

Advancing Technoeconomic Modeling of Hail Risk and Resilience

2024 PVPMC Salt Lake City

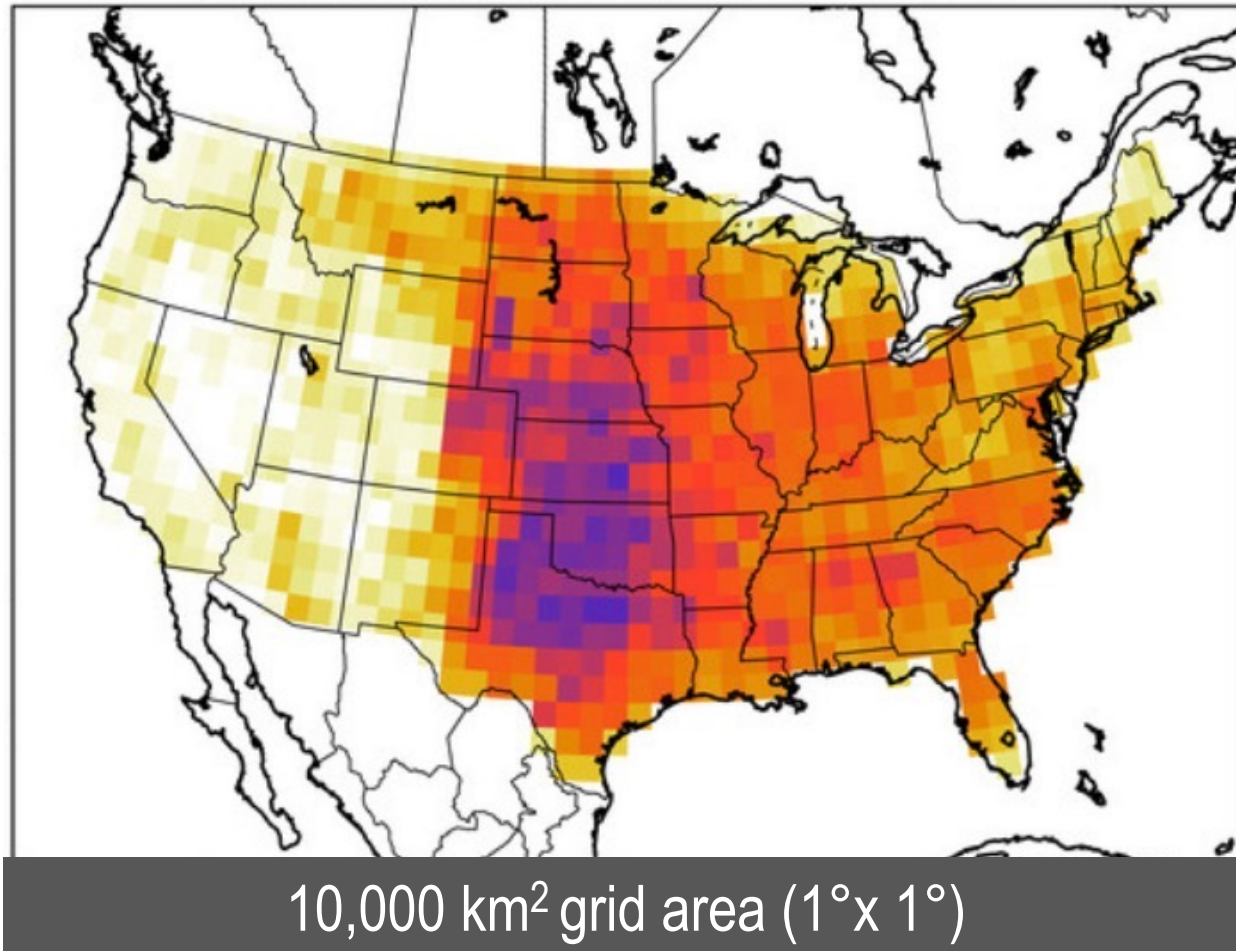


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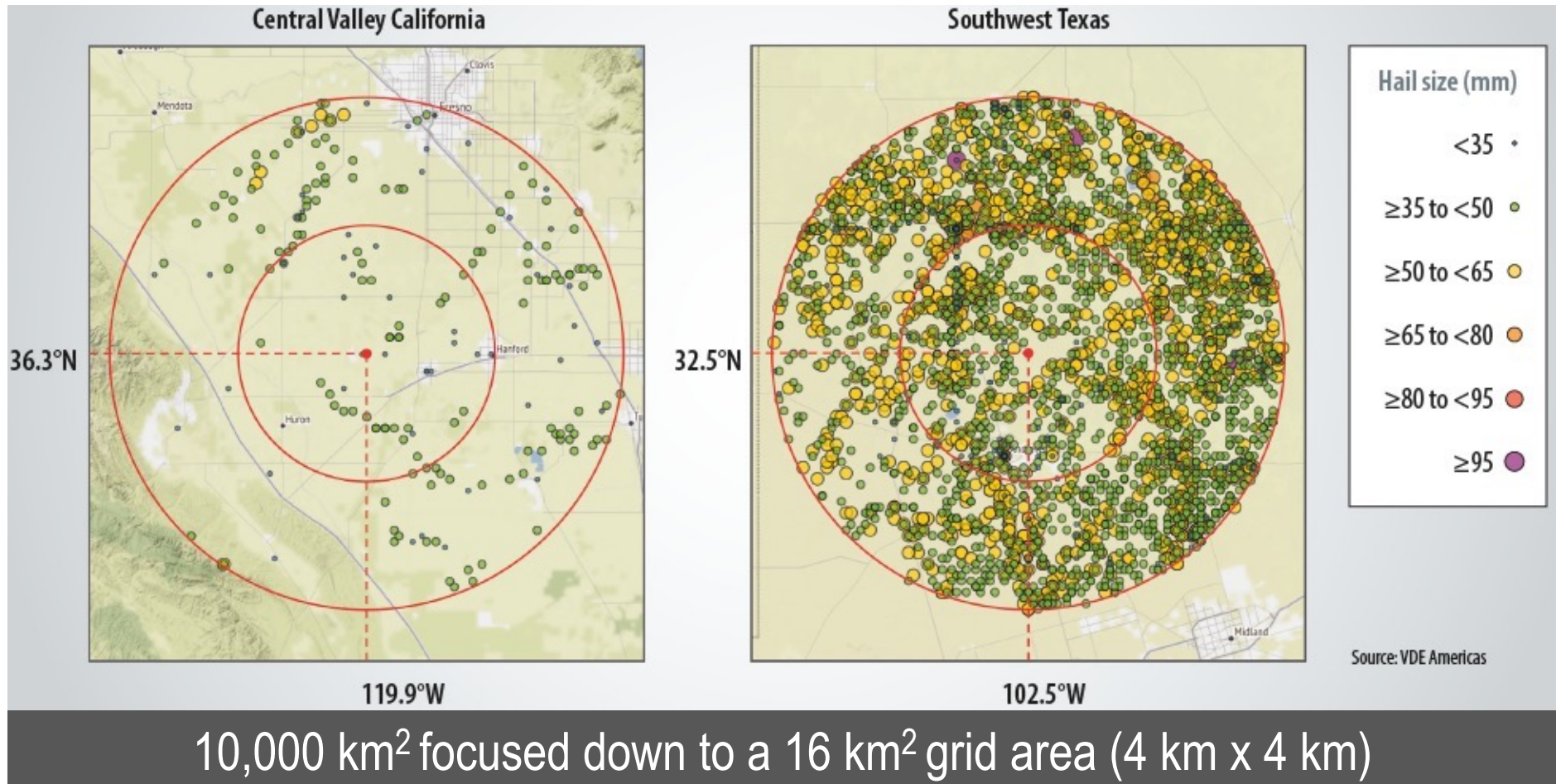


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Traditional hail maps lack granularity to characterize asset-level risk



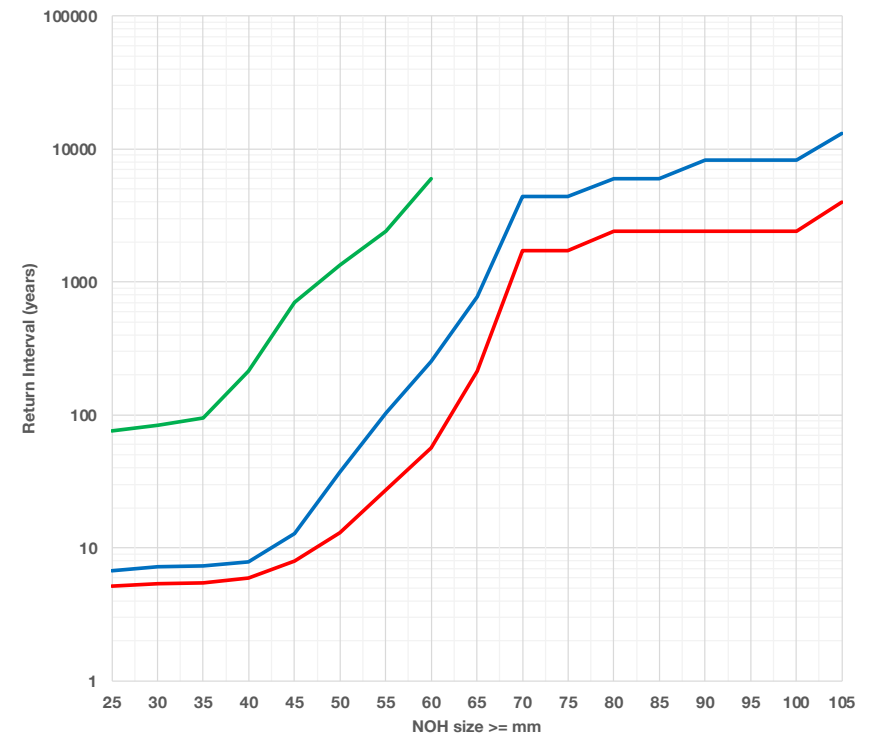
Advanced hail maps characterize risk at the local level of a PV plant



Statistical analysis of the cumulative RI_{NOH} at the customer-specified site

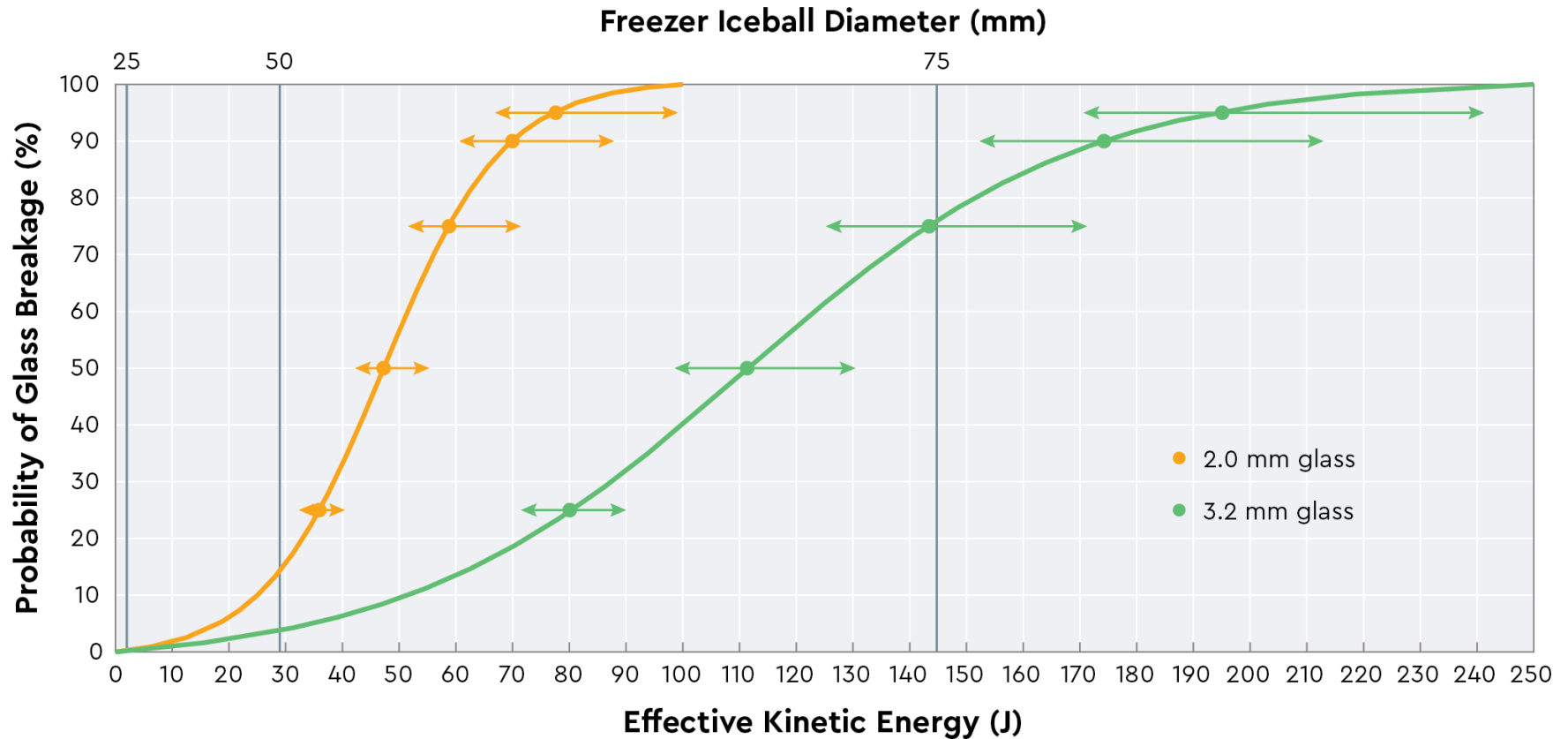
- Characterizes hail risk at the local scale of a solar asset
 - Characterizes the frequency and severity of damaging hail
 - Characterizes NOH size as reported by radar and calibrated by SPC (spotter) observations
- Significant variation based on project location
 - Green line** = Central Valley California (low-risk reference location)
 - Blue line** = Sample site (client-requested location)
 - Red line** = Southwest Texas (high-risk reference location)

Return Period (years)	Sample Site (mm)	SW Texas (mm)	CA (mm)
100	54.8	61.4	35.2
250	59.9	65.1	40.4
500	62.4	66.0	42.90
1000	65.3	67.6	47.3



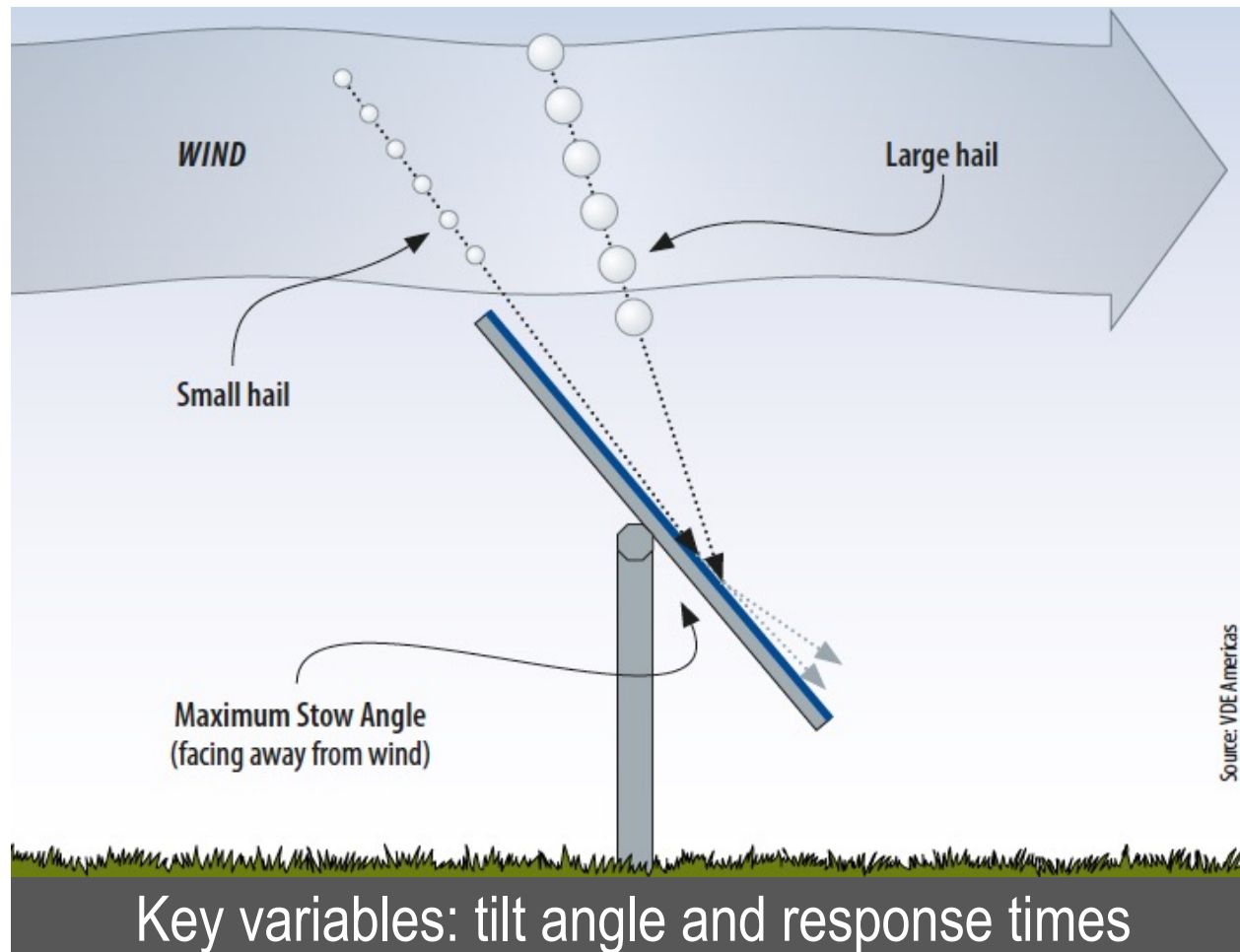
Return interval (RI) is the estimated amount of time between discrete events. Mathematically, it represents the value of a given quantity that is expected to be equaled or exceeded on average once every time interval (T) with an event probability in any given year of $1/T$.

Module construction informs hail resiliency or vulnerability

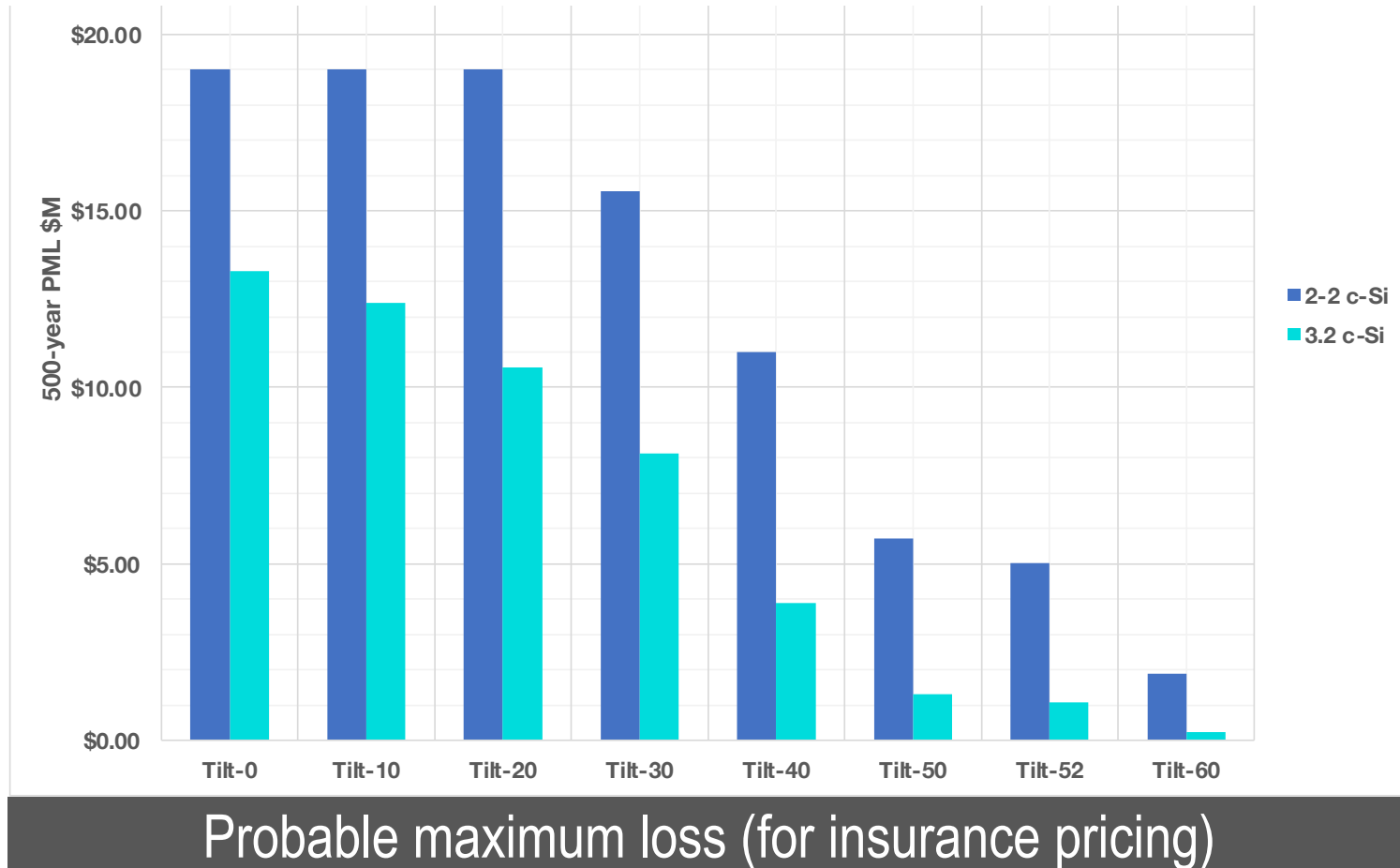


Key variables: front glass thickness and tempering (RETC data)

Tracker defensive stow capabilities can mitigate hail risk exposure



Insurance risk is a function of project location & fielded technology

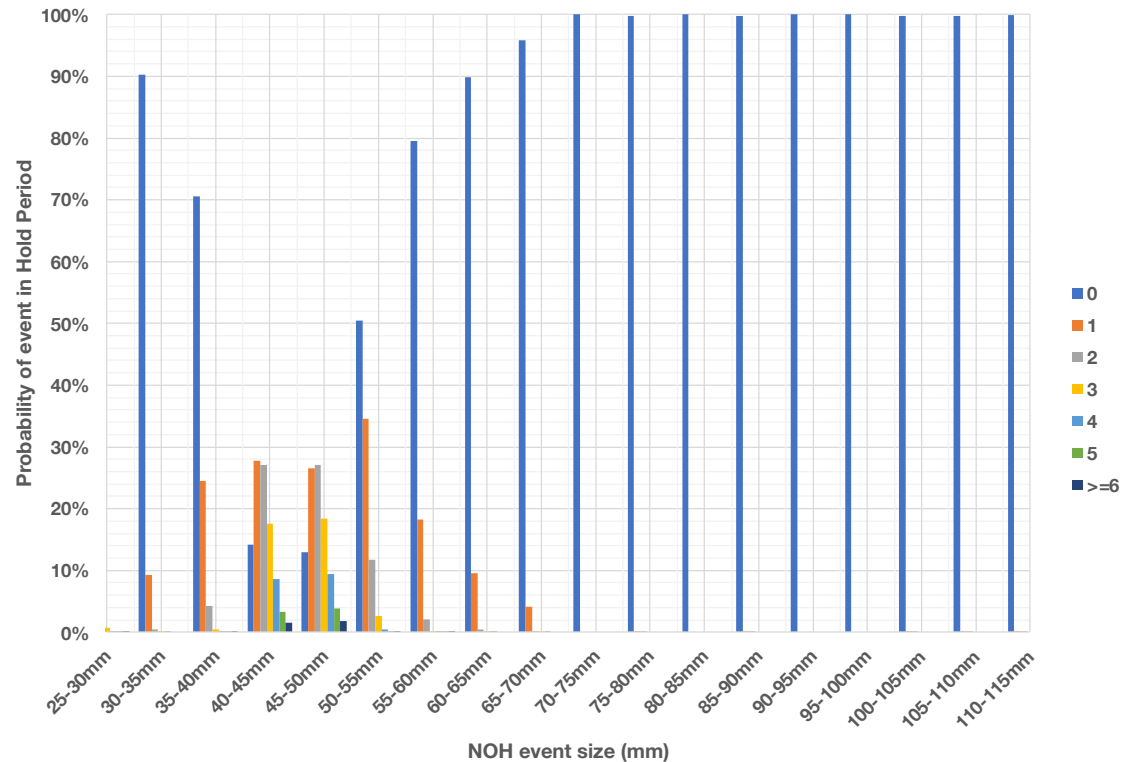


Poisson Risk Exposure (PRE) financial loss analysis methodology

Hail-size probability frequency function

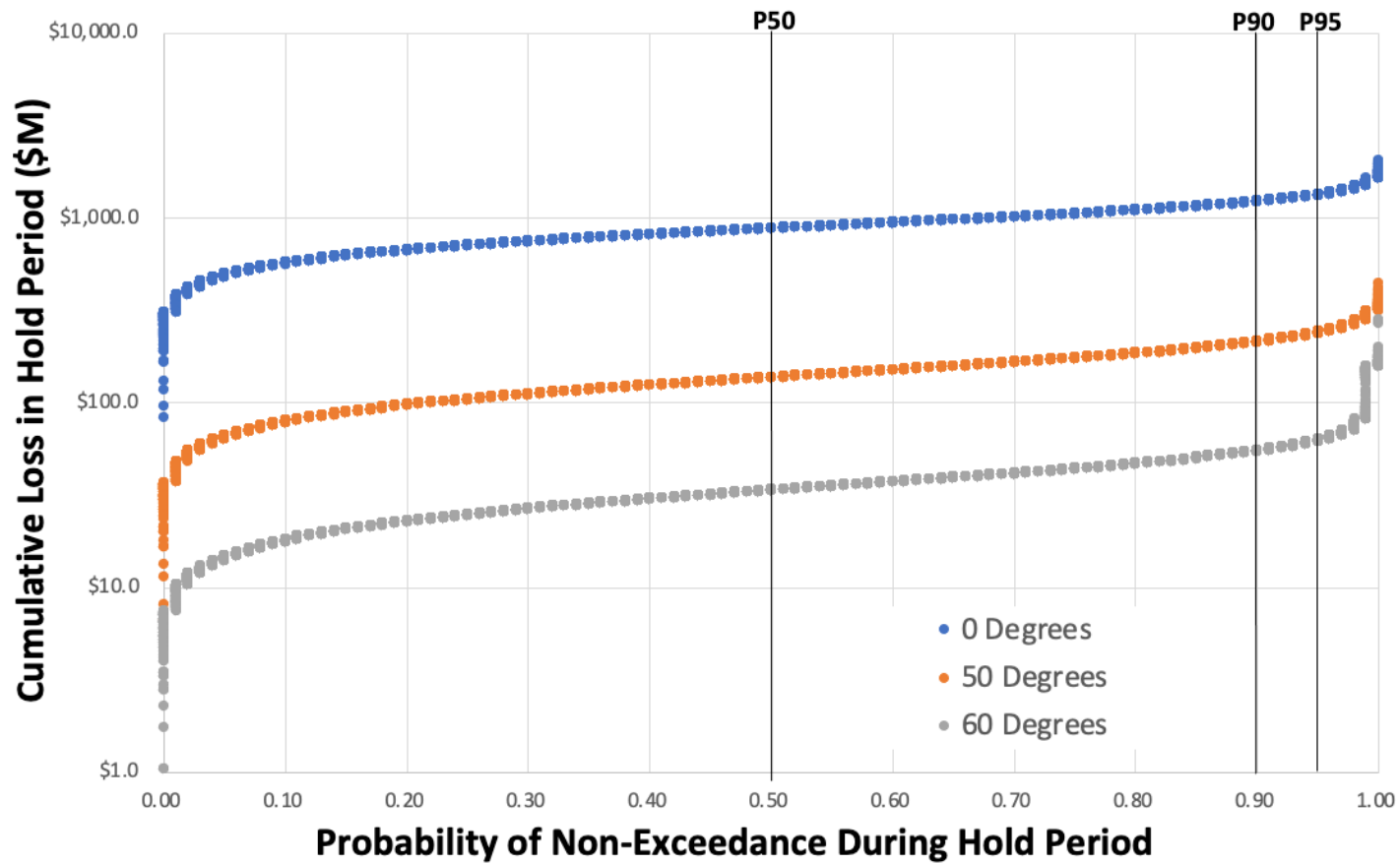
- Number of NOH-size events
 - 50 mm–55 mm NOH events, for example
 - ≈50% probability of no events (blue bar)
 - ≈34% probability of one event (red bar)
 - ≈11% probability of two events (gray bar)
 - ≈5% probability of three events (orange bar)

$$P_X(k) = \frac{e^{-(\lambda t)} * (\lambda t)^k}{k!} = \text{Poisson}(\lambda t)$$



Probability of the number of discrete hail-size events of a 40-year hold

Owner risk is a function of location, technology, & hold period



Financial exposure over hold period (for owners & investors)

Coming Soon: New Advanced Hail Resilience Test Protocol

Current Available data sets

IEC 61215 test results

- 11 prescribed impact locations- Modest kinetic energy
- Pass/fail outcome- Virtually all modules pass
- IEC and Extended Tests not tests to failure.

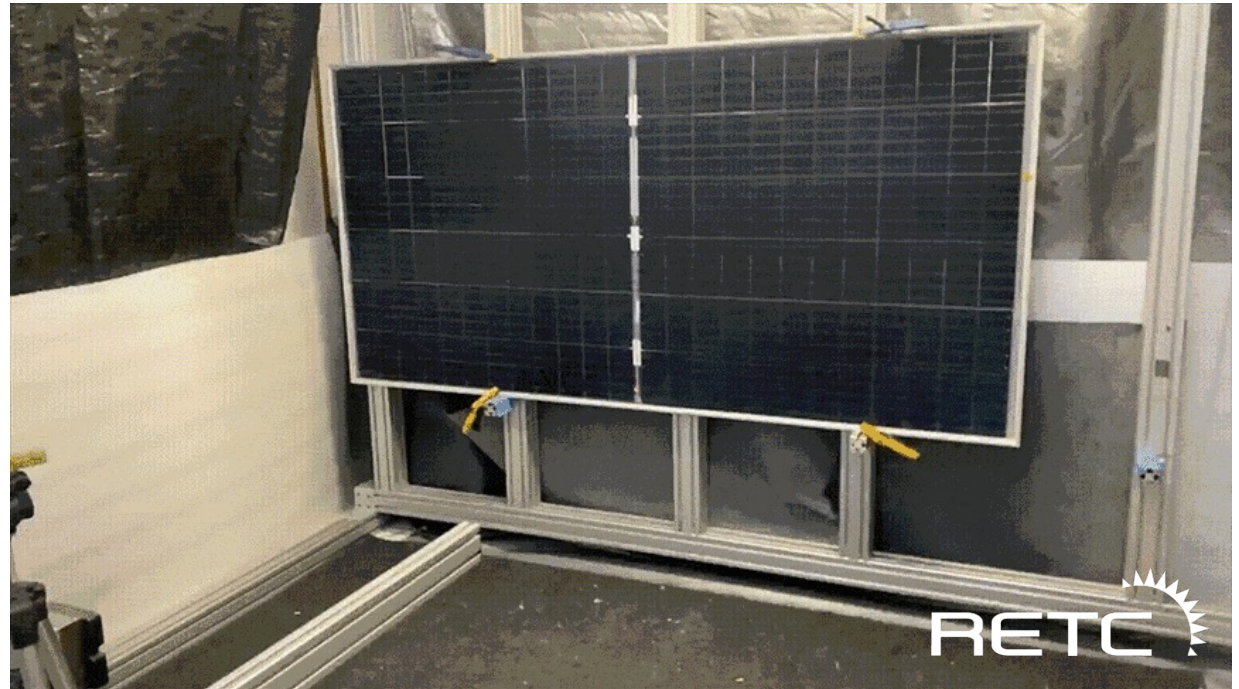
New Test Protocol:

Information-rich statistical approach

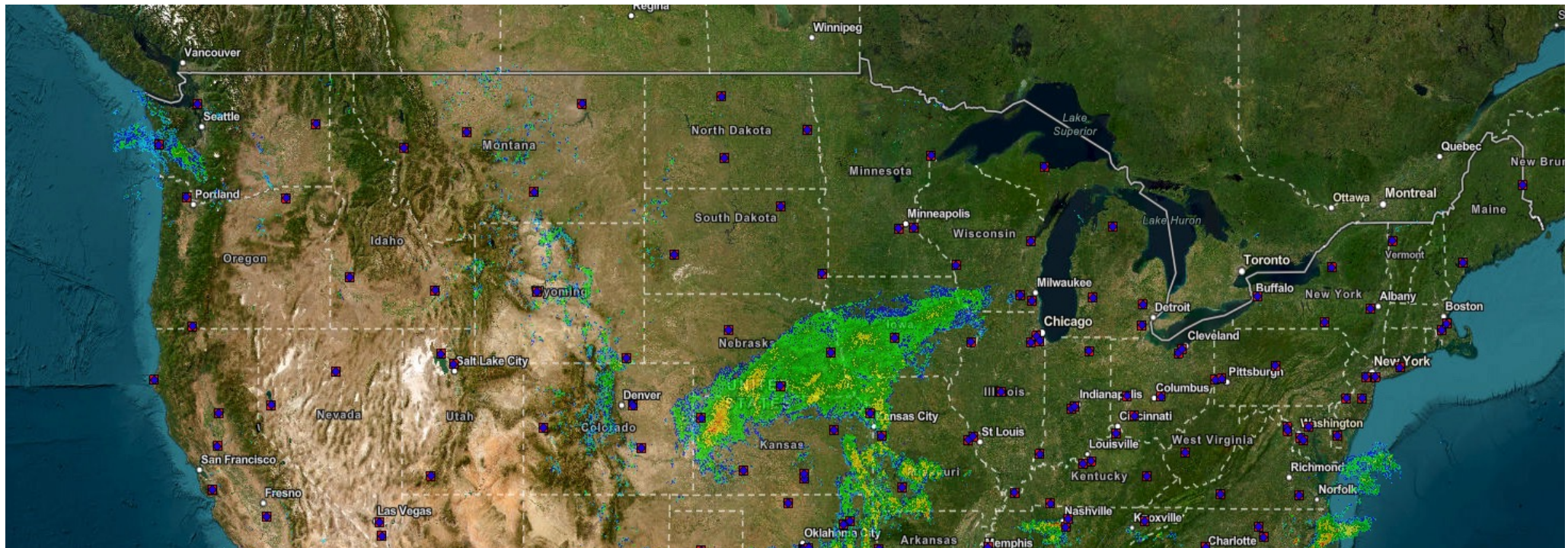
- Continuous variable (rather than just pass/fail)
- Comparative characterization with other module hail resiliency curves

Low-uncertainty statistical results

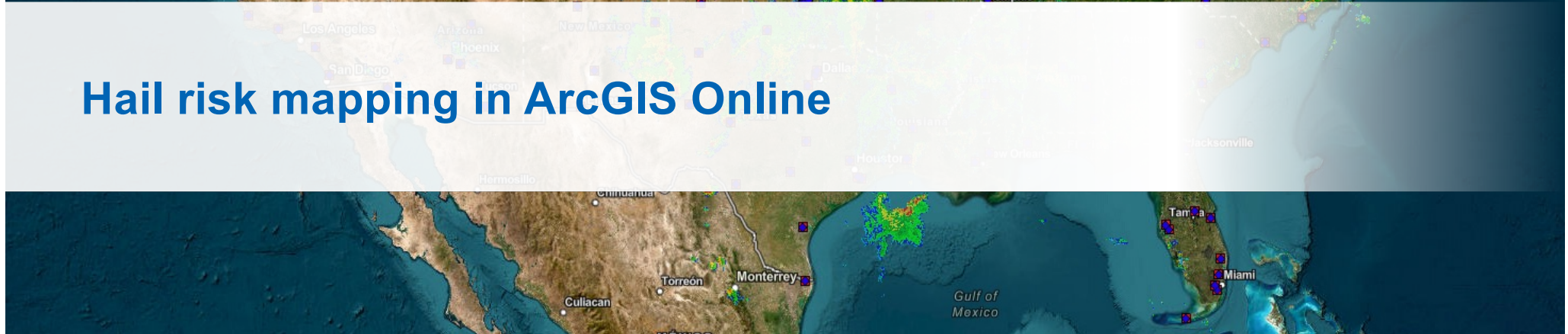
- Estimate Weibull shape and scale parameters
- Establish Confidence Interval boundaries



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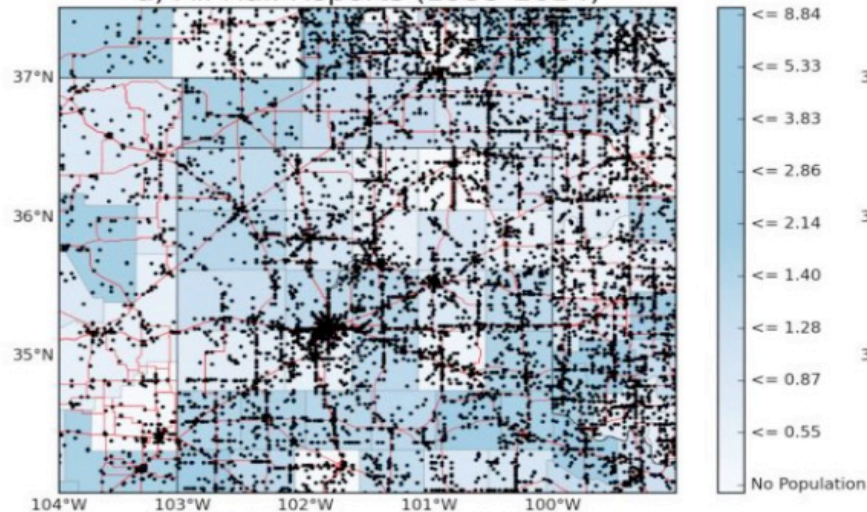
Hail risk mapping in ArcGIS Online



NOAA's severe hail databases for the continental United States

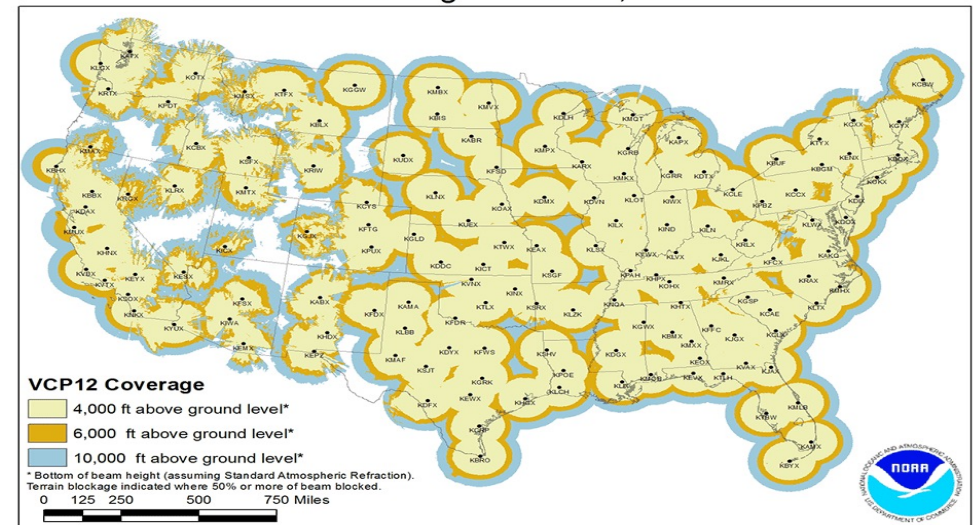
SPC Spotter Database

a) All Hail Reports (1955-2014)



Spotter database (SPC)

NEXRAD Coverage Below 10,000 Feet AGL



Doppler radar database (NEXRAD)

VDE Americas' meteorological model blends radar and spotter data to derive the return interval for naturally occurring hail (RI_{NOH}) based on historical events. Since hail is a local weather phenomenon, we model hail risk and financial loss based on a 4 km x 4 km grid.

Hail return interval (RI) data for in-house mapping in ArcGIS Online

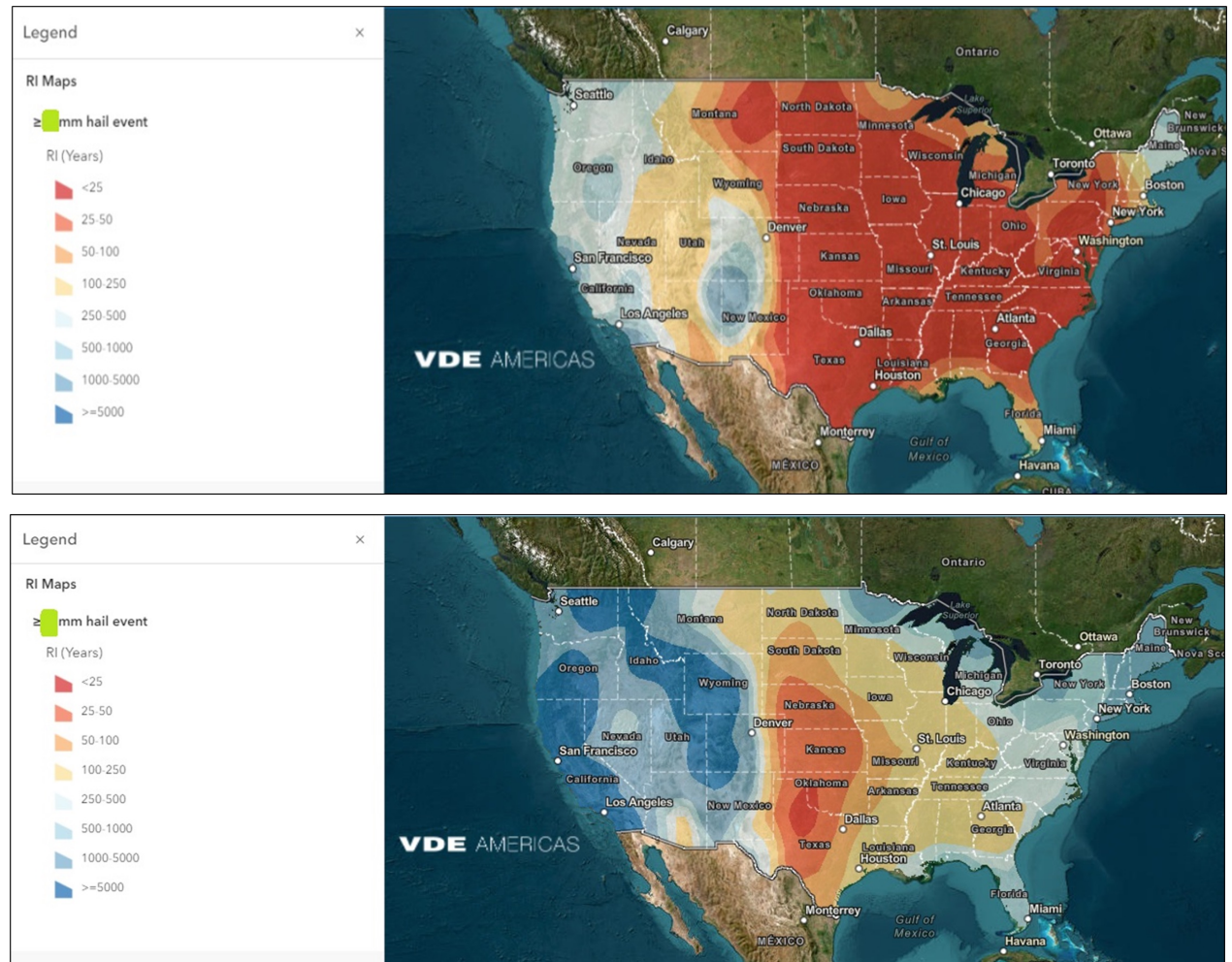
$$\text{Return Interval} = \frac{1}{\text{Mean Rate of Occurrence}}$$

- RI_{NOH} contour maps

- Early-stage project development and engineering tool
- Characterizes frequency of damaging hail (25 mm–95 mm)

- GIS mapping data informs

- Site selection
- Equipment specification
- Insurance cost estimates



Probable maximum loss (PML) data for in-house mapping in ArcGIS Online



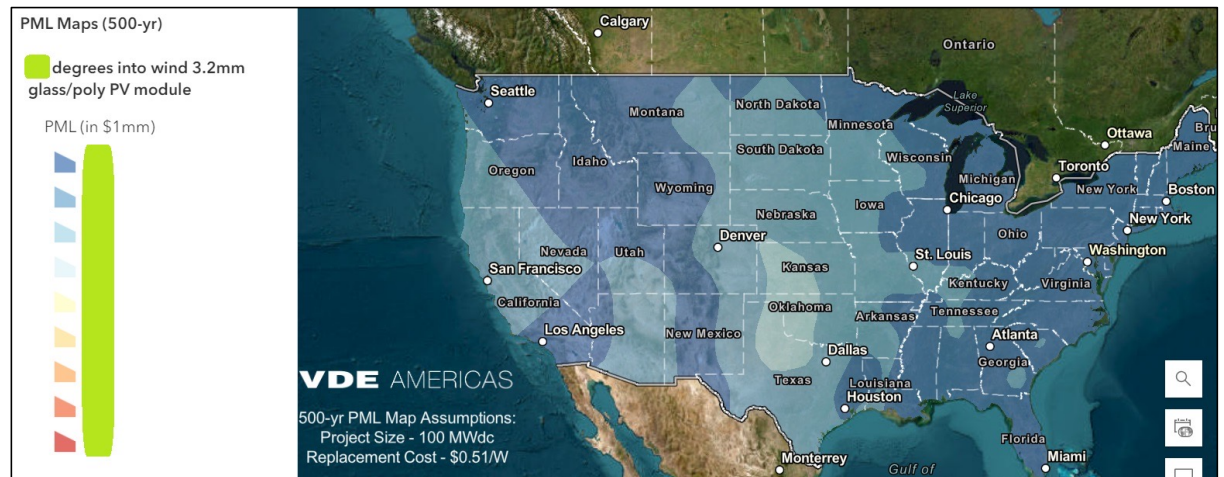
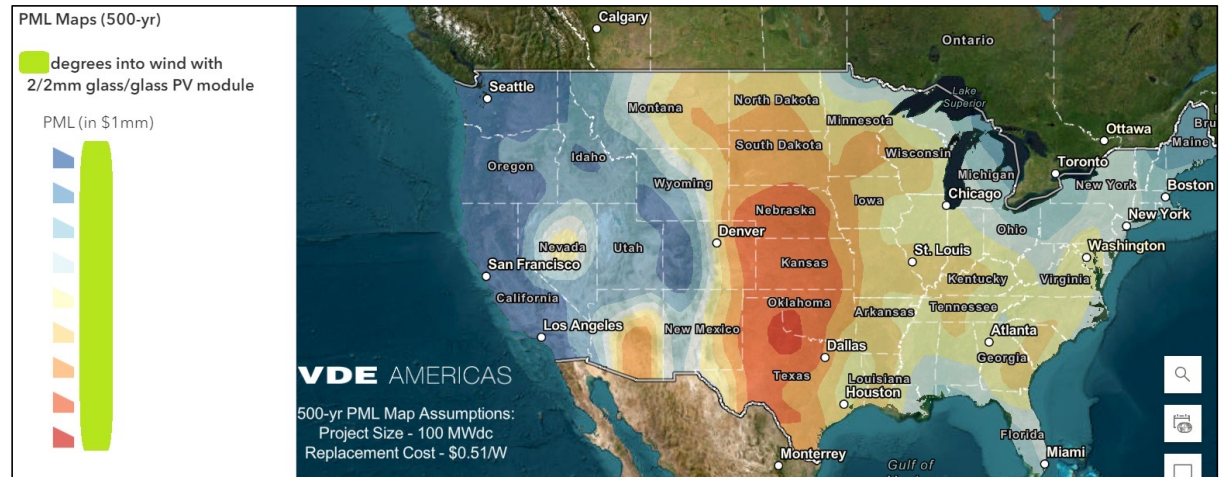
Probable Maximum Loss

[prā-bə-bəl 'mak-s(e-)məŋ 'lɒs]

The maximum loss that an insurer would be expected to incur on a policy.

Investopedia

- PML & AAL (Average Annual Loss) contour maps
 - Early-stage project development and engineering tool
 - Characterizes PML of damaging hail sizes (25 mm–95 mm)
- GIS mapping data informs
 - Site selection
 - Equipment specification
 - Insurance cost estimates



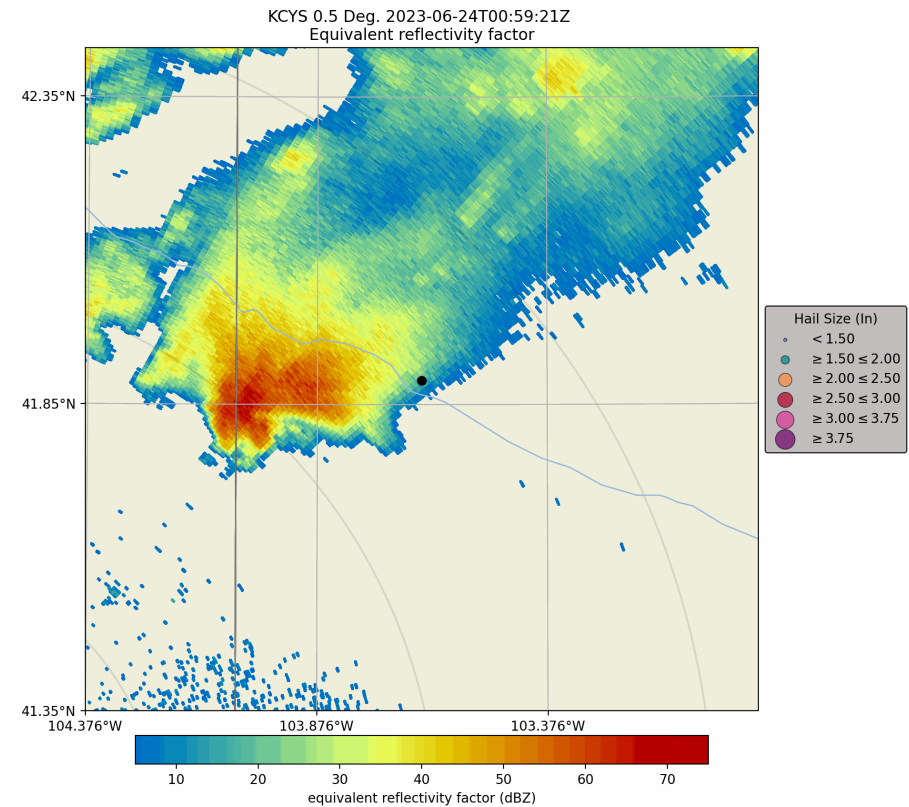
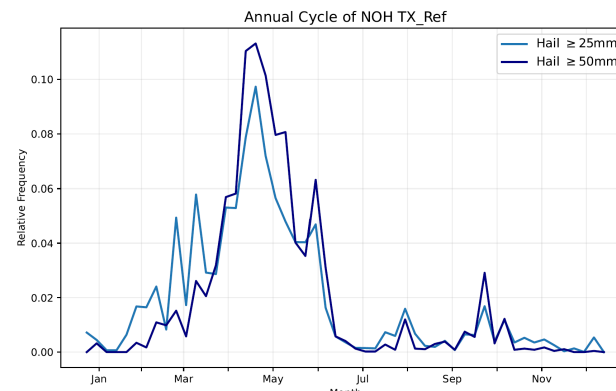
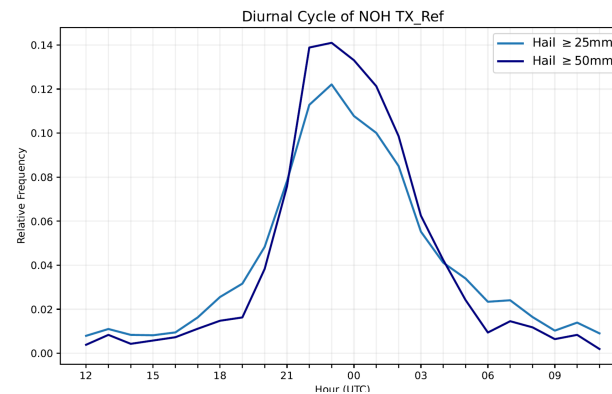


COMING SOON: VDE Americas hail risk web tools

Webservice

Product Offerings

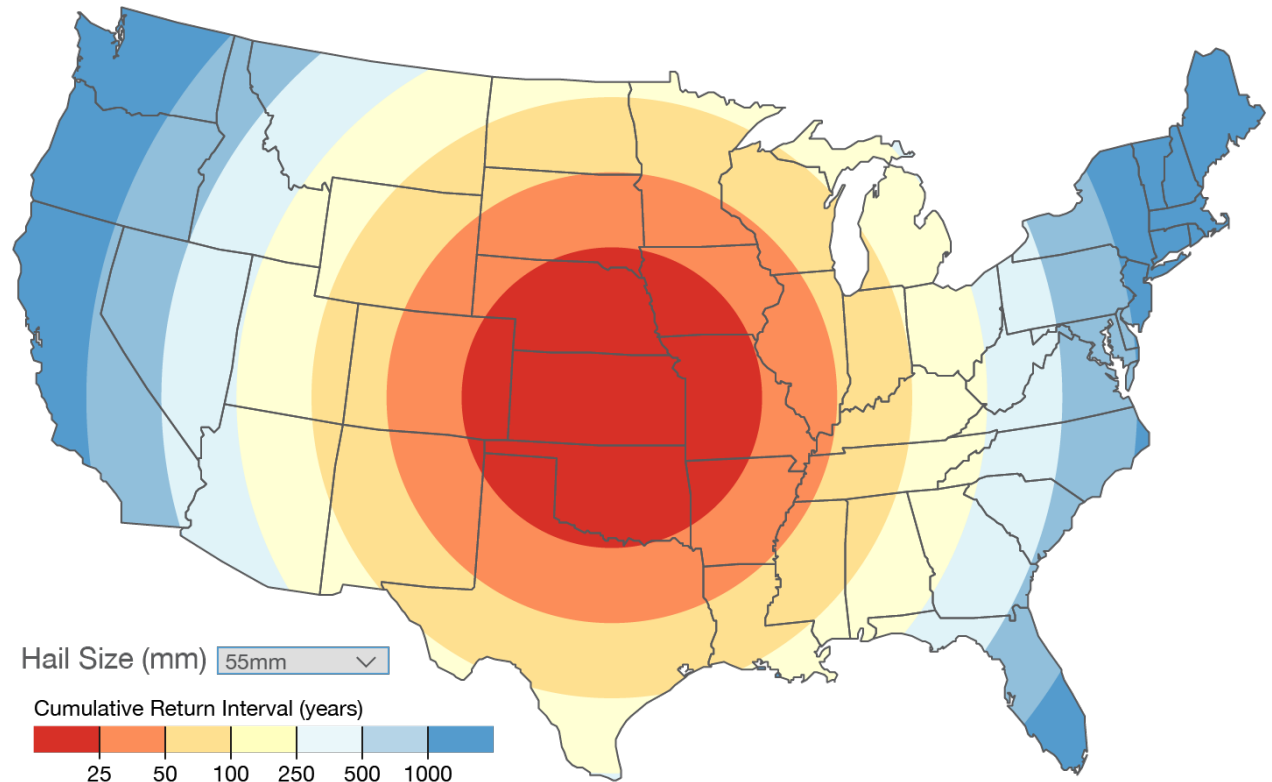
- Severe Hail Return Intervals
- PML & AAL Reports
- Business Interruption
- Capacity test



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Improved due diligence and risk mitigation practices

can limit catastrophic hail loss events



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