pv magazine

Charting the effect of climate change on solar project hail risk

Individual storms can cause tens of millions in damage to installations, demonstrating the vulnerability of critical infrastructure to severe hail events.

MARCH 24, 2025 JON PREVITALI

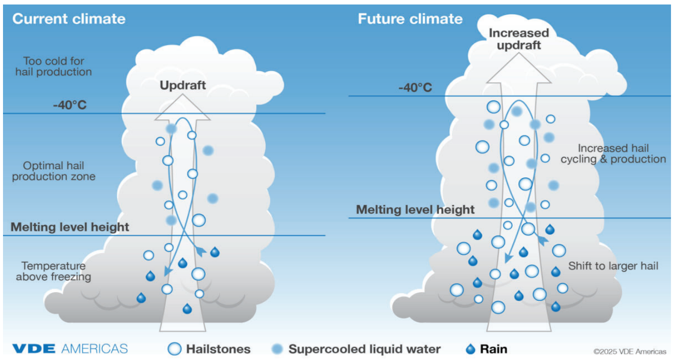

Image: VDE

Massive hailstorms causing catastrophic damage across multiple sectors, from agriculture to automotive to energy infrastructure, highlight a critical challenge in our changing climate. Solar power plants provide a stark example—where individual storms can cause tens of millions in damage to installations, demonstrating the vulnerability of critical infrastructure to severe hail events. This damage is part of a broader trend that has led to significant hardening in the hail insurance market across all sectors, with higher premiums and more restrictive coverage becoming increasingly common.

While defensive solutions exist, such as protective canopies over car dealerships and hail monitoring and solar tracker stowing systems for solar power plants, knowing where to implement these defenses and how much damage to expect, both on average and in worst-case loss scenarios, requires sophisticated location-based risk assessment. Perhaps the most challenging aspect of this risk modeling is incorporating the effects of climate change over the coming years and decades. The changing climate is an important risk assessment factor, one that is altering both the frequency and intensity of hail events in complex ways.

How the Climate Can Alter Hail Formation

Climate change is fundamentally altering the recipe for hailstorms, as shown in Figure 1. Think of the atmosphere as a complex kitchen where many ingredients and conditions must come together just right to create hail. The first crucial change is happening near the Earth's surface, where warming temperatures allow air to hold more moisture, approximately 7% more for each degree Celsius of warming, following a principle known as Clausius-Clapeyron scaling. Since sufficient moisture content in the lower levels of the atmosphere is a crucial ingredient in severe thunderstorm development, this change would help generate more time during the year with the energy needed to produce hailstorms and has been linked specifically with increased hail frequency.

Higher in the atmosphere, climate change creates an intriguing paradox. Hailstones form when "seeds", which could be any solid particle small enough to stay aloft (ice crystals dust, sand, organic matter), create a landing place for water droplets to freeze around—sort of like the wick at the center of a candle. Then, much like a candle that grows as it is repeatedly dipped in molten wax, hailstones grow with evermore concentric layers of ice as they are suspended in storm clouds rich with moisture and freezing conditions.

How these layers freeze influences the growth of their shape, from spheres of ice to large spikey shapes that seem more like medieval weapons than the ice balls produced in a freezer. While warmer surface temperatures strengthen the updrafts that suspend growing hailstones, they also raise the height at which ice melts. Similar to the way warm air near the surface turns what would be snow to rain, smaller hailstones in a warmed world now have a longer journey through warm air before reaching the ground, often melting completely. Only larger stones, which have enough mass to survive this gauntlet, make it to the surface.

The result? We would expect to see larger, more destructive hailstone sizes when these storms do occur.

particle small enough to stay aloft (ice crystals, dust, sand, organic matter), create a landing place for water droplets to freeze around—sort of like the wick at the center of a candle. Then, much like a candle that grows as it is repeatedly dipped in molten wax, hailstones grow with evermore concentric layers of ice as they are suspended in storm clouds rich with moisture and freezing conditions.

How these layers freeze influences the growth of their shape, from spheres of ice to large spikey shapes that seem more like medieval weapons than the ice balls produced in a freezer. While warmer surface temperatures strengthen the updrafts that suspend growing hailstones, they also raise the height at which ice melts. Similar to the way warm air near the surface turns what would be snow to rain, smaller hailstones in a warmed world now have a longer journey through warm air before reaching the ground, often melting completely. Only larger stones, which have enough mass to survive this gauntlet, make it to the surface.

The result? We would expect to see larger, more destructive hailstone sizes when these storms do occur.

As shown in Figure 2, there is some evidence that these hail meteorology changes are already occurring in the atmosphere. In a 2019 article for the scientific journal *Nature*, Brian Tang and his coauthors present evidence that points to an increase in the annual number of days with environments favorable for very large hail (≥50 mm in diameter) over the central and eastern United States, based on observational data from 1979–2017. These results, published under the title "Trends in United States large hail environments and observation," suggest statistically significant upward trends of 2–4 more hail-favorable days per year in parts of the Midwest during that 38-year period.

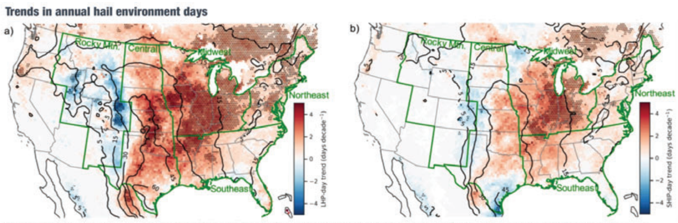

Figure 2 Change in average number of hail days per decade for a) large hail parameter (LHP) days where hailstones are ≥50 mm in diameter and b) significant hail parameter (SHIP) days where storms have large amounts of smaller hail per B. Tang, V. Gensini, and C. Homeyer.

Image: njp Climate and Atmospheric Science

The ENSO Factor

The El Niño-Southern Oscillation (ENSO) adds another layer of complexity to this changing picture. ENSO is a pattern of natural climate variation originating in the Pacific Ocean that alternates between two phases: El Niño (warm) and La Niña (cool). During El Niño, trade winds weaken, allowing warm ocean water to spread eastward across the Pacific. During La Niña, stronger trade winds push warm water westward, allowing cold water to upwell near South America. These ocean temperature changes interact with atmospheric pressure patterns (the Southern Oscillation) to influence weather worldwide.

For severe weather in North America, La Niña phases tend to increase storm activity by shifting the wind patterns of tracks of low-pressure systems over the southern United States. According to research by John Allen, Michael Tippett, and Adam Sobel, published in the March 2015 edition of *Nature Geoscience,* La Niña phases can shift where the favorable environments for hail come together and modulate the overall frequency of hail in some regions by 25% or more. El Niño typically suppresses severe weather, at least earlier in severe weather season, as cold air is drawn further south over the continent. This makes ENSO an important factor in modulating seasonal severe weather risks, including hail.

Climate change is amplifying the ENSO cycle, as shown in Figure 3. Since 1960, ENSO variations have intensified by about 10%, with models projecting another 15%–20% strengthening by 2100. This amplification means potentially more extreme weather during these already volatile periods. At 9 to 12 months, the length of ENSO cycles is relatively predictable, but unfortunately, the question of whether El Niño or La Niña will start is not. Nonetheless, this variation suggests we need to account for the range of possible outcomes due to ENSO in hail risk models for solar.

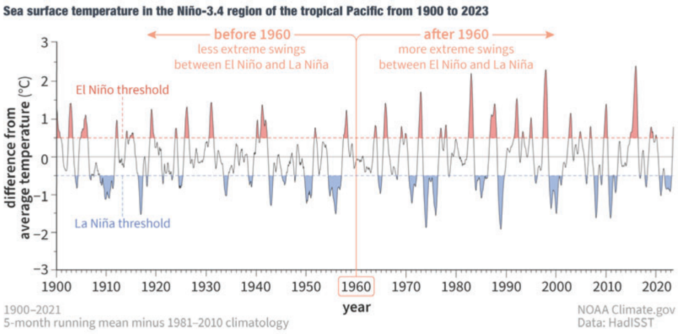

Figure 3 Monthly data have been smoothed with a 5-month running mean after removing a seasonal climatology for 1981–2010. Red peaks are El Niño events and blue troughs La Niña events. The approximate mid-point of the time series is indicated by the vertical black line in 1960. The white area between ±0.5°C signifies neutral conditions. Data is from HadISST, which uses satellites and other in situ observational data.

Image: NOAA Climate.gov

Future Projections and Risk Assessment Methods

Looking farther out into the future, climate models paint a picture showing a consistent progression of increased hail risk, but this trend varies in intensity and by region. Over the course of the next 75 years, climate change model projections suggest that the continental United States will see a mean annual increase of 7% in severe hail days (≥20 mm hail), 21% in large hail days (≥35 mm hail), and, most dramatically, a potential 146% spike in very large hail days (≥50 mm hail). The geography of this risk is also shifting. Areas that historically saw little hail activity may need to prepare for more frequent events, while traditional "hail alleys" may see changes in the timing and intensity of storms.

Looking ahead, several key conclusions emerge:

1. Severe weather expectations are expanding into previously low-threat months, creating a longer season of potential risk.
2. While annual storm frequency may increase overall, summer months could see reduced activity, particularly in southern regions like Texas.
3. There is modest but significant evidence suggesting a shift toward larger hailstone sizes, especially in the High Plains region, though this signal remains mixed across different areas.
4. New techniques combining storm simulations with environmental analysis are emerging, allowing for more efficient projections using ensemble approaches.
5. A critical unknown remains—namely, exactly when these projected changes will emerge definitively from natural variability.

The scientific community has not yet provided a single actionable conclusion that risk assessment professionals can use to account for changes in hail risk due to climate change. With that in mind, VDE Americas is addressing climate change in its loss models and hail risk maps by accounting for a range of possible outcomes, using scaling factors derived from climate model simulations. By looking at a range of potential model projections, we will be able to efficiently capture and quantify signals of change to modeled annual hail occurrences and characterize the associated uncertainty.

Using these scaling factors, we can apply low, average, and high adjustments to metrics like probable maximum loss (PML) and average annual loss (AAL) to account for the effect of climate change through the typical economic useful lives of solar power plants (e.g., 40 years). Impacts will depend heavily on location—and could go up, down, or have no material change for any given project site. Over time, we will calibrate our scaling factors as more data is collected and the latest research evolves.

As we work to expand renewable energy capacity, industry stakeholders must simultaneously adapt to the changes to the threat posed by hail damage. Success will require continued innovation in both protective technologies and risk assessment methods, guided by our evolving understanding of how climate change is reshaping the skies above us.

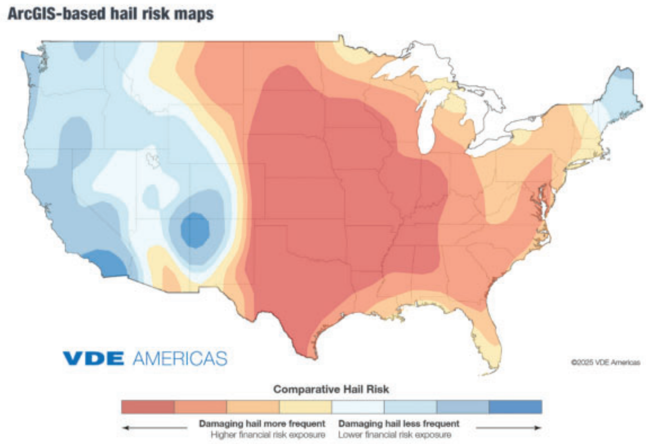

Figure 4 ArcGIS users can use the VDE Hail Risk Atlas to evaluate and compare site-specific hail risk on the basis of severe convective storm meteorology or solar project financial risk exposure.

Credit: VDE Americas>

Image: VDE

Jon Previtali is a 20-plus-year veteran of the solar power industry who has worked in project development, operations, asset management, finance, and engineering. He is currently the vice president of digital services and product manager for hail risk assessment and mitigation services at VDE Americas.

The author wishes to thank Dr. John T. Allen, professor of meteorology at Central Michigan University, for his technical contributions to this article and guidance in developing this approach to modeling climate change effects on hail risk. Dennis Weaver, staff meteorologist at VDE Americas, also contributed subject matter expertise to this article.