Update to Touchstone Re Loss Estimates

Version 2022 Technical Update

Publication Date: June 2022

Revision History

Date	Description
June 15, 2022	Original release

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1 Executive Summary

Verisk Severe Thunderstorm Model for the United States

The Verisk Severe Thunderstorm Model for the United States incorporates new scientific research and a significant amount of additional hazard and loss data. The historical and stochastic catalogs have been updated. The event generation module uses a new detrending methodology for both hail and straight-line wind, as well as a new derecho detection algorithm. Local hail intensity calculations have been refined using a new spatially-varying intra-swath hail intensity methodology. The damage estimation module includes an innovative, component-based hail vulnerability framework, regional building code enhancements and enforcement practices (current as of 2020), and updated damage functions that explicitly incorporate local building characteristics. The updated model includes 100 new construction classes and 2 new occupancy classes. It expands support for several specialty lines of business, including marine lines, wind turbines, greenhouses, and heavy construction/infrastructure risks.

Verisk Crop Hail Model for the United States

The Verisk Crop Hail Model for the United States has been updated to address the unprecedented loss ratios experienced 2016 through 2020. Verisk researchers have incorporated new meteorological, agriculture, and policy data, as well as new analysis techniques in this update. The model uses hail and straight-line winds from the new 10,000-year all-events catalog for the Verisk Severe Thunderstorm Model for the United States. The model also includes an improved understanding of the relationship between the growing stage at the time of a hail event and crop damage. For selected states, the model includes a new wind module that estimates wind-induced crop losses linked to wind endorsements under crop hail policies.

2 The Verisk Severe Thunderstorm Model for the United States

2.1 Model Updates and Changes

The June 2022 release of the Verisk Severe Thunderstorm Model for the United States includes new and updated features that:

- Represent a true "all-events" model that reflects the near-present climate and risk for all severe thunderstorm events, including a wide range of smaller, high-frequency to larger, low-frequency events
- Incorporate a new hazard detrending methodology
- Use a new granular approach to modeling hail intensity by allowing intensity to vary within a given hail footprint (i.e., "intra-swath hail intensity variation")
- Improve hail event footprints (length, width, and intensity probability distributions) using detailed radar reflectivity data run through an enhanced storm-tracking algorithm
- Incorporate a significant amount of new hazard data, including 7 additional years of storm reports and atmospheric reanalyses for all three modeled sub-perils and 20 years of detailed radar data for the hail sub-peril
- Include a new derecho detection algorithm
- Incorporate a significant amount of additional company claims, industry loss, building code enforcement, replacement cost, and roof age data as well as insights from in-house and published engineering studies
- Use a new innovative component-based approach to modeling hail vulnerability within an updated hail damage framework
- Account for building code evolution, adoption, and enforcement through updated wind and tornado damage frameworks, and extend building code assumptions to the hail damage framework
- Provide updated hail, straight-line wind, and tornado damage functions and/or distributions for residential and commercial structures, manufactured homes, automobiles, industrial facilities, marine, and infrastructure risks
- Expand support for several specialty lines of business, including wind turbines, greenhouses, marine risks (inland transit, marine hull, and marine cargo, among others), and heavy construction/infrastructure risks
- Include a fully-updated 2019 Verisk Industry Exposure Database for the United States

2.2 Catalogs and Event Sets

Historical Catalog

The Verisk Severe Thunderstorm Model for the United States historical catalog of severe thunderstorm events used to build the model has been updated with up to seven years of additional available data since the last model update. Data sources include the:

- National Oceanic and Atmospheric Administration's (NOAA's) Storm Prediction Center (SPC)
- NOAA's National Centers for Environmental Information (NCEI)
- NOAA's National Centers for Environmental Prediction (NCEP)
- Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network
- Severe Hazards Analysis and Verification (SHAVE) Project
- Climate Forecast System Reanalysis (CFSR)
- NOAA's Next Generation Radar (NEXRAD) Level II and III Data

Marquee/Historical Event Set

The Verisk Severe Thunderstorm Model for the United States includes a marquee event set consisting of 5 perturbations of 7 events, for a total of 35 events. While the historical events selected for the marquee catalog have not changed with this update, the marquee footprints and intensities have been updated using claims data (for the hail, straight-line wind, and tornado sub-perils) as well as detailed radar data (for the hail sub-peril).

Stochastic Catalog

The Verisk Severe Thunderstorm Model for the United States includes an updated 10,000-year (10K) cat-only stochastic catalog. This catalog includes more robust regional variation in hail swath length, width, and intensity distributions based on 20 years of detailed radar data processed in Verisk's storm tracking algorithm and validated using storm reports and claims data. Stochastic catalog macroevent frequency has increased by 92% due to the new hazard detrending methodology used to account for population and reporting biases in the annual number of SPC storm reports.

2.3 Event Generation

The event generation component of the Verisk Severe Thunderstorm Model for the United States incorporates:

- a significant amount of additional detailed observational data (radar reflectivity, SPC storm reports, CoCoRaHS, and SHAVE) and claims data,
- new research (particularly related to hail),

- a new derecho detection algorithm,
- reduction factor applied to SPC wind data to address reporting bias,
- a new hazard detrending methodology, and
- an improved Verisk storm-tracking algorithm.

The Verisk-developed derecho detection algorithm is based on scientific research and constructs a list of derecho event days using SPC wind reports between 1979 and 2018. This algorithm is highly skilled at detecting both individual historical events as well as the overall U.S. derecho climatology.

With this model update, Verisk researchers detrended the observed annual number of hail and straight-line wind SPC storm reports to remove the false linear time trend present in the earlier years (1979 -2010) due to population and reporting biases, as well as correct for climate change (particularly post-1990) in this dataset. The previous version of the model (released in 2014) assumed 2001 was a baseline year and detrended the data relative to 2001 because, at the time, it was not clear whether event frequency would continue to increase or stabilize. For the 2022 release, the data show that the event frequency has stabilized in recent years, except for 2011, which was a large outlier year. Thus, with this model update, Verisk researchers introduced a new detrending methodology that modifies the severe daily and annual frequencies present in the early years of the SPC storm reports (1979 - 2010) to make them more consistent with recent years. This methodology removes non-meteorological signals while preserving climate-related trends.

Furthermore, Verisk researchers' examination of the SPC convective straight-line wind speed data revealed that the preponderance of SPC reports in the eastern two-thirds of the United States are, in fact, estimated wind speeds, rather than actual measured wind speeds. In addition, Verisk internal research, as well as literature review, indicate that estimated wind speeds are biased 20-30% high when compared to the true/measured wind speed. To address this issue, Verisk scientists applied a reduction factor to the estimated SPC wind reports, by state and wind speed bin; the reduced wind speed reports were then used to build the wind sub-peril catalog.

Verisk researchers improved hail event footprints by incorporating 20 years of detailed NEXRAD Level II radar reflectivity data into the updated model. These data were run through a storm-tracking algorithm that identifies areas of intense storm activity and tracks them through time and space. This algorithm was run daily and identified over three million tracked storms. These storms were subsequently filtered into likely hailstorms using additional data sources, including CoCoRaHS, SHAVE, SPC, and NEXRAD Level III hail signatures. Finally, these event footprints were validated and tuned using storm reports and claims data and are used to inform hail footprint length, width, and intensity probability distributions. These probability distributions are ultimately used to update Verisk's stochastic catalogs.

With this model update, Verisk researchers used spatially-varying generalized additive models (GAMs) to fit a relationship between hail occurrence (obtained from the filtered radar reports) and individual environmental parameters, such as elevation, Convective Available Potential Energy (CAPE; a metric that approximates updraft strength and atmospheric instability), shear, lapse rate, 500 mb temperature, and specific humidity. While some of these variables are often combined to yield composite parameters, such as Significant Hail Parameter

(SHiP), which can indicate conditions favorable for hail formation, these variables were not combined when creating the GAMs to allow for interactions among them. The GAMs probability surfaces were augmented with SPC hail observations (via hybrid statistical-meteorological smoothing).

Impact of the Event Generation Update

New and enhanced event generation components included in the 2022 version of the Verisk Severe Thunderstorm Model for the United States result in a true all-events model that correctly represents the near-present climate. Verisk's new derecho detection algorithm provides an accurate view of derecho climatology in the U.S. The incorporation of a new hazard detrending methodology removes population and reporting biases present in the data and results in more events in the stochastic catalog than the previous (2014) version of the model for all three sub-perils. The improved Verisk storm-tracking algorithm also reduces population biases and provides a better hailstorm footprint extent and intensity distribution than just using storm reports alone.

The new hazard detrending methodology ensures that, when the stochastic catalog is built, the count and location of microevents on each simulated day are reflective of near-present climate conditions, no matter which seed day is selected. In addition, when the model is built, the attributes of each simulated hail microevent are drawn from probability distributions, which are created from a blend of SPC storm reports and radar-based hail swaths. Due to the growth in SPC storm reports over time (1979 - 2010), these probability distributions are implicitly weighted toward the more recent years (post-2010) to result in more hail events. The radar data used to create the hail distributions range between 1996 and 2018. Thus, the hail probability distributions are further implicitly-weighted toward more recent years, ensuring that each simulated hail swath's attributes are reflective of near-present climate conditions.

The updated model’s daily probability surfaces for hail represent a blend between environmental conditions and observations, like the existing model, while allowing for realistic interactions among variables that contribute to hail formation. Figure 1 is an example of underlying radar reflectivity data with Verisk-modeled ellipse footprints (dark blue ellipses) output by the storm-tracking algorithm for the May 10, 2010 historical event. Overlaid on this image are hail reports (green triangles) and claims data (blue circles). Using the radar data creates better storm footprints than just using storm reports alone, as evidenced by the sparsity of reports in some of the ellipses. Note that some of the claims data are outside the event footprints, which is most likely due to incorrectly assigned date of loss to claims. Severe thunderstorms (not shown) that occurred a few days after this event align with some of the clusters of missed claims seen in this image.

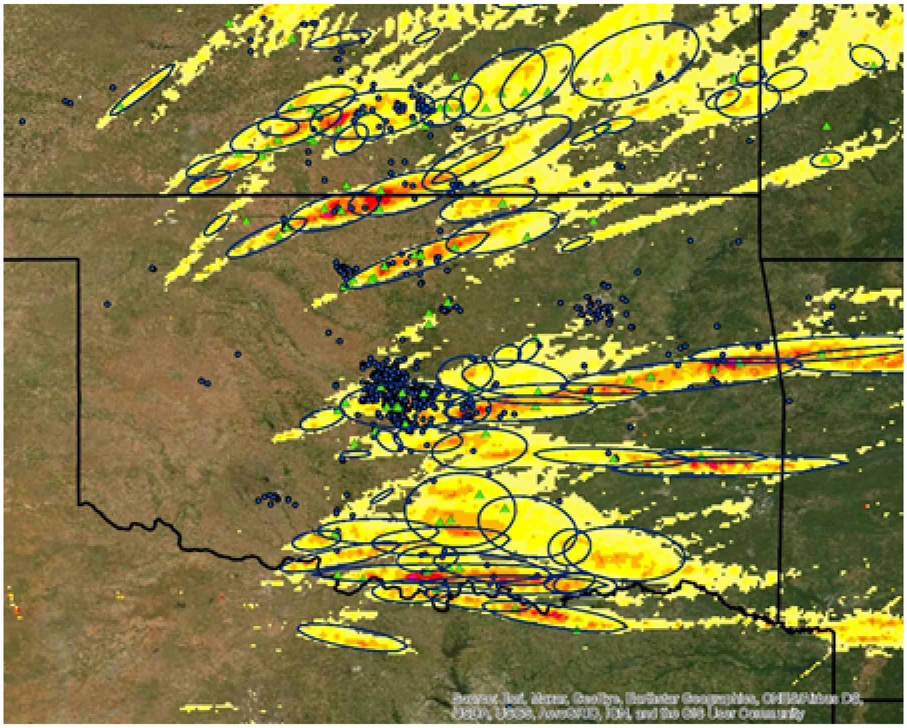

Figure 1. Example of radar reflectivity overlaid with Verisk-modeled ellipse footprints (blue ellipses), SPC hail reports (green triangles), and claims data (blue circles) for the May 10, 2010 historical event

Detailed hailstorm footprints provide accurate length, width, and intensity probability distributions, which are, in turn, sampled to inform Verisk's stochastic modeling and ultimately produce the model's stochastic catalogs. The inclusion of a large radar reflectivity dataset allows Verisk researchers to build robust regional variation into these probability distributions and, hence, Verisk's stochastic catalogs. For example, greater swath lengths occur, on average, in the central U.S. as compared to other regions (Figure 2).

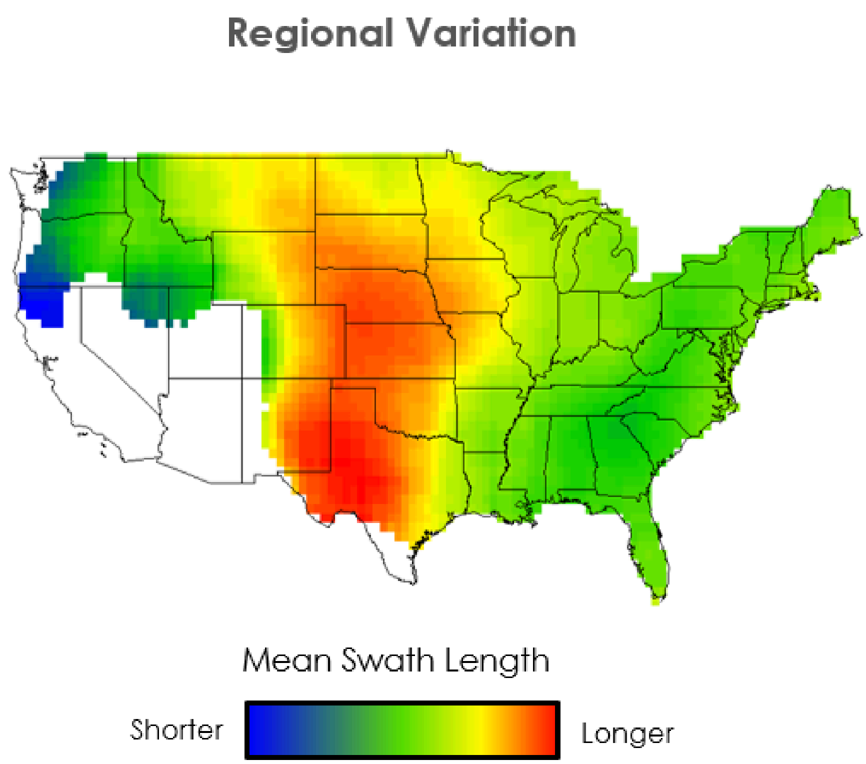

Figure 2. Example of regional variation in July hail swath length

2.4 Local Intensity Calculation

The local intensity calculation component of the Verisk Severe Thunderstorm Model for the United States incorporates a significant amount of additional observed and claims data, new research (particularly related to hailstorms), and a spatially-varying hail intensity profile within an event footprint. The previous (2014) version of the model keeps hail intensity uniform throughout an event footprint but, in reality, there is quite a bit of variability in intensity throughout a given hail swath. To account for this variability, Verisk researchers built an "intra-swath hail intensity variation" profile into the hail footprints in the updated (2022) model. As a result, areas close to the center of a simulated hail footprint have greater intensity than along the edges. The methodology for calculating straight-line wind and tornado intensity remains unchanged with this update.

Impact of the Local Intensity Calculation Update

The inclusion of a spatially-varying approach to hail intensity in the local intensity calculation component of the updated Verisk Severe Thunderstorm Model for the United States produces more granularity in hail intensity and less damage smoothing within an event footprint. As a result, users are provided with more realistic hail swath profiles, with greater damaged areas near the center and less damaged areas near the edges of an event footprint, as seen in Figure 3. Note that the pattern of hail sizes within a footprint can vary significantly between storms.

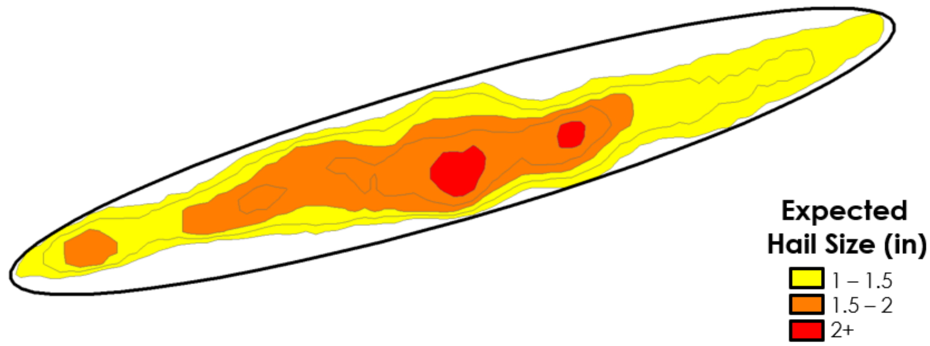

Figure 3. Example of a radar-predicted spatially-varying hail intensity footprint from May 10, 2010 using Verisk Respond data

2.5 Damage Estimation

The damage estimation component of the updated (2022) Verisk Severe Thunderstorm Model for the United States incorporates an innovative component-based hail vulnerability framework, significant amount of additional data (company claims, industry losses, building code enforcement, replacement cost, and roof age data), insights from in-house and published engineering studies, updated damage functions, and expanded specialty lines of business risk support. In addition, a fourth building year-built band is added to the updated model to capture the impacts of the 2012 and later versions of the International Code Council building codes. These codes reference the 2010 vintage of the American Society for Civil Engineers 7 (ASCE 7-10) load standard regarding design wind speed maps.

For the 2022 model release, Verisk engineers completely rebuilt the model's hail vulnerability framework based on engineering studies, literature, innovation, additional Verisk datasets, and market feedback. Within this framework, a structure is decomposed into a series of systems, including the roof (e.g., roof covering, roof deck, etc.), wall, interior, and non-damageable (i.e., additional building components that are not expected to experience hail damage) systems. Verisk engineers focused on evaluating roof-related damage, roof age, re-roofing details, building height granularity, and square-footage differentiation, among other aspects.

Additionally, the effect of aging has been updated for the 2022 model release. For example, a structure constructed in the year 2010 has aged since the 2014 version of the model was released and is therefore more vulnerable in the updated (2022) model than in the previous (2014) model version. The updated model also includes roof age band and roof age assumption updates within the wind damage framework. For all buildings built from 2010 to the current year, the Verisk model assumes a new roof, which leads to decreased vulnerability when compared to the prior version of the model. If a building was built between

2000 and 2009, it is reasonable to assume that, in the absence of user data, the roof has not been replaced. Therefore, an average roof is assigned to the structure, which leads to a slight decrease in vulnerability compared to the previous version of the model. Structures built before 2000 are assigned an unknown roof age in the absence of additional roof year-built information, which aligns with previous model assumptions. The exception to this assignment is for single- and multi-family homes as well as apartments and condos that are constructed from wood or masonry. In these cases, structures that are built prior to 2010 are assigned a roof age based on county roof age averages from the Verisk Roof Age dataset.

Individual damageability curves were developed for each component. Specifically for the hail sub-peril, these curves describe the percentage of the component that exceeds limit states/ damage mechanisms at various levels of hail impact kinetic energy. Limit states or damage mechanisms are component-specific and describe how the individual components perform when subject to hail impacts. For instance, these responses could be denting, cracking, or fracturing for roof covers. The relationship between various building features and the corresponding hail impact kinetic energy imparted on a structure are also considered (e.g., a building's roof slope impacts the number of hailstones affecting the roof and the energy they impart on the roof's components). Cost data, obtained from Verisk's 360Value and RSMeans, are used to understand the proportion of the total building replacement value that should be assigned to each component. Weights are developed using this information and are, in turn, used to aggregate the individual damageability curves to obtain a building-specific damage function. As a user inputs primary and secondary building characteristics, the building's cost breakdown changes. If a user specifies primary features (including the structure's location and year-built) but does not specify any secondary features, this information can be supplemented using assumptions determined from an extensive in-house building code adoption and enforcement study using data valid as of the year 2020. While the aforementioned building code study was already available and implemented for the straight-line wind and tornado sub-perils in the 2014 version of the model, the study is implemented for the hail sub-peril for the first time with this 2022 model update. In addition, all three sub-perils are now updated with building code data available through 2020.

The model incorporates updates to the hail, straight-line wind, and tornado damage functions for residential and commercial structures, manufactured homes, automobiles (hail update only), industrial facilities, and infrastructure risks. The wind and tornado vulnerability of reinforced masonry buildings greater than three stories tall, small industrial facilities, and concrete and steel single-family homes were modified to more closely align with engineering-based expectations based on learnings since the last model update. Additionally, all unknown wind and tornado damage functions were updated based on weights determined using the 2019 version of the Industry Exposure Database. These include functions for traditional building risks with occupancy codes 300 and 301, construction codes 100 and 111, and unknown height damage functions.

Manufactured home vulnerability has changed significantly with this update. A new U.S.-wide manufactured home damage framework was included in the updated model that accounts for spatially and temporally varying straight-line wind and tornado vulnerability differences in manufactured homes due to variability in HUD codes over time and space. Also included are new learnings from wind-related claims, largely from hurricane events, that were used to inform Verisk's manufactured home wind vulnerability relationships.

In addition, the 2022 version of the model expands support for several specialty lines of business, including infrastructure risks (bridges, pavements, dams, tunnels, storage tanks, pipelines, chimneys, towers, railway, canals, and earth-retaining structures), equipment, cranes, conveyor systems, wind turbines, greenhouses, and marine risks (inland transit/ transit warehouse, marine hull, marine cargo, and marine craft, among others). Building, appurtenant structures, contents, and time element damage relationships were re-evaluated in this model update and led to modifications to content and time element damage functions.

2.6 Industry Exposure Database

The 2022 version of the Verisk Severe Thunderstorm Model for the United States uses the United States Industry Exposure Database, which is current through the end of 2019. This database is at 90-m resolution. The 2019 Industry Exposure Database includes increased total insurable values across all lines of business and updates to the event-level demand surge factors for exposures in the United States.

2.7 General Impact of Model Updates on Loss Estimates

The general impact of the Verisk Severe Thunderstorm Model for the United States updates on gross insurable occurrence and aggregate losses is presented in the tables available through the link below. These loss changes are due to hail, straight-line wind, and tornado losses combined and include demand surge. They represent the percentage change in loss estimates calculated by the previous version of Touchstone Re [2021 (9.0)] as compared with those calculated by the current version of Touchstone Re [2022 (10.0)], for the model domain (conterminous United States), each region, each state, and the District of Columbia, using the 10,000-year cat-only stochastic catalog.

The following loss change tables are available:

- Gross Insurable Occurrence - Change with Constant Exposure
- Gross Insurable Aggregate - Change with Constant Exposure
- Analysis Settings

Constant Exposure tables show what the user will likely see if the same sums insured analyzed in the previous version of Touchstone Re are compared with the current version's results, using the same sums insured with the “use latest Industry Exposure Database” option enabled.

Caution should be exercised before relating the industry changes shown here to a particular portfolio. The changes to individual books of business may deviate from the losses

represented here to the extent that their exposure spatial distribution and construction/ occupancy mix deviate from industry averages.

While occurrence losses have remained relatively stable across the conterminous U.S. as a whole, occurrence and aggregate losses for all perils combined have generally increased across most regions and lines of business, with larger changes seen in aggregate losses, with this model update. Some of the more significant percentage increases are seen in the West and in Florida; and some of the smallest percentage increases and/or slight decreases in losses are evident across the Northern and Southern Great Plains and the Midwest. The manufactured home and automobile lines of business experienced the greatest percentage increases in loss, while the residential and commercial lines of business had the smallest increases and/or slight decreases overall. These changes can be explained by both the significant hazard and vulnerability updates made to the model. Details regarding these changes are described by sub-peril below.

Impact of Hail Updates on Loss Estimates

Hazard updates to Verisk's hail modeling approach results in an approximately 30% increase in the frequency of severe hail days in the model. However, these changes are not spatially uniform. Specifically, the model shows a broad increase in hail frequency across much of the contiguous United States, with notably higher hail frequencies in the Northern Plains (particularly Kansas, Nebraska, and Oklahoma), the Northeast, and the Southeast (particularly Georgia, South Carolina, and North Carolina) compared to the previous model version. These higher hail frequencies contribute to increases in aggregate losses in these regions. These changes validate well against near-present observed severe thunderstorm day frequency and are consistent with our expectations based on changing meteorological conditions.

Significant vulnerability updates include the introduction of an innovative component-based hail vulnerability framework and recalibration of all vulnerability relationships such that modeled losses closely align with claims data. The hail vulnerability update cannot be considered an incremental vulnerability update with respect to the previous version of the model because the hazard definition changed between the prior and updated versions of the model. Specifically, in the prior model version, each hail microevent was assigned a total hail impact energy, which is designed to capture the distribution of hail sizes in the ellipse, as well as hailfall duration and horizontal wind speed. In the updated model version, an intensity profile is additionally applied to each hail microevent, yielding a spatially-varying total hail impact energy within the swath—with higher intensity toward the swath midline and decreasing intensity toward the edges of the swath. Therefore, it is not possible to separate the impact of the vulnerability updates from the hazard updates. As a result, these changes must be collectively compared to the prior version of the model.

Relationships between lines of business were also reassessed. Manufactured home vulnerability compared to traditional building risks was re-evaluated based on material and cost information within the hail vulnerability framework. Quantifying the relative impact of this update is not straightforward, as various locations will result in different magnitudes of change due to spatial and temporal vulnerability variations for traditional building risks. However, on an industry-wide basis, these changes led to an increase in manufactured home hail vulnerability when compared to traditional building risks for low hail intensities.

In addition, automobile damage functions were re-evaluated for both personal automobiles and dealerships, which resulted in an expected increase in automobile line of business losses relative to loss changes for traditional building risks for low hail intensities.

Impact of Straight-line Wind Updates on Loss Estimates

As a result of the new hazard detrending methodology, the updated model shows a broad increase in convective straight-line wind frequency across the United States, most notably in the Great Plains, the Mid-Atlantic states, the Southeast, and the Northeast. However, this increase in frequency does not necessarily result in increased losses in these regions of the model domain, due to the application of a reduction factor to the estimated SPC wind speed reports. As a result, the average wind speed in the updated model has decreased relative to the previous model version, but the amount of wind speed reduction is region-specific. Therefore, the region-specific interaction between the increase in wind frequency and the decrease in wind intensity drives the hazard contribution to the loss changes seen in each region of the model domain. In general, regions that exhibit notably higher wind frequencies and lower average wind speed show an increase in aggregate loss, but not necessarily a decrease in occurrence loss. In regions with little change in frequency, the reduction in mean wind speed results in lower occurrence and aggregate losses.

Vulnerability updates to the wind damage framework (including updates to building codes and default damage framework features, the aging and deterioration of structures, recalibration of damage functions, and updates to unknowns due to the incorporation of new datasets) provide relatively minor changes at the industry level for most risks. In addition, the recalibration of contents and time element damage functions results in some decreases in contents and time element losses for lower intensity events.

This vulnerability update has implications for traditional buildings constructed since the last model update. In general, building vulnerability decreases for newer buildings because newer building codes are typically more stringent and better enforced than older codes. There are exceptions to this generality, most notably in some coastal areas where the 2012 International Building Code and International Residential Code specified lower design wind loads based on the 2010 ASCE 7 standards. The inclusion of recent building codes results in a varying degree of model changes based on the actual location of the risk.

The vulnerability updates described above are relevant to traditional building risks and affect the wind vulnerability of the residential and commercial lines of business. These updates have moderate impacts on the vulnerability of individual risks. Most of the vulnerability updates described above affect the vulnerability of primarily newer structures, which, on average, result in decreased vulnerability due to the incorporation of recent building code assumptions and more specific roof aging criteria. This decreased vulnerability is balanced by the aging of the overall building stock. Thus, these updates cause relatively small loss changes to the industry view of wind risk for residential and commercial lines of business. Commercial risks experience more significant decreases in vulnerability than residential risks due to the impact of damage function modifications to content and time element losses for lower wind speed events.

Manufactured home vulnerability updates have led to a significant increase in the vulnerability of manufactured homes that is visible in the industry-based manufactured home EP curves. Automobile wind vulnerability did not change significantly with this update. Therefore, it is expected that most of the gross insurable loss changes for this line of business are a result of region-specific wind hazard modifications. Specifically, many regions show an increase in automobile losses across several return periods, which is driven by the higher modeled wind swath frequencies in these regions with this update.

Impact of Tornado Updates on Loss Estimates

Hazard modifications for the tornado sub-peril include an increase in frequency in the Southeast and Florida (predominantly during the cool season). This frequency increase is due to the increase in tornado occurrence in these regions, as present in the new observational data with this model update. Increased losses for tornado are therefore expected in these regions across all lines of business. The Mid-Atlantic region also shows a modest increase in tornado frequency with this update. Thus, relatively small loss increases for tornado are also expected in this region.

Vulnerability modifications to the tornado framework are similar to those described for wind above. Losses associated with tornado damage for the residential and commercial lines of business result in minimal impacts due to damage function and tornado damage framework updates at the industry level. Content and time element damage function vulnerability relationship updates do not have as much of an impact on tornado loss changes as was previously noted for wind. The content and time element relationships were recalibrated primarily for lower intensity events. Tornado events are typically accompanied by high wind speeds. Therefore, as expected, these modifications result in less of an impact.

Manufactured home tornado vulnerability has increased due to the inclusion of new wind data and a manufactured home tornado damage framework that accounts for spatial and temporal vulnerability with this model update. Automobile tornado vulnerability was largely unchanged with this model update. Thus, the impact to the automobile loss changes associated with tornado damage are expected to be largely hazard driven.

3 The Verisk Crop Hail Model for the United States

3.1 Model Updates and Changes

The June 2022 release of the Verisk Crop Hail Model for the United States offers the following:

- A fully updated hail module in the 10,000 all events catalog that includes
  - Improved seasonality of extreme weather events
  - Sophisticated generation of both smaller, high-frequency events and larger, less common events to better capture the variability of the current climate
  - A new modeling approach that allows hail intensity to vary within a given hail footprint
  - New data and data analysis techniques
- A new wind module that estimates wind-induced crop losses in states with significant liabilities under wind endorsements attached to crop hail policies
- A fully updated Industry Exposure Database that incorporates year-to-year variations in crop area
- Updated crop damage functions
- Updated crop hail and production plan policy distributions by state
- Updated crop prices
- Updated Multiple Peril Crop Insurance (MPCI) yield catalog for production plan

3.2 Stochastic Catalog

The June 2022 release of the Verisk Crop Hail Model for the United States uses the same 10,000-year, all-events stochastic hazard catalog as the Verisk Severe Thunderstorm Model for the United States. This catalog has been fully updated for this model release.

Compared to the previous version, the updated catalog includes a 21% increase in the number of hail swaths and a 19% increase in their average area. There is a broad increase in hail frequency across much of the model domain, with notably higher hail frequencies in the Northern Plains (Kansas, Nebraska, and Oklahoma), the Northeast, and the Southeast (Georgia, South Carolina, and North Carolina) compared to the previous model version. These changes are well validated against near-present observed severe thunderstorm frequency and are consistent with scientific expectations based on changing meteorological conditions.

3.3 Event Generation

The event generation module includes new/updated data sources as well as improved data analysis and event probability distributions, which allow the model to more accurately reflect the current climate.

Data sources

Data sources used in the generation of the catalog include the:

- National Oceanic and Atmospheric Administration's (NOAA's) Storm Prediction Center (SPC)
- NOAA's National Centers for Environmental Information (NCEI)
- NOAA's National Centers for Environmental Prediction (NCEP)
- Community Collaborative Rain, Hail, and Snow (CoCoRaHS) Network
- Severe Hazards Analysis and Verification (SHAVE) Project
- Climate Forecast System Reanalysis (CFSR)
- NOAA's Next Generation Radar (NEXRAD) Level II and III Data

Improved data analyses, event probability distributions, and current climate

The attributes of the model's simulated hail microevents (e.g. footprint length, width, and intensity) were drawn from probability distributions generated using sophisticated data analysis techniques and scientific expertise. Due to the growth in SPC storm reports over time and the use of recent radar data, these probability distributions are implicitly weighted toward more recent years. That inherent bias toward recent climate variability and careful data analyses – such as the hazard de-trending methodology and the use of GAMs discussed below – ensure that the count and location of microevents on each simulated day in the stochastic catalog reflect current climate variability.

- **NEXRAD Level III radar reflectivity data** Verisk researchers improved hail event footprints by incorporating detailed NEXRAD Level III radar reflectivity data from 1996 to 2017 into the update. The NEXRAD data were instrumental in capturing the intensity, geometry, and regional variations of thousands of hail swaths used in the generation of the stochastic catalog. The inclusion of this radar reflectivity dataset allowed researchers to build regional variation into the probability distributions. Figure 4 is an example of the regional variation in the swath lengths of hail events in July.
- **Storm-tracking algorithm**. These data were run through a storm-tracking algorithm that identifies areas of intense storm activity and tracks them through time and space. This algorithm was run daily and identified over three million tracked storms. The improved Verisk storm-tracking algorithm also reduced population biases and provided a better hailstorm footprint extent and intensity distribution than just using storm reports.
- **Validating with data sources**. Hailstorms were identified using the data sources listed above, and event footprints were validated and tuned using storm reports and claims data.

- **Detrending methodologies**. To ensure that the model uses data that represent current conditions, this update includes a new de-trending methodology that modifies the severe daily and annual frequencies present in the early years of the SPC storm reports to make them more consistent with recent years. This methodology removes non-meteorological signals (such as observational biases) while preserving climate-related trends.

  For example, Verisk researchers' examination of the SPC convective straight-line wind speed data revealed that the preponderance of SPC reports in the eastern two-thirds of the United States were, in fact, estimated wind speeds, rather than actual measured wind speeds. In addition, Verisk internal research, as well as literature reviews, indicated that estimated wind speeds were biased 20-30% high when compared to the true/measured wind speed. To address this issue, Verisk scientists applied a reduction factor to the estimated SPC wind reports, by state and wind speed bin; the reduced wind speed reports were then used to build the wind sub-peril catalog.
- **GAMs**. In addition to new NEXRAD data and detrending methodologies, the updated model uses spatially-varying Generalized Additive Models (GAMs) that allow for more realistic interactions among the atmospheric variables that contribute to hail formation (these include temperature lapse rates, vertical wind shear, convective available potential energy (CAPE), and topography).

  GAMs allowed Verisk researchers to fit a relationship between hail occurrence and Significant Hail Parameter (SHiP) while maintaining the flexibility of accounting for regional differences, term interactions, and non-linear relationships. Observational data used in GAMs include SPC Storm Reports, CoCoRaHS, SHAVE and radar data. The individual SHiP parameters were obtained from the maximum and minimum CFSR values for their respective variables on a given day. The results were further calibrated to correct frequency biases in the data, and the resulting daily hail probability surfaces better captured the hail frequency and variability across the U.S. than would have been possible using single SHiP threshold values.

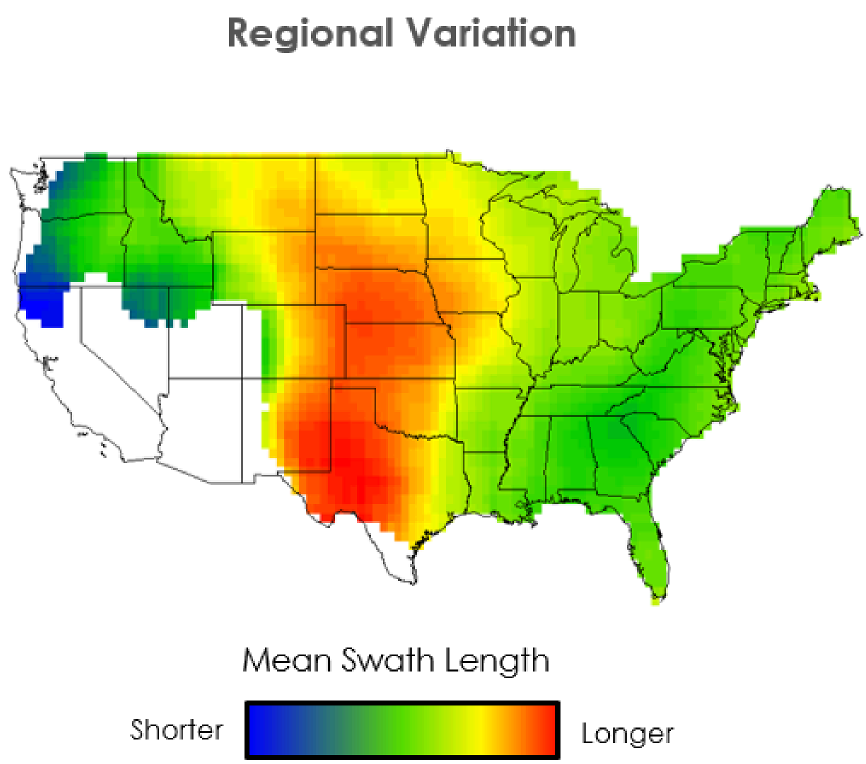

Figure 4. Example of regional variation in the swath lengths of hail events in July

3.4 Damage Estimation

Crop hail damage functions for explicitly modeled crops have been updated. The seven growth stages were reconfigured to better represent the modeled crops' vulnerability as a function of total kinetic energy of hail over the growing season.

As examples, the following figures show the previous and updated damage functions for soybeans, corn and barley.

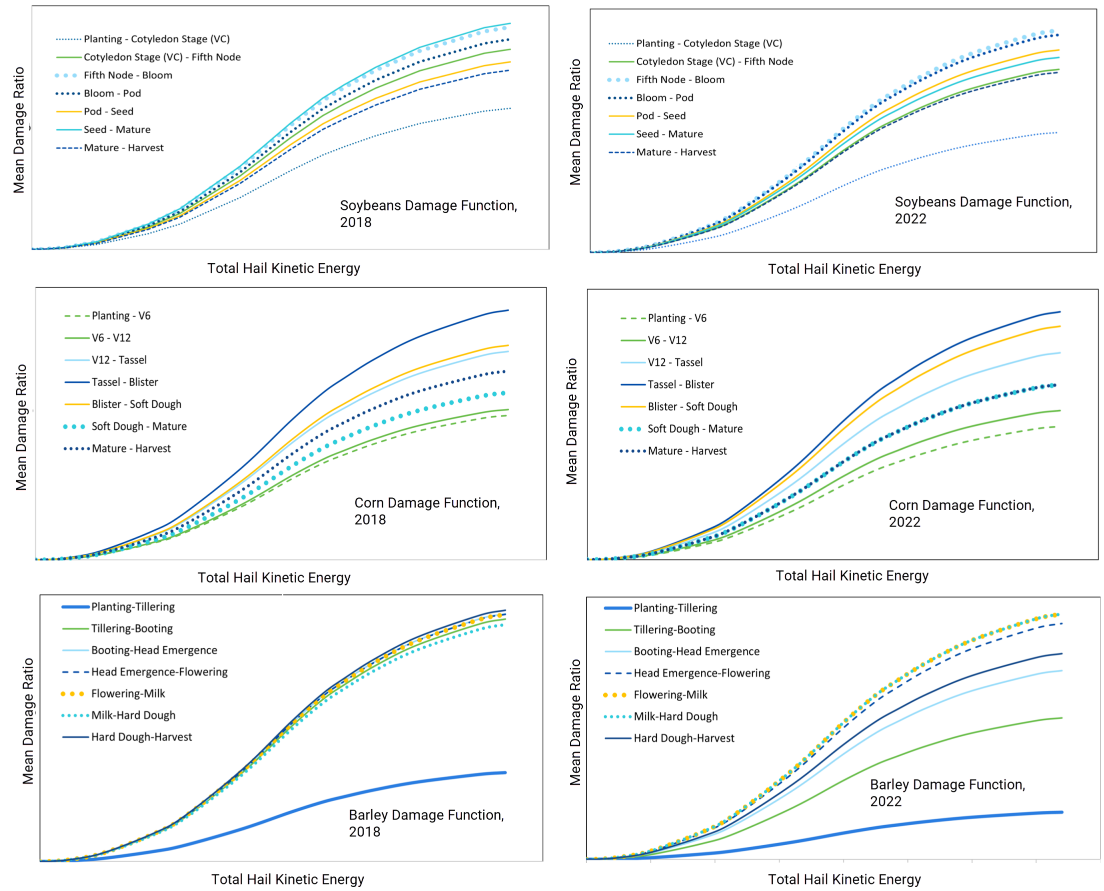

Figure 5. Damage function comparisons - soybeans, corn, and barley

3.5 Wind Module

Because wind endorsements in crop hail insurance have increased in popularity, the updated 10K loss cost catalog incorporates a new wind module that leverages wind frequency data from SPC storm reports and historical loss values associated with crop hail wind endorsements from the National Crop Insurance Services (NCIS).[1]

The new wind module calculates a relationship between the reported loss cost and the number of wind-based local storm reports per month per year at the state level, and uses this derived relationship between the loss cost and wind-based local storm reports along with exposure and liability data to calculate losses for wind at the annual and state level.

1 The wind module processes the straight-line wind hazard data for the following states: Arkansas, Iowa, Illinois, Indiana, Kansas, Kentucky, Louisiana, Minnesota, Missouri, North Dakota, Nebraska, South Dakota – these 12 states comprise more than 85% of total industry wide wind endorsement liability (2017-2020 average).

Once the wind module calculates the loss values for wind, they are incorporated into the final industry loss values for the entire model for each year of the 10K catalog. The annual losses at the state-level for straight wind and for production plan are split equally among counties.

The wind module calculates loss independent of crop type. Exposure data includes only corn because wind endorsements target corn; using exposure data for other crops overestimates the potential losses in each state.

Using the historical record to assess the risk of a crop hail portfolio that has substantial liability associated with wind endorsement is challenging because of the short claims history and the increase in the uptake in recent years. The wind module in the Verisk Crop Hail Model for the United States offers a probabilistic view of risk from wind damage that the historical record cannot provide.

3.6 Industry Exposure Database

The new Industry Exposure Database includes updated crop exposure and crop values.

Crop Exposure

The crop exposure database was developed using the National Agricultural Statistics Service's (NASS) Cropland Data Layer 30-m land use/land cover dataset. The 30-m NASS planted acreage data is aggregated by crop type to the 8-km Industry Exposure Database grid used for this model.

Because of annual variations (e.g., the corn-soybean rotation in the Midwest), Verisk researchers calculated grid-specific crop areas by averaging NASS crop data layers from 2017 to 2020. Prior versions of the model relied on a recent single year for the latest crop area information. By averaging several years, the updated version accounts for year-to-year variations in crop area.

The updated Industry Exposure Database includes the same crops that were in the previous version: corn, soybean, barley, winter wheat, spring wheat, durum wheat, cotton, and rice. As of 2020, the most recent year available, these crops accounted for 92.7% of the industry insured liability for the Crop Hail line of business and 96.3% of industry insured liability for the Production Plan line of business.

Table 1 shows the percentage change in planted area for all explicitly modeled crops combined.

Table 1. Percent change in planted area for each state from 2016 to the 2017-2020 average for all explicitly modeled crops combined

State	Change in planted area
Alabama	-1.8 %
Arizona	13.7 %
Arkansas	-1.8 %

State	Change in planted area
California	7 %
Colorado	-1.1 %
Delaware	0 %
Florida	11.3 %
Georgia	4.7 %
Idaho	3.2 %
Illinois	-1.1 %
Indiana	-3.2 %
Iowa	-1.6 %
Kansas	2.8 %
Kentucky	-28.4 %
Louisiana	-2.2 %
Maryland	2.2 %
Michigan	-48.4 %
Minnesota	-1.3 %
Mississippi	1.6 %
Missouri	-1.3 %
Montana	8.9 %
Nebraska	0 %
Nevada	119.5 %
New Jersey	-1.1 %
New Mexico	-8.3 %
New York	-2.8 %
North Carolina	1.8 %
North Dakota	-3.1 %
Ohio	-3.2 %
Oklahoma	-48.1 %
Oregon	4.9 %
Pennsylvania	6.5 %
South Carolina	9.5 %
South Dakota	-6.9 %
Tennessee	-1.8 %
Texas	6.9 %
Utah	6.6 %
Virginia	8.5 %

State	Change in planted area
Washington	6.3 %
West Virginia	9.8 %
Wisconsin	-0.3 %
Wyoming	-21.6 %

The following figures show crop exposure (2016 and 2020) at the county level.

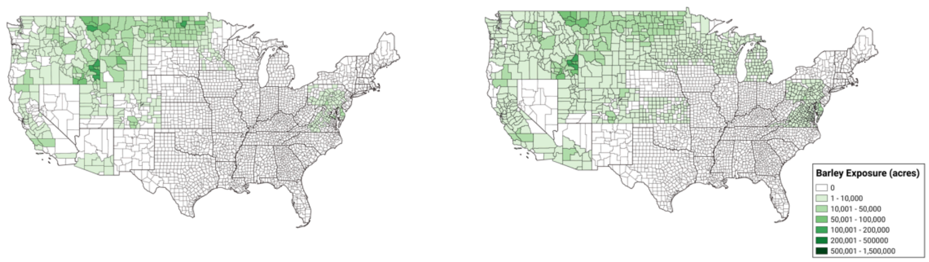

Figure 6. Barley exposure: 2016 (left) and 2017-2020, averaged (right)

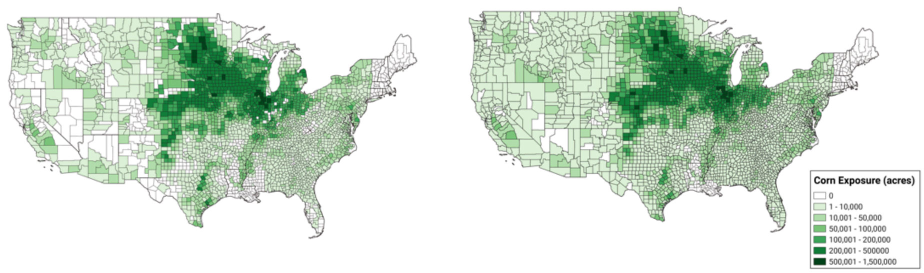

Figure 7. Corn exposure: 2016 (left) and 2017-2020, averaged (right)

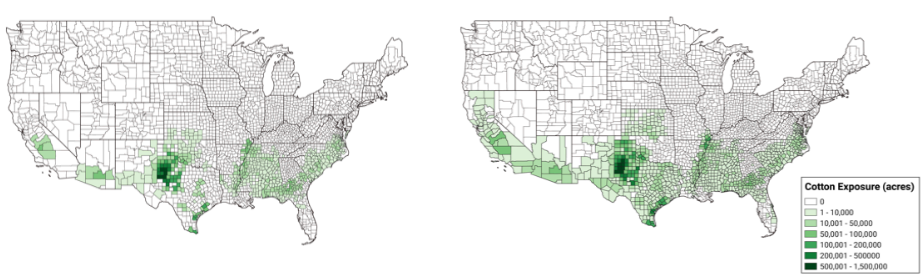

Figure 8. Cotton exposure: 2016 (left) and 2017-2020, averaged (right)

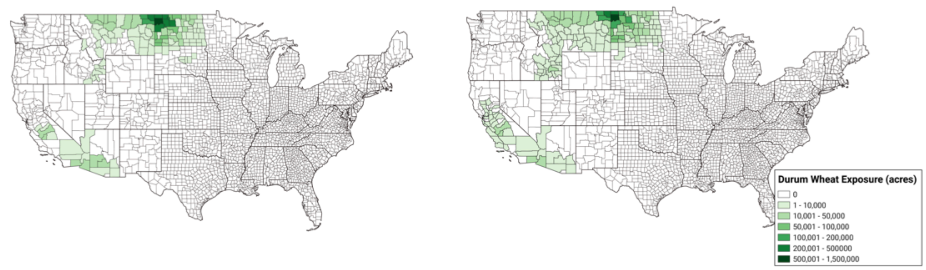

Figure 9. Durum Wheat exposure: 2016 (left) and 2017-2020, averaged (right)

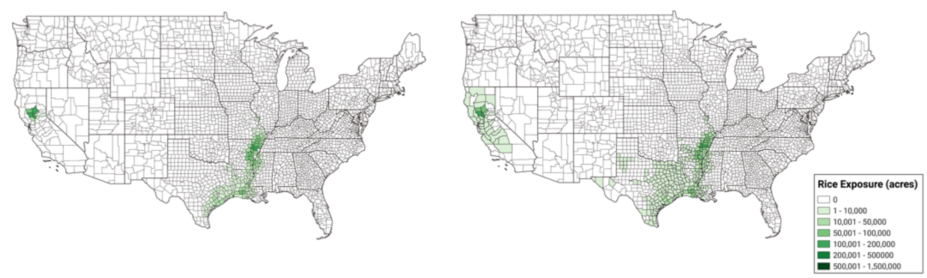

Figure 10. Rice exposure: 2016 (left) and 2017-2020, averaged (right)

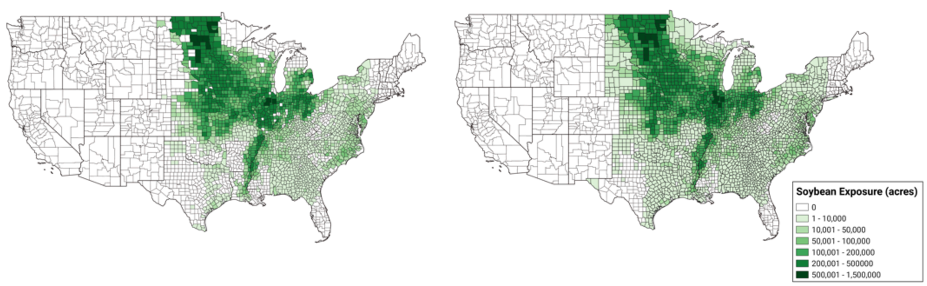

Figure 11. Soybeans exposure: 2016 (left) and 2017-2020, averaged (right)

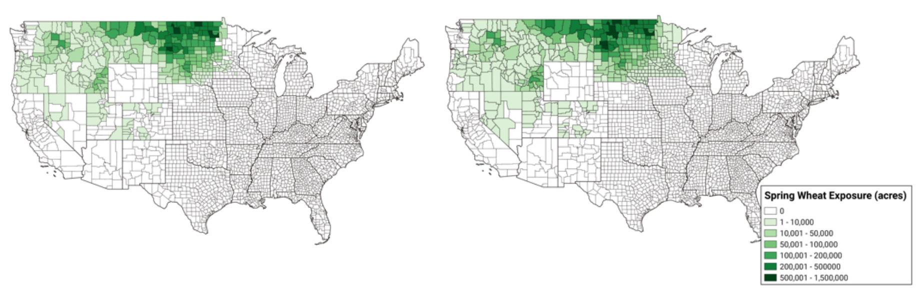

Figure 12. Spring Wheat exposure: 2016 (left) and 2017-2020, averaged (right)

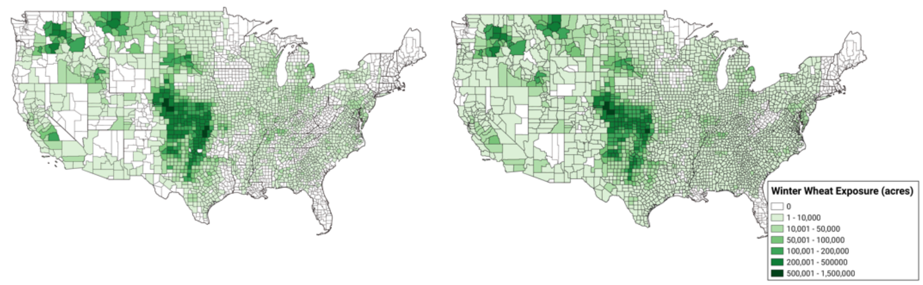

Figure 13. Winter Wheat exposure: 2016 (left) and 2017-2020, averaged (right)

Crop Values

Crop values in the updated model are based on 2021 national prices. Values in the previous version of the model were calculated based on 2017 national prices. Prices have seen a significant increase since that time, resulting in increased modeled losses. Table 2 shows percent change in national crop prices from 2017 to 2021, for all explicitly modeled crops.

Table 2. Percent change in national crop prices from 2017 to 2021

Crop	Change in Price
Barley	55.5 %
Corn	53.9 %
Cotton	60.3 %
Rice	14.3 %
Soybean	26.2 %
Durum Wheat	25.3 %
Spring Wheat	36.2 %
Winter Wheat	35.3 %

3.7 Policy Conditions

Incurred losses within the Verisk Crop Hail Model for the United States are estimated using 2020 policy conditions (the most recent year available); the previous version used 2016 policy conditions. The state-specific policy conditions included in the financial module of the model account for at least 95% of each state's liability, as did the previous version at the time of its release.

Table 3 compares the 2016 and 2020 crop hail policy distribution in Nebraska. The percentage of liability written toward CPIP2F (companion plan with increasing payment factor of 2) has significantly increased in 2020, while the liability under several deductible policies such as DXS10, DXS5, DDA have decreased. Since CPIP2F policy pay higher losses than the deductible policies, this change in policy distribution will result in higher modeled losses in Nebraska if all other model components were unchanged.

Table 4 compares the 2016 and 2020 production plan policy distribution in Nebraska. Production plan policies are yield-dependent and have three terms: the yield guarantee, the Multi-Peril Crop Insurance (MPCI) coverage level, and the minimum loss parameter. These policies cover the portion of a planted crop that is not covered by an MPCI policy, and losses are not paid until the damage ratio experienced by the crop exceeds the minimum loss. The magnitude of the production loss depends upon the difference between the guaranteed yield and the actual yield at harvest. The percentage of liability written toward lower MPCI coverage levels (70-75%) have generally increased compared to higher MPCI coverage levels (80-85%), implying that most of the farmers in Nebraska, the states with the largest production plan insured liability, have opted for larger crop hail production guarantee.

Table 3. Percentage of Nebraska crop hail liability written toward each policy form, in 2016 and 2020

Policy Form	2016	2020
CPIP2F	24.2%	44.8%
BASIC	17.8%	17.6%
DXS10	16.5%	7.6%
DDA	15.7%	10.4%
DXS5	10.8%	5.9%
DDB	5.8%	5.5%
XS20IP	4.6%	2.6%
XS5	-	2.8%

Table 4. Percentage of Nebraska production plan liability written toward each policy form, in 2016 and 2020

Policy Form	2016	2020
APH120 CL75 ML0	27.7%	40.2%
APH120 CL80 ML0	24.0%	19.7%
APH120 CL70 ML0	17.8%	20.2%
APH115 CL75 ML0	7.8%	9.1%

Policy Form	2016	2020
APH120 CL65 ML0	5.9%	5.6%
APH120 CL85 ML0	5.8%	-
APH110 CL75 ML0	3.9%	-
APH115 CL80 ML0	3.7%	5.2%
APH120 CL60 ML0	3.3%	-

3.8 Premium Rates

The default rates for the 2022 release have been updated to reflect premium rates used by the industry in 2020. The 2018 release of the model incorporated default rates based on 2016 industry data. The default rates will only impact the modeled losses if exposure is input as premium without entering user-specified premium rates.

Higher premium rates will result in lower losses and lower premium rates will result in higher losses, if all other model components are unchanged.

Table 5 and Table 6 show the percent change from 2016 to 2020 in crop hail and production plan premium rates (production plan is available in the given subset of states).

Table 5. Percent change in crop hail premium rates, from 2016 to 2020

State	Change in crop hail premium rates
AL	17.1 %
AZ	19.1 %
AR	28.8 %
CA	20.8 %
CO	4.3 %
DE	19.3 %
FL	10.2 %
GA	17.1 %
ID	-3.4 %

State	Change in crop hail premium rates
IL	6.7 %
IN	2.2 %
IA	-1.9 %
KS	-11.1 %
KY	-18.3 %
LA	14.8 %
MD	-6.9 %
MI	-5.8 %
MN	15.1 %
MS	22.1 %
MO	0.1 %
MT	-4.0 %
NE	2.6 %
NV	80.3 %
NJ	-22.0 %
NM	5.3 %
NY	-39.3 %
NC	-7.3 %
ND	15.3 %
OH	-11.0 %
OK	-14.4 %
OR	-14.6 %
PA	-49.9 %
SC	33.3 %
SD	5.6 %
TN	23.3 %
TX	16.8 %
UT	42.2 %
VA	-30.6 %
WA	-8.5 %
WV	11.7 %
WI	2.3 %
WY	-13.9 %

Table 6. Percent change in production plan premium rates, from 2016 to 2020

State	Change in production plan premium rates
CO	11.3 %
ID	25.8 %
IL	73.6 %
IN	-37.0 %
IA	26.0 %
KS	-5.2 %
MN	33.0 %
MO	17.7 %
NE	16.4 %
ND	22.7 %
OH	-0.6 %
SD	5.0 %
TX	78.7 %
WI	-8.8 %

3.9 General Impact of Model Updates on Loss Estimates

The general impact of the Verisk Crop Hail Model for the United States updates on gross insurable losses is presented in the tables available through the link below. The loss changes represent the percentage change in loss estimates calculated by the previous version of Touchstone Re [2021 (9.0)] as compared with those calculated by the current version of Touchstone Re [2022 (10.0)]. Loss changes are presented for the model domain and by state.

The following loss change tables are available:

- Gross Insurable Losses
  - Overall Change
  - Change with Constant Exposure

Overall Change refers to the change in industry gross insurable losses. These data indicate the combined effects of all changes (e.g., updates to the hazard catalog, crop area, policy conditions, crop prices as well as addition of the new wind module). Overall Changes are calculated by comparing the total industry insurable losses in the prior industry loss file to the total industry insurable losses in the new industry loss file. In Touchstone Re, 100% sums insured based market shares are analyzed against each loss file and the percentage differences calculated in the resulting loss distributions.

Constant Exposure presents what the user will likely see comparing results from the previous version of Touchstone Re with the current version, using the same sums insured with the “use latest Industry Exposure Database” option enabled.

Caution should be exercised before relating the industry changes shown here to a particular portfolio. Changes to individual books of business may deviate from the losses represented here to the extent that their exposure spatial distribution deviates from industry averages.

The updated hail catalog and the addition of the wind module were the two main factors behind the changes in modeled insurable loss estimates. The crop hail line of business shows an increase (Overall Change) of 26% in Average Annual Loss for all crop hail states and the production plan line of business exhibits a 14% increase in Average Annual Loss for all production plan states. Changes in policy conditions and crop prices also contributed to increased losses, albeit to a lesser extent.

4 Event ID Updates

The following table lists changes to event IDs in the updated models forTouchstone Re in 2022.

Table 7. Stochastic Event ID Updates

Verisk Model	Stochastic Event IDs
Verisk Severe Thunderstorm Model for the United States	All event IDs are new.
Verisk Crop Hail Model for the United States	All event IDs are new.

About Verisk

Verisk Analytics (Verisk) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, a Verisk subsidiary founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber incidents. Insurance, reinsurance, financial, corporate, and government clients rely on Verisk's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, longevity modeling, site-specific engineering analyses, and agricultural risk management. Verisk (Nasdaq:VRSK) is headquartered in Jersey City, New Jersey with many offices throughout the United States and around the world. For information on our office locations, visit https://www.verisk.com/about/locations/.

Contact Information

Verisk Analytics
Lafayette City Center, 2nd Floor
Two Avenue de Lafayette
Boston, MA 02111
USA

Tel: (617) 267-6645
Fax: (617) 267-8284

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