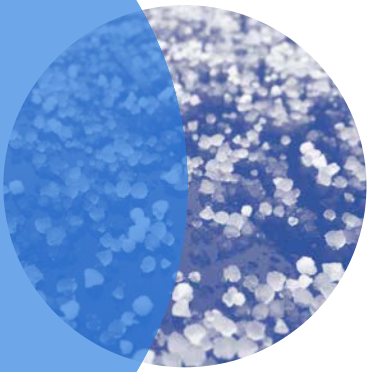
2022 WHITEPAPER

Hail in the United States



Hail in the United States

Every year, thousands of thunderstorms develop and move through areas of the United States, producing lightning, rainfall, and, in some events, large hail. While it's impossible to predict exactly when and where hail will fall, most large hailstorms occur during the spring and early summer months across the middle of the country. Locations across the Great Plains are no strangers to hail, and instances of large hail tend to be relatively common in areas of the Midwest and Southeast as well. These hailstorms are responsible for creating an average of over a million hail-related property losses per year, according to claims data processed by Verisk. That equates to around $10 billion in losses per year across the country. Individuals impacted by these hail events obviously want to have their homes and businesses returned to normal in a timely manner, much like insurance carriers who want to minimize claim handling expenses. Therefore, it is important for restoration industries responding to these events to have timely and accurate data to support their decision making.

How the United States Weather Radar Network Works

General Background on the Network

The United States government operates and maintains an extensive doppler radar network. The current network, known as the Next-Generation radar system or NEXRAD, was deployed starting in the early 1990s and today consists of 143 doppler radars across the contiguous United States. The primary purpose of this network is to provide real-time information to protect life and property in the event of severe weather. However, this same data can be used as an input for creating post-event products to better understand where severe weather, such as hail events, occurred.

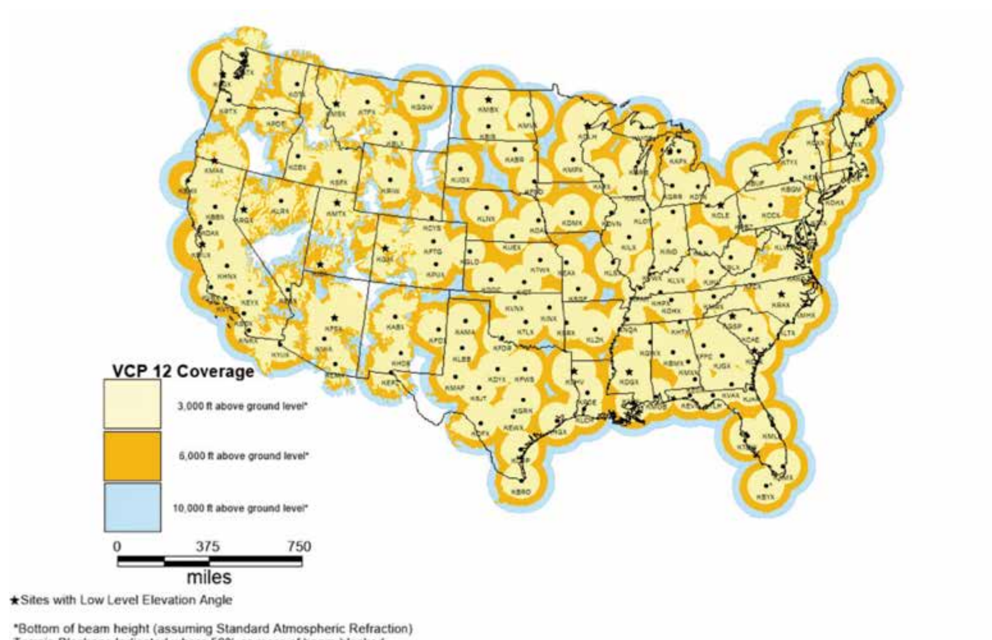


Figure 1: NEXRAD radar sites and coverage across the contiguous United States, where areas shaded in yellow, orange, and blue have sufficient radar coverage and those in white have limited or no coverage from the NEXRAD network (Source: NOAA1)

How a Weather Radar Works

Weather radars are a subset of radars that operate at a frequency that optimizes the detection of precipitation-size particles. A radar emits a pulse of energy and then listens for any of that emitted energy to be returned to the weather radar. As the emitted energy encounters some object (rain droplets, hail, birds, insects, tornado debris), the energy is scattered. Some of that energy is reflected back to the weather radar. In general, the larger the object being hit, the more energy is returned to the weather radar. Based on the amount of time it takes for this energy to return, it is possible to understand where the object was encountered. This means a weather radar can sense where and approximately how large objects are that it encounters when scanning the sky.

A weather radar captures data by making full circle scans at several different elevation angles, with nearly all weather radar data being captured above the surface of the Earth. At a typical NEXRAD site, the lowest scanning angle is 0.5°. Near the radar site this is of course just above the ground, but as the pulse of energy moves further away from the radar site, it becomes higher and higher above the ground. The spherical nature of the Earth's surface also causes the surface to drop away from the beam path, adding further increase to the height of the beam above the surface. At about 100 miles from the radar site, the beam is typically at least two miles above the surface of the Earth. Radar site locations are generally positioned close to major population centers, and their proximity to each other means few areas are more than 100 miles away from a radar site. The overlapping coverage of weather radars therefore makes it possible to combine information from multiple weather radars to even better understand what is happening just above any location.

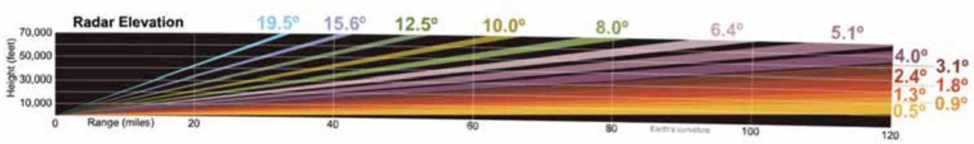


Figure 2: Image depicting a typical five-minute scanning pattern of a NEXRAD site during precipitation events, where the various non-black shaded areas indicate where the radar beam collects data when scanning at certain elevation angles with respect to distance from the radar site (source: NOAA2)

What a Weather Radar Actually Measures

Reflectivity is the most popular weather radar data variable as it generally indicates where precipitation is falling and how intense it is. This is the variable that is typically shown when you view a weather radar image or loop, such as on television. While reflectivity is great for this general understanding of where precipitation is falling, it is limited in its ability to provide information on precipitation type. The NEXRAD radar network was upgraded to dual-polarization scanning beginning in 2011 and finishing in 2013. Dual-polarization (or dual-pol) emits radar signal at both horizontal and vertical incidence, compared to just horizontal incidence for conventional radars. This results in two-dimensional power returns in the horizontal and vertical planes, allowing for more distinguished information about precipitation particles. While it's not a direct measurement, the data does better allow the inference of the size, shape, and phase (water, ice, or mixed) of the objects. In the case of hail, it is possible to better distinguish between falling hail and heavy rain, which can often look the same if just using a single polarization radar.

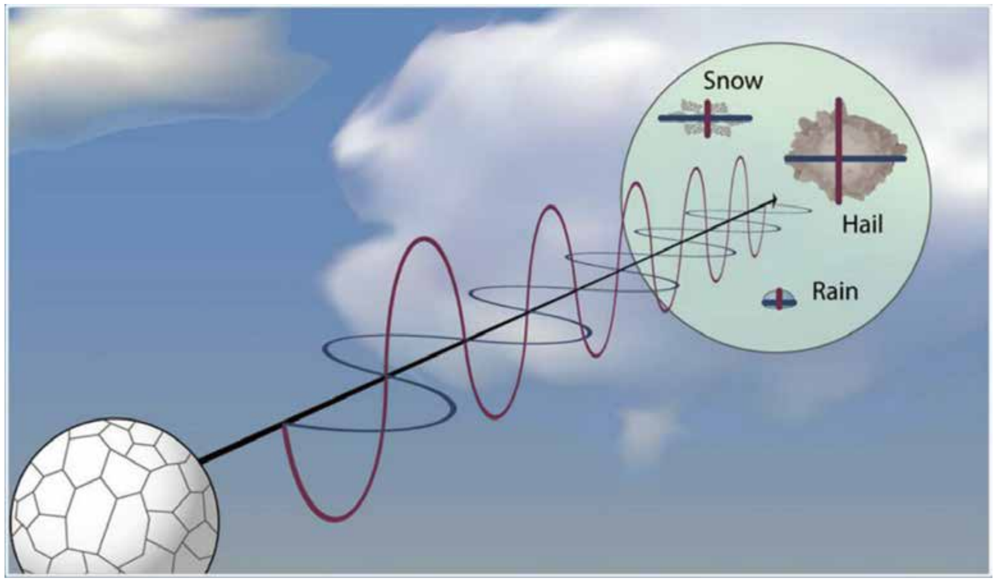


Figure 3: An illustration of how a dual-polarization radar works and can distinguish different precipitation types by comparing the horizontal and vertical pulses of energy (Source: NOAA3)

The Resolution of Weather Radar Data

Weather radars observe by emitting energy as the antenna rotates in a full circle, called a scan. This results in polar coordinate data, meaning the data have varying resolution dependent on the azimuthal angle of rotation and the distance from the radar. The emitted energy, or beam, is analogous to a flashlight; it expands as it gets further away from the radar site which means that the data have varying resolution. The highest resolution data captured by the United States radar network is approximately 0.25 km long by 0.5° wide. The 0.5° measurement is because the radar emits 720 pulses of energy as it rotates around this circle. Therefore, when very close to the radar site this 0.5° measurement can equate to widths of much less than 0.25 km. However, at further distances from the site, the width can grow to a kilometer or more. As such, there is really no one set resolution of a weather radar and instead, the native resolution of the radar data is a function of distance to the radar site.

The History of Hail Products

While research on hail detection via weather radars had been conducted for many years, the field really took off in the late 1990s with the development of the Hail Detection Algorithm by The National Severe Storms Laboratory, a division of NOAA. This algorithm made use of the weather radar reflectivity values and atmospheric temperature data, from model data or other sources, to estimate things like maximum hail size and probability of severe hail. The relationships in the algorithm were developed by comparing the weather radar reflectivity and atmospheric temperature data to actual observations of hail, predominately across the Great Plains. The goal of the algorithm was to provide critical information to weather forecasters issuing weather warnings for severe thunderstorms, and hence the algorithm tended to overestimate the frequency and size of hail to minimize the number of instances where hail events were missed.

Over the next decade, incremental improvements to this algorithm were proposed and, in some cases, implemented. This started to allow for the first post-event hail products to be created, which were initially drawn by hand by trained meteorologists. This was a time-consuming process and was open to a range of human errors. One of the most significant advancements during this period came with increased computing power and the ability to process multiple weather radars' data together. This was initially accomplished by merging the native polar coordinate weather radar data onto an approximately 1-kilometer three-dimensional grid. By merging the data onto this structured grid, calculations such as the Hail Detection Algorithm were able to be carried out across larger regions while remaining within the constraints of the computing power of the time. While this was a major advancement, the merging of the data onto a standardized grid did come at the expense of throwing away some data collected by weather radars. But it did open the door for the first automated post-event hail products, with early versions introduced to the market around the start of the 2010s.

Soon after, dual-polarization radar data became available operationally thanks to the NEXRAD upgrades, allowing for the next major advancement to hail algorithms. Incorporation of this data would significantly improve algorithms and products, including the skill with which hail could be identified. After the network upgrade, most advancements in the area of hail were predominately related to the addition of better quality-control algorithms. These algorithms could use dual-polarization data to better eliminate non-meteorological data, such as energy returned from birds and insects or other sources of clutter, such as wind farms or ground interference. While there were other obvious applications for hail algorithm improvement, few researchers and organizations were able to use the new data to produce a completely new hail algorithm. One significant reason for this was a lack of verification data to use to create a new hail algorithm, given the relatively short period of time that the dual-pol data has been available from the U.S. radar network. Most advancements remained in research papers indicating how dual-polarization data could be used, but not actually creating anything that could be fully implemented as an operational algorithm. And while some organizations claim to use dual-polarization data, most, if not all, still base their hail algorithm largely off the late 1990s Hail Detection Algorithm, at most using dual-pol data to quality-control the output of this algorithm.

The Verisk Respond Hail Size Algorithm

The proprietary hail size algorithm created by scientists at Verisk makes use of cutting-edge developments in both the sciences of hail detection and data processing. The scientists designed the weather radar data processing pipeline natively on the cloud, allowing Verisk to process large amounts of data quickly, providing near real-time hail data that updates every five minutes. The cloud native pipeline also provides the advantage of redundancy by allowing Verisk's processing engine to run across multiple server regions located throughout the world, rather than being entirely dependent on one or two locally maintained data centers. These advanced computing resources also allow Verisk to run more complicated and sophisticated methods for determining where hail is falling. Plus, cloud computing offers a scalable infrastructure at an affordable price.

All of these advantages mean that Verisk can focus more on the science of hail detection. One major advancement is in the ability to use all data that weather radars provide to determine where hail is falling. As mentioned, early hail products had to transform polar coordinate data into a static grid with equal grid spacing. Today Verisk is able to use the data in its originally observed location with little to no data loss, increasing the number of independent observations. This approach is unique considering that many, if not all, other hail products are produced by first gridding the data. It yields a couple immediate advantages for Verisk's data:

- Gradients in hailstorms can be better identified thanks to the use the native, full resolution United States weather radar data

- Finer resolution is possible by not needing to combine multiple independent observations into one gridded value

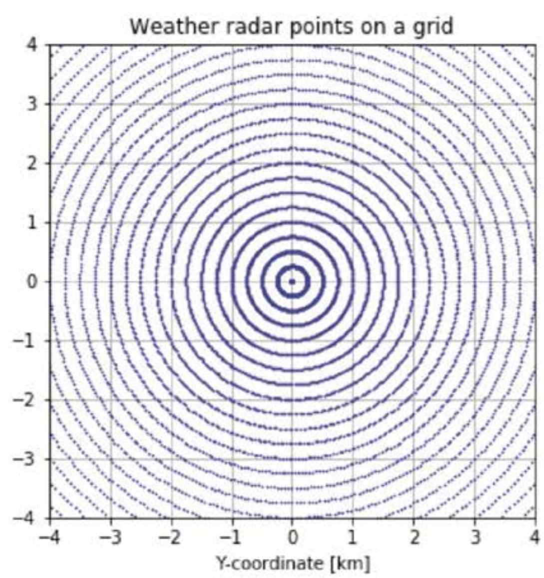


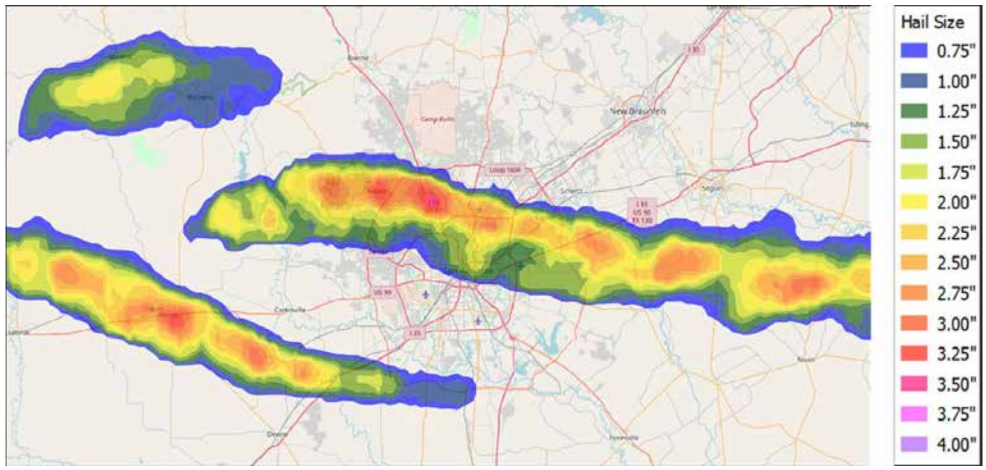
Figure 4: An image showing the sensed locations (blue circles) from a weather radar showing how multiple sensed data points can fall within a single 1-km grid, especially near the radar station location, which is in the center of this image.

The Verisk hail size algorithm assesses every data point sensed by the United States weather radar network within the contiguous United States. As with most hail algorithms, a series of algorithms are performed on the input weather radar data to quality control for common issues. With high quality data points remaining, the proprietary Verisk hail size algorithm independently assesses each point's sensed weather radar variable data, such as reflectivity, correlation coefficient, and differential reflectivity, alongside other data inputs, such as weather model information, to determine where hail is falling and approximately what size it is.

Comparing the sensed weather radar data for a point to similar historical observations where a hail size is known helps to determine how likely it is that a current sensed data point matches those of historically sensed data points. Algorithms then assign the point a most likely at ground hail size, accounting for the effects of things like melting of the hailstones as they fall to the ground.

These independently calculated hail sizes are combined to produce a geospatial layer depicting an estimate of what a hailstorm's impacts looked like. By using the additional information from dual-pol data variables alongside more traditional weather radar data variables, such as reflectivity and weather model data, Verisk's algorithm can obtain hail size estimates without relying on the late 1990s algorithm as a basis. This is a key distinguishing factor between the Verisk algorithm and most, if not all, other operational algorithms.

The Verisk Respond Hail Size solution showing hailstorms that impacted the San Antonio area on a single date in 2016.



A Further Advantage to Cloud Computing

A direct benefit of Verisk's cloud native weather radar data processing pipeline is the ability to rerun multiple years of historical radar data in just days to produce its hail product output. This not only allows testing of new hail algorithm approaches across a variety of cases, but also makes it possible to create a database of hail information based on a consistent hail size algorithm over multiple years. This leads to improvements to hail data both future and historical, yielding more precise and timely insurance underwriting decisions today, for example, rather than years from now when enough new future events would have been processed to justify these decisions.

Applications for the Insurance Industry

Accurate and timely post-event hail data like Verisk's Respond helps professionals make decisions in response to weather events. Immediately after a hail event, insurance companies can use Respond to identify exactly where a hail event occurred and determine the impact to their book of business, whether it be a portfolio of homes, farms, commercial properties, crop lands, or even automobiles.

Depending on the size of the expected impact, insurance companies can make immediate response decisions regarding internal and third-party staffing as well as deployment of field teams to the impacted areas. Information may also be used to determine bulk reserves that may be necessary for the future the payment of yet-to-be-reported claims likely generated by the hailstorm.

As claims begin to flow in, Respond hail data can aid in the triaging process as well as within claims investigation itself via Benchmark property-specific hail history reports, which provide details on hail events that have occurred at or near a particular property or claim location. Benchmark reports can help determine whether a claim should be associated with a specific date or cause of loss, which may have repercussions for that claim due to issues such as:

- Claim filing limitations, such as conditions to file claims within one year of the date of the loss
- Policy inception date considerations with respect to whether the policy was underwritten by the company when the event occurred
- Cause-of loss-issues related to covered or excluded perils
- Fraudulent claims

There can also be impacts in the aggregate when it comes to:

- Accurate reinsurance recoveries with respect to claims being properly associated with a reinsurable event, such as a 72-hour severe weather event
- Internal and external key performance indicators, such as CAT to non-CAT ratios
- Having internally accurate data for post-mortem and future underwriting decisions

To learn more about how Verisk's Respond and Benchmark products can help you, please contact your Verisk account executive or email the weather solutions team at **weathersolutions@verisk.com.**

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