Residential Links
Under the Weather

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Dave Levin, Neil Spring

8 years: Less hair, more wisdom (and a couple of PhDs)

We know how the Internet is affected by

cataclysmic weather events

Government regulators mandate reporting of
large-scale failures

But what about the **far more common** weather events?

Lightning

Destroys equipment;
causes outages

Lightning

Destroys equipment; causes outages

Wind

Knocks down trees onto wires

Lightning

Destroys equipment; causes outages

Wind

Knocks down trees onto wires

Snow

Weighs down wires; attenuates wireless signals

Quantifying weather's effect on residential Internet

… Cold Heat Lightning Wind Snow Rain …

Weather affects the most common links people use to get on the Internet

Data

Ping residential links before, during, and after weather events

Challenges

Outages are rare and may be unrelated to weather events

Analysis

Use tools from epidemiology to analyze rare events

Results

Weather effects depend on intensity, geography, and link

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Quantifying weather's effect requires collecting data…

Everywhere

Weather is localized

Affects a specific region

Over long periods of time

Weather is seasonal

Some conditions only happen in certain months

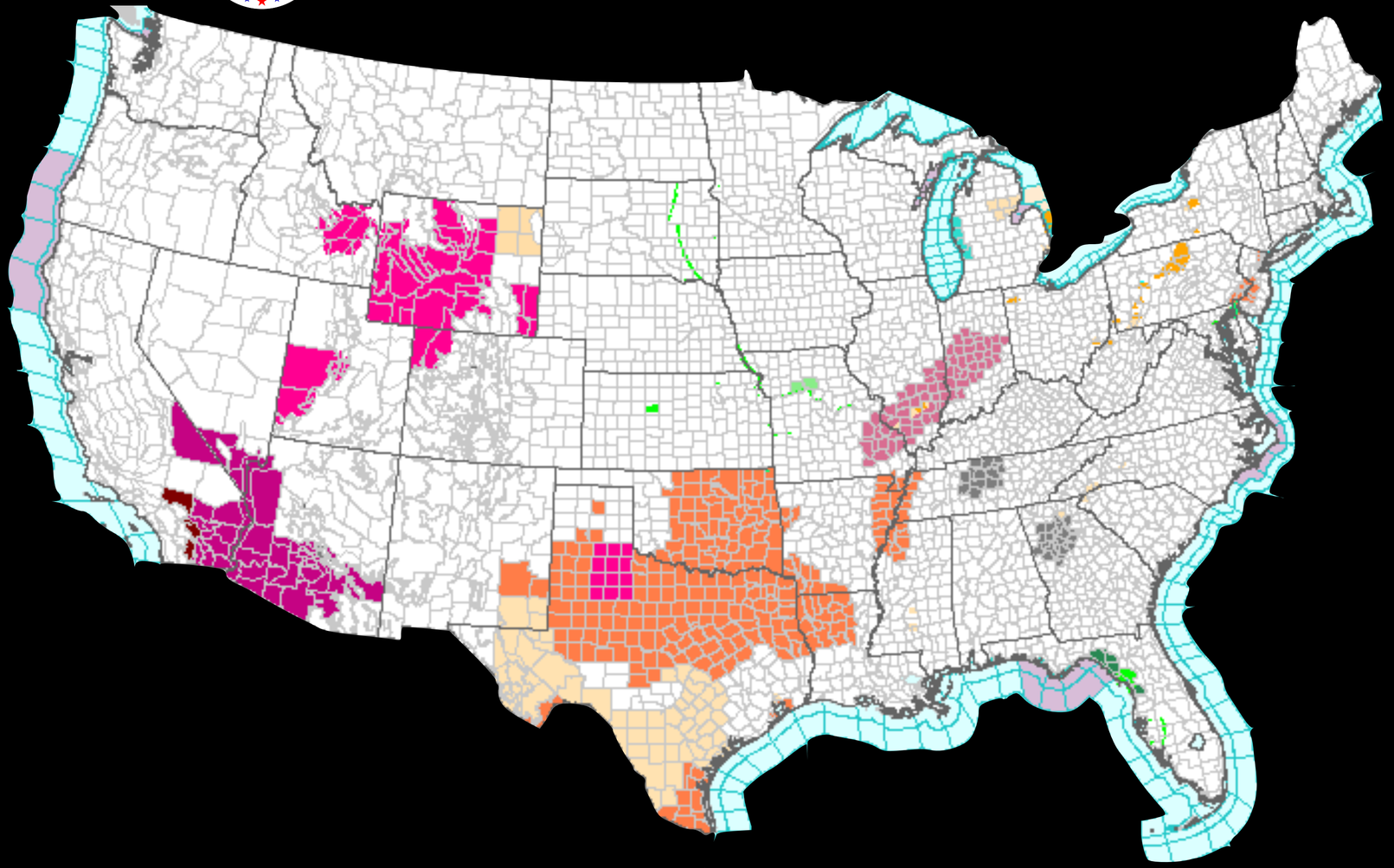
Across all link types

Links are heterogeneous

Variety of technologies, vendors, installations

Storm-chasing with Thunderping

US National Weather Service



High Wind
Flood
Ice Storm
Snow
Hurricane
Tornado
Thunderstorm
Tropical Storm

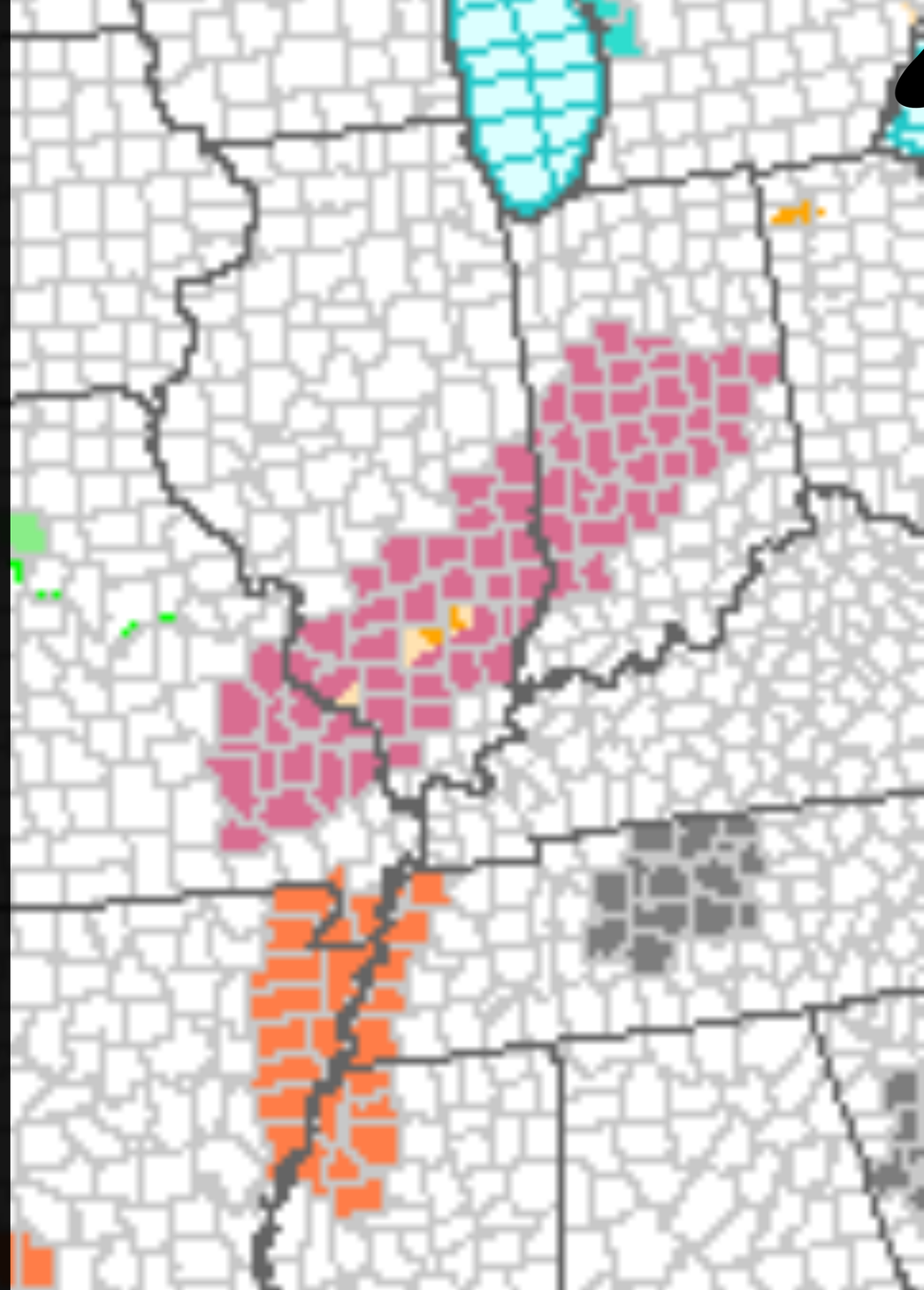
Pingin' in the Rain, Schulman and Spring, IMC'11

Storm-chasing with Thunderping

US National Weather Service

Weather condition

FIPS codes (approximately US counties)



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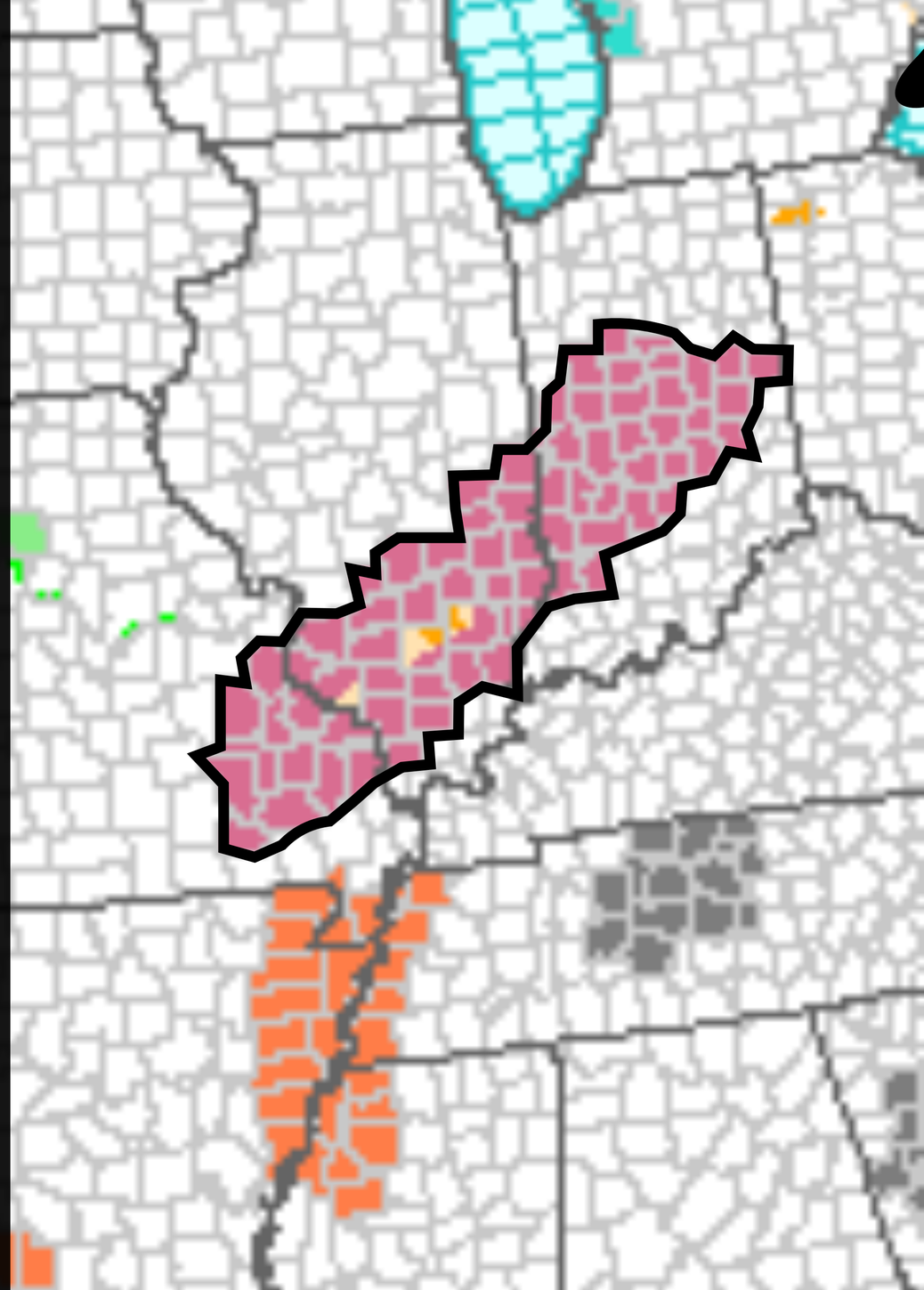

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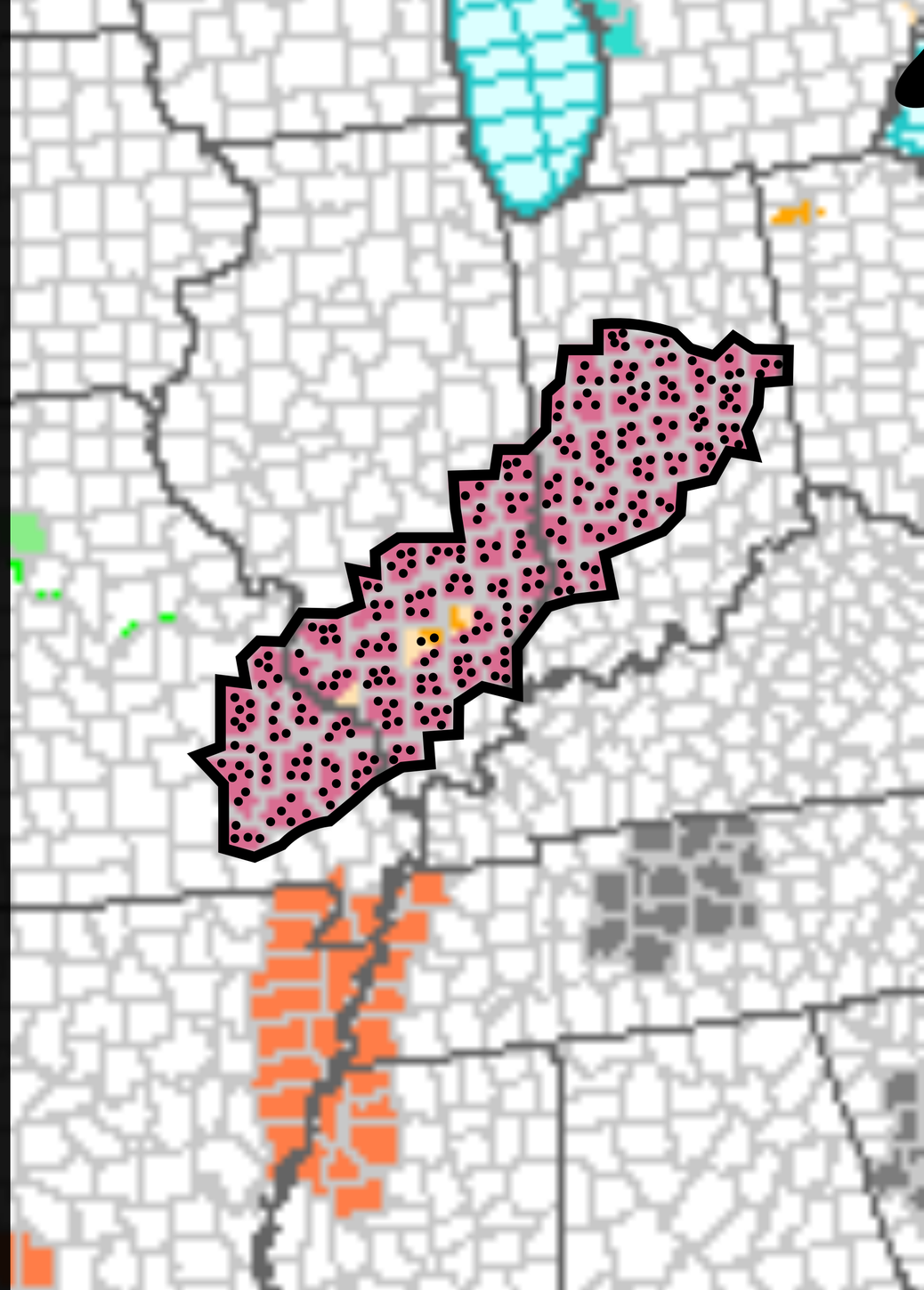
MaxMind GeoIP and rDNS

IP addresses in the affected county

- **Provider**
- **Link type**

} Thunderping chooses a representative set of residential links



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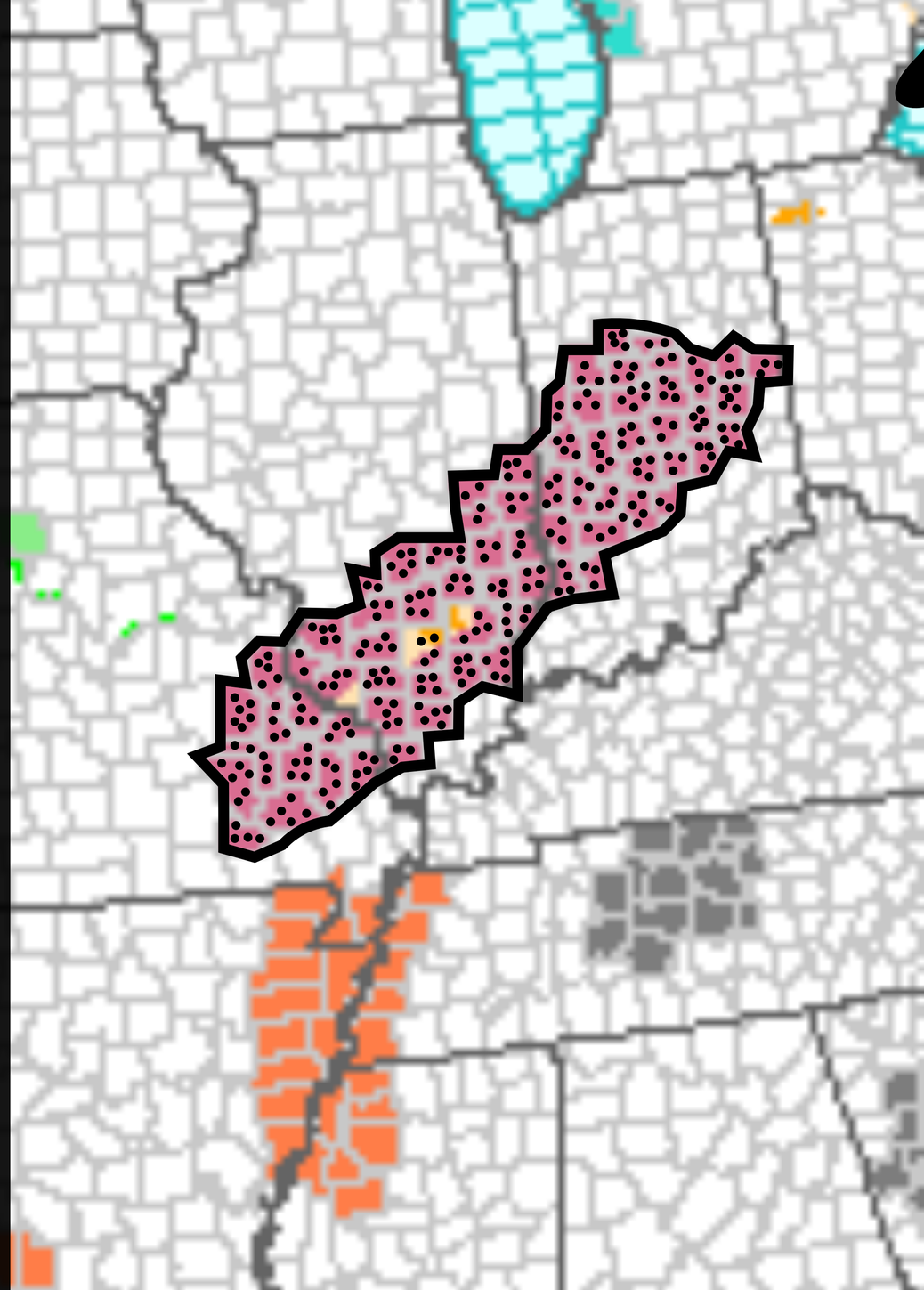
ping

Before	During	After
Baseline	Weather's effect	Recovery



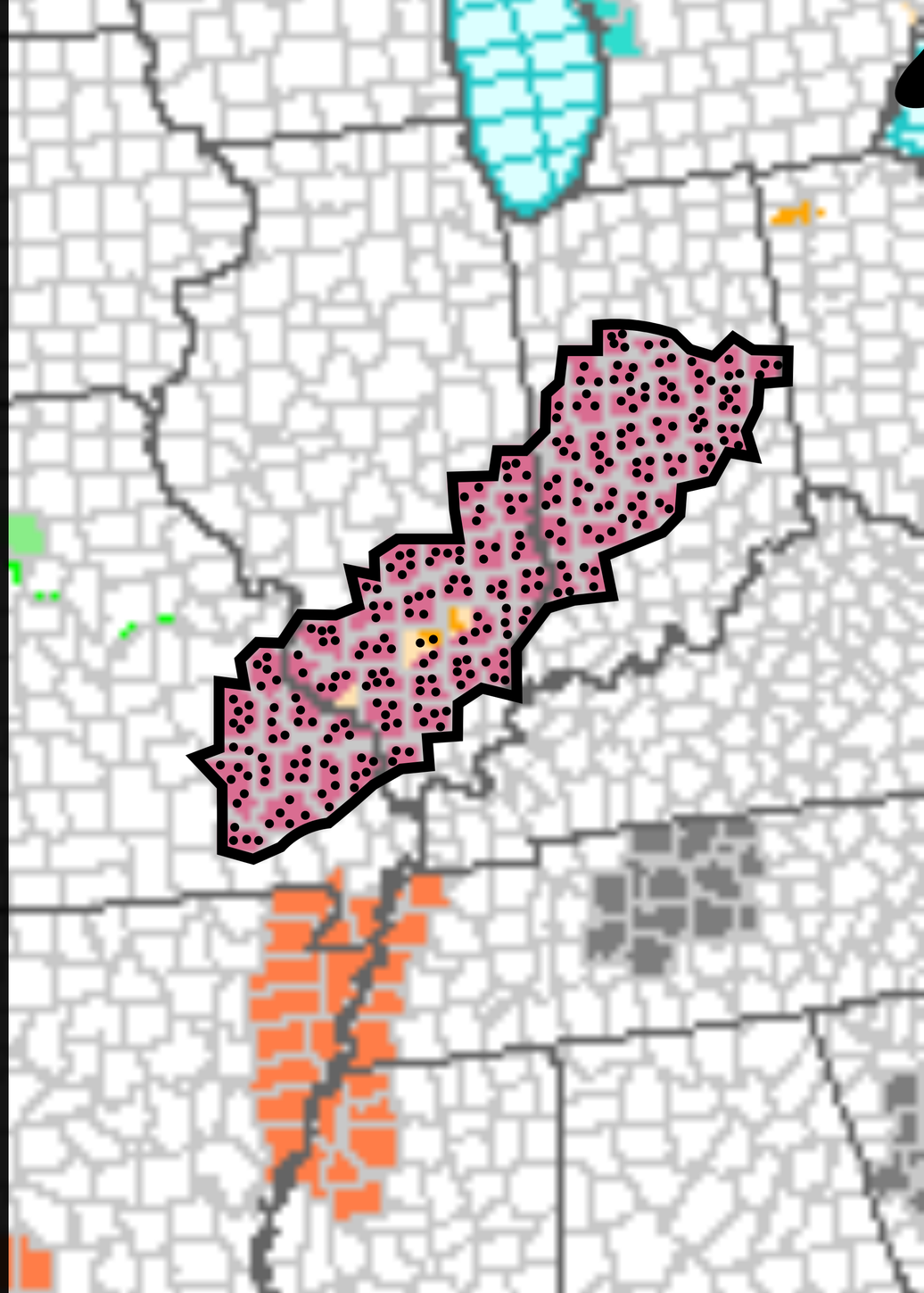
Detecting dropouts

ping

Before
Baseline

During
Weather's effect

After
Recovery



Detecting dropouts

ping

Before
Baseline

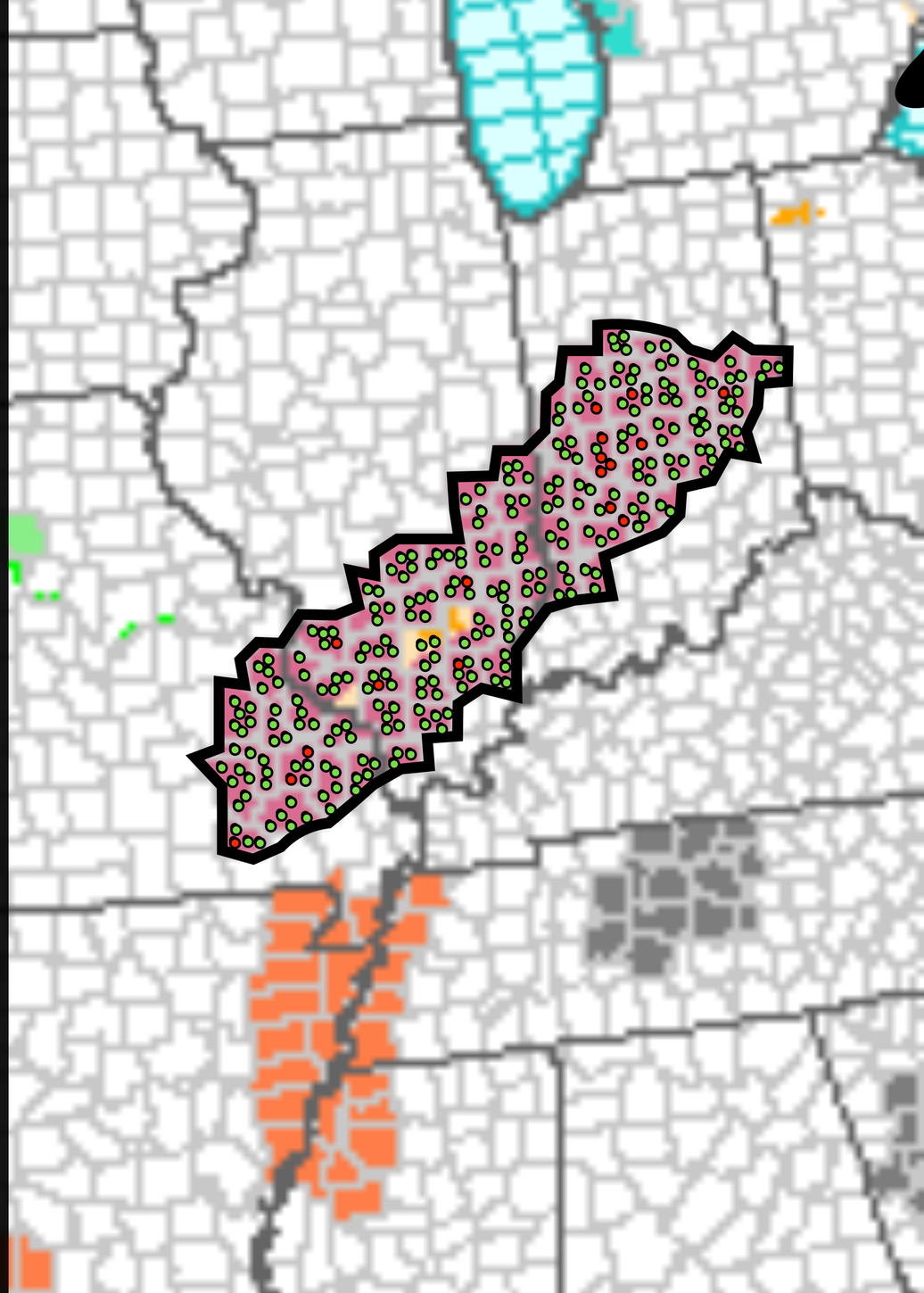
During
Weather's effect

After
Recovery

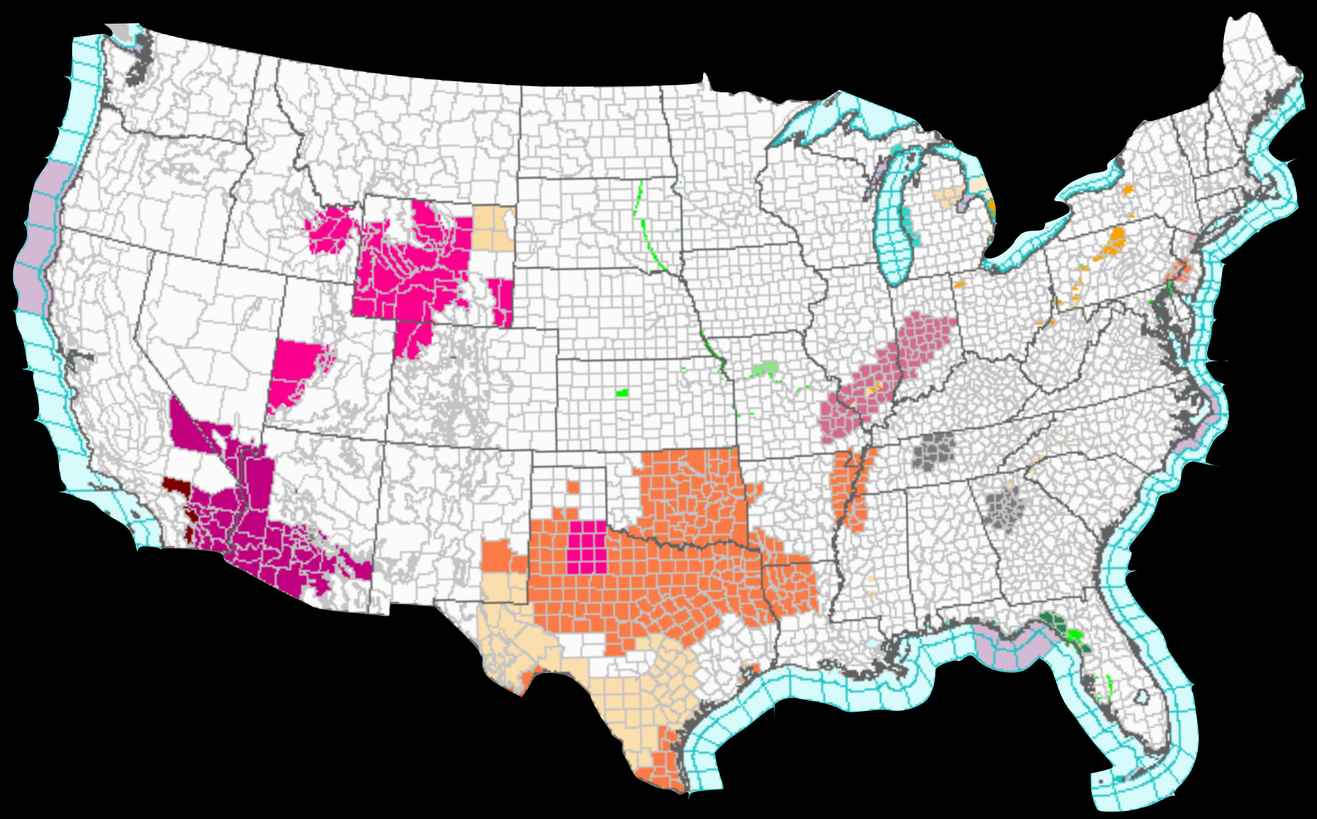
- From multiple **vantage points**
- We analyze on a **per-link** basis

Responsive Successfully responds to pings

Dropout Previously online, but fails to respond to *any* vantage point



8 years of Pingin’ in the Rain



10 Million
IP addresses responded

2 Billion
Responsive address-hours

12 Million
Address-hours included a **dropout**

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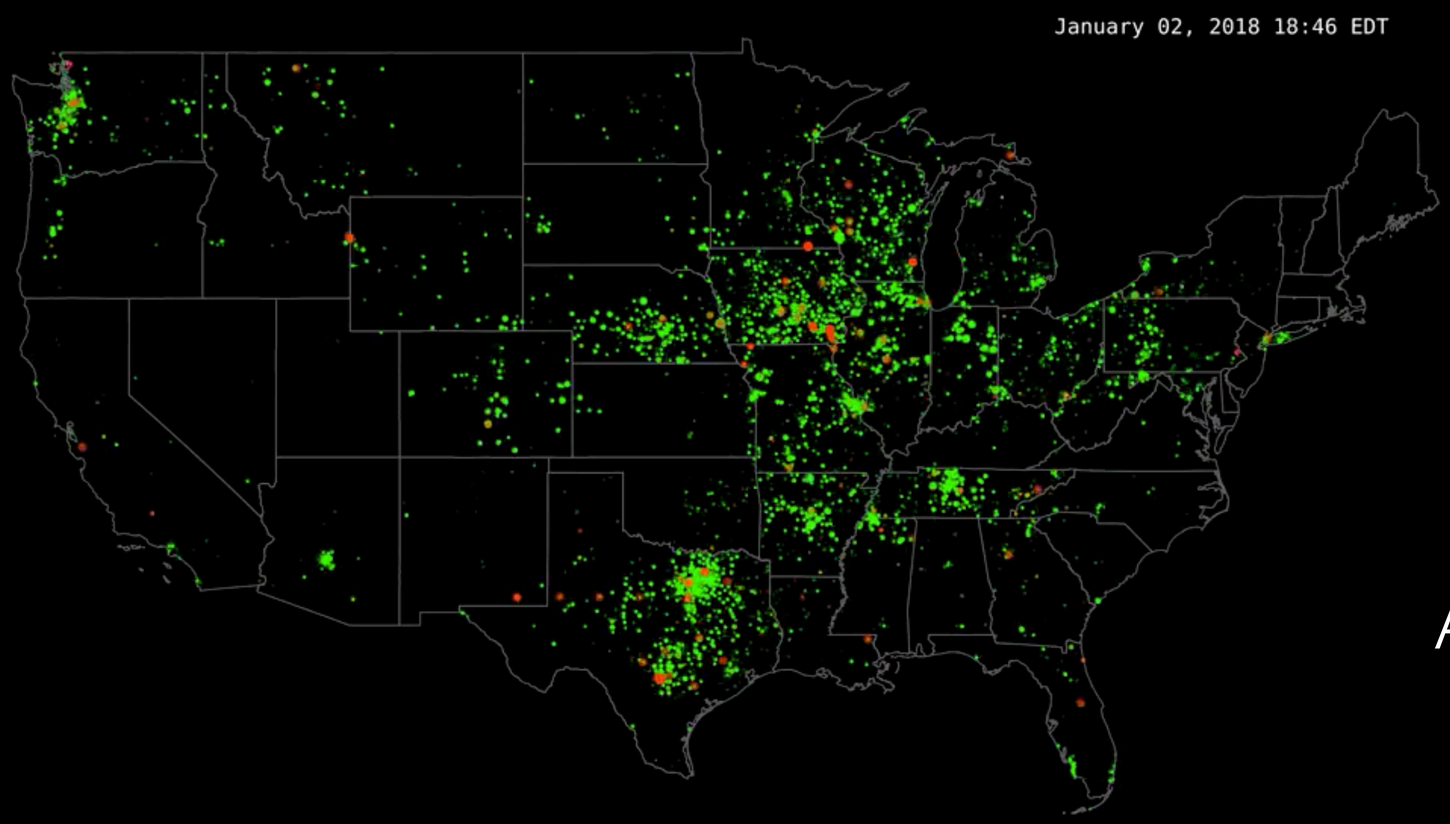

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Challenges in quantifying weather-related outages

Goal: Attribute a dropout to an *outage*

Dropouts have many causes

- Responses arriving after timeouts
- Dynamic addressing
- User/ISP behavior
- Weather-related Internet outages

Challenges in quantifying weather-related outages

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Goal: *Compare* weather events, link types, regions, …

Dropouts are rare

An additional dropout can significantly affect an estimate of its probability

	Fiber	Cable
Avg. # of days between dropouts	**35**	**22**

Comparing rare events

1 We apply statistical techniques from **epidemiology** to determine **how long we need to observe rare events**

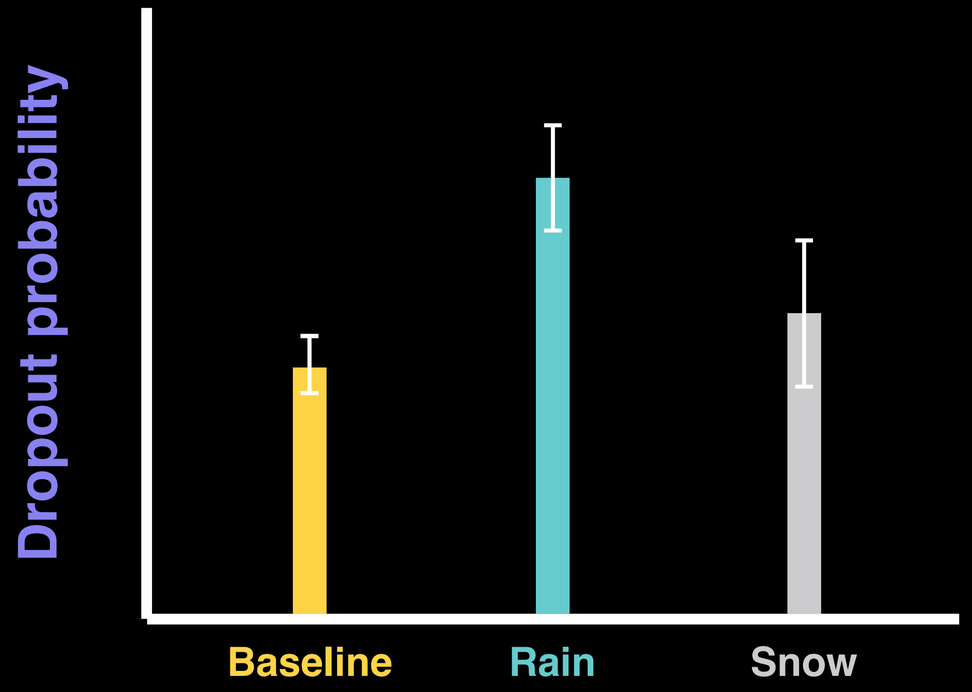
95% confidence

1 dropout-hour per month
requires 7205 samples

Comparing rare events

2

We factor out non-weather sources of dropouts by **subtracting a baseline dropout probability**



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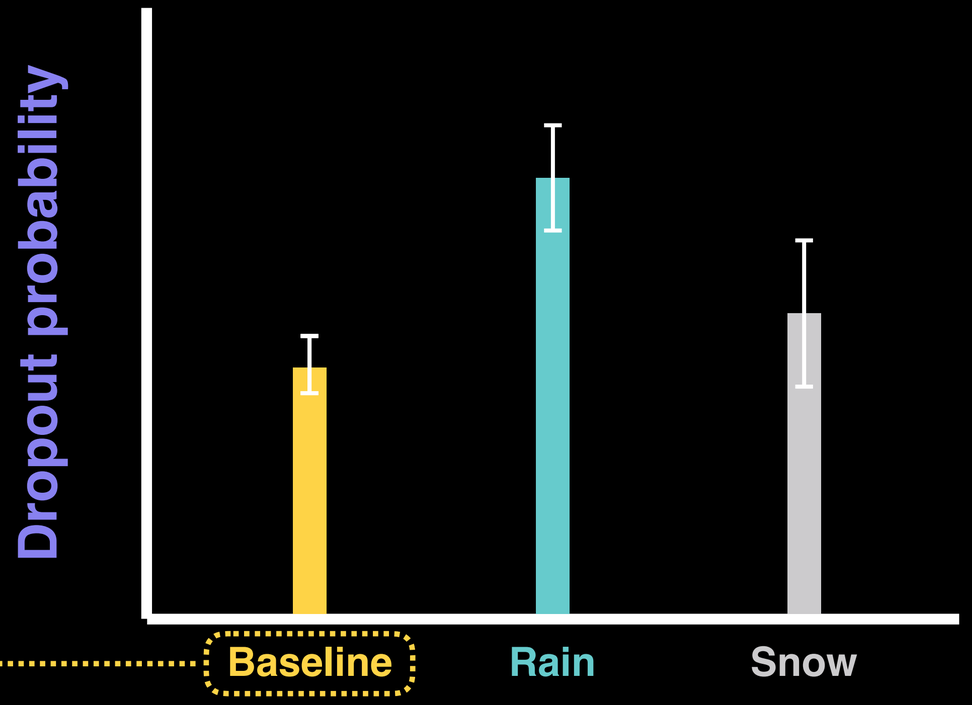

Collected during baseline conditions

Comparing rare events

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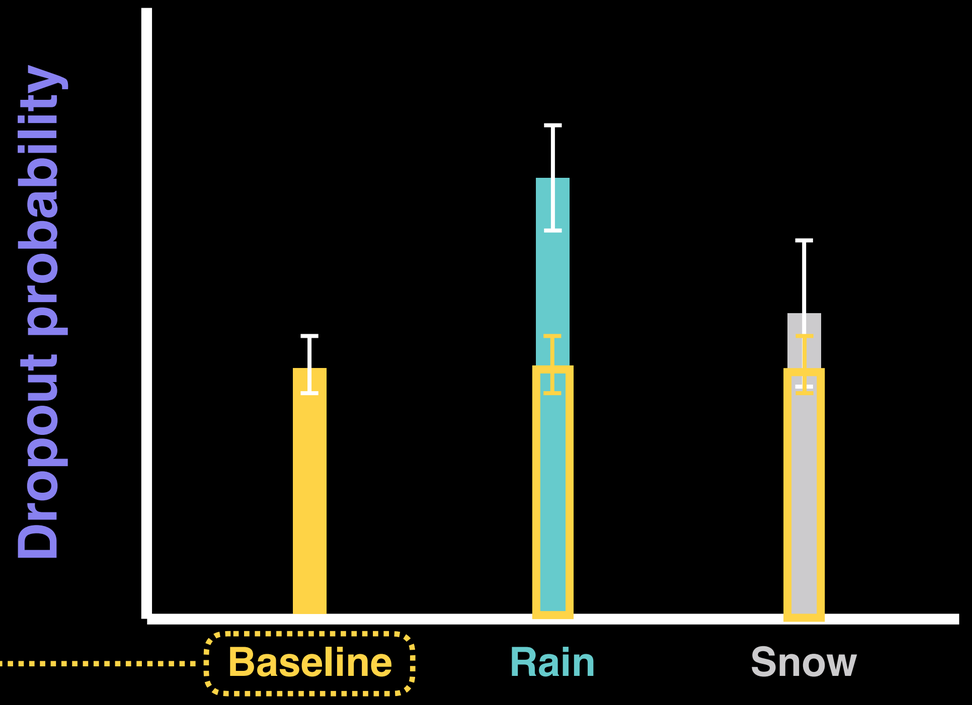

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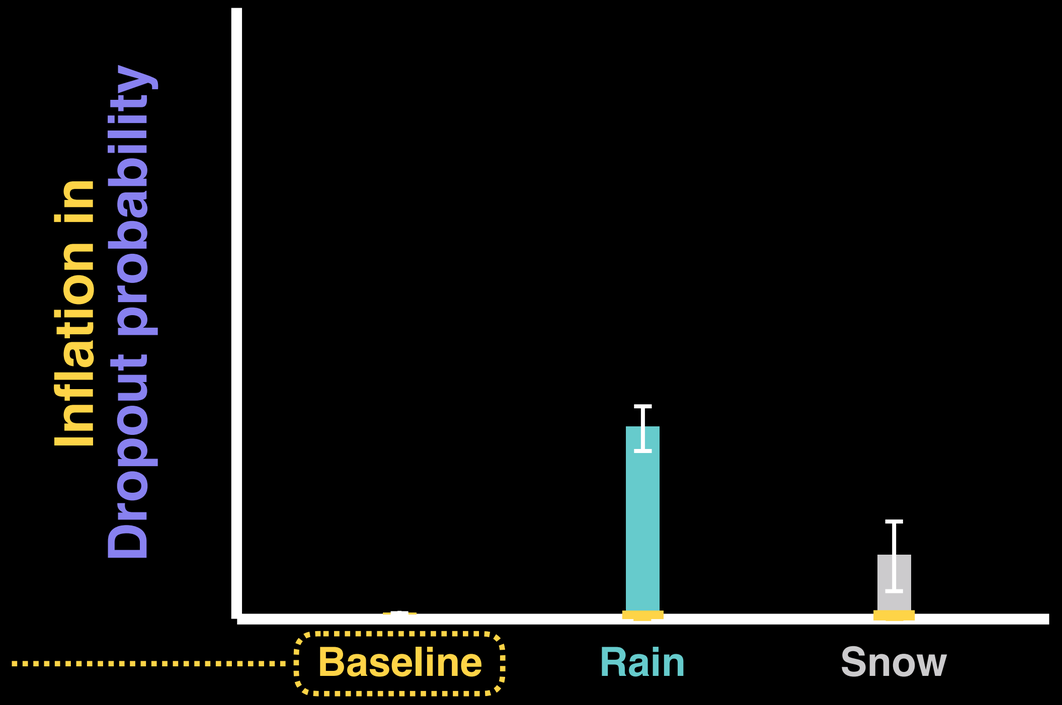

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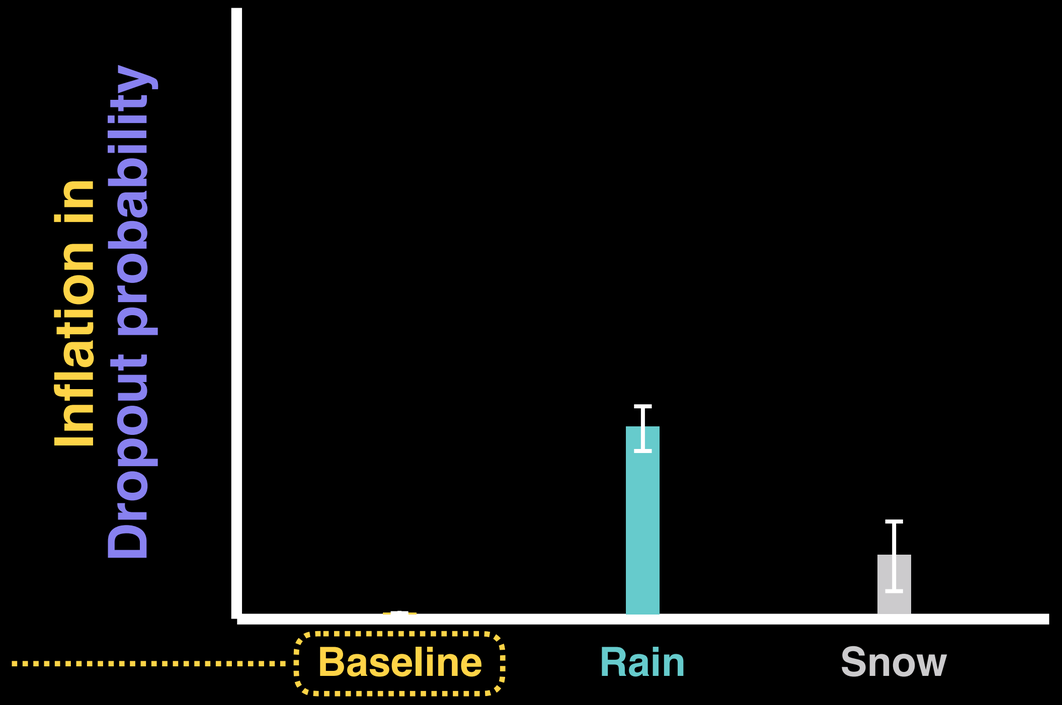

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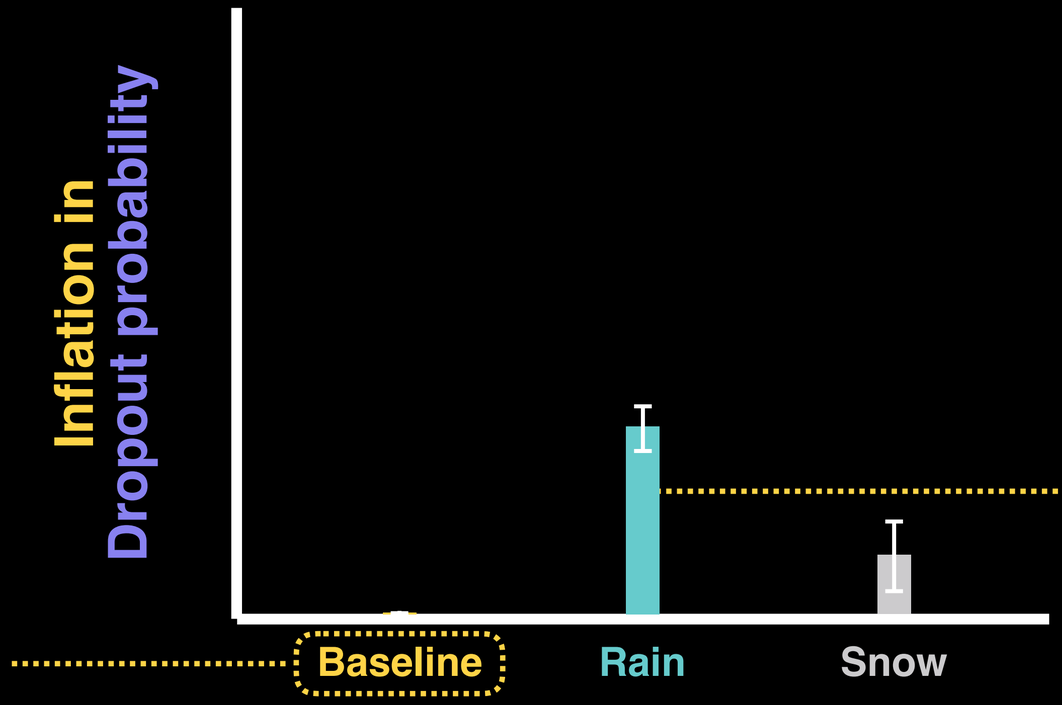


Permits direct comparison of weather events' effects

Collected during baseline conditions

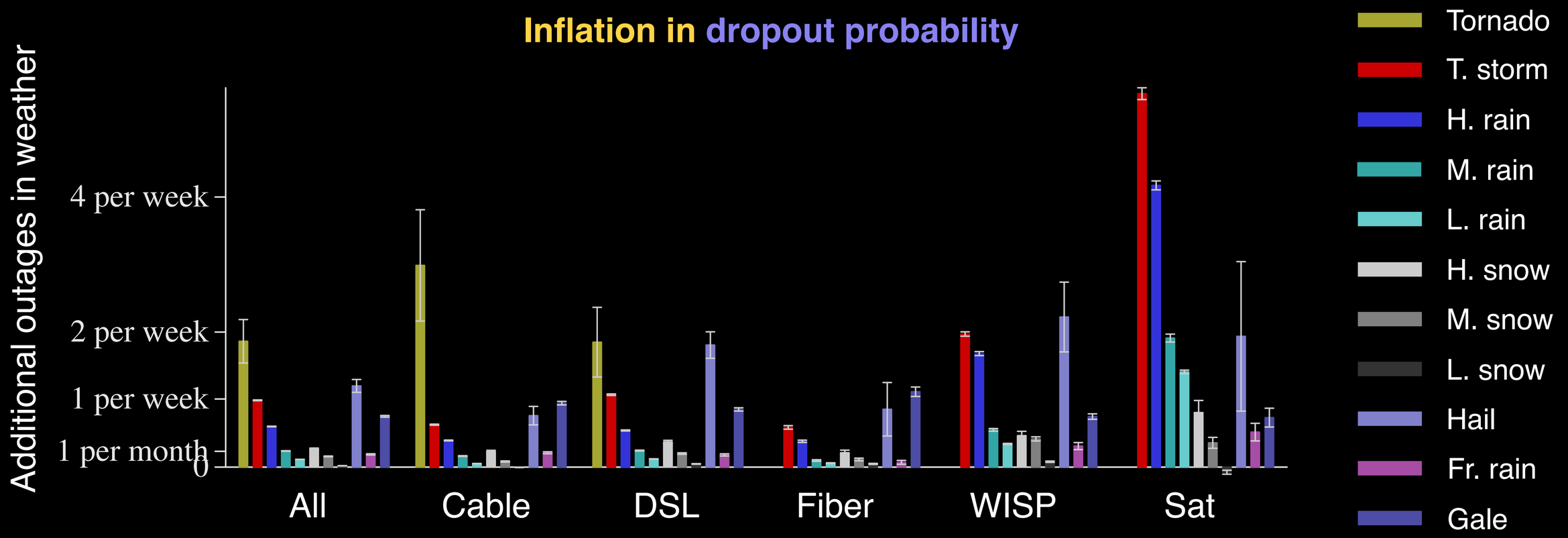
Analyzing the effect of weather on residential links

Link type

Geography

Intensity

Quantifying the increase in frequency of weather-related outages by link type



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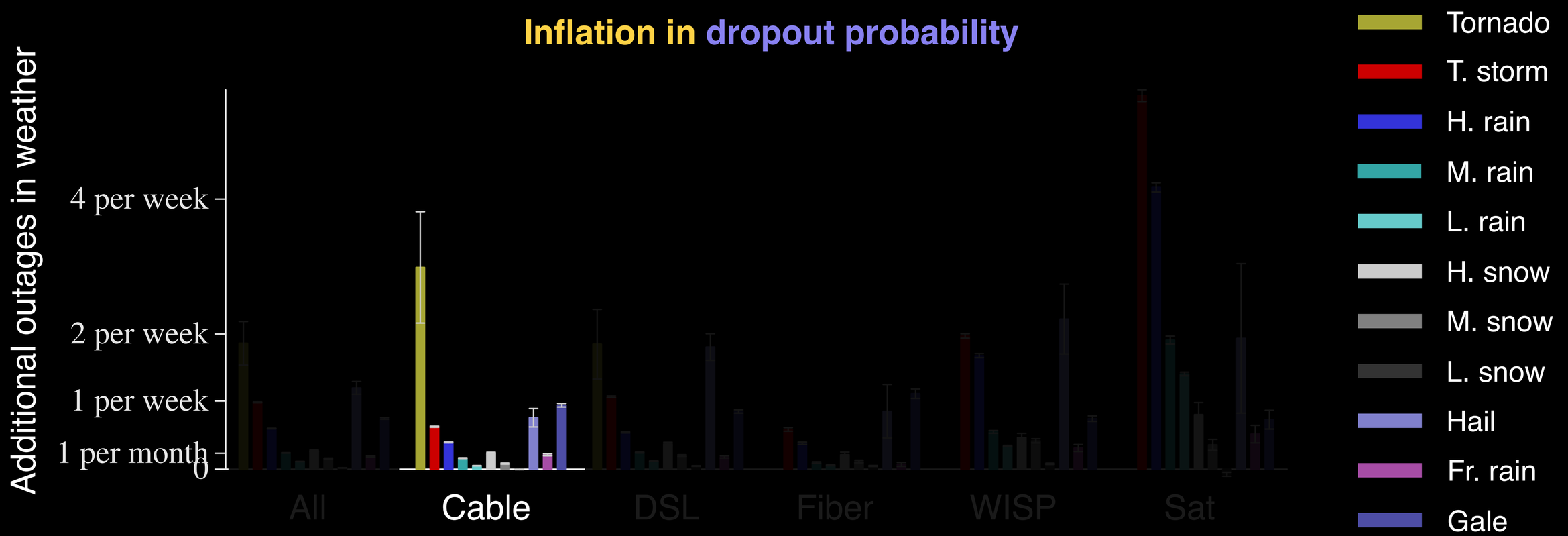

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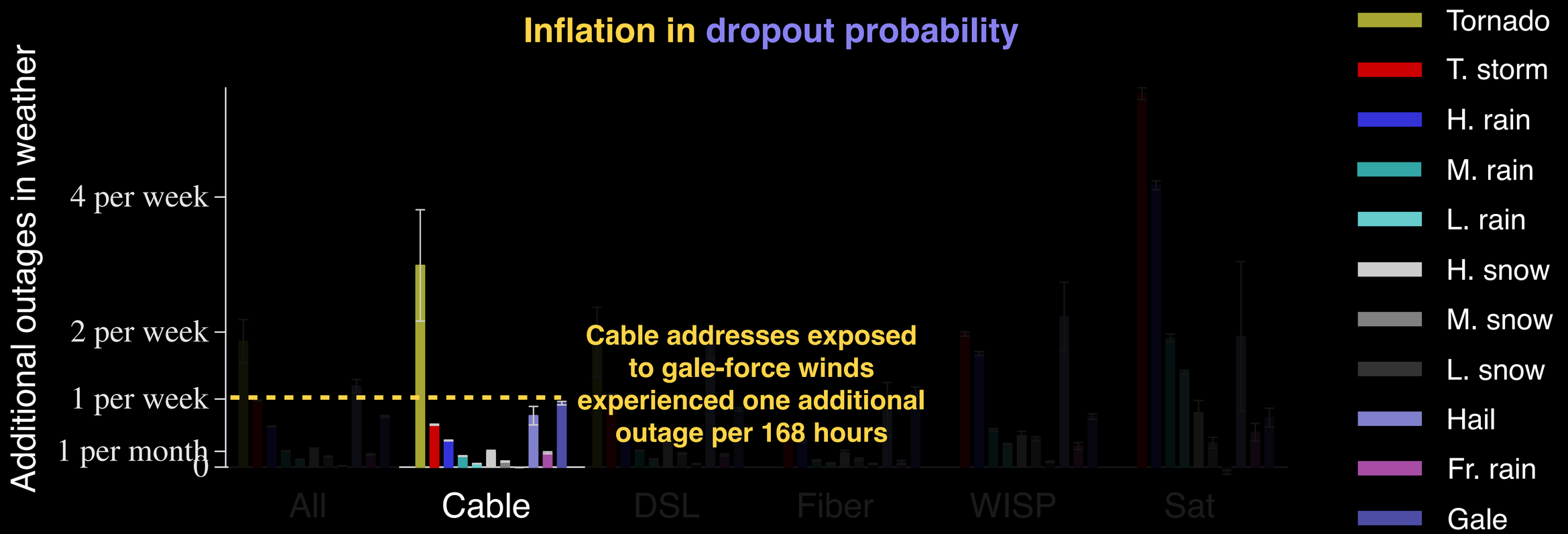

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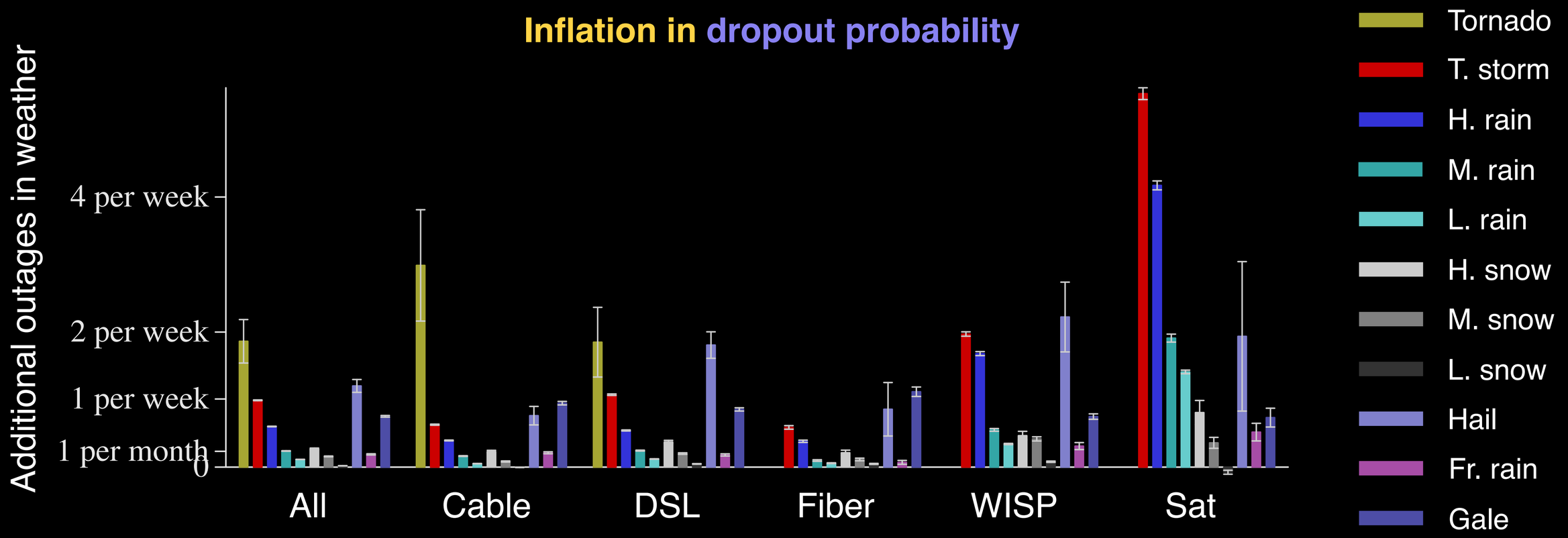

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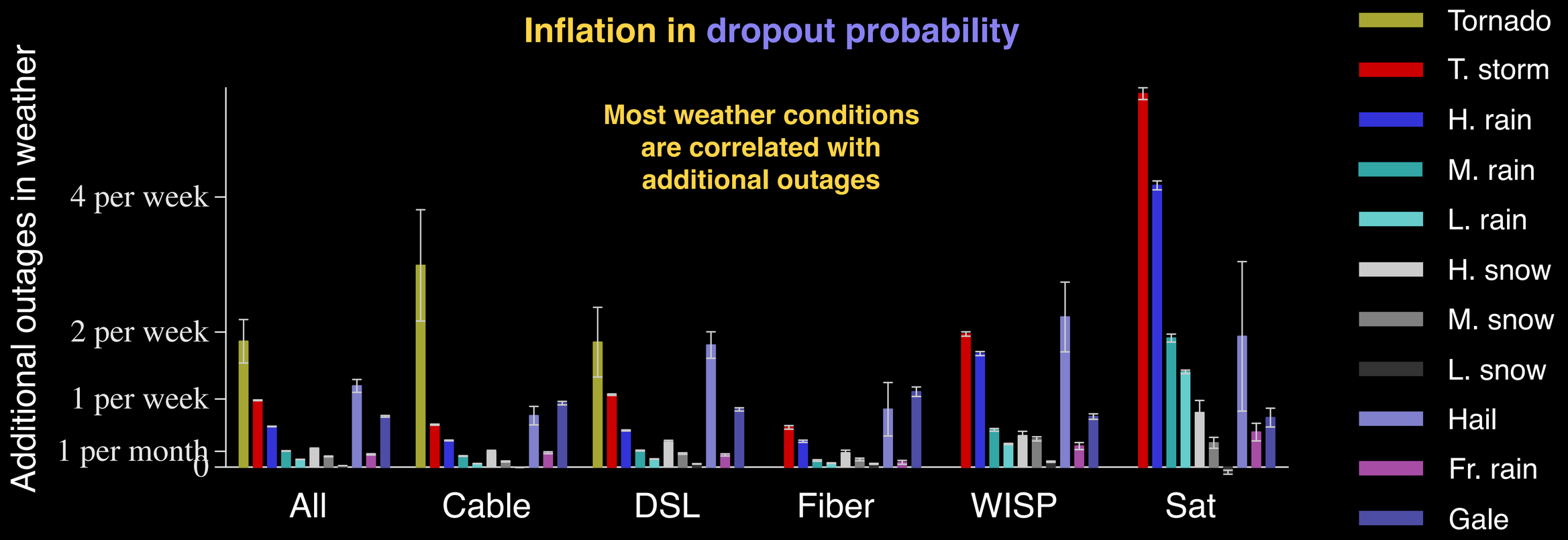
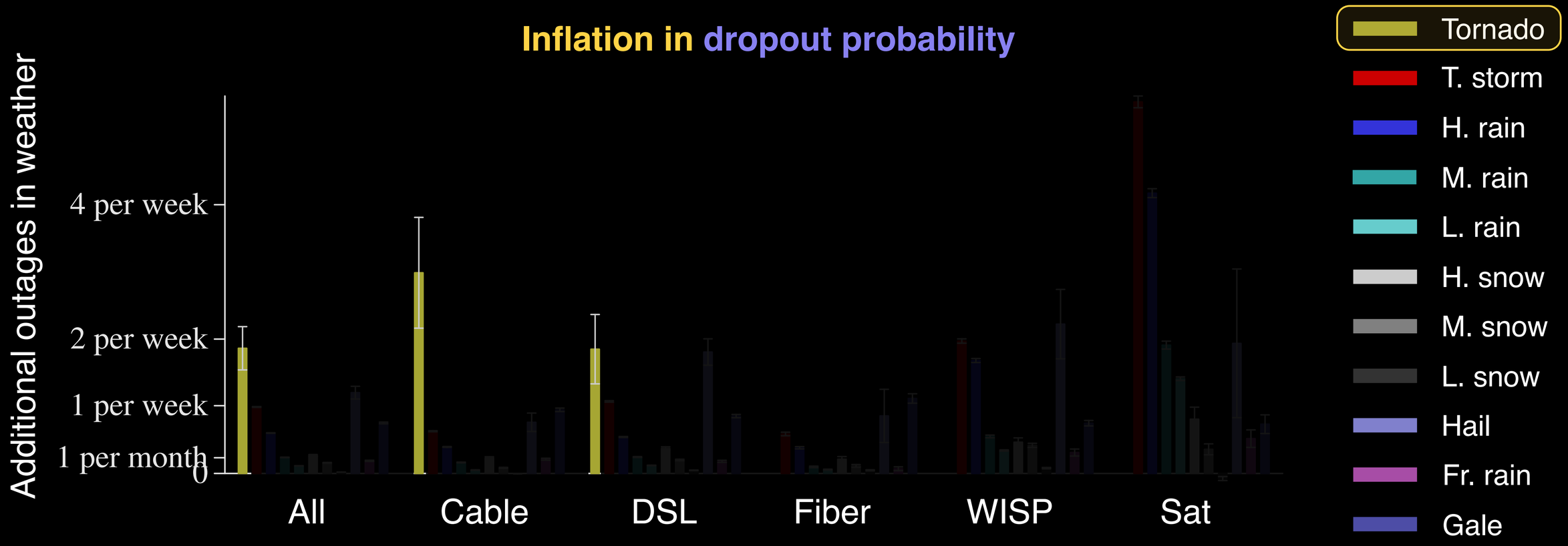


Tornadoes are particularly devastating



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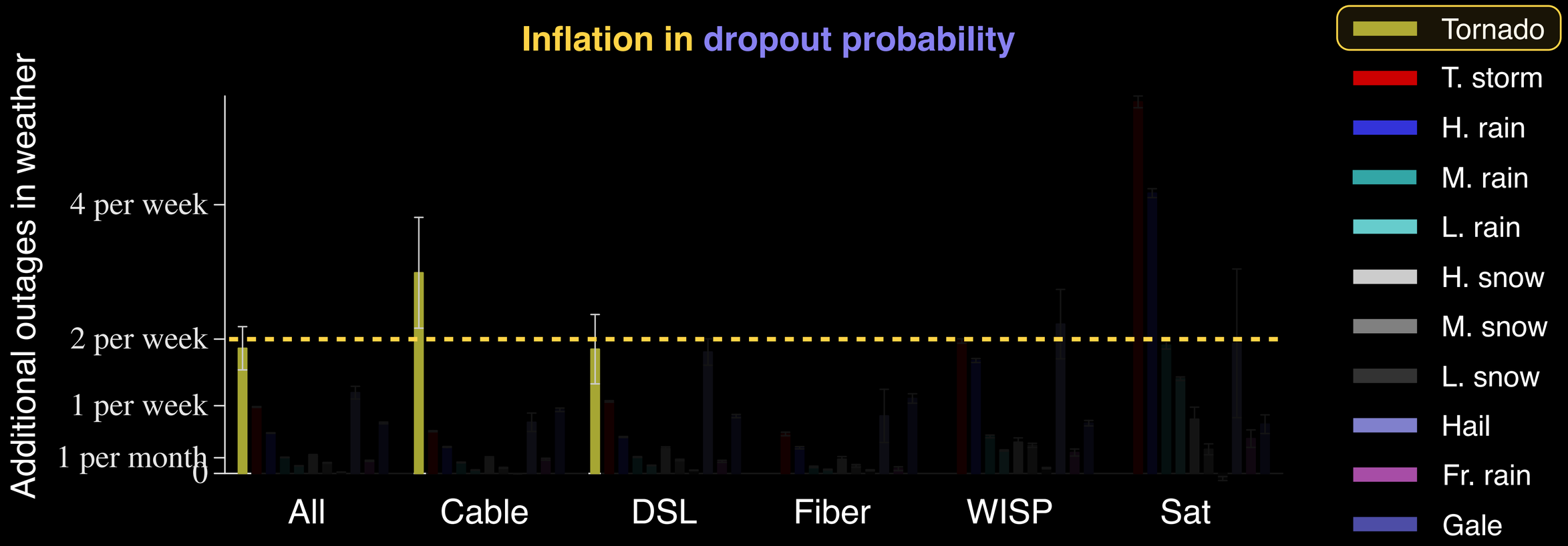

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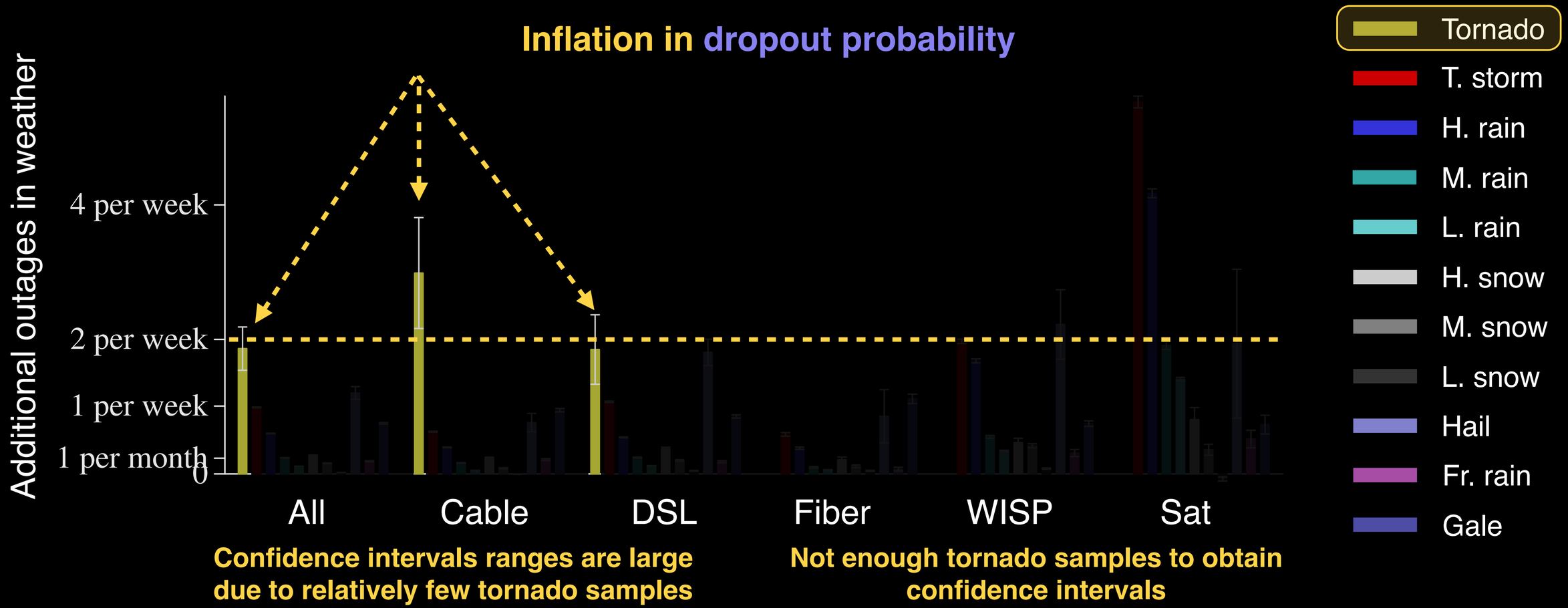
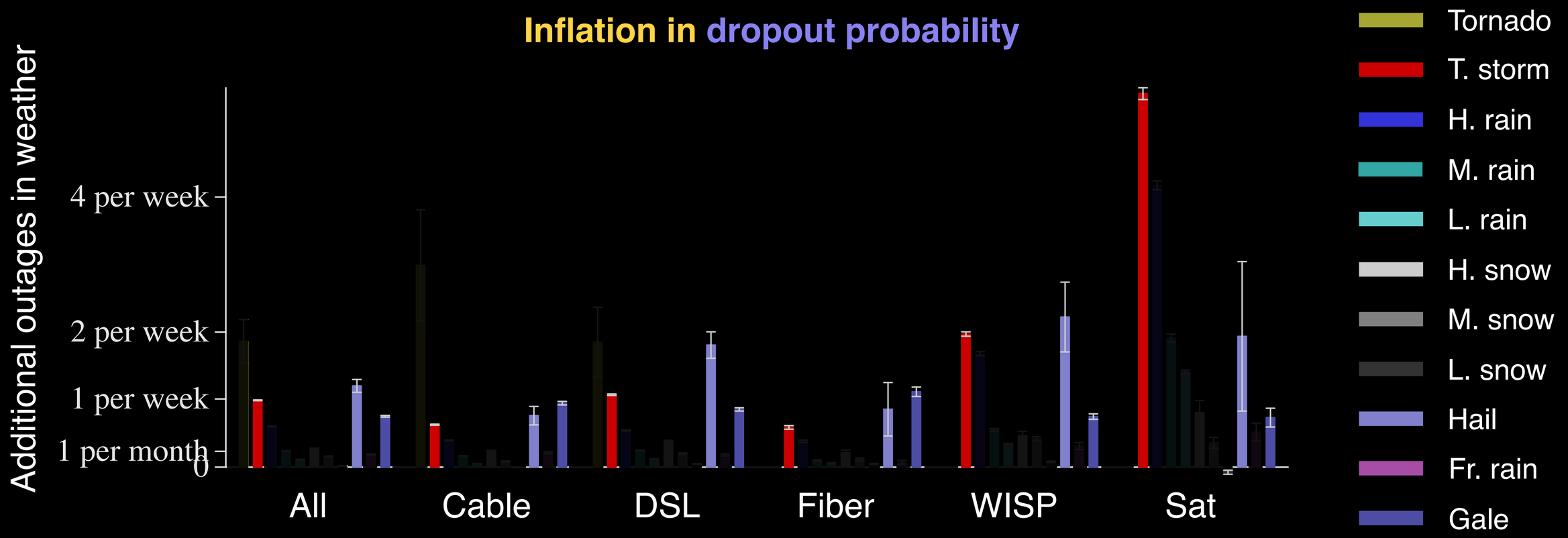


Thunderstorms, hail, and gale-force winds are also damaging



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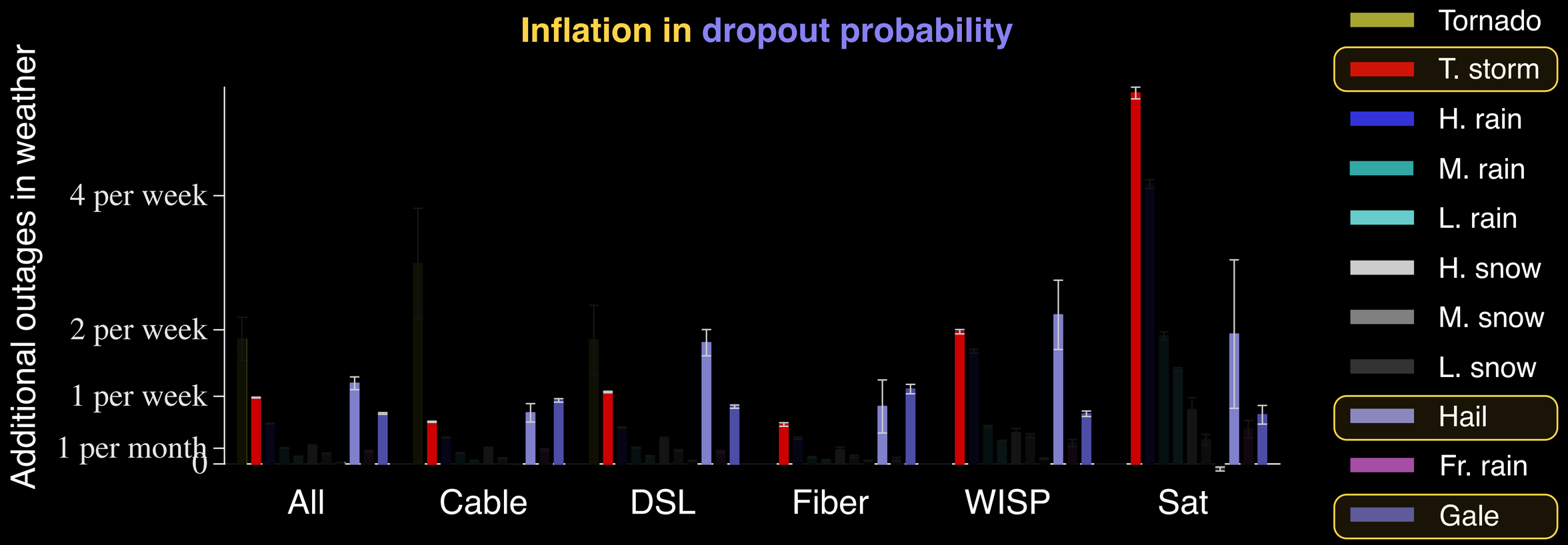

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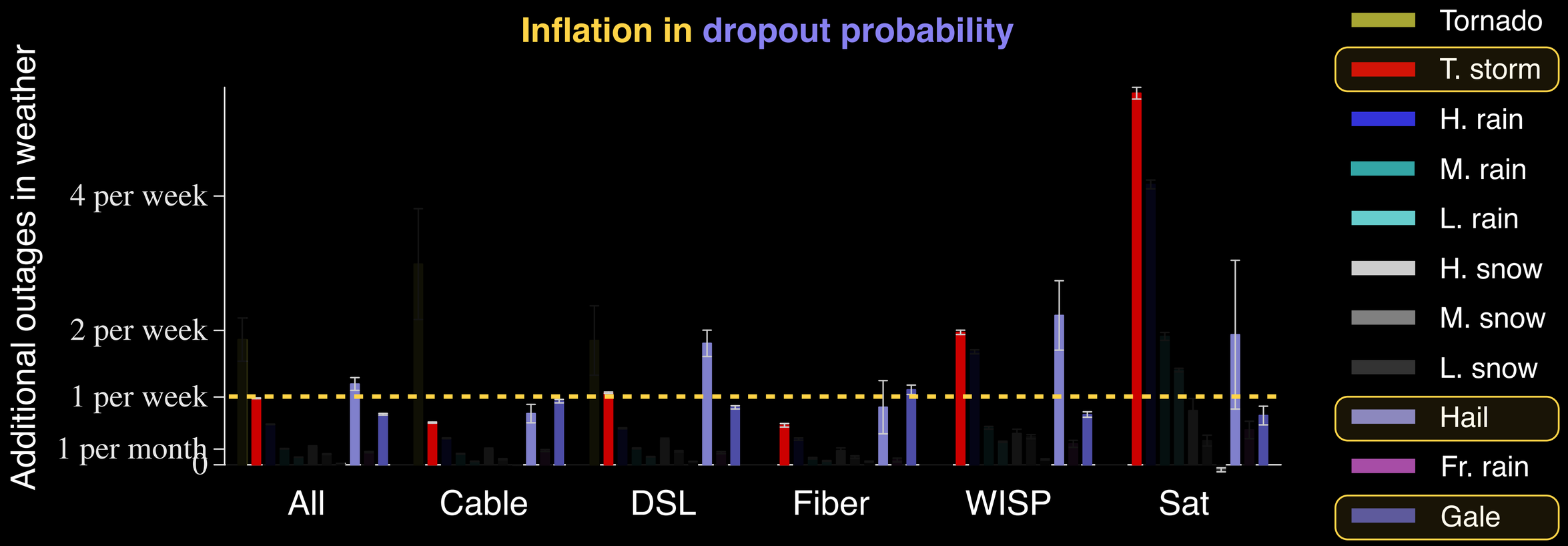
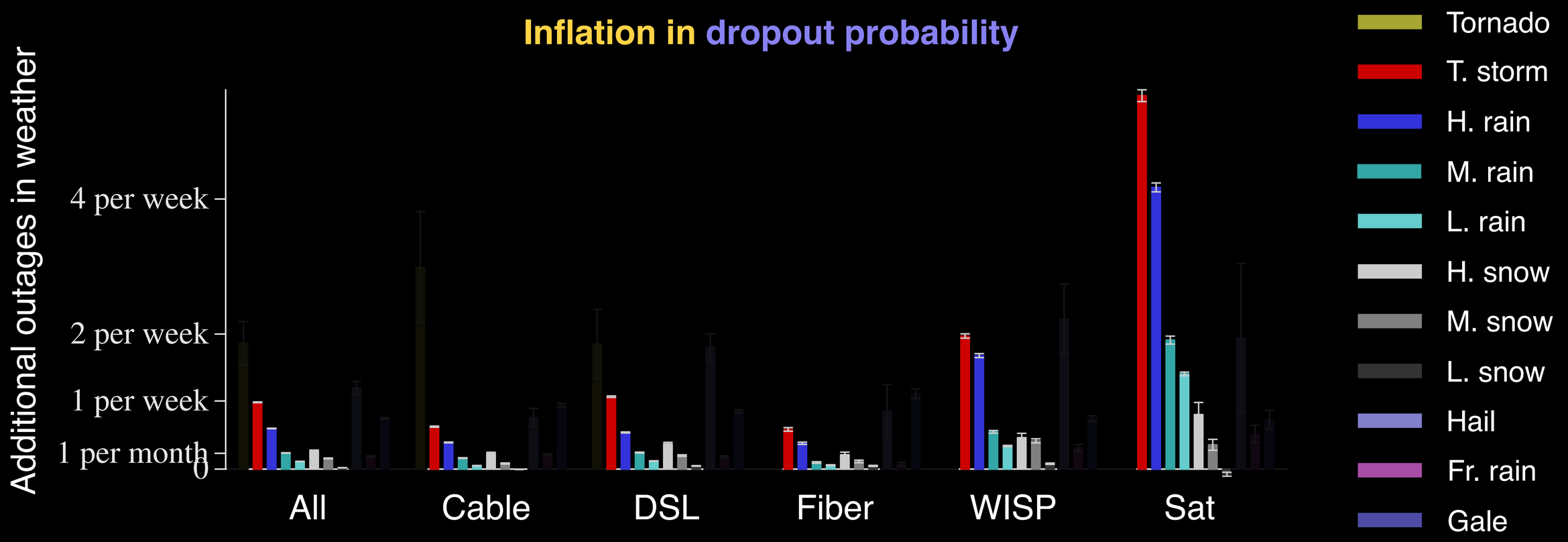
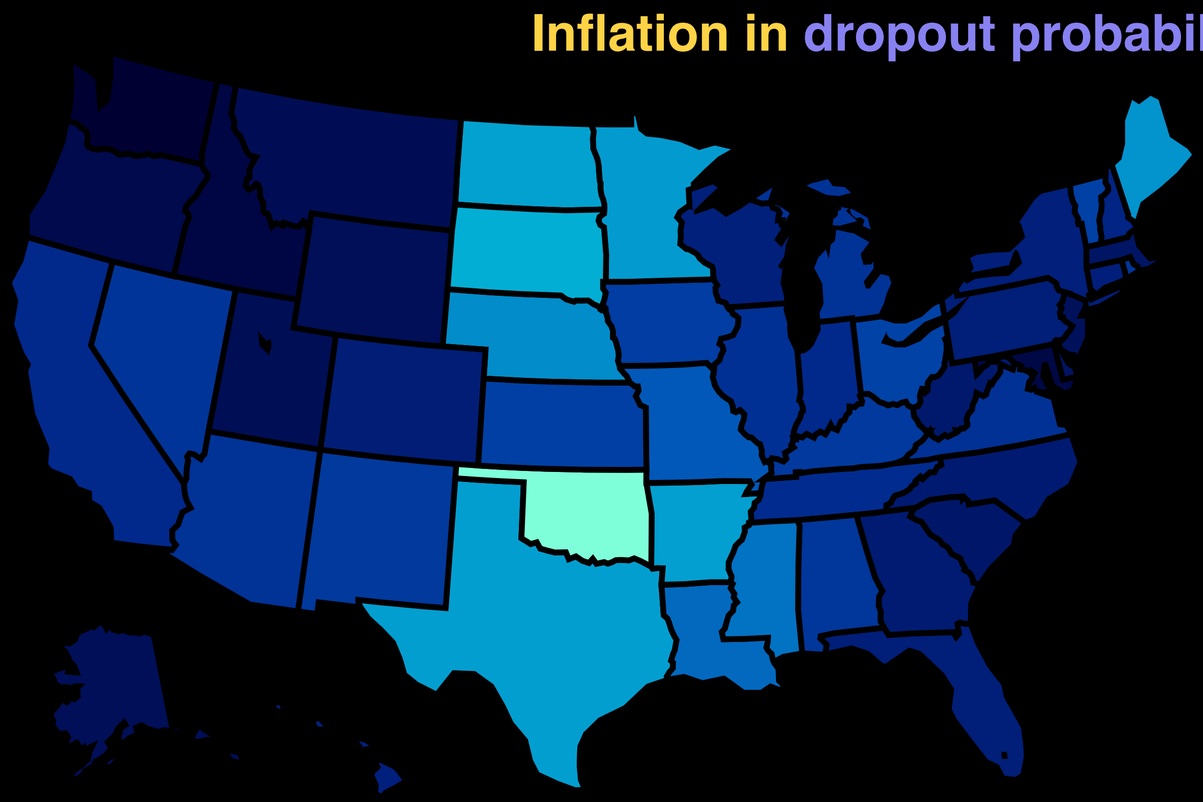


Wireless link types are particularly affected by precipitation

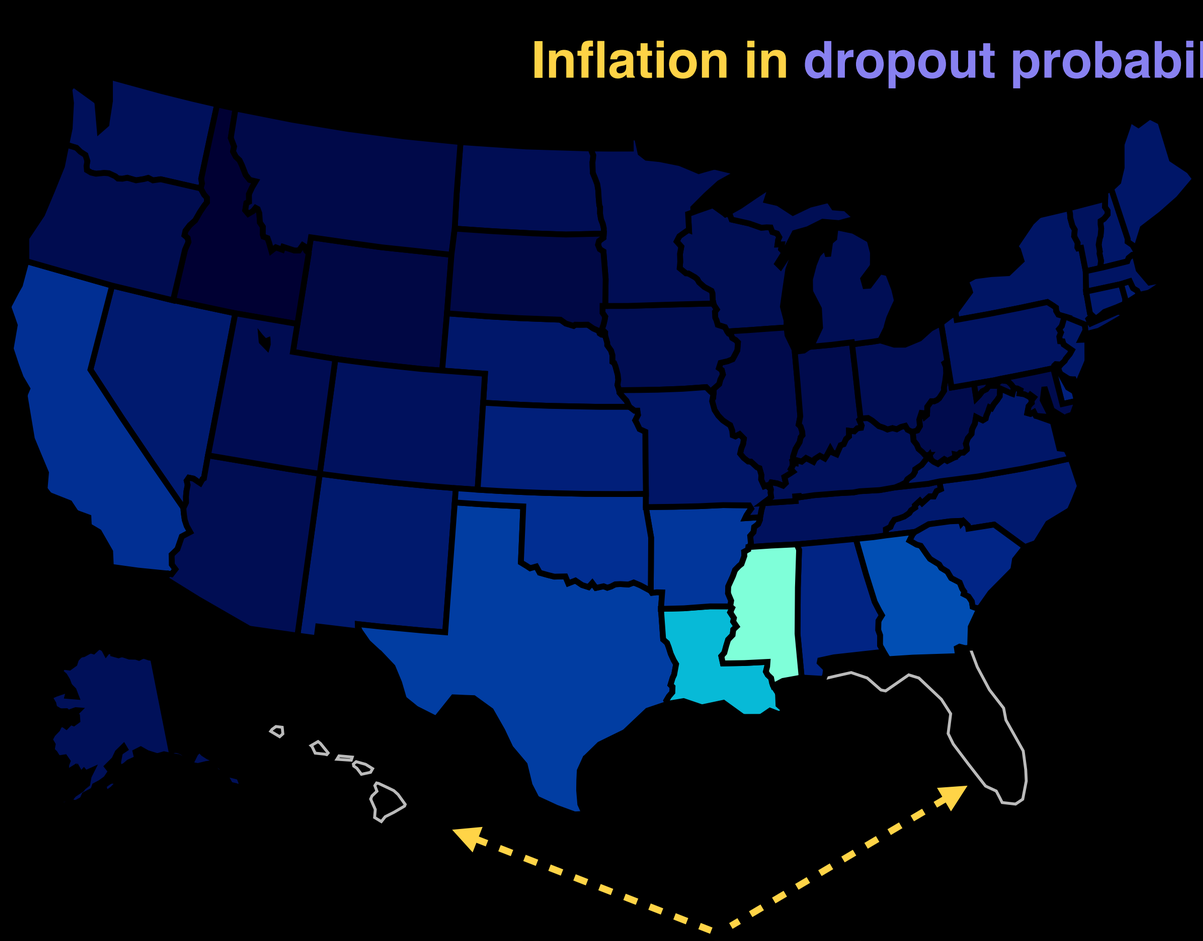


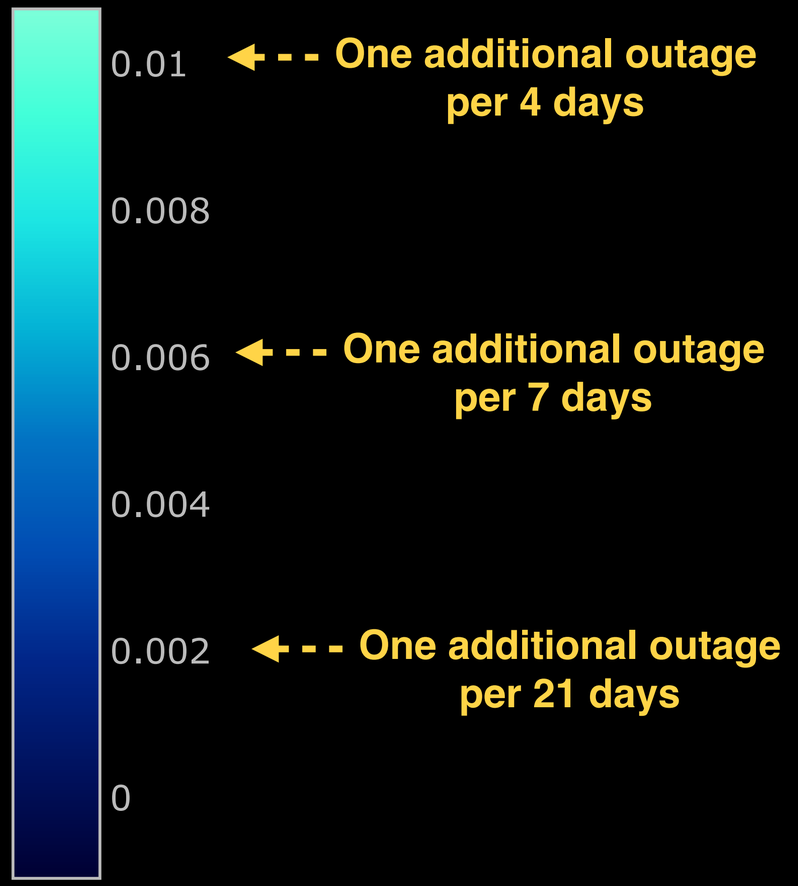
Midwestern states are more vulnerable to rain



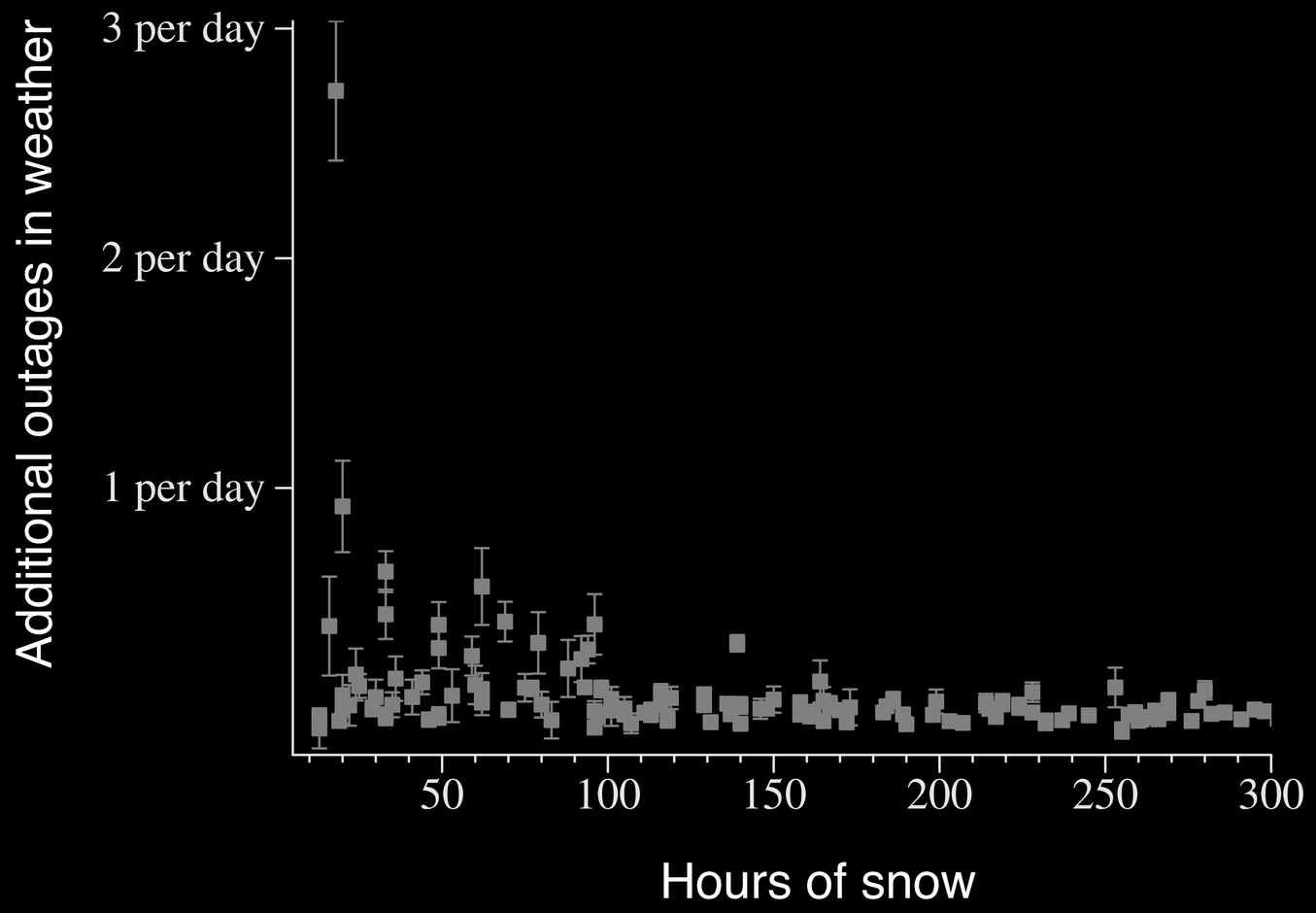
Midwestern states have more wireless links

Southern states are more vulnerable to snow

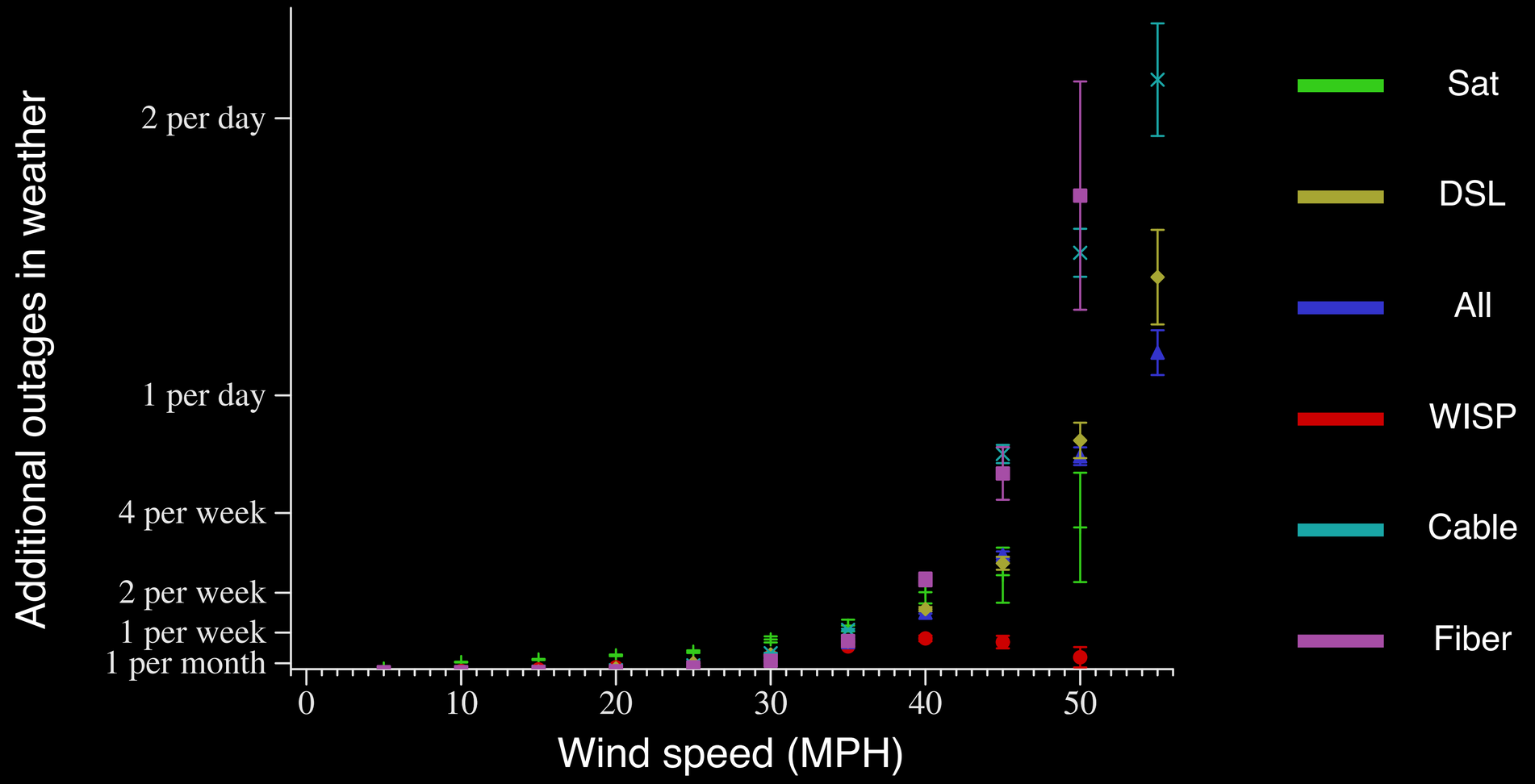




Regions that are less familiar with snow observe more snow-related outages



Wind affects wired links more than wireless links



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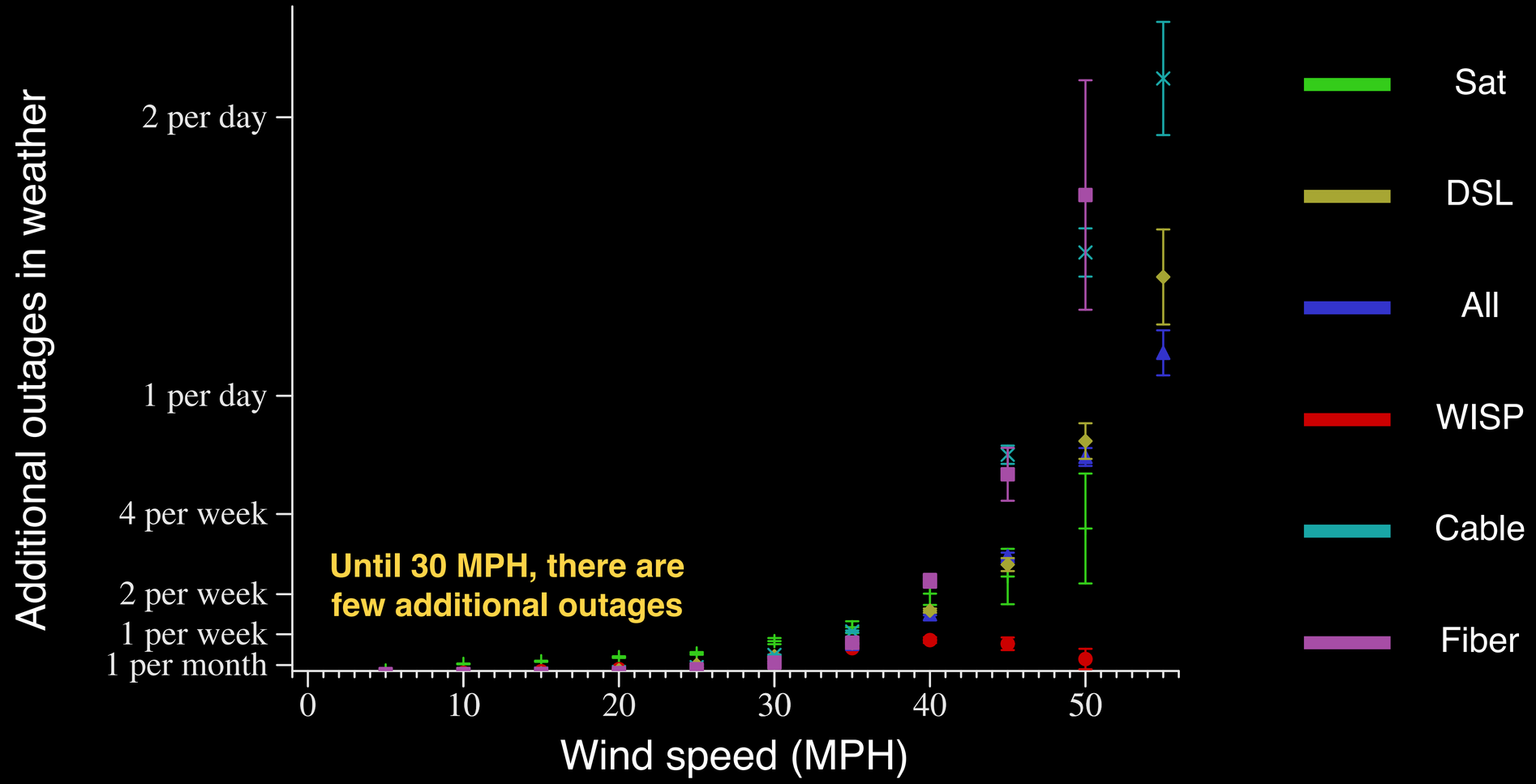

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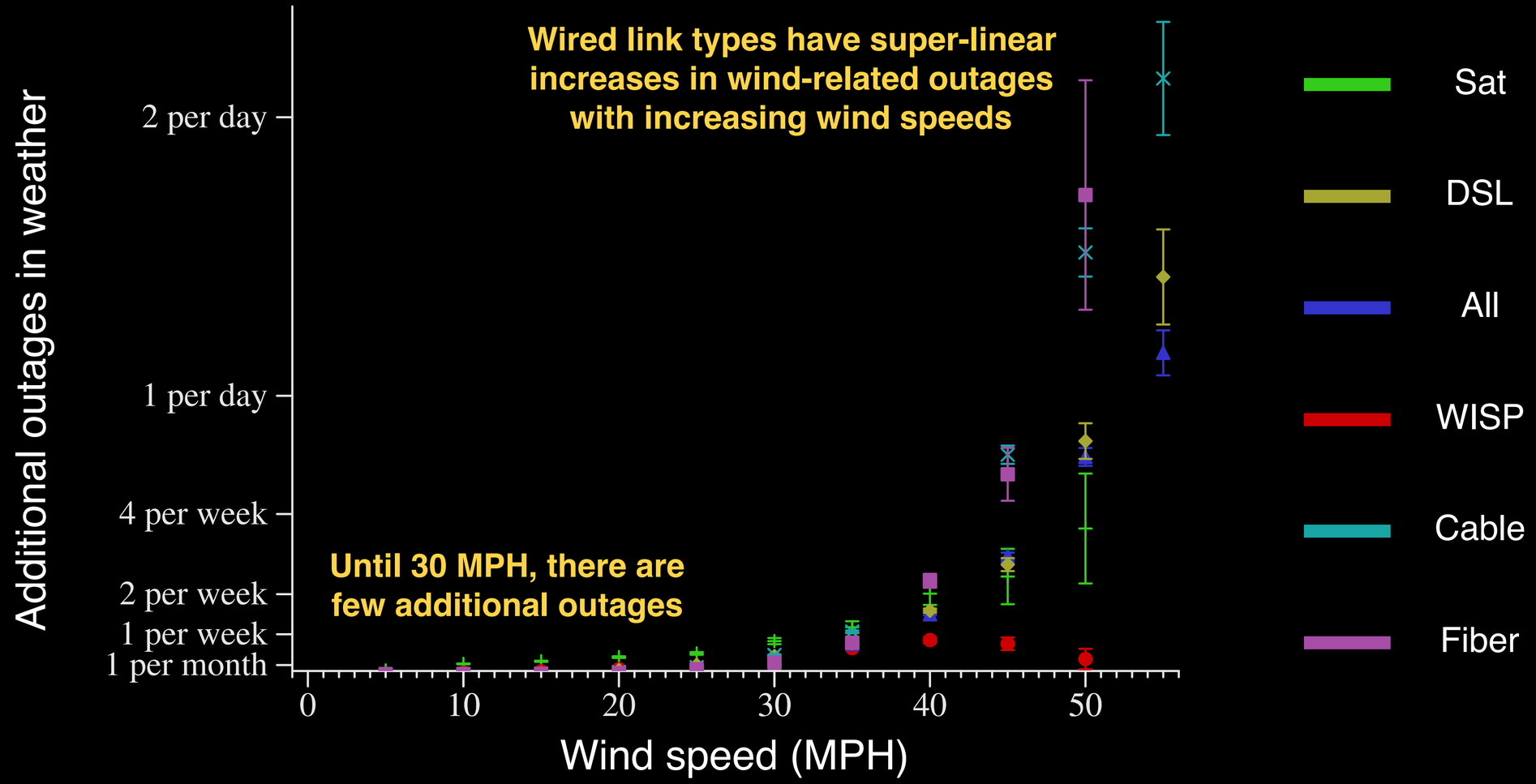

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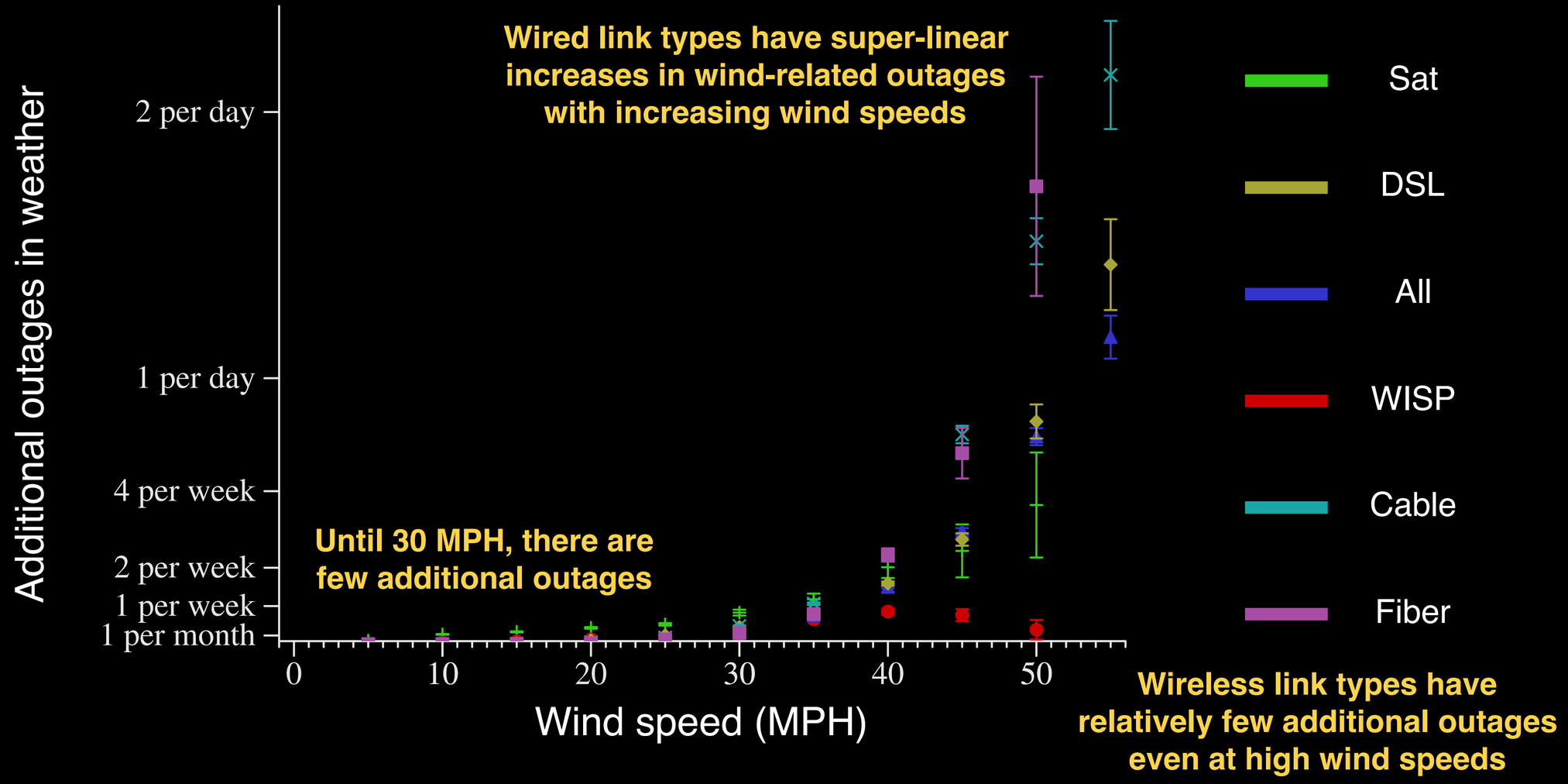

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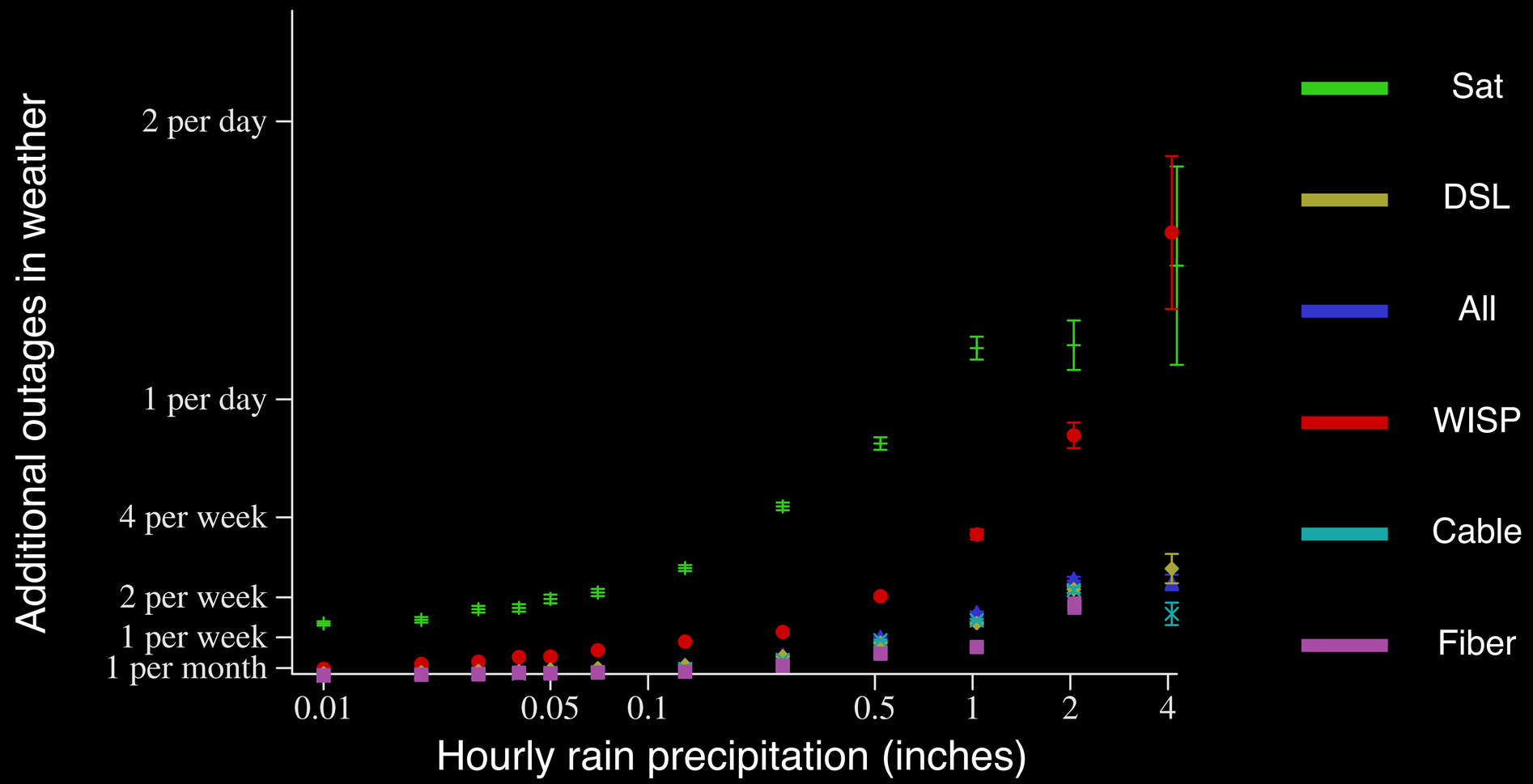

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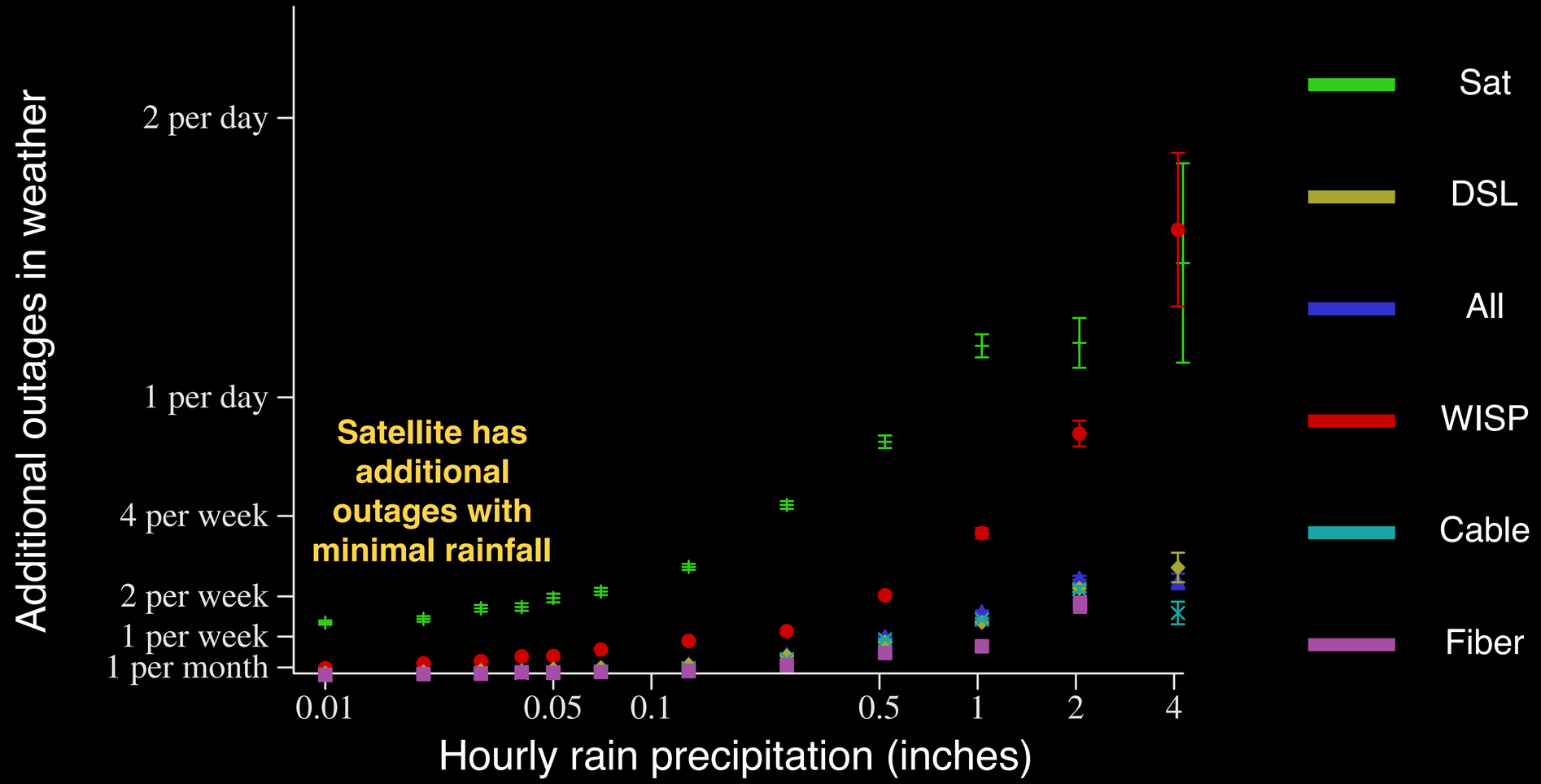

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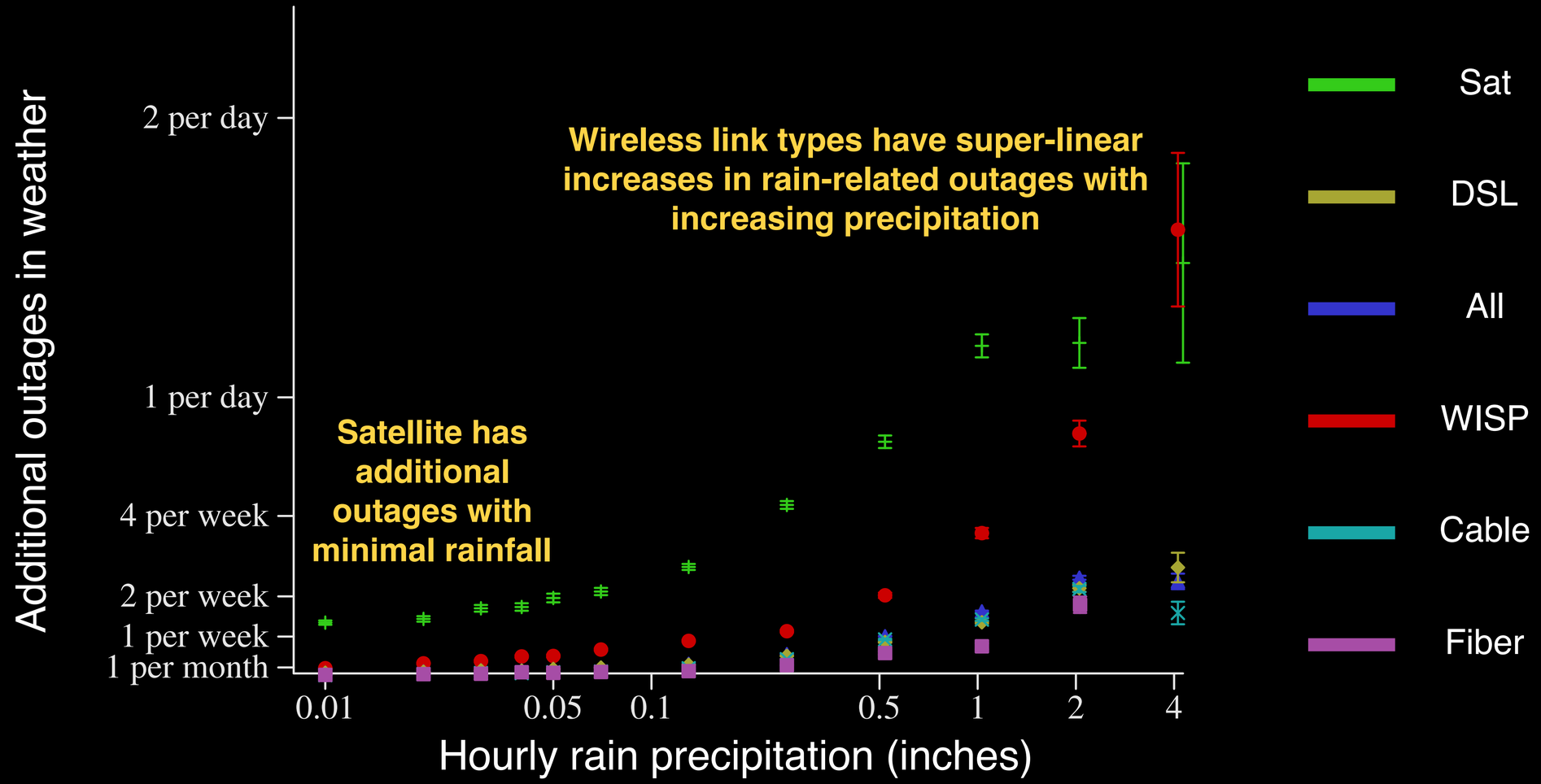

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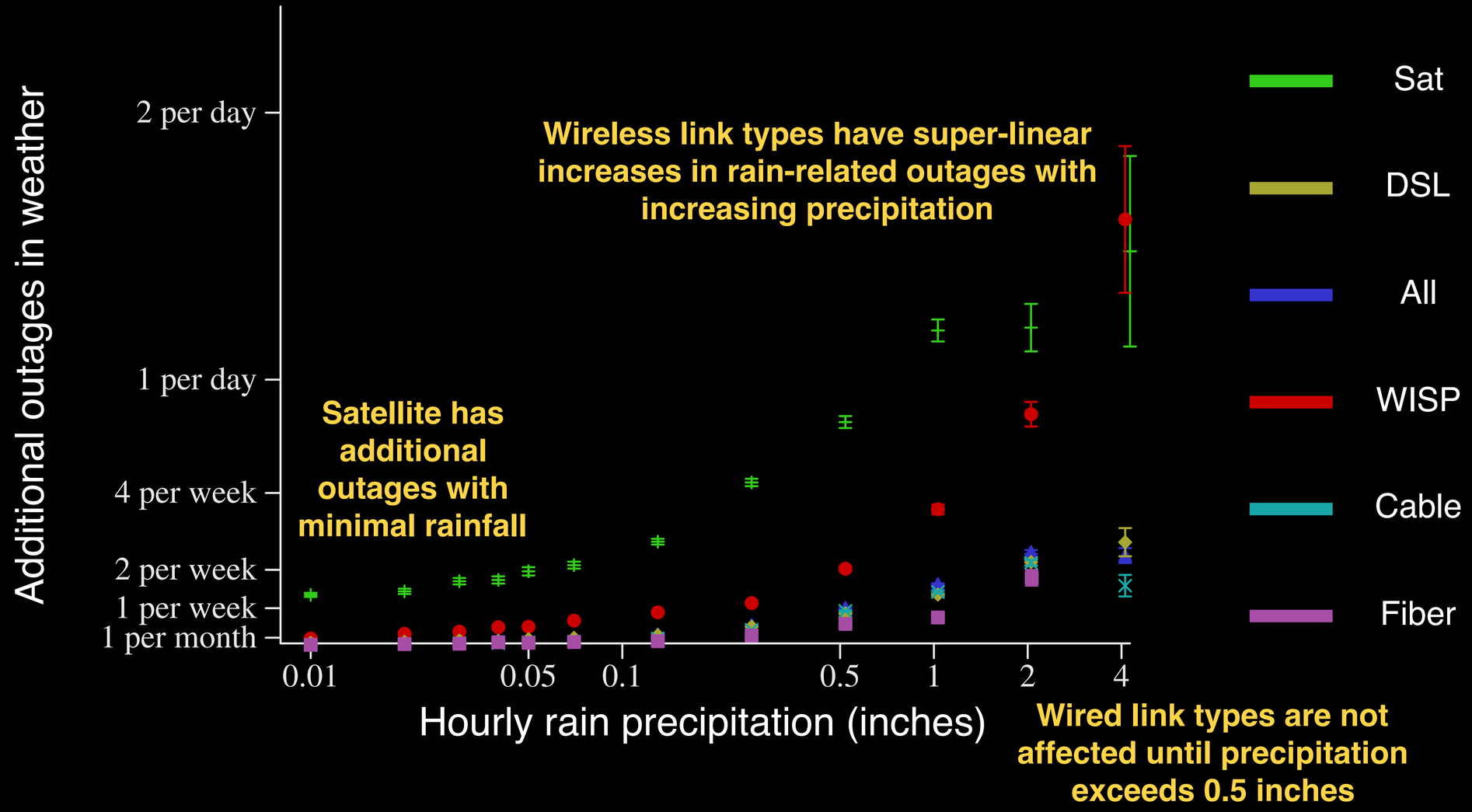
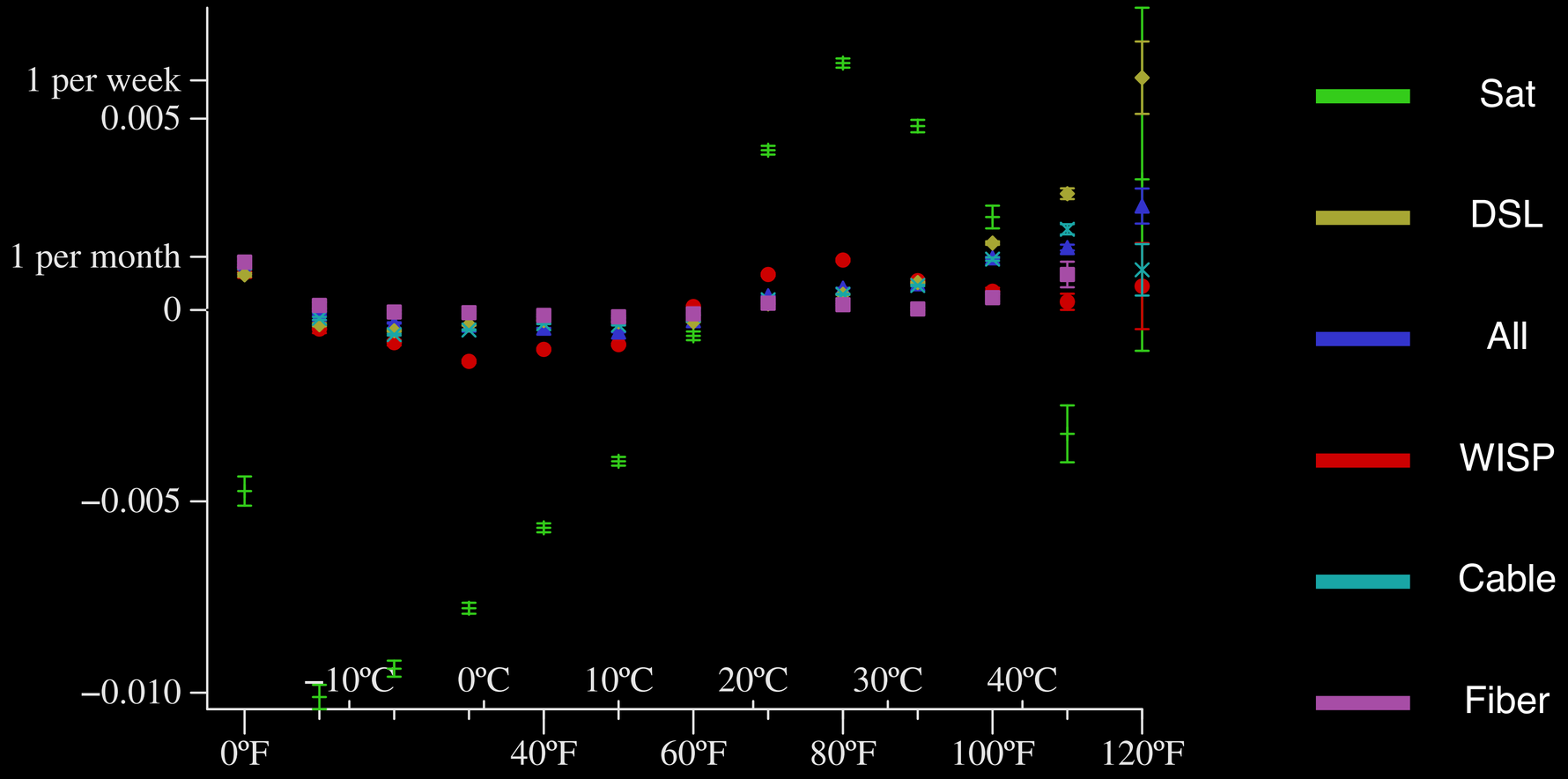
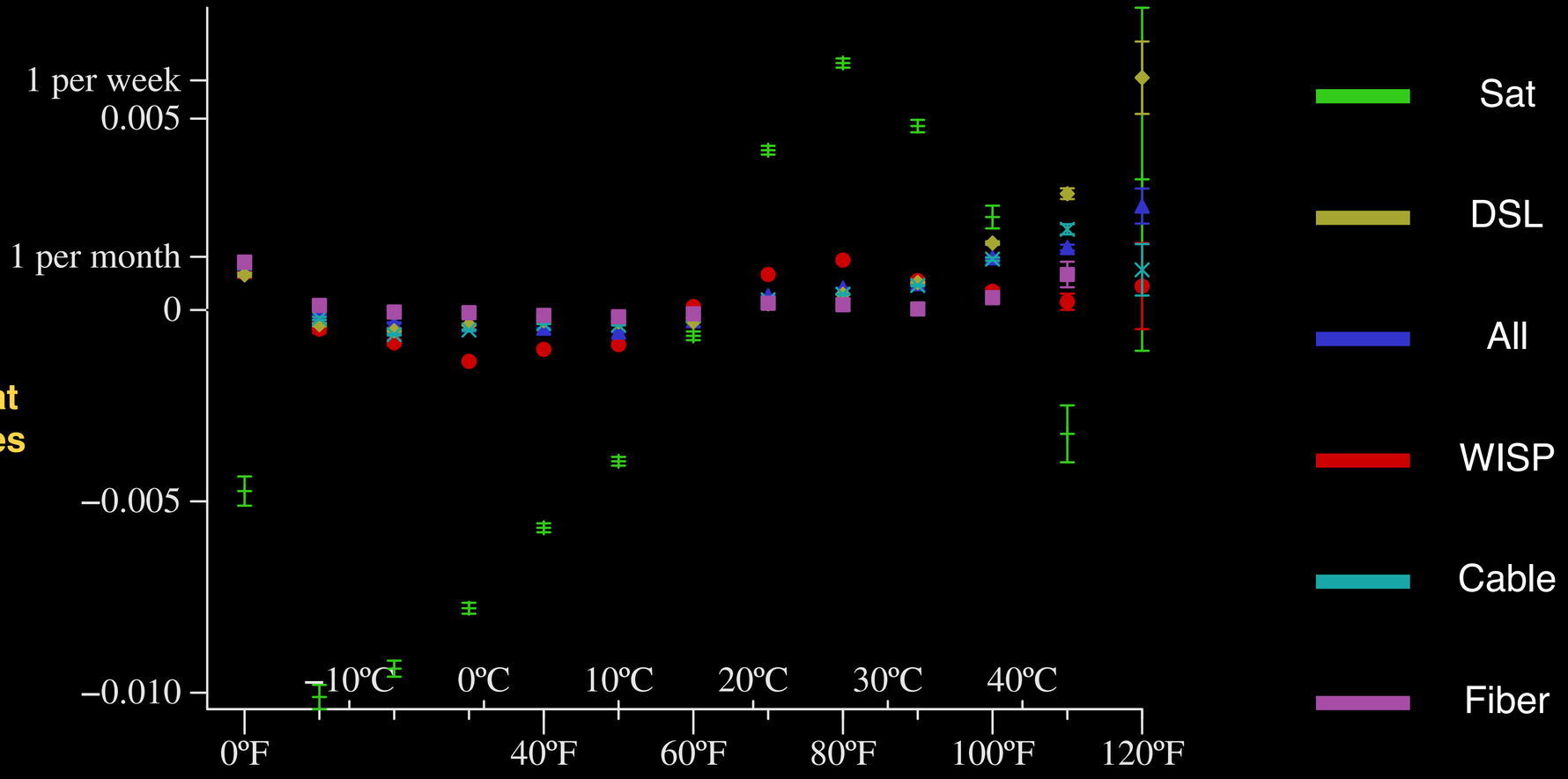


Temperature has unexpected effects



Temperature has unexpected effects

Satellite has fewer additional outages at extreme temperatures



This dataset can benefit many stakeholders

Dataset will be publicly available
http://thunderping.cs.umd.edu/

Businesses
Can estimate revenue loss due to everyday weather

Governments
Can identify problem areas and guide investment

Customers
Can learn about the resilience of ISPs in their area to weather

We quantified weather's effect on Internet connectivity

Link type

Wireless link types experience more outages during precipitation

Wired link types experience more outages in gale-force conditions

Geography

Midwestern states are more affected by rain

Southern states are more affected by snow

Intensity

Wind, precipitation, and temperature, have non-linear effects on connectivity

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