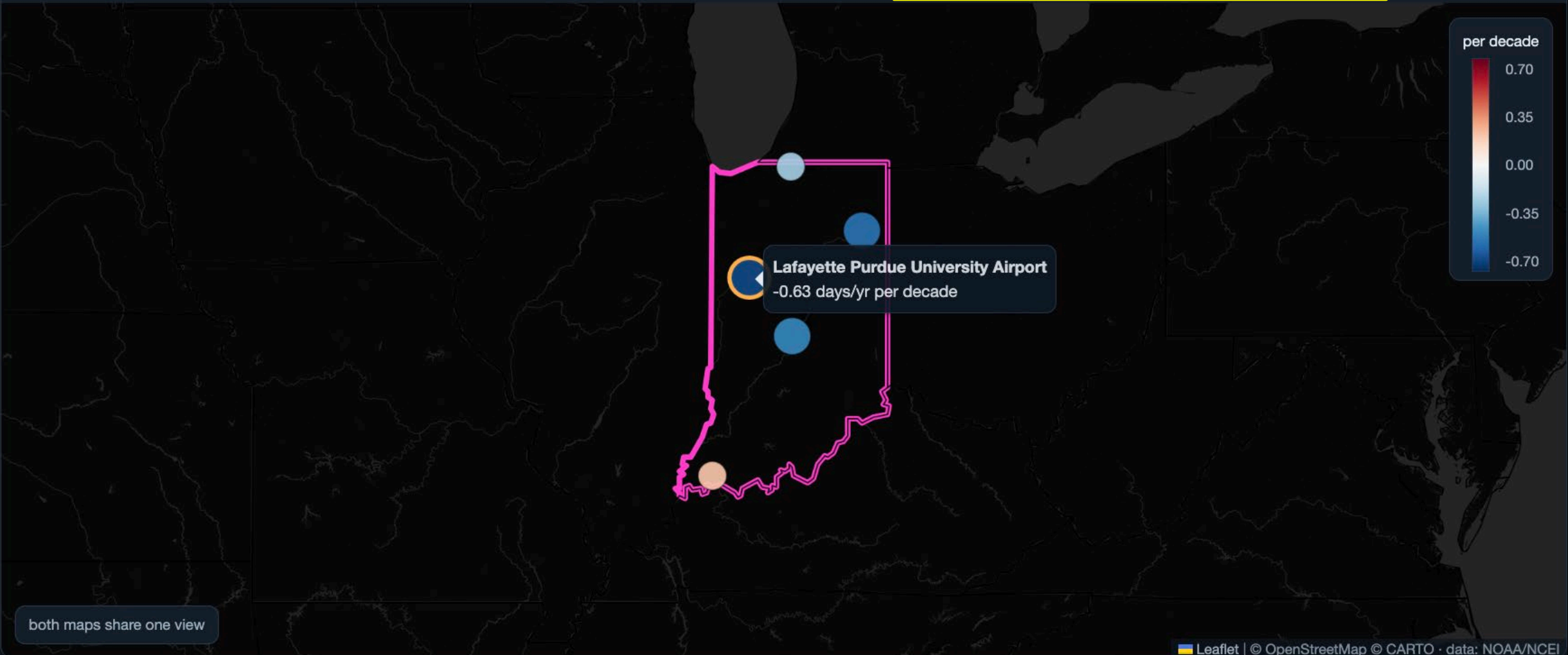
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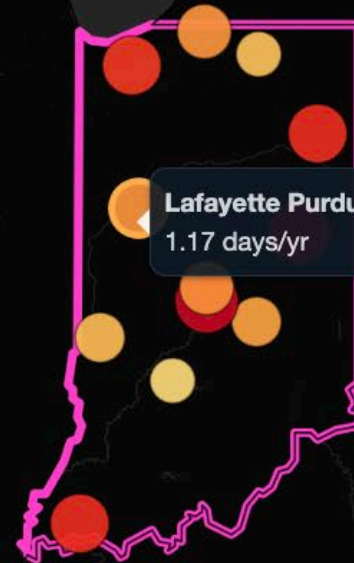
A new public interface for extreme weather maps and trends (development ongoing)

Severe wind (>58 mph)

Source: NOAA ISD surface station obs

Climatology

Mean annual peak wind days per station, 2001–2024



drag · scroll to zoom · click a state to centre

A new public interface for extreme weather maps and trends (development ongoing)

Trend

Change per decade · ringed where $p < 0.05$

Trends are inherently far noisier: focus on coherent spatial patterns, not the value in any single county.

Serves multiple goals:

- Answer basic questions: about how, when, and where different types of extreme weather are changing based on available data
- Inform decision-making: relevant to where you are
- Inform research: climatology and trend data for input to economic and energy risk modeling

Try it out!



New features being added regularly.

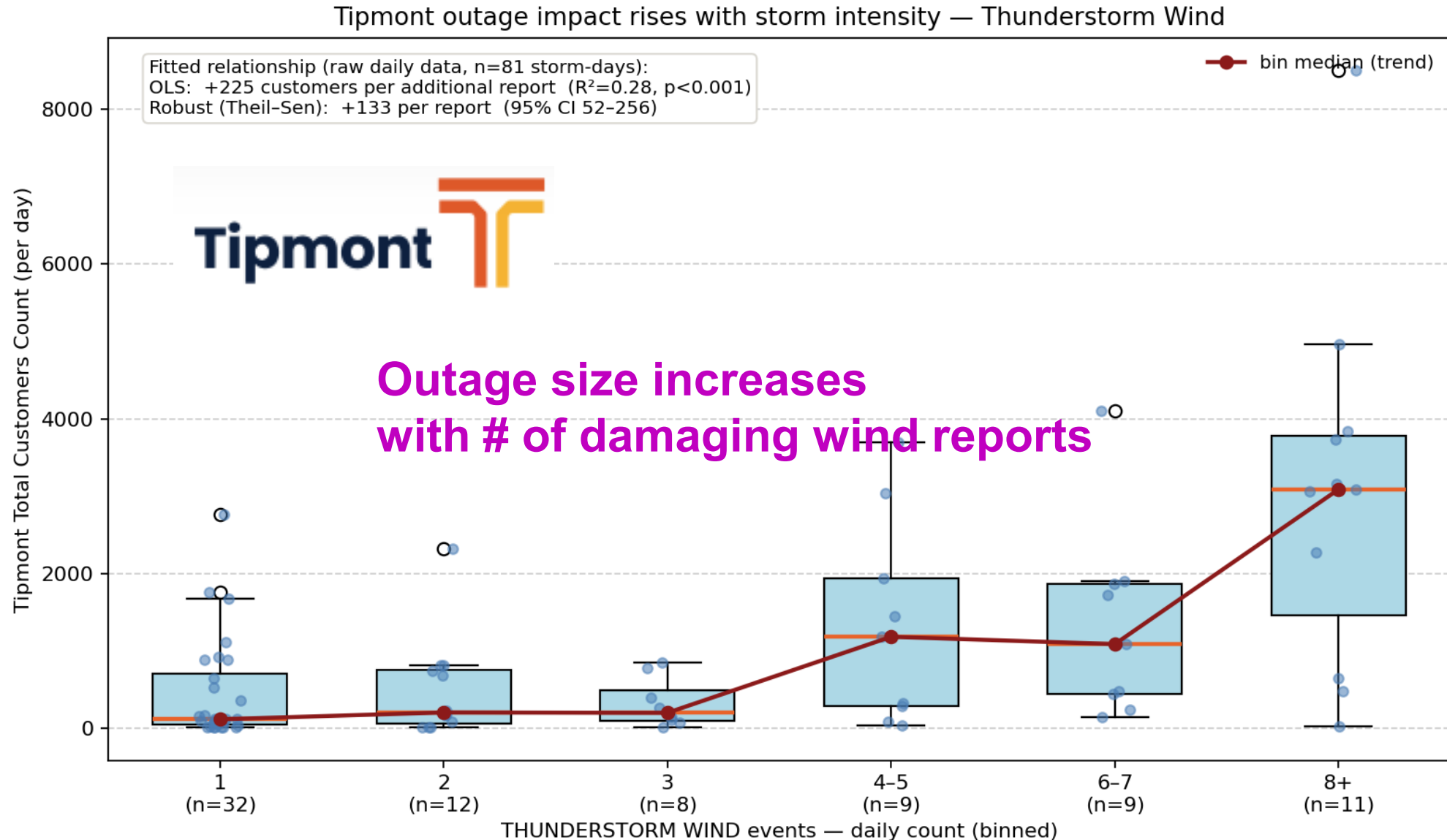
What data/functionality
do you want to see added?

both maps share one view



data: NOAA/NCEI

We can use weather data to understand what would make us more resilient



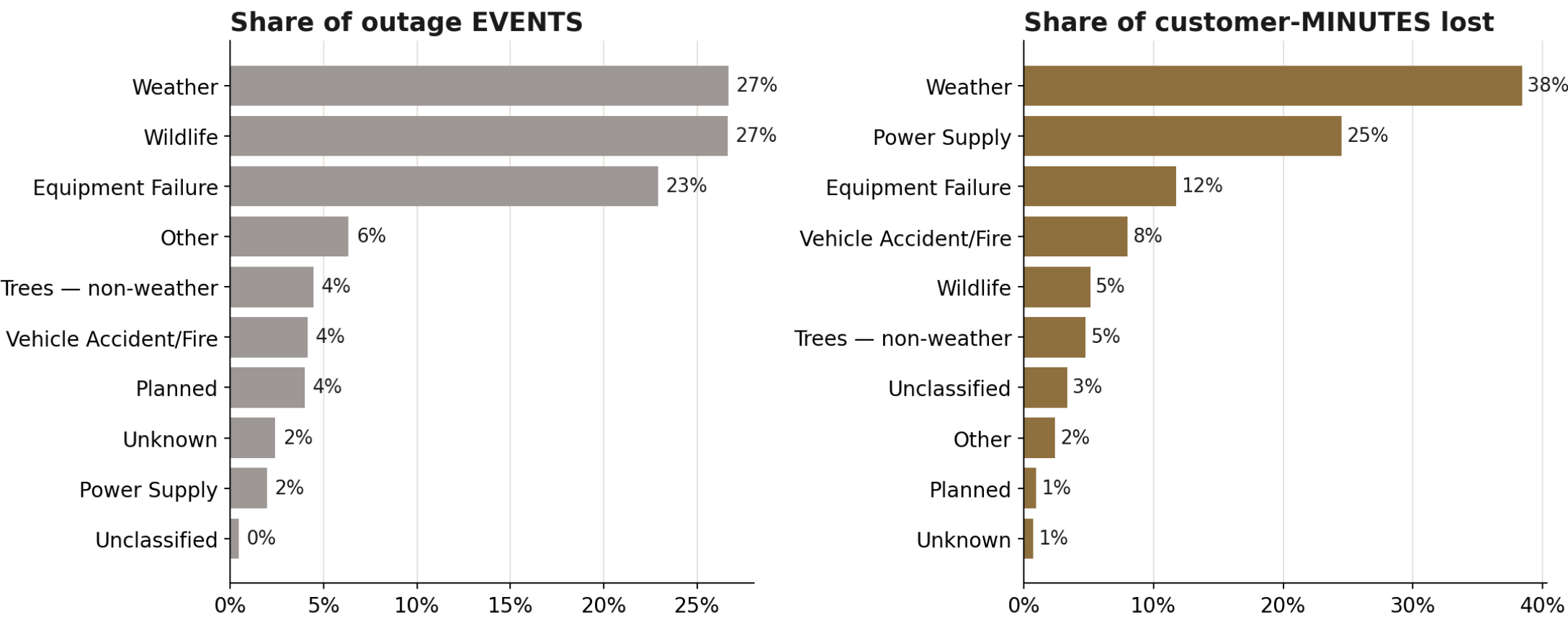
Energy resilience

Xiaonan Lu

Purdue University, Engineering Technology and Electrical and Computer Engineering

Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Indiana Outage Events and Weather Drivers



Correlation between Power Outages and Weather Events

- Significant impact of weather events on outage frequency and severity
- Prolonged outage durations on the customer side

Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Concept of Resilience and Quantifiable Resilience Index

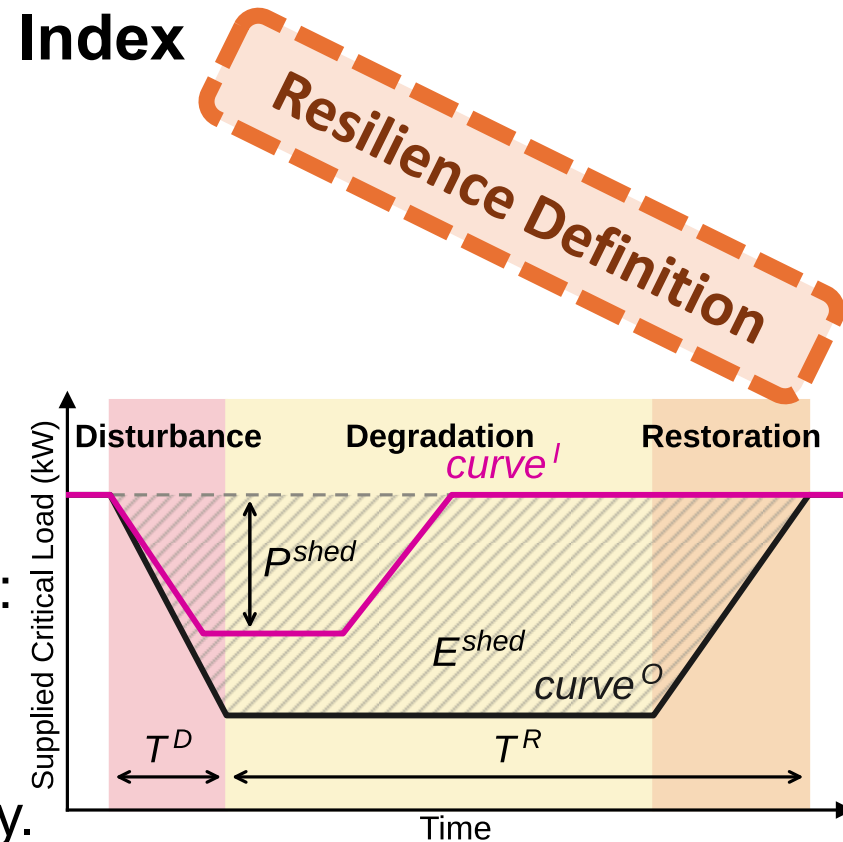
Concept of Resilience

- ✓ Ability to resist, withstand, and adapt to a major disruption, possibly with reduced performance.
- ✓ Ability to “bounce back” to a normal state after the disturbance

Resilience Trapezoid

- ✓ The figure shows a classic multi-phase **resilience trapezoid**: the y-axis tracks performance, e.g., **uninterrupted critical load supply**.
- ✓ It covers the period from disturbance impact through recovery.
- ✓ The **resilience trapezoid** is the foundation for resilience evaluation.

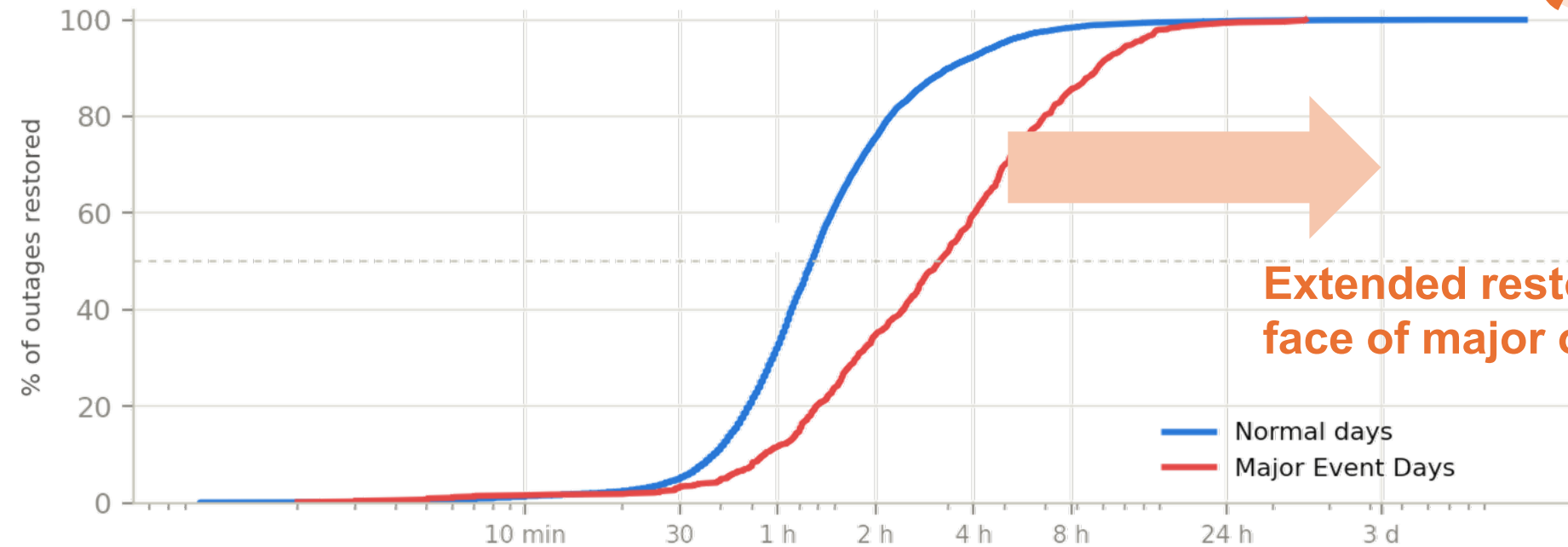
Resilience Metrics: The most common **resilience metric** is the load energy shortage (E^{shed}); the peak load shedding (P^{shed}) and event duration (T^R) are also widely used.



Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Concept of Resilience and Quantifiable Resilience Index

Restoration curve: outage duration on Major Event Days vs. normal days



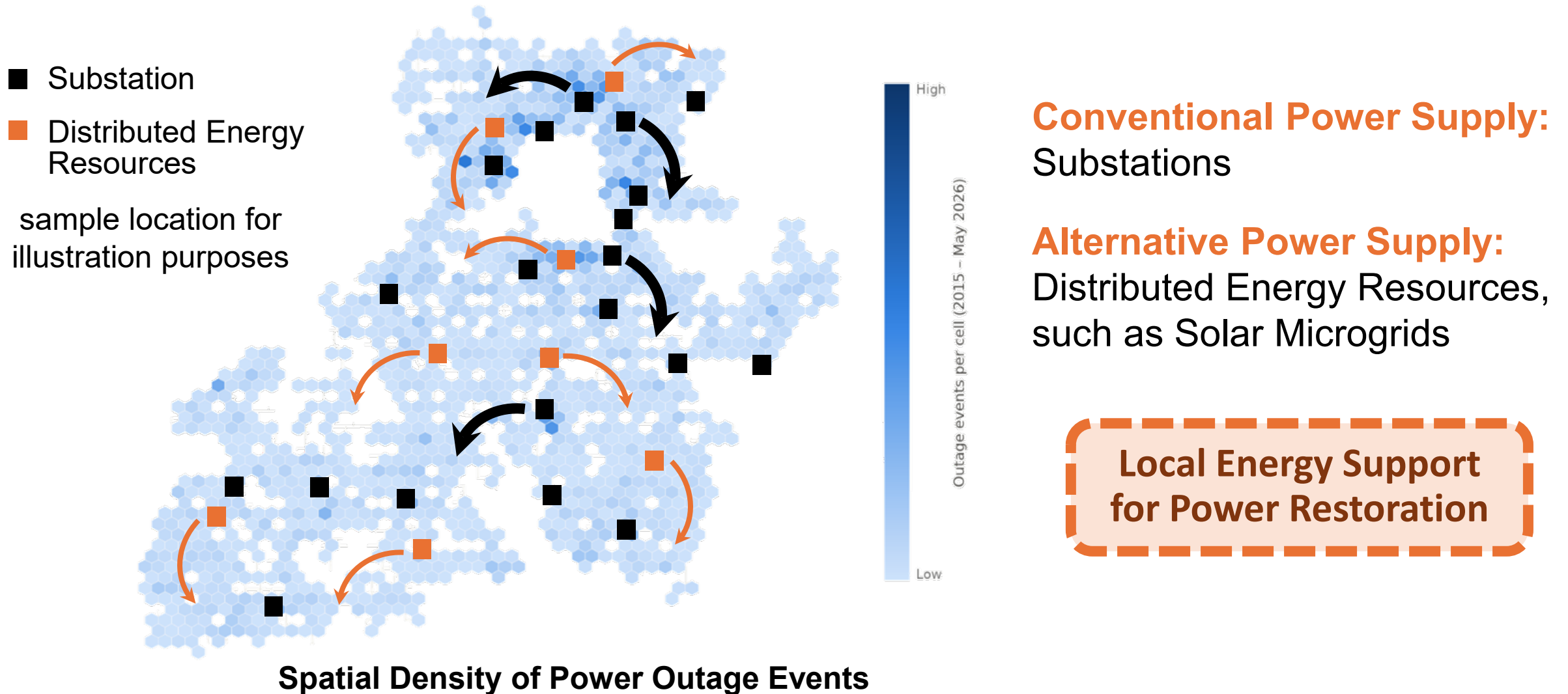
Real-World Resilience Interpretation

Extended restoration time in face of major outage events

Question: How can we shorten the required restoration time, even in face of major power outages?

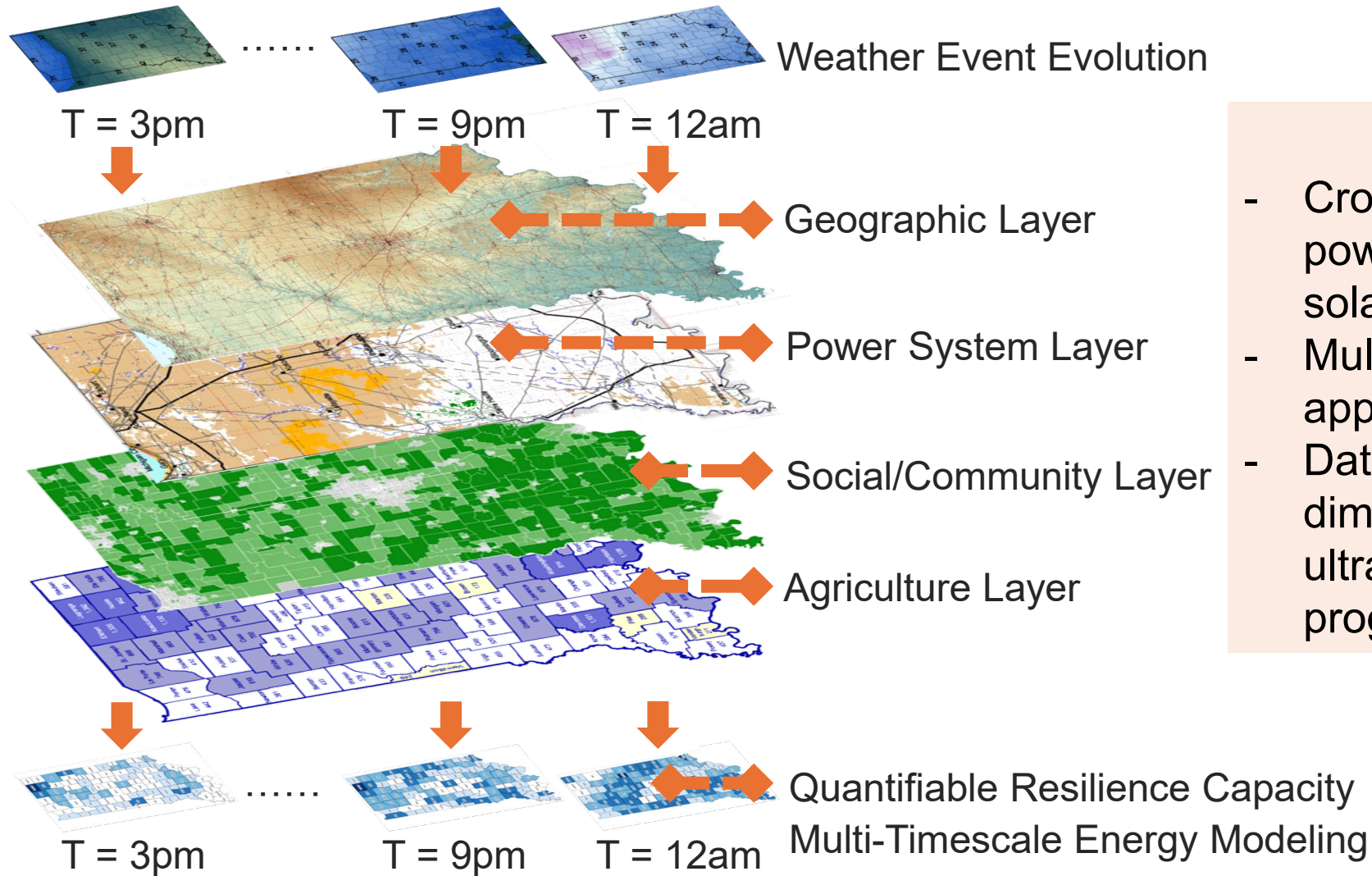
Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Grid Resilience Enhancement with Solar Microgrids



Power Outage, Grid Resilience, and the Role of Solar Microgrids

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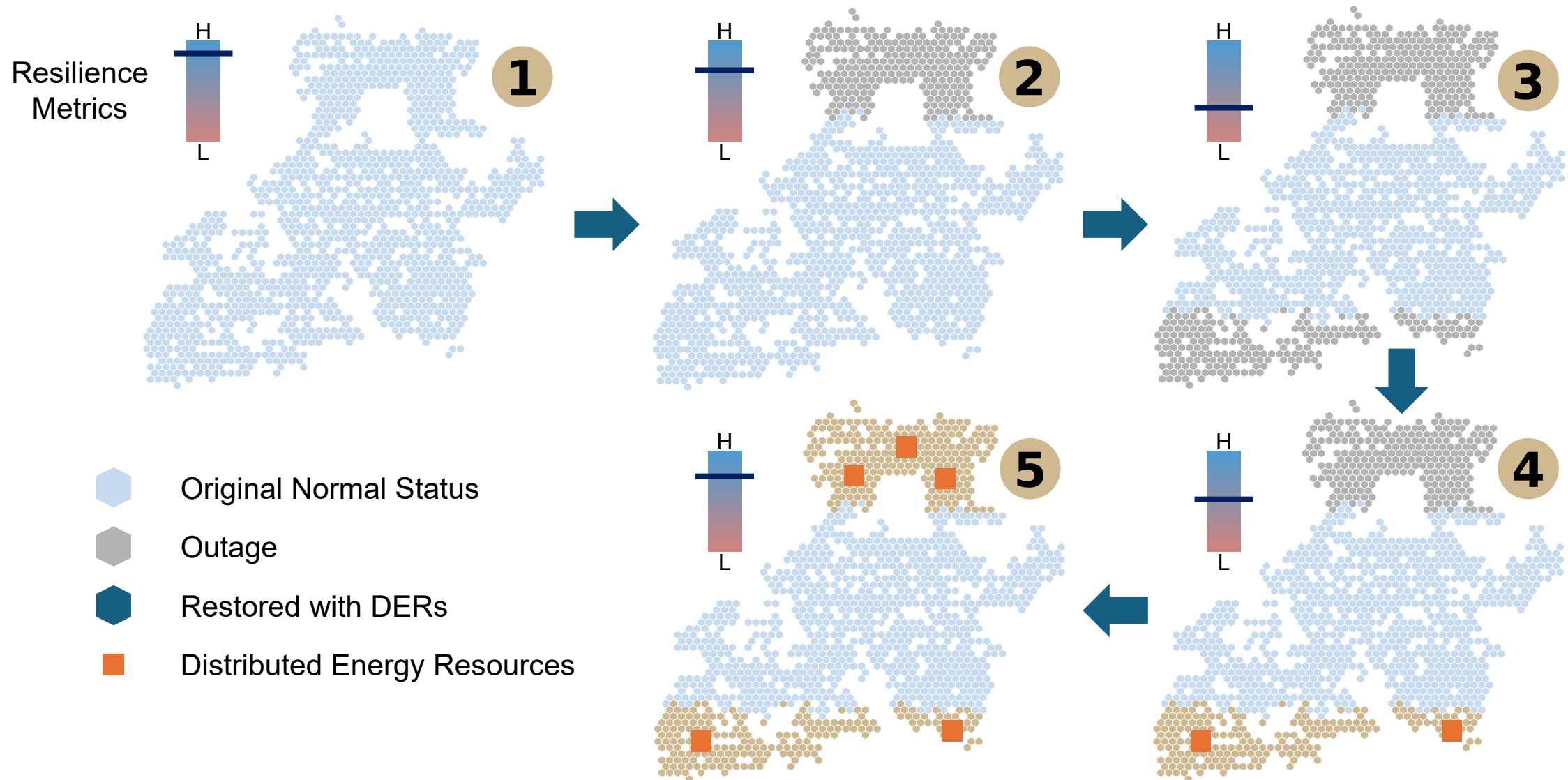


Resilience Capacity

- Cross-domain concept quantifying power grid resilience with or without solar microgrids
- Multi-factor resilience quantification approach
- Data-driven offline training for high-dimensional resilience capacity and ultra-fast online diagnosis and prognostics

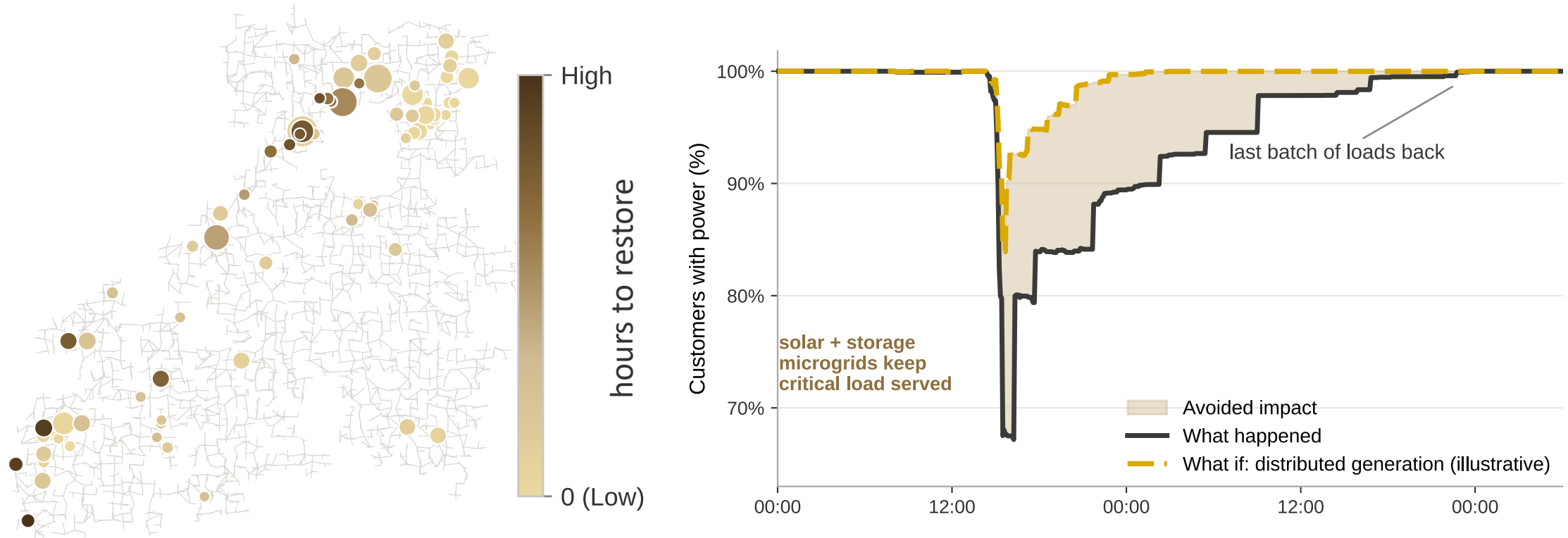
Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Grid Resilience Enhancement with Solar Microgrids



Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Mitigating Outage Impacts, **Reimagined**



How Our Approach Mitigates Power Outage Impacts

- The real storm: severe outages, significant customer service interruptions
- With solar microgrids: most outage hours avoided (illustrative scenario)

Power Outage, Grid Resilience, and the Role of Solar Microgrids

- Future Vision



Data Correlation Analysis

Combine weather and power outage data to identify their correlation



Cross-Domain Resilience Quantification

Integrate extreme weather models and fragility curves for cross-domain resilience quantification based on resilience capacity



Expanded System Dimensionality

Expand the system dimensionality by incorporating additional degradation factors



Real-World Model Integration

Integrate real-world electric utility and cooperative models (e.g., from Tipmont RMEC)

Economic resilience

Juan Sesmero

Purdue University, Agricultural Economics

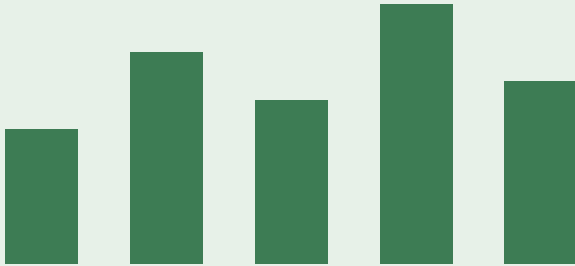
Can solar make a farm more resilient?

Not by making crops tougher — by changing what the farm depends on.

AGRICULTURE

Weather + technology + prices

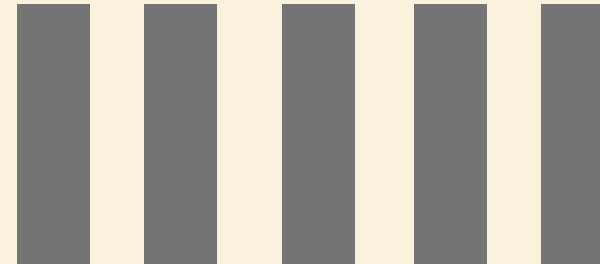
→ uncertain annual returns



SOLAR LEASE

Long-term contract

→ stable annual payment



The land-use decision is also a portfolio decision.

One question. Four disciplines. One farm-income distribution.



STOCHASTIC SIMULATION

Generate thousands of plausible farm years, then ask how the entire income distribution changes as land moves from crops to solar.

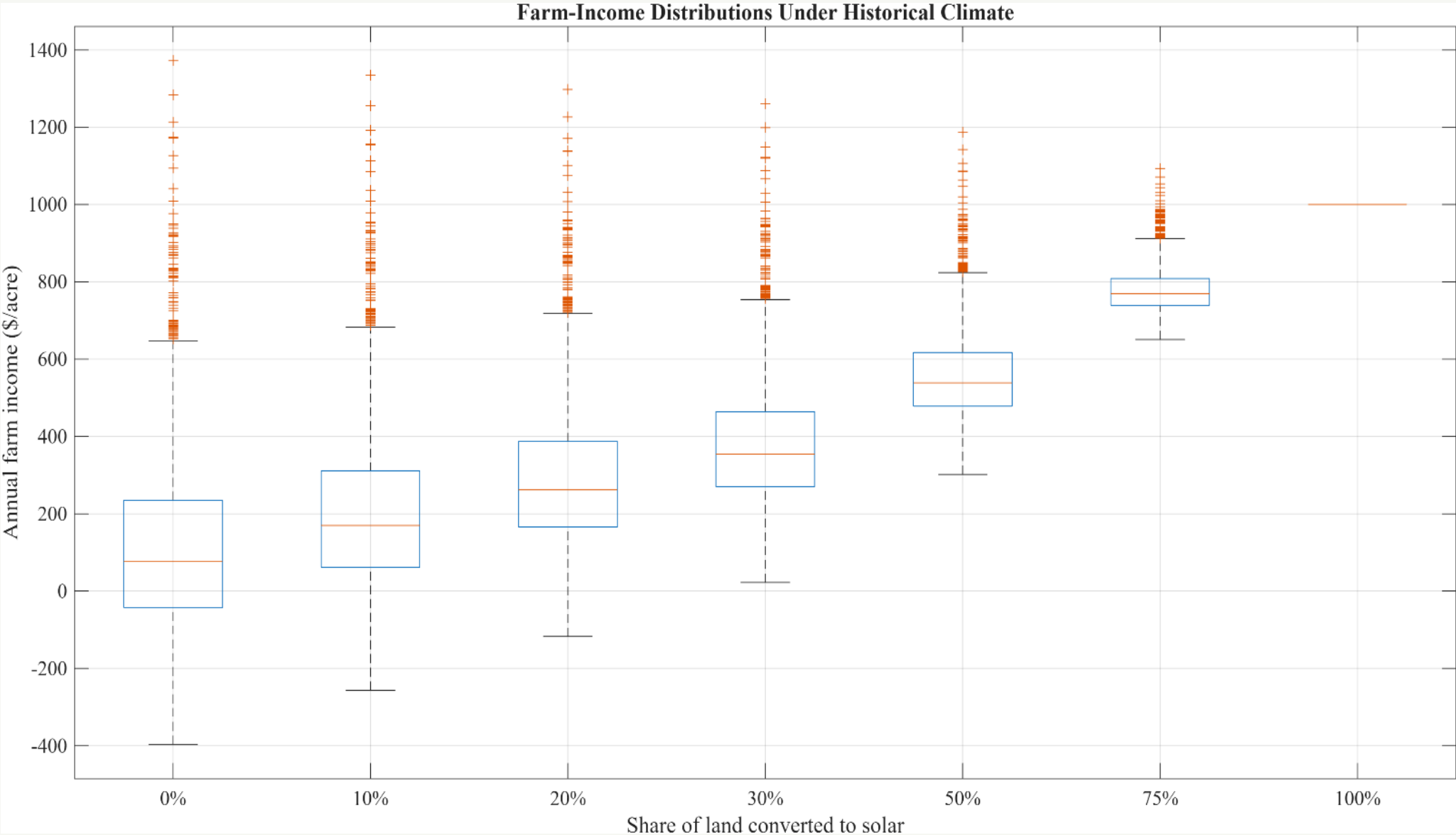
We measure resilience as more than “less volatility”:

● **higher expected income**

● **more stability**

● **less downside risk**

A stable lease raises the floor and smooths the ride



30% solar



30% lower income volatility



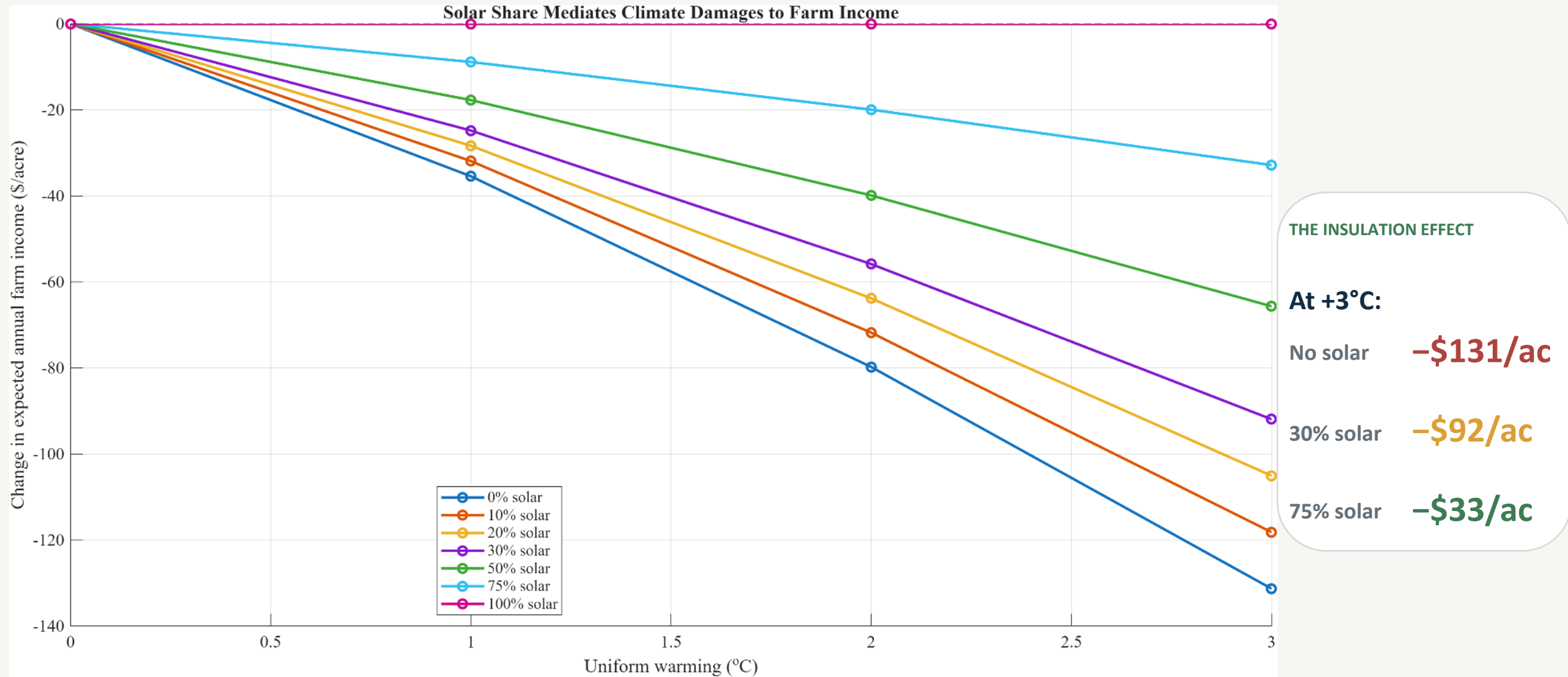
negative-income years fall from 34% to ~0%

Solar share



would have limited farms struggles in bad years without giving up upside potential

Solar limits how much farm income is exposed to warming



The mechanism is simple: less of the farm's income comes from temperature-sensitive production.

What should you remember?

Agrivoltaics can be more than a land-use compromise.

1

Think portfolio, not just production.

Solar changes the composition of farm income by replacing some weather- and price-sensitive returns with contractual income.

2

Resilience is multidimensional.

The relevant question is not only “How volatile is income?” but also “How high is it?” and “How bad are the bad years?”

3

Diversification can create climate insulation.

Solar does not protect crop yields from heat; it reduces the share of whole-farm income exposed to temperature-sensitive agriculture.

Bottom line: The value of solar on farmland includes the resilience of the farm business — not just the average dollars per acre.

Discussion time!

Imagine a resilient future with us.

What does “resilient” mean to you?

What are we missing?

What do we need to get there?



Midwest Agrivoltaics for
Resilient Communities



PURDUE
UNIVERSITY®

Institute for a Sustainable Future

Ideas/partnerships?
Come talk to us!

menti.com

4454 6954



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Kara Salazar: salazark@purdue.edu

Dan Chavas: dchavas@purdue.edu

Juan Sesmero: jsesmero@purdue.edu

Xiaonan Lu: lu998@purdue.edu

+ many internal and external partners!

EXTRA



**Economic
resilience**



**Energy
resilience**

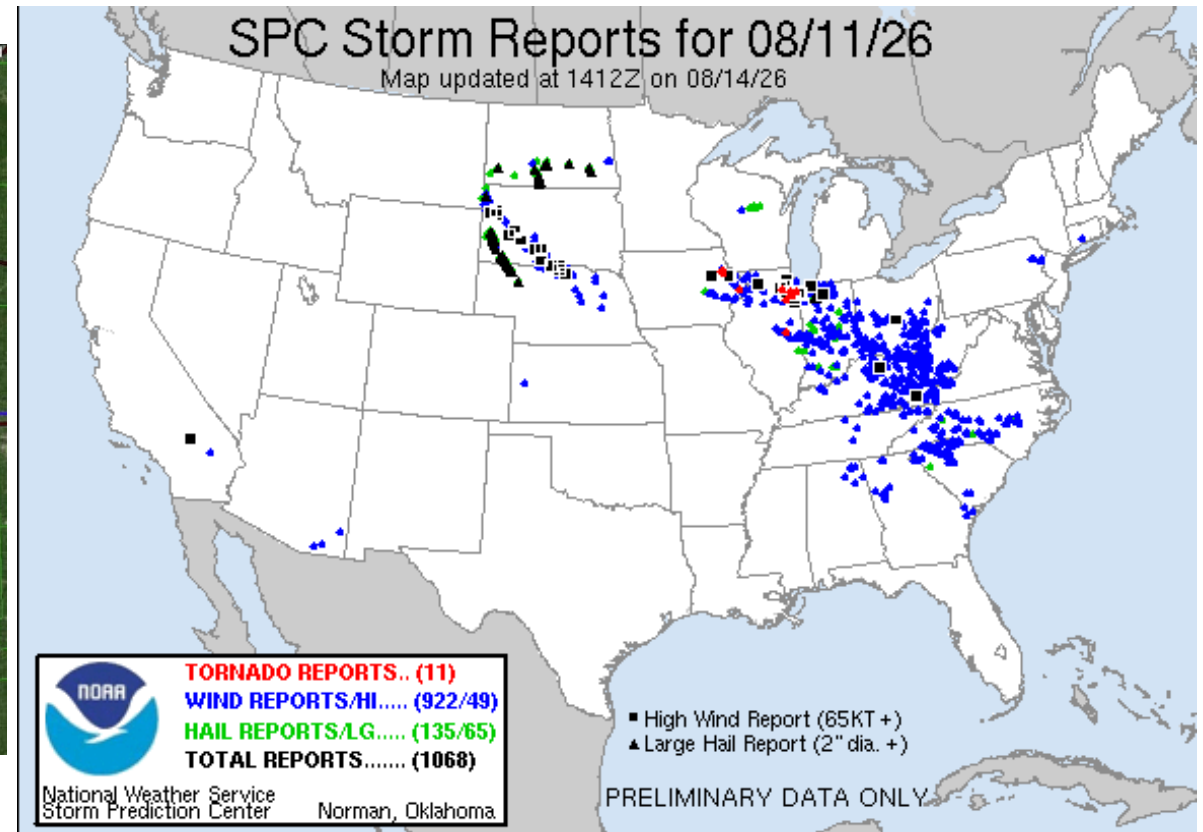
**Goal: imagine a world *not* affected
by extreme weather
Can agrivoltaics help?**

Aug 11, 2026 derecho

A widespread straight-line wind event, with a few embedded tornadoes (IL)



https://www.weather.gov/lot/2026_08_11_Derecho



Agrivoltaics can boost rural resilience and prosperity

Economic Diversification

Farmers gain additional revenue streams from solar energy production while maintaining agricultural operations.

Energy Resilience

Local power generation and storage can reduce grid outages and provide reliable electricity for farm operations.

Agricultural Productivity

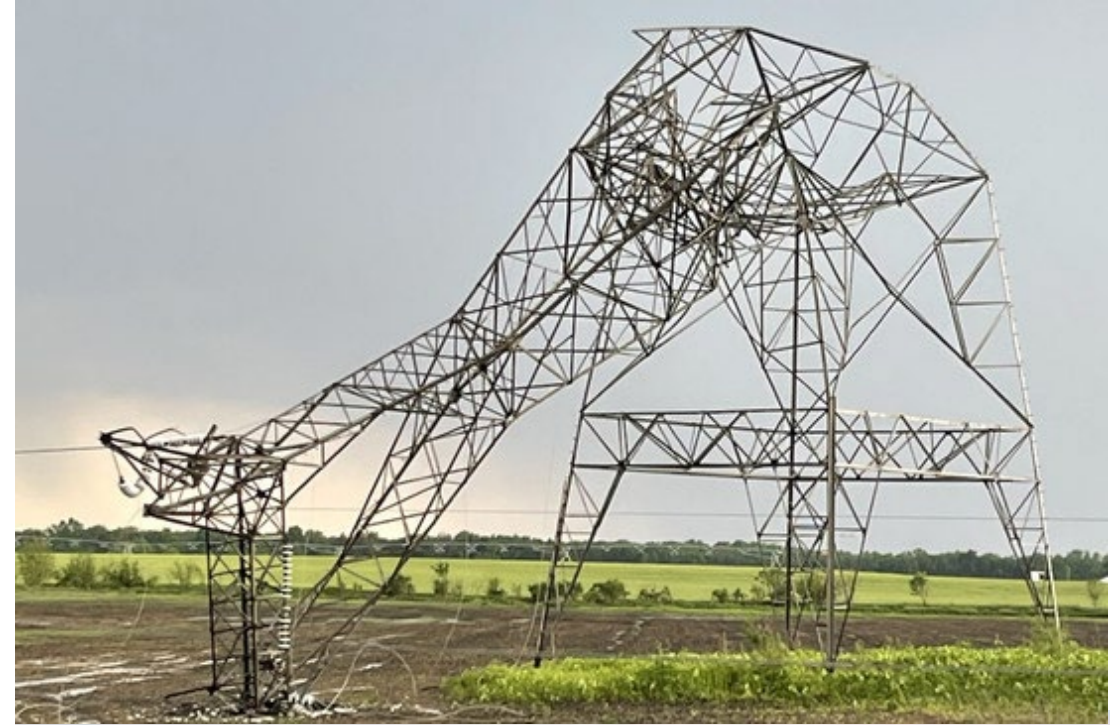
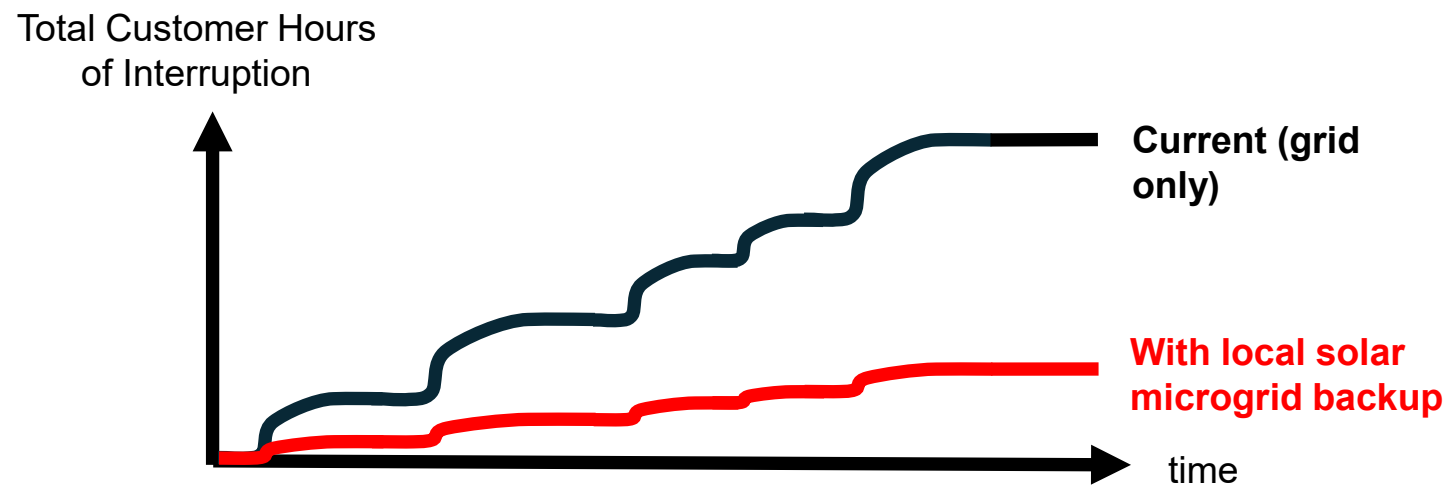
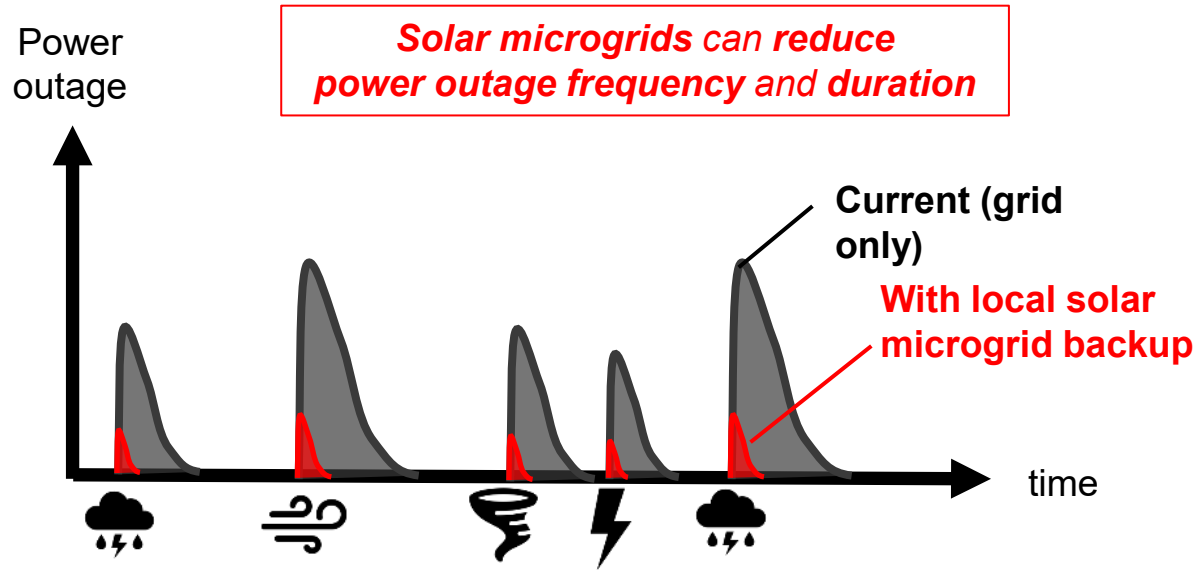
Partial shade can increase soil moisture, reduce water needs in arid climates, and protect sensitive crops from extreme heat.

Workforce Development and Community Prosperity

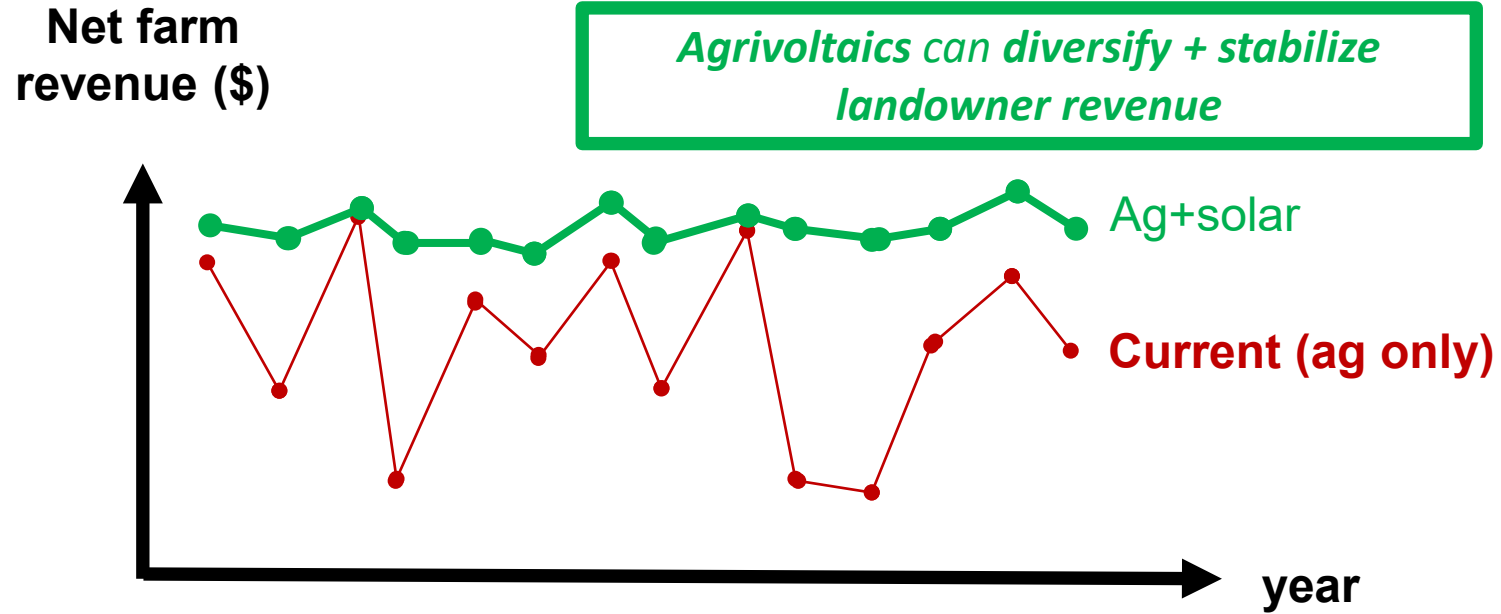
Keeps working lands productive, supports rural economies, strengthens the shrinking rural workforce in rapidly changing



Transformational potential: energy resilience



Transformational potential: economic resilience and prosperity



Tackle key barriers – three prongs

1. Extreme weather resilience
(ag + energy)
2. Suitability (design)
3. Acceptability (trust)



MARC one-slide summary

[One slide 4 boxes full slide what are we doing visual accessible scientific — weather data, focus groups/summit, energy resilience modeling, econ resilience modeling]

Target: ~5 slides

1. Motivation + Research question

2. Accessible methods – what datasets are you bringing together? What can you predict from the model that lets you answer that question?

3. 1-2 interesting takeaways that are tangible to broad audience (e.g. “can show that adding X% solar means you won’t lose money)

4. Future goals: where we’re going and why this matters for people on the ground

Use pictures / schematics! This is not a science/engineering conference lecture.

A draft outline of ideas as a starting point – please simply start adding slides with anything you think is relevant, and then we will organize + trim for the final summit presentation.

1. Extreme weather (Dan)
 1. maps/databases – MRCC
 2. Plan for public-facing website
2. Energy resilience / modeling (xioanan/dan): *just an initial draft!*
 1. Visuals: Indiana power outage (rural vs. urban would be nice), top weather drivers (+ nice case example) based on data (Tipmont)
 2. What energy resilience means (less prone to grid failure → fewer outages)
 3. How solar microgrids can make more resilient network: **modeling demonstration example** with Tipmont data (possibly NiSource data), → 1) grid resilience index, based on [load, capacity] + its sensitivity to node failures; 2) resilience enhancements (reduced power outages) when adding Distributed Generation points to the grid
 4. Future vision
3. Econ resilience / modeling (juan/dan): *just an initial draft!*
 1. Visuals: ag revenue variability, weather drivers (+ nice case year example) based on data (Indiana)
 2. What economic resilience means (less year-to-year revenue volatility)
 3. how mix of ag+PV can make revenue more resilient: **modeling demonstration example** with Indiana data → optimal mix of PV
 4. Future vision – detailed modeling agPV → agrivoltaics