Small Hail, Big Problems, New Approach

WHAT WE LEARNED FROM THE FIELD, THE LAB, AND DECADES OF PROPERTY DATA

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Why Insurers Should Pay More Attention to Less Severe Hailstorms

Executive Summary

Hail losses are a persistent problem for property insurers' risk management efforts. Research from the Insurance Institute for Business & Home Safety (IBHS) and ZestyAI demonstrates that insurance carriers should pay more attention to the cumulative effect of all hailstorms, not just the largest and most recent.

Historically, claims verification processes focused on very intense hail events. These events contain hailstones larger than one or two inches, which are considered a critical marker for roof damage.[1] Consequently, most predictive hail risk assessments today have adopted this focus on the largest stones and the most severe storms in what we call a "Salient Event" approach.

However, research shows small hailstorms occur so much more frequently than large hailstorms that their cumulative annual damage is much higher. Experiments show smaller stones, especially in high concentrations, can cause degradation to the underlying roof material, increasing a property's susceptibility to future storms. Accounting for these effects with a "Predictive Susceptibility" approach can lead to more profitable underwriting, a greater ability to rate previously-avoided areas, and significantly reduced loss-ratios.

Hail Risk is a Growing Problem

Hail presents a growing risk to insurers across the United States. Three of the nation's five largest publicly-traded Property and Casualty (P&C) carriers mentioned hail as a key concern in 2022 financial reports. Greater losses have brought attention to hail risk, and the insurance industry needs new approaches to solve this problem.

Hail risk can be especially costly to insurers because, unlike other catastrophic perils like earthquakes and wildfires, it can be difficult to identify the storm that caused a hail claim. As a result, many insurance carriers are forced to raise overall premiums or introduce high deductibles. Additionally, insurers might assume fraud to account for the discrepancy in predicted risk vs. actual claims, and even exit the market when hail damage makes their business unprofitable, leaving homeowners with limited options for insurance.

Figure 1. Stones less than one-inch in diameter cause accumulated damage to roofs.

[1] See (Changnon 1999)

Small Hail is a Blind Spot for Current Risk Modeling

Stone Diameter	Scientific Classification	Damage Potential	Included in Current Modeling?	Proportion of all Stones
Small (0-1")	Sub-severe	• Accumulated effect on Susceptibility • Individual granule loss	No	99.4%
Large (1-1.75")	Severe	• Moderate granule loss • Possible threat of water entry	Sometimes	0.6%
Very Large: (1.75"+)	Very large	• Granule loss in patches • Immediate threat of water entry	Yes	0.005%

Figure 2. Commonly used techniques for managing hail risk factor less than 1% of all hailstones

Insurers primarily focus on tracking more intense hailstorms. Many current risk solutions only consider damage from stone sizes above two inches.[2] While major storms can produce large hailstones, these storms do not occur frequently enough to account for the volume of claims made. Furthermore, the largest hail events occur most frequently in lower population density areas, like the Great Plains.

Figure 3. Most industry models omit storms with stones less than one inch.

If carriers limit their data to storms which contain "large" or "very large" stones, they disregard the vast majority of storms. Carriers making decisions based on individual severe events are throwing away valuable data on smaller hailstone impacts, which are likely responsible for more than 99% of observed damage[2]. While it is true that a very large stone carries more damage potential than a small stone, very large stones make up less than 0.01% of all stones, and more than 95% of hailstorms do not contain very large stones at all.

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Work from both IBHS and ZestyAI seeks to empower carriers to respond to hail risk in a better way. By considering the accumulated damage from smaller hail events, carriers can more effectively assess hail risk. With a new approach, they can achieve more profitable underwriting and rate previously-avoided areas. To achieve this, carriers must incorporate additional property-specific data sources and direct their hail risk efforts earlier in the insurance life cycle.

[2] Hailstorm severity (measured by maximum stone size), as well as hailstone sizes, have been measured to approach an exponential distribution. See (Sanchez et al. 2009).

As an analogy, a singular focus on large hail events to explain losses is like blaming a single candy bar when a tooth develops a cavity. Large doses of sugar can cause cavities, but predicting cavities is best achieved with data that is more personal in substance and broader in scope. Dental history, hygiene, and genetics are more responsible for the risk of a cavity.

Similarly, the risk of hail damage involves a roof's current condition, the hail climatology to which it has been exposed over its lifetime, and the inherent impact resilience for which it was designed. These property-specific building characteristics are discernible in advance and greatly enhance the effectiveness of risk assessment strategies.

Gathering hail risk insights from rare storms will not significantly reduce claims. Modeling efforts focused on predicting major hailstorms will not significantly affect loss ratios. Instead, future hail risk must be evaluated at the property level, with predictive models grounded in climate and materials science. The best time to address hail risk is before the damage occurs.

Making Better Decisions About Climate Risk

The decision-making framework for addressing hail risk is important. To gain maximum benefit, insurers can't simply change data sources. They also need to act upon the resulting insights differently than they did before.

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To appropriately assess climate risks to property, insurers need to understand the following elements:

- Exposure to the hazard
- Individual structural vulnerability
- Resulting claim severity

Individual Structural Vulnerability

IBHS and ZestyAI investigate each of the climate risk elements through various products and research efforts, but **for the purposes of this study the primary focus is on structural vulnerability of the roof covering material**. Structural vulnerability involves historic patterns of climatological exposure and the impacts on material property increasing the probability of claims.

The Traditional vs. Predictive Approach

There are several types of traditional hail risk tools, including those designed for claims verification and future hail risk prediction. Claims verification tools match single events to each claim. The predictive tools resulting from claims verification use data from prior severe events to simulate hail risk to help carriers rate territories in a portfolio. Despite having different purposes,

Predictive Risk Insights Offer a More Comprehensive Approach

Approach	Strategy	Scope	Use Case
Salient Event Assessment (Traditional)	Price retroactively based on claims, react regionally to losses.	Risk approaches that limit hailstorm data to only the most severe and/or the most recent.	Territory-based rating and under-writing and salient event simulation.
Predictive Susceptibility (Recommended)	Price proactively based on risk pre-diction, respond to climate and materials science.	Risk approach that considers all available hailstorm data. Integrates climate and materi-als science to understand hail frequency and severity	Property-level rating and underwriting.

Figure 4. Hail risk approaches vary in strategy, scope, and use case, but both approaches are easily implemented at time-of-quote.

both approaches only consider storm data of a specific severity and recency, which means they only focus on the most salient events.

Unfortunately, for what the Salient Event approach offers in simplicity, it lacks in accuracy. If risk models are built with a biased selection of data, they will struggle to make accurate predictions. This has led carriers to make territory-based rate frameworks using only historical events. As a result, regions that have suffered from hail events are effectively being penalized, and future risk in other areas is not being accounted for. As climate and materials science has developed, and data availability has improved, better decisions have become available at earlier stages of the policy life cycle. Now, hail risk can be evaluated at the property level using multiple decades of hailstorm data. This Predictive Susceptibility approach provides superior performance and allows for property-specific risk decisions.

For what the Salient Event approach offers in simplicity, it lacks in accuracy.

Reassessing Hail from the Roof Up

Insurers have historically focused on severe hailstorms because the agriculture industry spearheaded early models for crop insurance, where poorly-timed events could wipe out an entire year's harvest.[3] As a result, many insurers still look to these events to explain the damage. If an insurer could not find such a storm to account for a claim, they had few other options than to assume it was fraudulent. The Salient Event approach has created a demand for stochastic models predicting the likelihood of these "damaging hail events."

But roofs, unlike crops, do not immediately fail at the first impact of a large hailstone. The underlying resilience of a roof can be reduced by a range of impacts from stones of various sizes. Resilience is also affected by roof material, building characteristics, and accumulated exposure to the elements. These factors are measurable in advance through imagery, and allow a Predictive Susceptibility approach to predict loss.

Research by IBHS advances the most thorough explanation for the observed damage: hailstone impacts, even small ones, cause asphalt shingle roofs to lose resilience and performance. Data from ZestyAI shows that this explanation from IBHS performs very well in predicting loss and provides a significant advantage over a Salient Event approach to hail.

The Predictive Susceptibility approach offers gains in predicting hail risk, even if it does not find discrete events to blame for the damage. Nonetheless, the approach explains how claims can surge after accumulating damage from low-severity events.[4]

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[3] For further discussion, see (Brown et al. 2015)

[4] For further discussion, see Appendix section: "Additional Discussion on ZestyAI analysis".

Measuring Hailstones, Hailstorms, and Roof Damage

Research and Results from IBHS

In order to address the growing problem of hail damage across the U.S., IBHS and its members have worked to understand how hailstones damage roofs across several areas of research. The organization conducts:

- Field measurements of hailstorms and hailstones
- Lab experiments to measure shingle damage from controlled impacts
- Roof aging experiments to measure how roofs are affected by natural exposure to the elements.

Combining these three avenues of research has resulted in the following conclusion: Small hail in high concentrations damages roofs by reducing their underlying resilience. Smaller impacts and elemental exposure lead to a significant portion of observable roof damage.

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This qualifies the assumption that large hailstones cause the majority of the damage, especially where a roof's susceptibility has been damaged by natural exposure to the elements.

The Results

IBHS experiments have demonstrated two key findings in quantifying small hail damage.

- First, smaller hailstones up to one-inch in diameter can cause nearly 30% of the granule loss of two-inch stones. Despite smaller stones causing less damage individually, the vast majority of roof damage is likely caused by smaller hailstones due to the rarity of large hailstones.
- Second, roof shingles are susceptible to roughly 10x more damage after exposure to natural weathering and small hail impacts, compared to new shingles. The damage to weathered shingles was visible to the naked eye and could have triggered an aesthetic-driven claim.

Impacts from the largest hailstones can cause an immediate threat of water entry, while smaller stones do not. Even so, small hail events can reduce a roof's lifespan, increase susceptibility to future hail events, and exacerbate the natural aging of asphalt shingles.

Recreating Hailstones

Figure 5. IBHS's hail field research program collects fundamental data on the properties of hail, allowing the organization to recreate realistic hailstones in the laboratory for testing.

The Evidence

To demonstrate the importance of small hail's contribution to overall roof damage, IBHS experiments highlight the prevalence of small hail in storms, the relative damage of small hail, and small hail's impact on a roof's resilience to large hailstones.

Most Hail is Small

Many storms contain hailstones of a size well below what is considered damaging by property insurers. Included in Figure 7 are measurements of hailstones sizes from a 2018 storm in Kerrick, Texas. Although there were large stones, most of the accumulated hail stones were less than one inch (~2.5cm) in diameter. If smaller stones cause any damage, that damage is not directly captured by many current efforts at measuring hail risk by insurers.

Figure 6. Impact Disdrometer, ready to measure hail impacts from an oncoming supercell storm. It will record the number, size, and impact energy of hailstones.

Live Hailstorm Data Shows Rarity of Large Stones

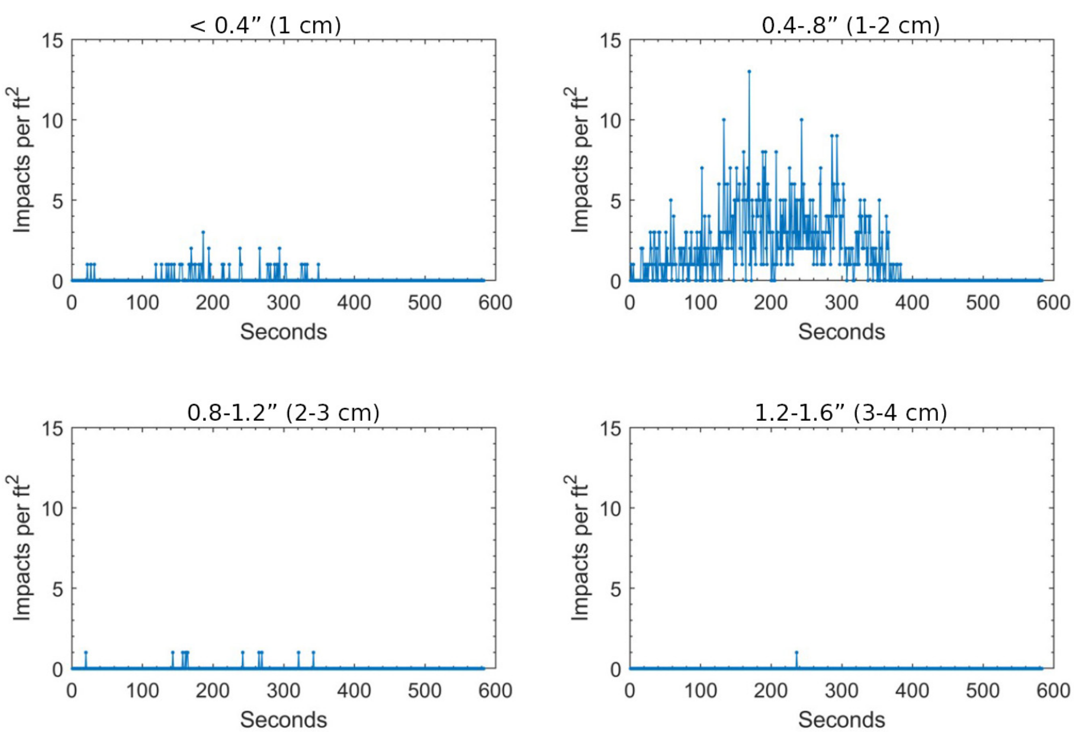

Figure 7. May 30, 2018: A disdrometer field recording from Kerrick, Texas. Over 900 impacts observed upon 1-square-foot in 10 minutes

Small Hail Rivals the Damage of Large Hail

While carriers traditionally only flag events containing large hailstones, small hailstones can generate nearly 30% of the damage large hailstones do. To compare the damage between small and large stones, IBHS conducted two experiments. The first measured the effect of 500 impacts from sub-severe (small) stones on granule loss for commercially-available asphalt shingles. The second measured the effect of single impacts from large hail on the patch and individual granule loss on the same type of shingles.

The smaller stone experiment involved 500 impacts to replicate a high-concentration hail exposure, similar to the storm measured in the Figure 7. However, to aid in comparison, each experiment was converted to an average per-impact granule loss. While the average granule loss per impact of sub-severe stones is unsurprisingly smaller, it still significant. When the damage per stone is paired with field measurements suggesting severe storms still contain more than 99% small stones, it becomes clear where the majority of cumulative roof damage comes from.[5]

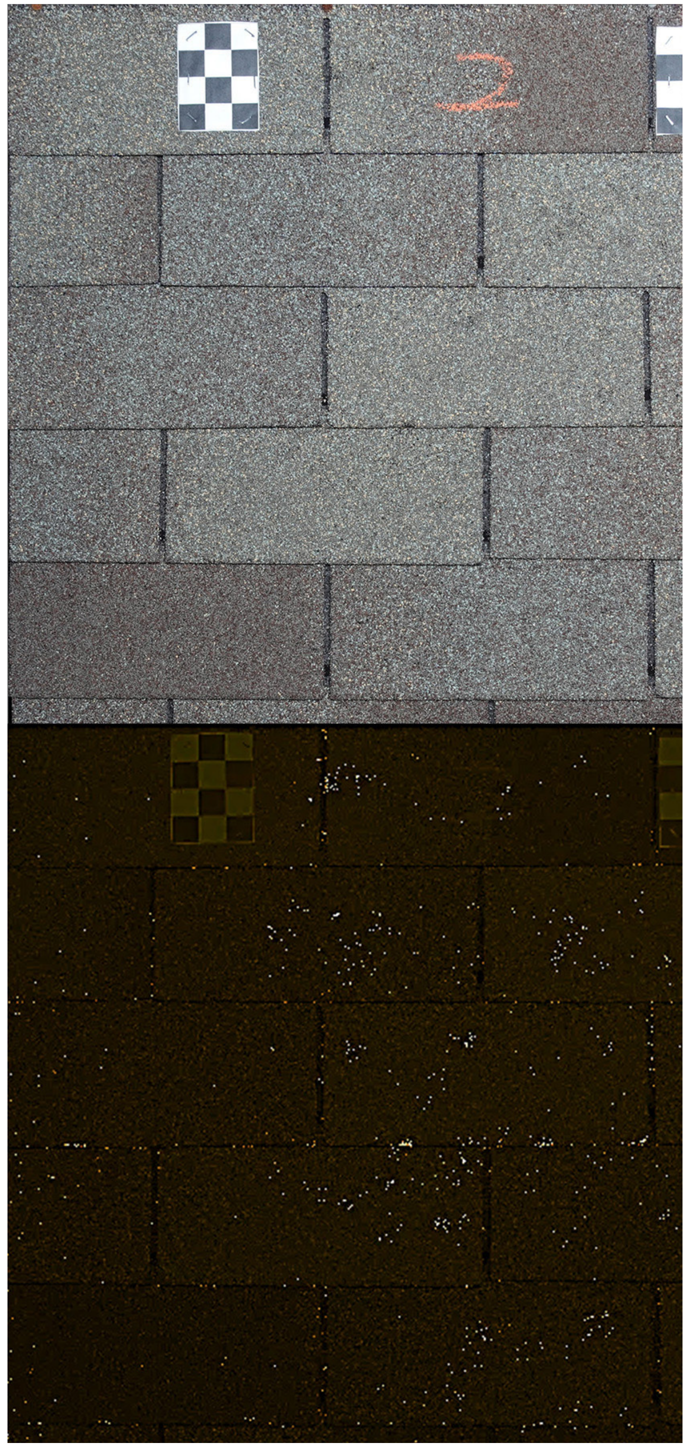

Figure 9. Granule Loss from a weathered roof panel after exposure to small hail impacts. A machine vision algorithm measures granule loss at each yellow dot.

Granule Loss Caused By Small Impacts Is Significant

Small Hailstones (.75 to 1-inch)		Large Hailstones (2-inch)	
Granule loss per 500 impacts	2855.8 mm²	Average patch loss per impact	6.8 mm²
		Average individual granule loss per impact	13.2 mm²
Average granule loss per impact	5.7 mm²	Average granule loss per impact	20.0 mm²
Relative Damage per stone	**28.5%**		**100%**

Figure 8. Comparison of damage between small and large hailstones

[5] Measurements from Figure 7 indicate 1 of 900 impacts came from a stone approaching "very large" size. For additional discussion, see (Sanchez et al., 2009)

Combining Small Hail with Natural Weathering Makes Roofs More Susceptible

Figure 10. A large hail strike captured during IBHS roof material testing.

	New Panels (Baseline)	Stored Panels (Control)	Naturally-Weathered Panels
Round 1, Small Hail: .75-1" Average granule loss per impact after 1 year. (500 impacts)		9.5 mm^2	10.2mm^2
Round 2, Small Hail: .75-1" Average granule loss per impact after 1 more year. (500 impacts)		5.7 mm^2	8.0mm^2
Round 3, Large Hail: 2" Average granule loss per impact. (40 Impacts)	20.0 mm^2	57.2 mm^2	192.2 mm^2
Damage Multiplier	**1X**	**2.9X**	**9.6X**

Figure 11. Round 3 large impacts cause 2.9X more damage when preceded by small hail, and 9.6X more damage after both natural weathering and small hail.

Small Hail and Natural Exposure Makes Roofs Susceptible

Exposing a roof to small hail and natural weathering can increase susceptibility to large hail impacts by 9.6X, when compared to a new roof. In an experiment to explore how climatological exposure affects resilience, IBHS exposed panels to 3 rounds of damage. The first round included one year of weathering for each panel before impacting with 500 sub-severe stones. The second round followed an additional year of natural weathering with 500 more sub-severe stones.[6] The third round subjected each panel to forty stones at a two-inch diameter.[7] While it is evident that large hail can be the final catalyst for a hail claim, these results show that the underlying roof susceptibility is more responsible for the damage.

Figure 12. This IBHS roofing farm is one of five locations across the country. Roofs are subjected to years of natural aging from severe weather, UV exposure, and temperature fluctuations.

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[6] Two small-hail rounds were conducted to allow the panels to measure progressive increases in susceptibility, as well as allow for the panels to lose their "access granules", which are added by the manufacturer to account for expected loss during installation.

[7] Following the IBHS Impact Test Protocol for Asphalt Shingles

Accumulated Damage Explains Loss Better Than Any Storm

Research and Results from ZestyAI

ZestyAI, an AI-based property risk analytics company and the creator of the AI-powered hail risk solution Z-HAIL™, has partnered with IBHS to validate these experimental results. To achieve this, ZestyAI used data from historic climatology and actual claims to measure risk on a real insurance portfolio.[8] This data can show how accumulated damage from small hail exposure relates to claims, whether the trigger for those claims was aesthetic or from a loss of function.

The Predictive Susceptibility approach performs nearly 58 times better at splitting hail risk than the Salient Event approach.

The two lift charts presented in Figure 13 show the results of two different predictive models that aim to categorize homes based on their risk of loss due to hail. The left chart considers only large hail events that occurred in each year, while the chart on the right takes into account the average number of recorded hail events of any size from 2000-2020. Both charts divide homes into above/below median rates of hail events, with each bar representing an equal number of properties from the dataset. For a more detailed analysis of the relative claim rates across hail exposure, please refer to the Appendix.

The Predictive Susceptibility approach performs nearly 58 times better at splitting hail risk than the Salient Event approach. This means a model using two decades of storm data can predict hail losses significantly better than a model considering large hail events from the same year. Single-event analysis for hailstorms with large hailstones does not provide a substantial risk separation for observed hail losses. Broader hail climatology data allows a predictive model to split a much greater proportion of hail losses.

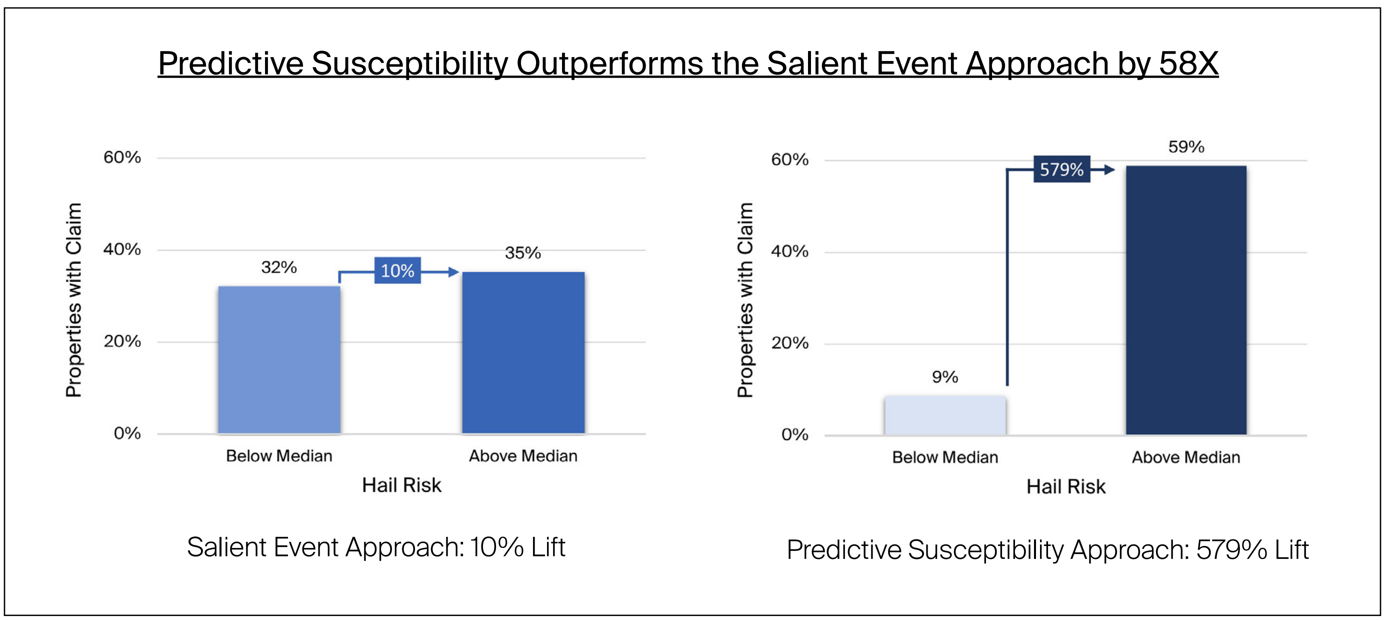

Figure 13. The Predictive Susceptibility approach explains claims much more effectively than Salient Events.

8 Note: Z-HAIL™ was not used to conduct the analysis for this paper.

Results From the Lab, Field, and Industry Agree: Hail Science Provides More Value to Insurers

Concluding Remarks

The Predictive Susceptibility approach is powerful at predicting hail losses, outperforming traditional Salient Event approaches at splitting hail risk by nearly 58 times. Insurers can leverage this data, alongside a risk decision framework that prioritizes proactive underwriting and rating decisions, to more effectively address hail risk in their portfolios. This strategy incorporates results from climate and materials science, as well as new sources of previously-ignored data. Furthermore, these results help to explain why previous tools for predicting damaging storms have struggled to solve the growing problem of hail losses. These tools are often simulation-based, and attempt to estimate the probability of damaging events. Focusing on damaging events disregards the data that is responsible for accumulated damage. The primary purpose of these tools has been automated claims verification, not risk selection. They generally ignore the individual history of a roof, other property-specific building characteristics, and the impact resilience.

In short, carriers would benefit from using the Predictive Susceptibility method for pricing and underwriting hail risk. More modern solutions such as Z-HAIL™, ZestyAI's AI-powered hail risk solution, allow carriers to intersect vast amounts of historical climatology data with property-specific features for accurate risk assessment. While the results in this paper only explore the predictive benefits of studying structural vulnerability, further benefits are available when carriers explore other elements of hail risk. As stated previously, the risk of hail damage to a roof involves its current condition, the hail climatology to which it has been exposed over its lifetime, and the inherent impact resilience for which it was designed. All of these features should be addressed in chosen risk solutions.

To produce these findings, IBHS and ZestyAI have combined evidence from the lab, field, and industry analytics into a single effort. Having all three sources of evidence is extremely valuable and offers a unique opportunity to take theories developed in the lab, measure them in the field, and critically test them with data from real hail claims. Combining lab and field experiments with industry experience allows insurers to take measured actions informed by climate and materials science. Furthermore, the agreement between these three sources increases the level at which insurers can trust the results.

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Sources:

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Additional Discussion on ZestyAI Analysis

If only large hailstones caused damage to roofs, then data from recent large hailstorm events would be very useful in predicting claims. Data from a wider severity or timespan of events would not be associated with significant increases in predictive performance because those storms would not be causing the damage.

Unexpected Claims from Salient Event Approach

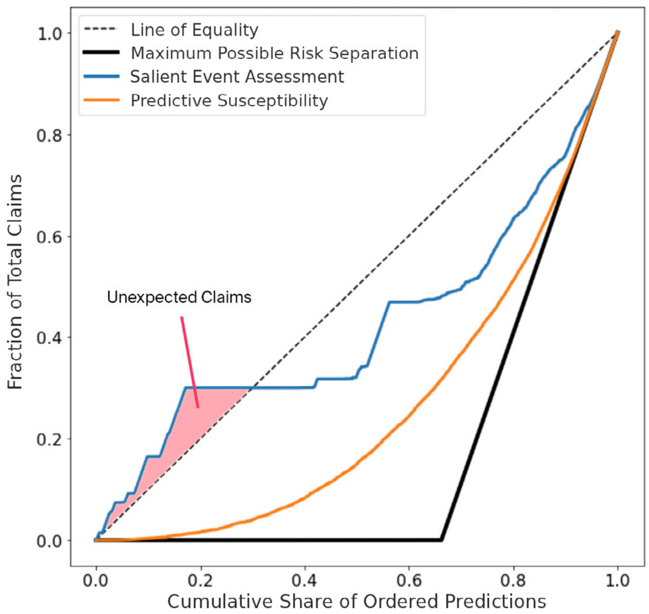

Figure 14. Lorenz Curve for Hail Risk Approaches

This study tested this hypothesis by comparing the performance of two different factors for predicting hail claims:

- Frequency of hail events with a maximum hail size greater than or equal to two inches in the year prior (Salient Event approach). Normalized Gini = .23.
- Average annual hail frequency with hailstones of all sizes for the years 2000-2020 (Predictive Susceptibility approach). Normalized Gini = .73.

As can be seen in Figure 14, the Salient Event approach performs poorly at separating hail risk. At low predicted risk, the Salient Event approach underestimates risk because the approach only considers a small subset of storms and ignores a significant source of accumulated damage. In other words, the Salient Event approach performs worse than simply guessing the average because it assumes zero annual hail activity by major storms will be associated with very low future hail risk. This gap in performance, where the Salient Event approach performs worse than guessing, is likely a contributing factor to insurers suspecting increased levels of fraud.

Conversely, the Predictive Susceptibility approach performs much better across the range of assessed risk. There are no points along the line of predictions for which the model performs worse than guessing, so there are no groups of properties for which the model underestimated risk. Furthermore, there are no points along the risk prediction line where the Salient Event approach outperforms the Predictive Susceptibility approach. Despite considering a much broader set of storm data, the method would offer superior risk separation for insurers at any risk level or chosen risk tolerance.

Data

In order to test these approaches on real claims data, ZestyAI sourced data from an insurance partner on homes with and without hail damage claims. This data was supplemented with randomly-sampled properties from around the U.S., assessed to be without hail claims. This supplemental data was collected to more accurately reflect the reality that few homes file claims in a given year. In total, there were more than 100,000 properties across the contiguous United States, including more than 35,000 hail claims and 68,000 properties without a recorded claim for a control. For each property, the following data was collected:

- Average annual hail frequency for 2000-2020.
- Frequency of events with large hail (two inches or greater) from the year prior.
- Whether the property had a hail claim. Further description of the data is available in the Appendix.

Reports of Hail were assembled with data available from the NOAA Storm Prediction Center (SPC), which is available for

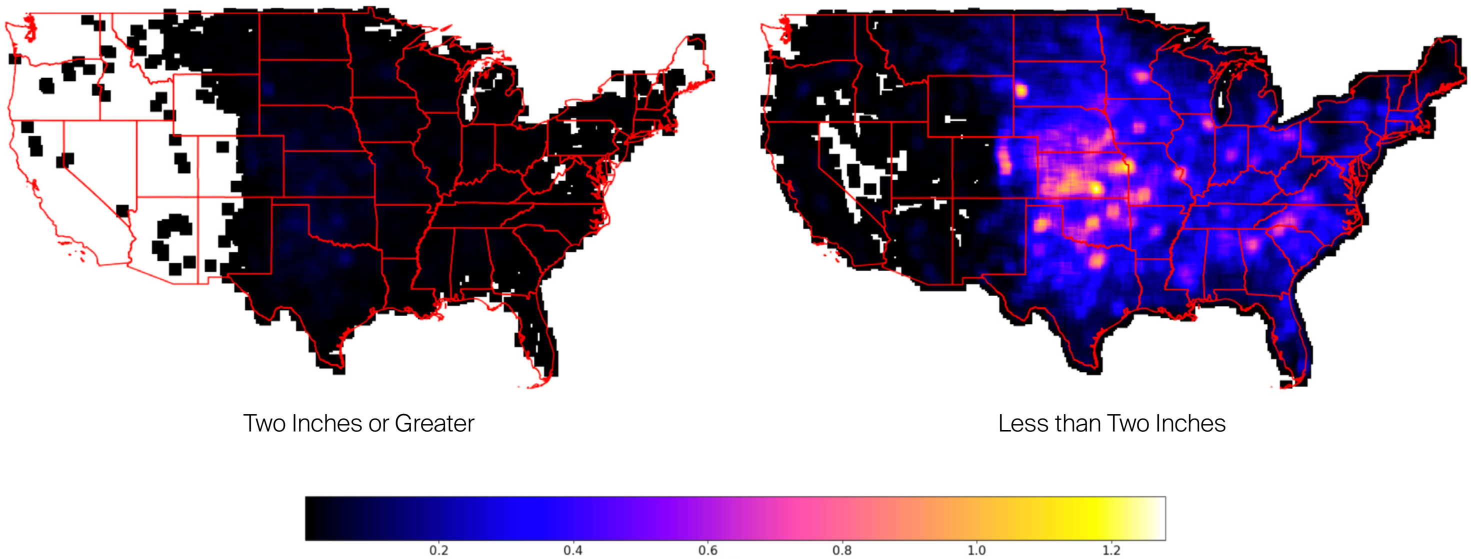

Figure 15. Average Annual Frequency for Hailstorms by Maximum Stone Size

the years 1955-2020. It contains data for hailstorms of all sizes above .75 inches and relies upon voluntary reporting. The majority of hail reports are concentrated around high-population areas because of the data collection strategy, so smoothing methods are used to account for this bias.

Despite these limitations, SPC data remains one of the most comprehensive severe weather datasets available. The value of including small hail data in risk estimates can also be seen in Figure 15, where many more events are collected for hailstorms with stones less than two inches in diameter. The areas of more frequent large hail correlate strongly with small hail (Pearson correlation coefficient = .85), but there are approximately 17 times more recorded small hail events than large.

In order to account for the biases in the data, the area of both large and small hail events was smoothed to represent the natural broad geographic distribution of hail. After smoothing, many parts of the USA experience some form of hail risk, and relative rates can be compared for a greater proportion of developed areas.

Small Hail, Big Problems, New Approach

WHAT WE LEARNED FROM THE FIELD, THE LAB, AND DECADES OF PROPERTY DATA

Related Research from IBHS and ZestyAI:

Wildfire Fuel Management and Risk Mitigation

Research across more than 71,000 properties involved in wildfires draws significant links between fuel management and property survival.

The IBHS mission is to conduct objective, scientific research to identify and promote effective actions that strengthen homes, businesses and communities against natural disasters and other causes of loss. Learn more about IBHS at IBHS.org.

Insurance Institute for Business & Home Safety®

ZestyAI offers insurers and real estate companies access to precise intelligence about every property in North America. The company uses AI, including computer vision, to build a digital twin for every building across the country, encompassing 200 billion property insights accounting for all details that could impact a property's value and associated risks, including the potential impact of natural disasters. Visit zesty.ai for more information.

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