2021 WHITE PAPER

The Science of Hurricane Wind

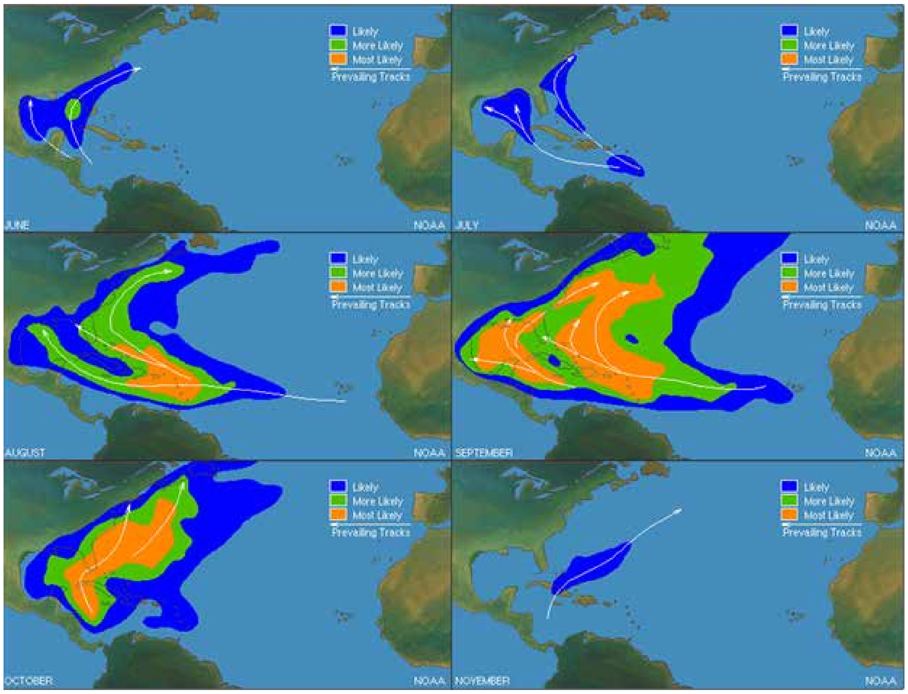
Verisk's Proprietary Hurricane Wind Solution

Tropical Storms and Hurricanes in the Atlantic Ocean

June 1 through November 30 marks the official period of the Atlantic Ocean hurricane season. Although tropical cyclones may develop outside this date range, most activity in the Atlantic occurs during this period, with the majority occurring during the months of August, September, and October. Tropical cyclones can develop over a large portion of the Atlantic basin, but most form in an area just north of the equator from off the coast of Africa to Central America, as well as north of this region into the Gulf of Mexico and off the East Coast of the U.S. (as depicted in Figure 1). These systems develop over the warm ocean waters often present in these locations during hurricane season.

Based on information from several possible sources, such as ships, buoys, satellites, and reconnaissance flights, the National Hurricane Center (NHC) monitors tropical activity. A tropical system officially becomes a tropical cyclone when it develops a central area of low-pressure, at which point the system typically either becomes a tropical depression or a tropical storm, depending on the strength of its maximum sustained winds.

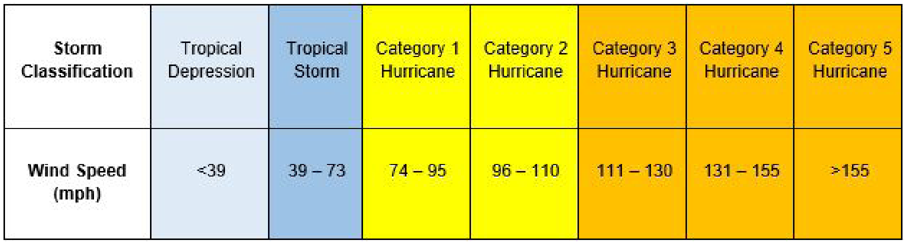
Figure 1: Climatological areas of hurricane formation and typical tracks by month during the Atlantic Ocean hurricane season (NOAA).



The NHC will officially name a system when it reaches tropical storm status, defined as having sustained wind speeds of at least 39 mph. A tropical system becomes a hurricane when its sustained winds reach at least 74 mph. Hurricane storm intensity is often referred to using the Saffir-Simpson Hurricane Scale (shown in Figure 2), which splits hurricanes into categories based on their maximum sustained winds. These categories range from 1 on the low-end to 5 on the high-end. A hurricane that is category 3, 4, or 5 may also be referred to as a major hurricane.

Over the last 30 years, the Atlantic Ocean has seen an average of almost 14.5 tropical storms annually, with around 7 of these becoming hurricanes, and around 3 becoming major hurricanes. Regardless of the intensity of a tropical system, any may produce heavy rains leading to possible flooding, high winds, tornadoes, large waves, and storm surge—and a single system can produce tens of billions of dollars in damages.

Figure 2: Saffir-Simpson Hurricane Scale



Storm Classification	Tropical Depression	Tropical Storm	Category 1 Hurricane	Category 2 Hurricane	Category 3 Hurricane	Category 4 Hurricane	Category 5 Hurricane
Wind Speed (mph)	<39	39 – 73	74 – 95	96 – 110	111 – 130	131 – 155	>155

Given the potential for large losses and disruption to everyday life, accurate and timely hurricane information is vital for those looking to prepare for or respond to these tropical cyclones. Verisk’s Respond™ hurricane solution provides high resolution wind data that can assist in making these decisions both pre- and post-event.

Possible Sources of Pre-Event Hurricane Forecasts

Tropical cyclone forecasts can be an important tool for understanding the potential impacts of a storm. However, not all forecasts will be able to provide the same level of information. When assessing pre-event forecasts, it is important to understand the limitations of these forecasts and potential sources of error.

National Hurricane Center Five-Day Forecast Track and Cone

The most popular graphic produced by the NHC to provide forecast information on the potential track and intensity of a tropical cyclone is a five-day forecast track and cone visual, as seen in Figure 3. While this graphic provides some valuable information, all the information is only with respect to the center of the storm, meaning that:

- The cone of uncertainty (the shaded and hatched areas in the image) shows the possible areas where the center of the storm could impact given forecast uncertainty, hence the increasing width of the cone as the forecast length increases.
- The storm intensity (denoted as S for tropical storm, H for hurricane, and D for tropical depression in this graphic) is indicative of only the maximum sustained wind intensity, typically found within the eyewall near the center of the storm, not the range of wind speeds present.
- The times only indicate the most likely time when the center of the storm will be at this location, and do not convey when impacts may begin and end.

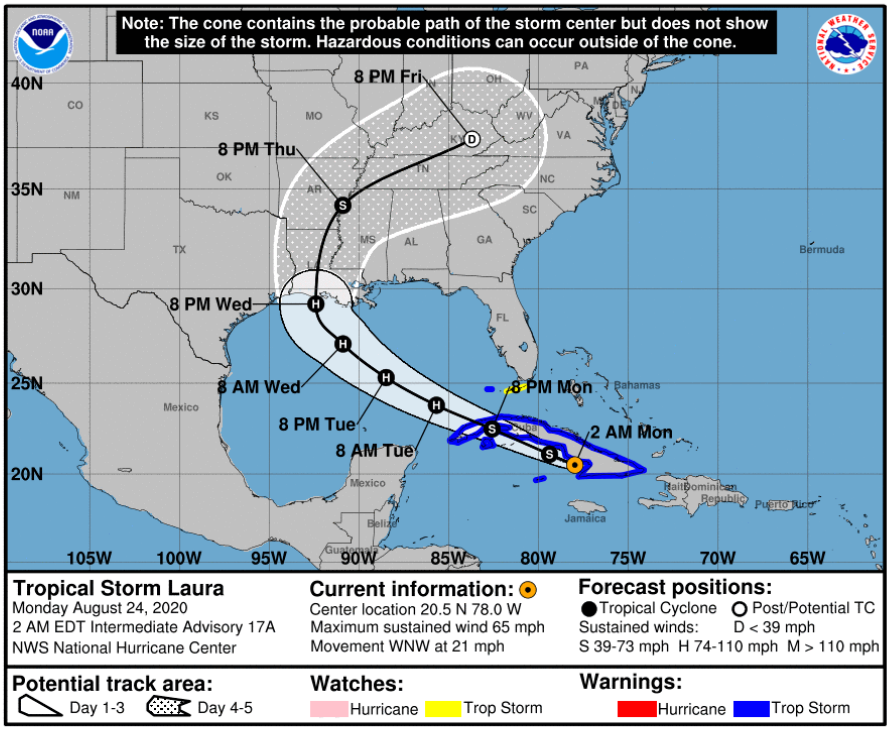


Figure 3: NHC five-day forecast track and cone for what would become Hurricane Laura as presented about three days before landfall.

Therefore, while this graphic provides good information about the center of the storm, it lacks key information about what is happening away from the center of the storm. This can lead to a key misunderstanding: If you are not within the cone then you will not be impacted. This is most certainly not true; this graphic provides no way to determine anything about the spatial extent of the system.

Weather Forecast Models

The NHC bases their forecasts, among other things, on several different weather forecast models. These models typically use information related to the current storm location and intensity as well as information about surrounding conditions to make predictions about the future of the storm. There are pros and cons to each of these models that must be weighed before making decisions based on the data.

The models can be broken down into two groups, dynamical and statistical. Dynamical models use physical equations that govern atmospheric motion and various sources of current state observational data to predict what may occur in the days ahead. On the other hand, statistical models do not use physical equations and rather rely on the use of historical relationships about similar storms to make predictions about what may occur with this storm.

Further, there are differences between models within these groups. Dynamical models, for example, have differences in vertical and horizontal resolution, physical model schemes, and data assimilation choices that may make one model more adept at predicting one storm versus another storm. In addition to these complexities, it is often the case that output from these models is presented as snapshots in time.
For example, a forecast may show what the storm may look like 6 hours from now, 9 hours from now, and so on. As a result, it is not always easy to understand the specific impacts from a storm for a particular location of interest.

Possible Sources of Post-Event Wind Data

NHC Wind History

As a named tropical system impacts areas, the NHC also produces an output that provides an estimate as to where tropical storm and hurricane force winds have occurred. This wind history output, as seen in Figure 4, tends to be an overgeneralized overview of the wind field and doesn’t account for more localized differences. It also attempts to use simple measures, such as how far tropical storm forced winds extend from the center of the system, to display what is largely a much more complex wind field. The data are also limited by having only two levels of magnitude and fail to provide an extent of tropical depression strength winds, which can still be strong enough to cause minor wind damages. Also note that when comparing with observational data from weather stations, often the areal coverage of this wind history swath covers more area than is truly impacted by these sustained wind speeds. In reality it seems the wind history product has a tendency to overestimate areal coverage to ensure it captures any location where winds may have been this strong.

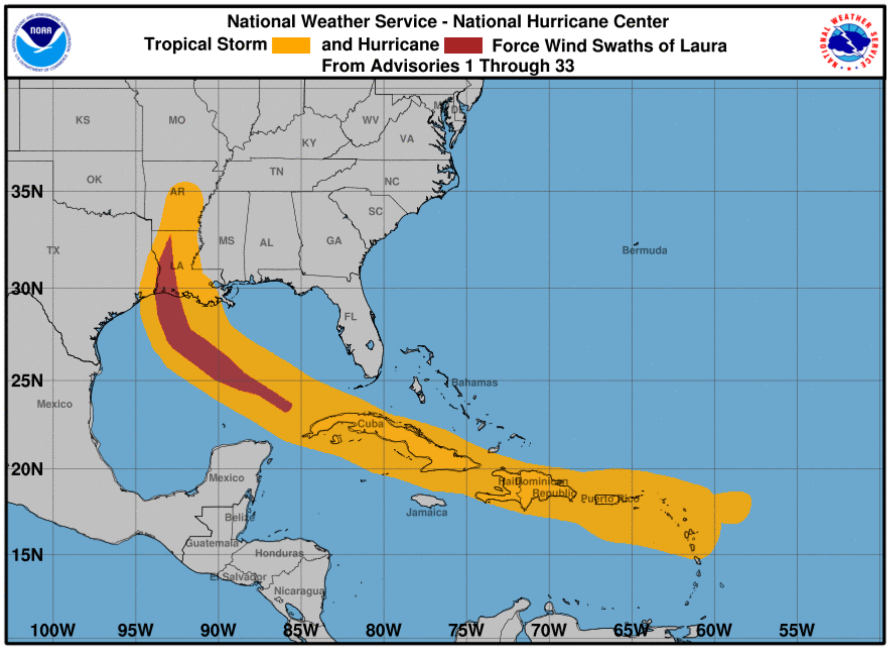


Figure 4: NNHC Wind History for Hurricane Laura

Observations

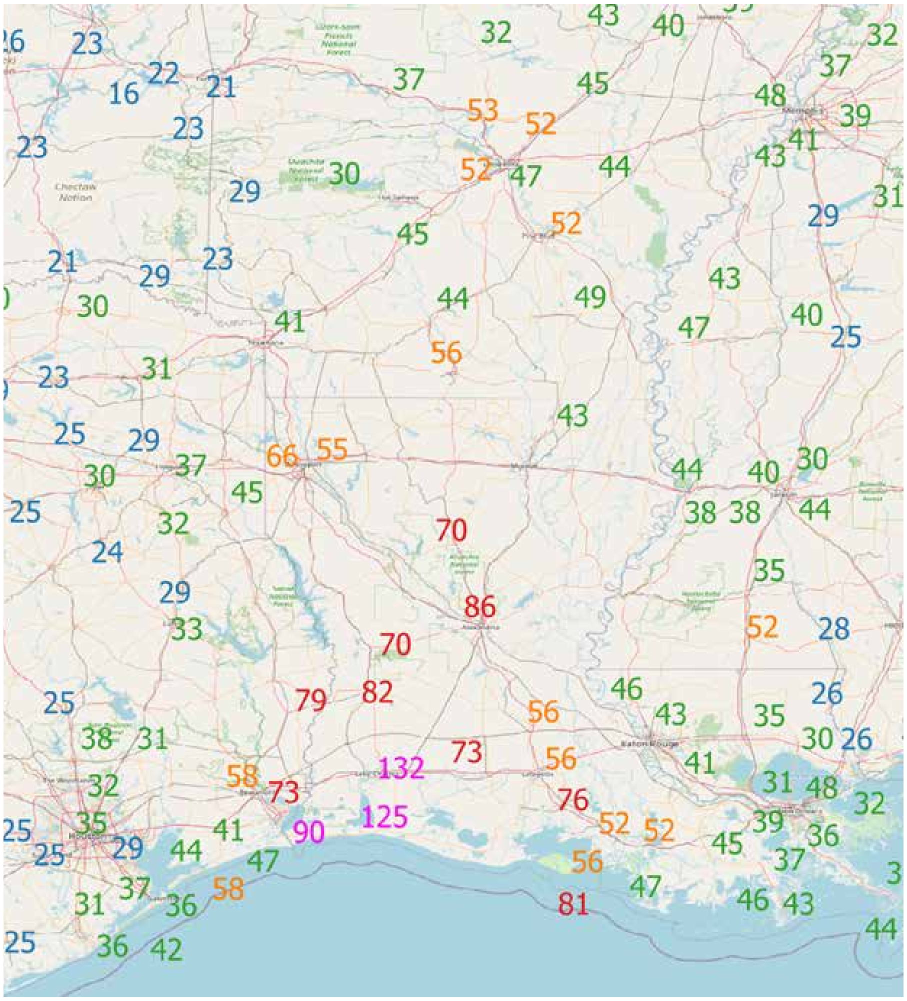
Weather station observations are the most accurate source of post-event wind data, but these sorts of observations tend to be sparse. In the U.S., official weather station observations are often sited at airports, which leaves much of the country some distance from the nearest observation. Other networks, such as mesoscale or coastal buoy networks, as well as spotter reports of wind can be added to supplement these observations, but gaps will remain between observations. Further, as additional sources of observations are added, there is a need to ensure that the wind being measured is consistent.

The standard measurement of wind at official reporting stations in the U.S. is to measure the wind speed at 10 meters (about 33 feet) above the local ground level. Standard measurement for wind speed is calculated as the two-minute average wind and wind gusts are the 5-second average wind speed. However, the height at which the wind is measured above the ground and the averaging period for wind speed and wind gust measurements can vary across different networks of observations, with some networks having differences within the network from station to station. This can add complexity to understanding wind speeds from station observations and can lead to confusion about the winds that may be impacting locations on the ground.

This is further complicated in the context of hurricanes, as the NHC reports hurricane intensity as the maximum one-minute sustained wind and three-second gust, which do not align with how most observing stations in the U.S. record wind data. Fortunately, if the differences in measuring standards are known, there are methods to standardize wind speeds and gusts measured using different measuring standards to achieve a common measurement. While these methods are not perfect, they can provide a more consistent understanding from observations taken using different measurement criteria and can reduce potential confusion associated with these different measurement techniques.

Another issue with observational data that often arises during hurricanes is the loss of power to or destruction of the equipment. Most weather stations that are exposed to hurricane-force winds go offline for one reason or another and stop recording observations. And even those that are exposed to tropical-storm-force winds risk outage. As a result, peak wind observations from weather stations within the more intense areas of a tropical system tend to be somewhat unlikely. Figure 5 presents a view of maximum wind gust observations from Hurricane Laura. Note how observations tend to be sparser throughout Louisiana where the higher wind gusts occurred during this event.

Figure 5: Maximum wind gusts (in miles per hour) recorded during Hurricane Laura for stations in a couple observing networks that reasonably can be assumed to have recorded the actual highest wind gust for the location of measurement.



Weather Models

Weather models can be used to produce a full wind-field understanding of a tropical system, generally accomplished in one of two ways.

The first involves using multiple short-term forecasts from the same weather model over time to estimate a wind swath. This process requires additional computations to the raw model output to create this view and, if done correctly, should also consider wind impacts between model time steps. Further, simply aggregating together the raw model output would typically result in an overgeneralization of the winds, like the NHC wind history graphic. This comes from the tendency for models to be at a lower resolution than would be needed to pick up on the more local impacts, where wind speeds may change somewhat dramatically over relatively short distances. Short-term forecasts are also susceptible to errors and biases since they are still a modeled forecast and not actual observations. Therefore, it is possible that a model's estimate of wind speeds for a particular location may not match well with actual observed wind speeds at that location even for these short forecast periods.

The second approach involves creating a post-event model that would use various observational sources, such as storm characteristics like maximum sustained winds and radius of maximum wind speeds, to create a wind field of the entire life of the storm. The NHC wind history graphic is an example of this sort of approach, which, as stated previously, tends to provide a good big picture view but lacks the granularity to truly understand impacts on a more local level. As previously discussed in the observations section, the limited view of observational data in terms of its spatial understanding of a system means that local impacts between observations will largely be unable to be discerned. The same issue arises with variables like the radius of maximum winds, which are too simplistic of a parameter to completely capture the finer details of the storm.

Verisk's Proprietary Hurricane Solution

Verisk's hurricane solution uses a multi-input approach to present the most comprehensive and accurate possible view of tropical storm and hurricane winds. The solution couples a five-day forecast of wind with a post-event view to provide a complete picture of the impacts that have already occurred alongside the potential impacts that have yet to occur from a tropical system. The model updates every six hours and automatically generates output for any named storm in the Atlantic Ocean basin. Wind information is expressed both in terms of one-minute sustained wind speeds as well as three-second wind gusts. In addition, wind speed durations of 39 mph or greater (tropical storm force), 50 mph or greater, and 74 mph or greater (hurricane force) are also conveyed to provide a more comprehensive understanding of the wind threat.

Verisk's hurricane model adds multiple stages of improvement to a leading National Oceanic and Atmospheric Administration (NOAA) hurricane model. For each forecast time step of the model, the Verisk model performs computations to translate winds from above the surface of the Earth into 10-meter wind speeds and gusts, accomplished not only by understanding how winds above the surface of the Earth can be translated to these near surface wind speeds, but also through an extensive understanding of the frictional factors that have an impact on winds blowing across the surface of the Earth. Verisk's hurricane model also uses information derived from satellites to compute these differences in surface friction from one area to another. For example, wind blowing across a lower friction surface feature like water or barren land will tend to maintain strength versus wind blowing across a higher friction surface like a forest, which will act to slow the winds down.

Verisk's model then temporally interpolates the data to present a more comprehensive depiction of the winds throughout the life of the system, including wind impacts between model time steps. This is accomplished by identifying the center of the system in each time step, which allows for calculating system movement over time. From here, the model can translate three-hour model time steps into much higher temporal resolution views of the system, which are then stitched together to present a complete picture of the impacts of the storm. The entire process is done every six hours with each model update producing the five-day forecast data.

For the post-event portion of the wind swath, short-term forecasts from prior model runs are aggregated in a similar manner as the forecast data to develop a best estimate modeled view of the full wind field throughout the life of the system. This view is further improved by creating the final post-event data. Once a storm has been downgraded to a tropical depression or post-tropical, and generally no longer poses a threat for producing additional strong winds, a final output is generated to present the complete and final wind history of the event.

For U.S. landfalling hurricanes, this final view of the event also incorporates observational data from official weather stations and other observing networks, such as buoys, to provide ground-truth data points. This is done for the maximum wind gust data by first ensuring that the observations represent the true maximum 10-meter height wind gust for that location, accommodating for any gaps in the observational record that may have come about due to a loss of power to a weather station, for example. Once the observations go through this quality-control process, they are assimilated into the final Verisk model and used to bias-correct the entire wind field.

As a result, the final wind field will not only more closely match the assimilated observations, but final wind field values will be more accurate in general across the entire wind field as they benefit from the modeled wind field estimates. And while most observations tend to differ from the model estimate by only around 10% or less, even these relatively small adjustments can make a big difference when trying to understand loss expectations across the entire event.

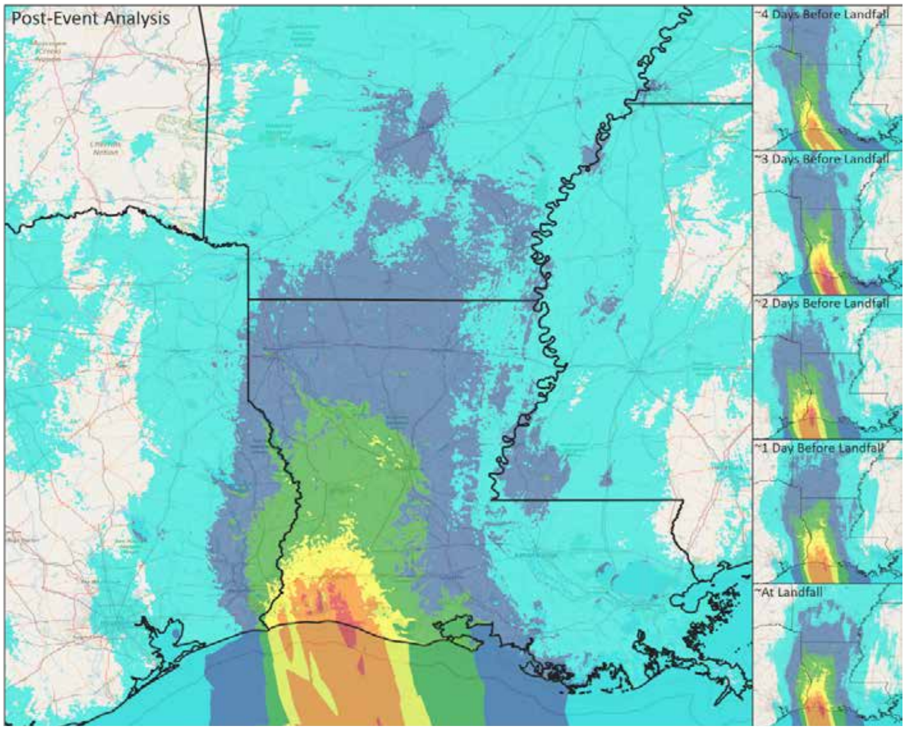


Figure 6: Hurricane Laura maximum wind gusts as depicted by the Respond hurricane solution showing the post-event analysis on the left and selected forecasts from 4 days before landfall to at landfall on the left. Light blue represents maximum wind gusts in the range of 30 to 49 mph, dark blue is 50 to 69 mph, green is 70 to 89 mph, yellow is 90 to 109 mph, orange is 110 to 129 mph, red is 130 to 149 mph, and pink is 150 mph or greater.

Table 1: Comparison of the various hurricane wind forecast and post-event datasets available.

	NHC Forecast Cone	**NHC Wind History**	**Weather Forecast Models**	**Observations**	**Respond Hurricane**
FORECAST					
Five days in length	✓		✓ Most but not all		✓
Full wind field			✓ Most but not all		✓
Accounts for llocal surface characteristics					✓
Sustained winds	✓ Maximum only		✓		✓
Duration of sustained winds					✓
Wind gusts	✓ Maximum only				✓
POST-EVENT					
Includes post-event observations				✓	✓ For US landfalling hurricanes
Full wind field		✓			✓
Accounts for local surface characteristics					✓
Sustained winds		✓			✓
Durations of sustained wind					✓
Wind gusts					✓

Applications for the Insurance Industry

Accurate, timely information is vital when a hurricane impacts a location of interest. Respond hurricane delivers the information needed to both prepare for and react to the wind impacts associated with tropical systems.

Insurance companies can use Respond hurricane to identify exactly where the strongest winds are impacting their book of business, whether it be a portfolio of homes, farms, commercial properties, crop lands, or even automobiles. With this information, they can make immediate decisions on internal and third-party staffing and field team deployment. They can also determine bulk reserves that may be necessary for yet-to-be-reported claims resulting from the event.

As claims begin to flow in, Respond data can aid in the triaging process as well as within claims investigation itself via Benchmark™ location-specific hurricane history reports, which provide details on the wind conditions at or near a particular claim location. The Benchmark reports can aid in determining whether the damages being reported align with the winds estimated at that location, providing confirmation of the loss date and cause of loss. Consequently, issues can be uncovered and thoroughly investigated as part of the claims process. Issues may include:

- 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
- Ensuring a hurricane deductible is applied for a hurricane related loss
- Possible fraudulent claims identification

At the same time, claims that do not have any of these issues can be fast-tracked, allowing adjusters to use their time and get impacted people and businesses back to normal more quickly and more efficiently.

In aggregate, Benchmark reports can also be a useful tool for aiding in ensuring:

- Accurate reinsurance recoveries by providing data to better capture all claims associated with a hurricane
- Internal and external key performance indicators, such as CAT to non-CAT ratios, are more representative of actual experience
- Internal data for post-mortem and future underwriting decisions are more accurate

To learn more about Verisk's Respond and Benchmark hurricane solutions please contact **weathersolutions@verisk.com** or your account representative.

verisk.com