Liberty Mutual
REINSURANCE

Today. Tomorrow. Together.

Beyond the Eye
Benchmarking Hurricane Risk Assessment Models

Introduction

Over the years, we have observed how hurricanes have significantly impacted our economies. Not only is it important to understand how hurricanes develop but assessing their behavior accurately is crucial to mitigating their impact.
Hurricanes develop from a combination of atmospheric instability, warmer sea surface temperatures, and the Earth's rotation. It is true that climate change and other climatological anomalies contribute to their formation, severity and intensity. Recent events, such as Hurricanes Beryl and Helene, have demonstrated this impact. According to the National Hurricane Center (NHC), these storms caused approximately $7.2 billion and $78.7 billion in damages to the United States, respectively.

At Liberty, we have developed a parametric insurance solution that allows us to perform a risk assessment for any location exposed to hurricane risk. In this document, you will find the result of years of dedicated work aimed at developing a product that not only replicates the outcomes of historical events but also provides rapid assessments of post-event scenarios. We will also explore how this peril has been evaluated in the past from an insurance and reinsurance perspective, the different sources used to analyze this risk, and how our model compares to other solutions available in the market.

It is relevant to mention how the rise of the parametric insurance has changed market dynamics by bringing payouts that are quick and straightforward, without the usual drawn-out claims process, and products that are based on the client's specific needs. As this new approach gained popularity, it opened a whole new world of possibilities. This breakthrough meant we were able to deploy our solutions effectively, helping our clients stay resilient in the face of devastating events.

Understanding and improving these assessments is vital as it enables better preparation and resilience, ultimately reducing economic losses and aiding in recovery efforts. Through continuous research and technological advancements, we strive to enhance the accuracy of our models and provide valuable insights to our clients.

The Insurance Sector's Response to Hurricane Risk and the Rise of the Parametric Insurance Market

Initially, traditional insurance policies offered coverage for hurricane-related damages, primarily focusing on property damage. These policies often had limited terms and were not highly tailored to individual risk profiles. Over time, policies were adjusted following hurricane events, resulting in increased premiums, higher deductibles, and changes in coverage terms as insurers assessed the hurricanes' financial impact.

The need for more detailed information about hurricane risks prompted several agencies worldwide to begin collecting and analyzing data on hurricanes' paths and characteristics before and after each event. In the United States, the National Hurricane Center (NHC), part of the National Oceanic and Atmospheric Administration (NOAA), plays a crucial role in forecasting and monitoring hurricanes in the Atlantic and Eastern Pacific regions. Globally, the World Meteorological Organization (WMO) collaborates with regional centers such as the Japan Meteorological Agency (JMA) in Tokyo, which monitors cyclones in the Western Pacific and the Bureau of Meteorology (BOM) in Australia, which tracks cyclones in the Australian region.

These agencies, along with research institutions and various universities, conduct research to improve understanding and prediction of these powerful storms, sharing data and insights to enhance global preparedness and mitigation efforts.

With the introduction of more data, the parametric insurance market has developed new structures tailored to individual risks. These innovative solutions typically pay out a predetermined amount based on specific parameters, such as wind speed or storm surge levels, which are highly correlated with the actual damage. This approach provides faster claims resolution and greater financial certainty for policyholders.

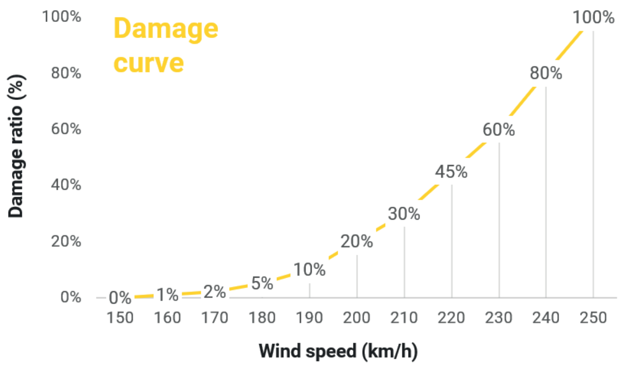
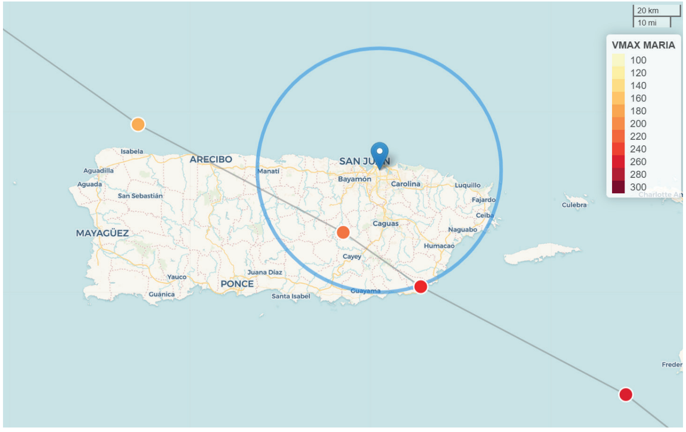


Figure 1. Tailored Damage Curve

As a result, the insurance market has begun to adopt parametric structures, such as "Cat-In-Circle" (CIC) and "Cat-In-a-Polygon" (CIP). In the CIC model, the client selects a fixed location, and from that point, the structure covers all hurricane events passing through a predetermined circular radius. The payout amount is typically determined based on the maximum wind speed within the circle and a predefined payout table that correlates the client's historical losses with hurricane wind speeds.

Similarly, in the CIP model, the client designates a specific area they wish to cover. The structure then calculates the payout amount based on the maximum wind speed of any event passing through the designated area, also using a predefined payout table. These parametric structures enable quicker and more transparent claims processes, as payouts are triggered by specific, measurable criteria, rather than assessments of actual damages, which often take considerable time and incur high costs due to the need for hiring loss adjusters. The parametric approach provides policyholders with greater certainty and financial security, allowing them to align coverage with their risk tolerance and historical loss patterns.



Vmax represents the maximum sustained radial speed as provided by NHC

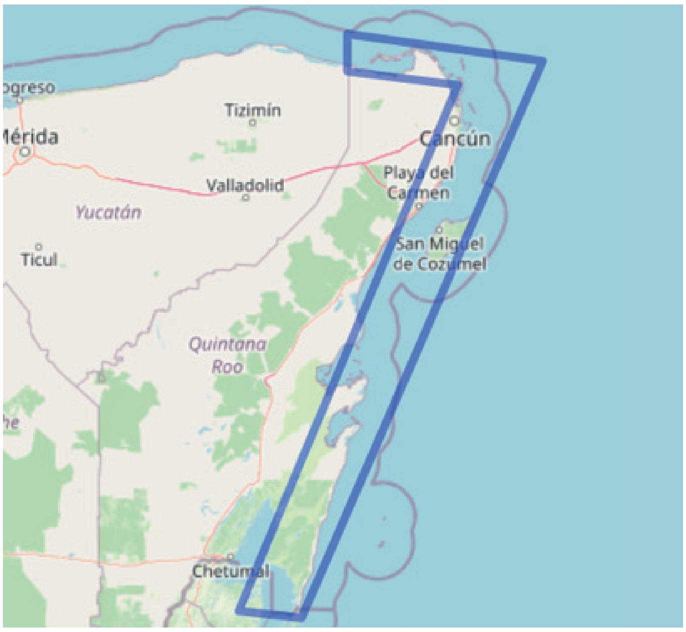


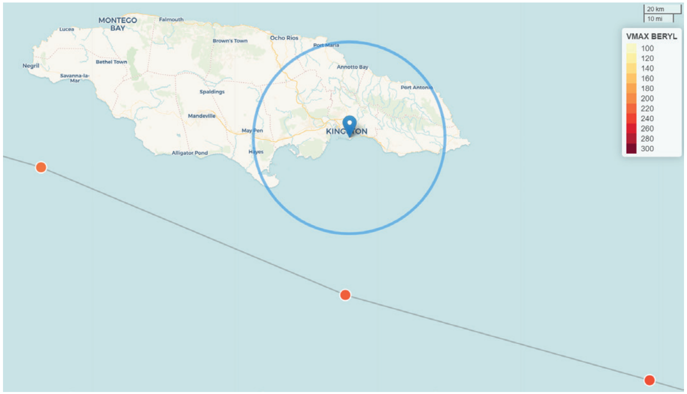
Figure 2. Examples of CIC and CIP structures

Another key development in parametric insurance is the introduction of innovative structures for Business Interruption (BI) and Non-Damage Business Interruption (NDBI) coverage. Parametric insurance enables businesses to receive timely financial support in situations where operational disruptions occur without physical damage, such as supply chain interruptions or loss of revenue due to adverse weather. By focusing on measurable external parameters, parametric insurance provides a streamlined and efficient claims process, ensuring that businesses can access funds quickly to maintain continuity and mitigate the financial impacts of unforeseen events. This approach not only enhances resilience but also promotes more comprehensive risk management strategies tailored to the modern business landscape.

Nevertheless, these solutions have introduced challenges in the market affecting both insured parties and insurance companies. Below we have outlined some key challenges:

- **The difference between what the client experiences and what the model captures: the so-called basis-risk**

CIC and CIP often fail to accurately reflect the actual wind speeds at the client's location, increasing basis risk (the difference between the index payout value and the observed losses). For instance, a hurricane may pass near the predefined coverage area without triggering a payout, even when the client incurs damage due to high wind speeds. The following images illustrate the trajectory of Hurricane Beryl (2024), which did not cross a 50-kilometer radius (Blue circle) at Kingston, resulting in no payout, despite NHC reports mentioning winds of more than 130 km/h, loses of up to 40 million in Jamaica and 3 direct deaths.



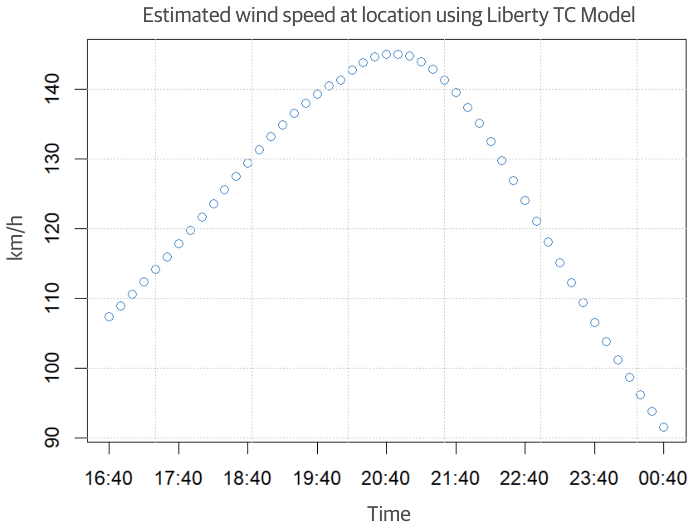


Figure 3. Hurricane Beryl: CIC Structure vs Liberty TC Model Windspeed

- **The importance of considering translational wind speed**

Wind speeds can vary significantly depending on the client's location. Hurricanes rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, exhibiting varying speeds based on position relative to its path. These factors, along with other variables, can create significant differences in wind speed based on the specified location. The following example shows two relatively close locations with similar CIC structures. Nevertheless, when hurricane Patricia (2015) passed across their coverage areas, each reported different wind speeds, yet the CIC structures registered almost identical wind speeds for both.

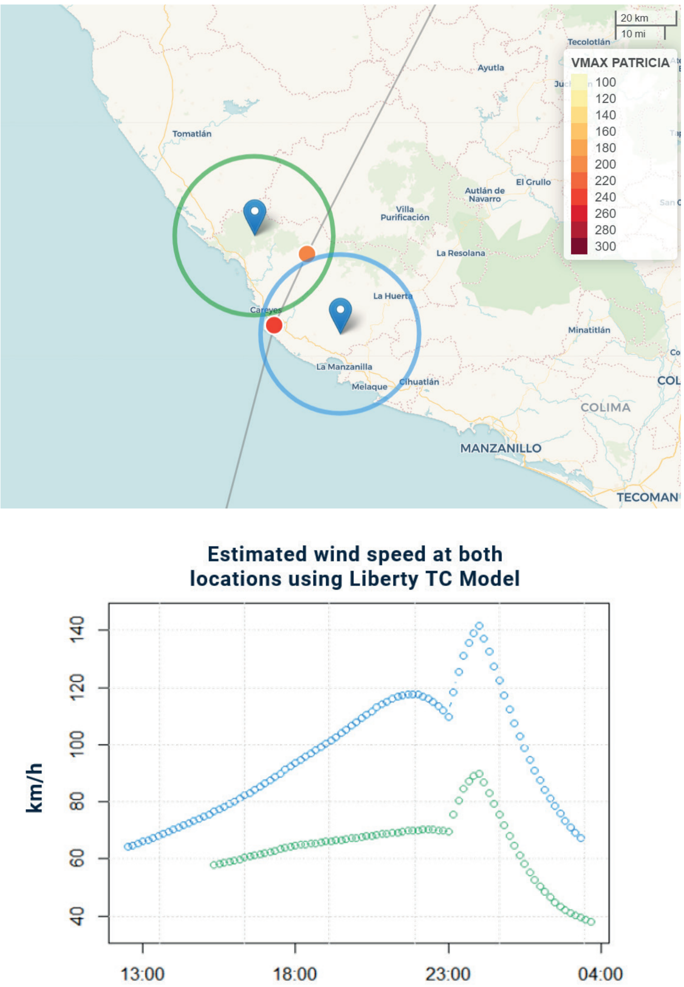


Figure 4. Hurricane Patricia: Wind Speed Variability in Adjacent Locations

- **When the term "Tailor-made" spins out of control**

The parametric insurance market allows participants, who sometimes prioritize pricing over realistic coverage of the client's exposure, to construct tailor-made structures. The following example shows how some participants in the market handle a client's request with multi-locations by exaggerating with the use of CIC making the structure and payout incomprehensible for the client.

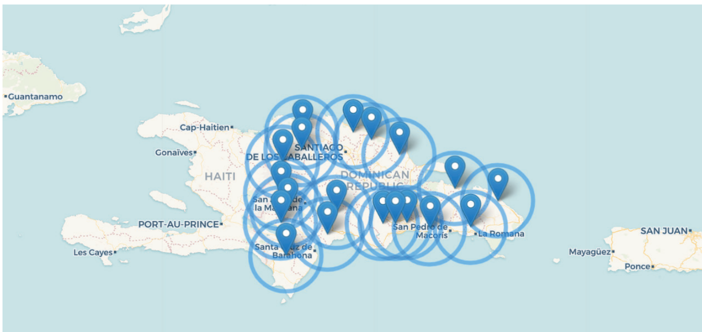


Figure 5. An overly complex CIC solution

Another example is this CIP structure, where the structuring deliberately excluded the path of Hurricane Irma by not completing a rectangular shape. Such designs may not effectively cover the client's risk and are made to reduce the structure's burning cost.

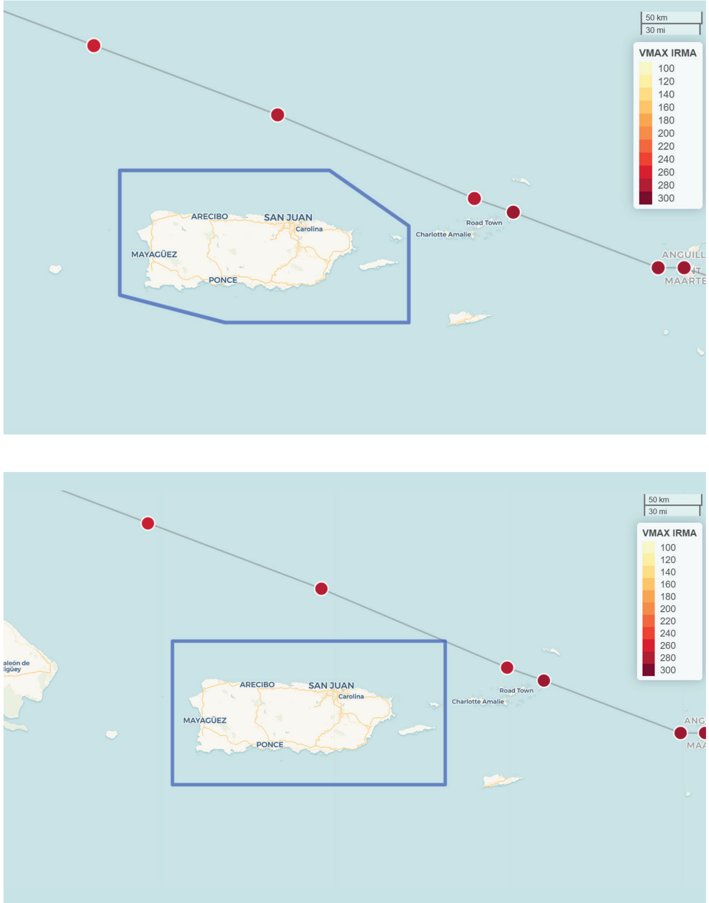


Figure 6. CIP design to avoid historical events

While it is easy to highlight the limitations of current methodologies, the pertinent question remains: how can we transform these challenges into opportunities for improvement? In the following section, we invite you to join us as we explore Liberty's innovative approach and the significant advancements it introduces.

Introducing Liberty's Wind Speed at Location Model: A Performance Analysis Against Other Market Solutions

At Liberty we have developed a parametric solution that can estimate the experienced hurricane's wind speed at a specified location. Our model has been refined over the years by cross-referencing detailed reports, anemometer readings, and client loss experiences, ensuring robust calibration across all hurricane-exposed areas.

Unlike complex black-box models, our solution is transparent and easily understandable for our clients. We can fit any data provider available for sustained wind speed based on the client's exposure or needs. We are familiar with databases such as the 1-minute sustained wind speed data issued by the National Centers for Environmental Information (NCEI), which is part of NOAA and most commonly used in the market.

How does it work?

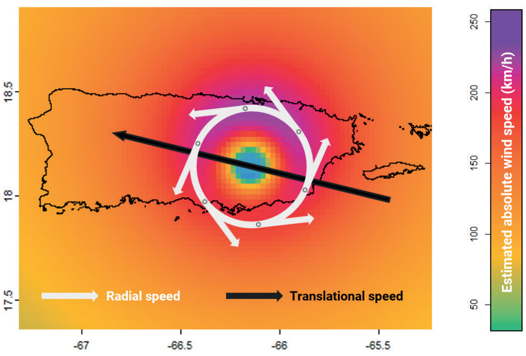


Figure 7. Conceptual representation of the absolute wind speed of a tropical cyclone based on its radial speed and transitional speed. Example based on Hurricane Maria passing over Puerto Rico the 20th September 2017 at 1:40pm.

To obtain a more accurate estimate when interpolating to the client's location, our model considers the hurricane's displacement and rotation speed, which results in the estimation of the absolute speed or gradient wind speed. All this information is derived from the same datasets commonly used in the CIC and CIP models. Moreover, the entire formula for obtaining the data is included in our policy so that either the client or the calculation agent can compute the same results in a transparent and independent way. Finally, our payout curve is based on research papers studying wind damage to structures, and it can be adapted to BI/NDBI covers to reflect the client's historical losses.

Gradient vs Surface Wind Speed

As previously mentioned, our model estimates the gradient wind speed which represents the theoretical speed derived from the combination of translational speed and rotational speed. In other words, the model measures the wind speed as if we were over open sea water with no resistance of any kind.

On the other hand, the Surface wind speed should represent the speed as it could be assessed anywhere on the ground. Any model that wishes to reproduce this estimation should include more parameters that will help to replicate the experienced wind speed on the ground such as the land occupation that can be translated into a roughness coefficient, elevation, topography, vertical wind shear, boundary layer height, etc.

The difference between these two models is their level of complexity. Surface wind speed models rely on intricate methods to match theoretical predictions with the complicated realities of ground-level winds. In contrast, gradient wind speed models like ours offer a straightforward approach that consistently delivers reliable results across various regions exposed to risk. Additionally, it's important to note that gradient wind speeds are typically higher than those produced by surface wind speed models.

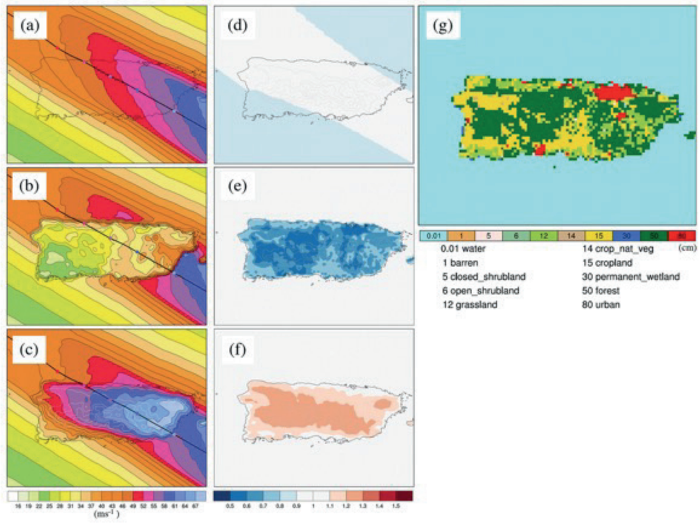


Figure 8. Simulated footprints of Hurricane Maria (2017) over Puerto Rico. (Done, J. M., Ge, M., Holland, G. J., Dima-West, I., Phibbs, S., Saville, G. R., and Wang, Y, 2020)

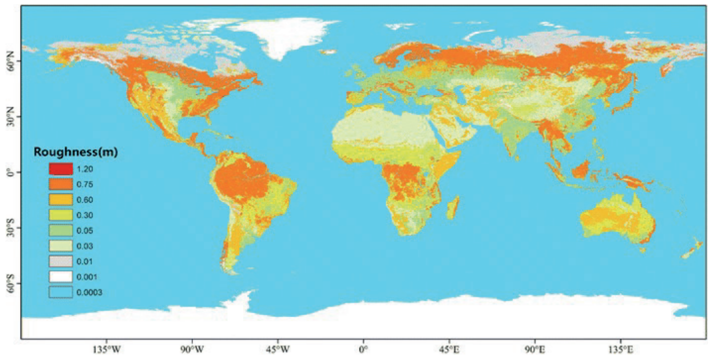


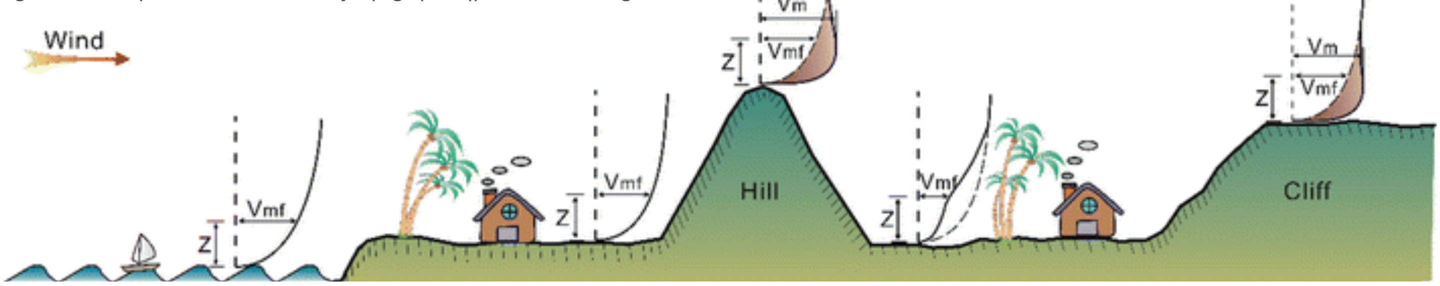
Figure 9. Global roughness length. (Tan, C., Fang, W, 2018)

Advantages of Using Gradient Wind Speed for Parametric Insurance

Our model based on gradient wind speeds offers significant advantages for the parametric insurance market by providing robust and fast wind speed estimation, essential for parametric structure and policy trigger definition, but also incorporates:

• **Transparency:** Our model enables the creation of clear contracts with straightforward steps and formulas, allowing both parties to find identical results without hidden processes generated by machine learning, artificial intelligence or proprietary procedures that cannot be fully disclosed in the contract. In contrast, other models in the market, including those utilizing surface wind speed, function as black-box models, making it difficult to translate the underlying mechanisms behind the presented results into a contract.

Figure 10. Wind speed variations caused by topographic effects. (Tan, C., Fang, W, 2018)



• **Calibration:** Our model is applicable to any location exposed to hurricane risk and can be easily calibrated using recent events, thanks to its straightforward formula and steps. In contrast, surface wind speed models face challenges in calibration across diverse regions due to its multiplicity of parameters which implies a high volatility into the results and could bias the output with overfitting or unperfect modelling of attenuation parameters. We have observed that gradient wind speeds provide a very robust correlation with actual losses and the selection of the right damage curve could account for the specificity of the location (land occupation, topography, elevation, etc).

• **Consistency:** Since gradient wind speeds are measured as if over open water without obstructions, the results are more consistent across different geographical areas, providing a standardized basis for policy triggers.

• **Adaptability:** We can fit any data provider for sustained wind speed, tailored to the client's specific exposure or requirements.

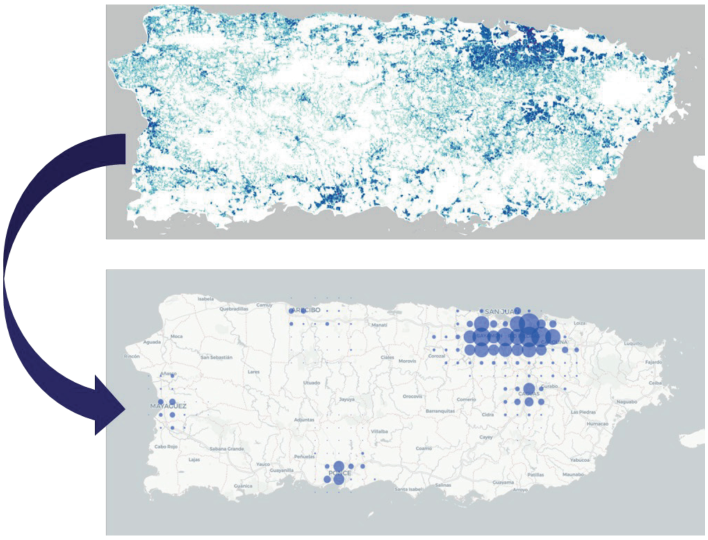


Figure 11. Combining client's information and population density layer to build an exposure grid

A Practical Look at How the Model Is Used and Its Ability to Create Innovative Solutions Based on Client Needs

Our model is built with flexibility and adaptability at its core, enabling us to address a broad spectrum of client needs—from simple structures involving a single location to complex solutions encompassing multiple locations or extensive operations represented by an entire area. This versatility allows us to engage in various types of insurance contracts, ranging from facultative contracts for single locations to comprehensive insurance portfolios covering multiple sites, as well as Public-Private Partnership (PPP) programs where exposure may be measured using population metrics.

By leveraging advanced data analysis and geographic insights, we create realistic risk exposures tailored to specific criteria, such as population density and historical data trends. For example, we can work with high density population maps to reproduce a more realistic exposure based on population distribution, which allows us to replicate historical losses adjusting the weight to higher populated sites. Another example is structuring covers for BI or NDBI, where clients that operate in an extensive network of business locations by using their records for each site—such as financial records, sales data, and daily visitor metrics—we can develop a tailored strategy.

Our goal is to provide a comprehensive support and peace of mind, allowing our clients to focus on maintaining and growing their enterprise without the stress of unforeseen interruptions.

Case Studies: Outperforming Market Alternatives

Liberty TC Model vs Surface Wind Speed Model Provider A

For this case provider A (an unnamed competitor's model) utilizes a surface wind speed model with proprietary parameters, which remain undisclosed. By applying this model to a client's exposure on Saint-Barthélemy Island and comparing estimates for historical events that affected the island with our own, we obtained the following results:

Year	Hurricane Name	Wind Speed Liberty TC Model (km/h)	Wind Speed Provider A (km/h)
2017	IRMA	288.01	199.11
1999	LENNY	197.36	Not captured
1998	GEORGES	175.50	119.64
1995	LUIS	200.77	140.18
1960	DONNA	201.69	141.07

Figure 12. Comparative Table of the Liberty TC Model and Model Provider A

To have a clear view of Irma's path across the island, we used our model to estimate the wind speed for various points around the island to demonstrate Irma's consistent and strong winds (see the following map).

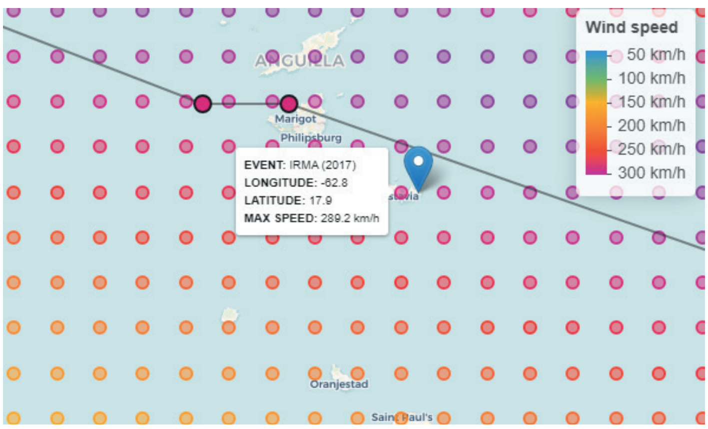


Figure 13. Liberty TC Model wind speed estimates for hurricane Irma (2017) across Saint-Barthélemy

There is a significant difference in wind speed measurements between the two models, despite the island's relatively uniform terrain. In the case of the most recent event, Hurricane Irma (2017), reports indicated wind speeds of more than 300 km/h (173 knots) that align more closely with our estimates and the actual conditions experienced on the island. The black-box nature of a surface wind speed model adds a layer of complexity to the justification of such a deviation in the estimation of this event.

NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

"Irma's estimated minimal central pressure of 914 mb at 0600 UTC 6 September is based on a dropwindsonde surface pressure measurement of 915 mb at 0503 UTC 6 September, which was accompanied by a surface wind of 15 kt. This estimate is also consistent with a weather station on St. Barthelemy that reported a minimum pressure of 915.9 mb, and a station on Barbuda that reported a minimum pressure of 916.1 mb. The Barbuda station reported sustained winds of 105 kt and a gust of 139 kt when it was in the southern eyewall. Also, an unofficial observation in St. Barthelemy reported a maximum wind gust of 173 kt."

(National Hurricane Center Irma Report, 2017, p. 5).

Figure 14. Eden Rock Hotel St Barts (Facebook)

Liberty TC Model vs Surface Wind Speed Model Provider B

Another example is the surface wind speed model from provider B (another competitor's model). We had the opportunity to compare it against our model using a client's request at Cabo San Lucas and Sinaloa, both in Mexico. Similarly to provider A model there is a significant difference between the model results:

Year	Hurricane Name	Wind Speed Liberty TC Model (km/h)	Wind Speed Provider B (km/h)
2021	PAMELA	153.02	111.04
2014	ODILE	208.01	144.84

Figure 15. Comparative Table of the Liberty TC Model and Model Provider B results

Meanwhile, for Odile (2014) on Cabo San Lucas location, reports are aligned with our estimated winds of 110-knots (204 km/h approximately).

NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

"With the tropical-storm-force wind radii nearly doubling in size over the 36 h that Odile had been a hurricane. Odile's inner eyewall eroded further after the plane departed and nearly dissipated after 0000 UTC 15 September, while the out eyewall began to contract slightly (Fig. 4). The hurrican further accelerated while Odile's cloud pattern remained well organized, with a symmetric central dense overcast and a roughly 30 n mi wide eye. Odile made landfall with 110-kt winds (category 3 on the Saffier-Simpson Hurricane Wind Scale) on the southern tip of the Baja California peninsula at 0445 UTC 15 September, just to the east of Cabo San Lucas."

(National Hurricane Center Odile Report, 2014, p. 3).

Figure 16. Collapsed building in Cabo San Lucas. Courtesy of Josh Morgerman. (National Hurricane Center, 2014)

Liberty TC Model Damage Curve vs Traditional Stepped Damage Curve

When assessing structural vulnerability and loss in the parametric insurance market, damage curves play a critical role in translating hazard intensity into expected physical damage or loss. A linear payout curve can more accurately represent the relationship between wind speed and damage to a structure because it reflects the continuous and gradual nature of damage escalation as wind speeds increase. Unlike a stepped payout curve, which assumes that damage occurs in discrete jumps at specific wind speed thresholds, a linear curve captures the incremental accumulation of damage that typically occurs in real-world scenarios.

Structural deterioration and failure often progress gradually rather than abruptly, with small increases in wind speed causing proportionally small increases in damage. Therefore, a linear payout curve provides a smoother and more realistic estimate of losses, enabling more precise risk assessment and more equitable insurance compensation.

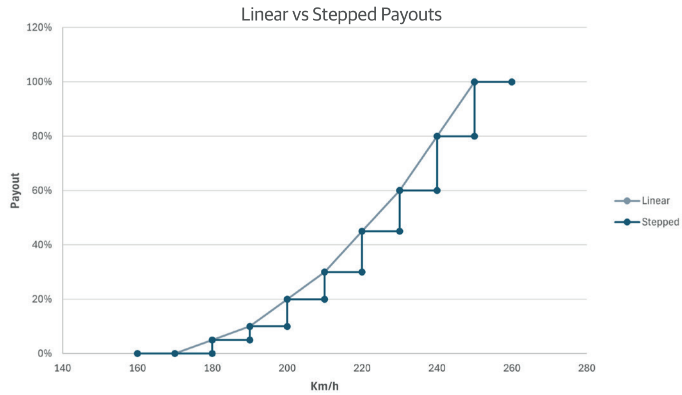


Figure 17. Comparison between Linear and Stepped payout curve

Nevertheless, it is important to note that when using the same payout percentages for both curves, the linear payout curve will always result in higher payouts than the stepped curve. This might give the false impression that linear payout curve contract are more expensive while they are in reality more protective. However, a more meaningful approach is to compare the payout amounts against historical loss data from both structures. By doing so, we can better align the payout structure with the client's actual experienced losses, ensuring that the model reflects real-world damage patterns more accurately and provides a fairer compensation.

Comparative Analysis of Market Solutions

We have developed a model that stands out in a competitive landscape. The following table provides a concise comparison of our solution against other market offerings, highlighting key features, benefits, and unique advantages.

	Parametric Insurance?	Index	Transparency	BI/NDBI Covers	Loss adjustment cost	Payout speed	Site-specific assessment	Basis Risk
Traditional catastrophe insurance	✗	Loss adjustment at location	Moderate	✗	High	Several Months	Yes	Low
Cat-in-a-box or Cat-in-a-polygon	✓	Maximum Wind Speed in a Circle/Polygon	High	✓	None	Days	No	High
Liberty TC Model (Gradient Wind Speed)	✓	Wind Speed at location	High	✓	None	Days	Yes Estimated	Low
Surface Wind Speed	✓	Wind Speed at location	None	✓	Varies depending on model provider	Days	Yes Estimated	Moderate

Our goal is to share our expertise with the highest standards: Contact us!

Accurately assessing hurricanes and their potential impacts is critical to minimizing economic losses and improving resilience against such natural disasters. Our model offers precise historical risk assessments tailored to specific locations, providing crucial insights into wind speeds and impacts. By comparing our model with existing approaches and leveraging robust data sources, we aim to deliver enhanced understanding and preparation strategies for the insurance and reinsurance industries. Continuous advancements in research and technology underscore our commitment to refining these assessments, ultimately supporting our clients in making informed decisions for better protection and recovery.

We invite you to reach out to us for further information on how our solutions can be integrated into your strategies. Together, we can forge a path toward improved protection and effective recovery measures. We look forward to collaborating with you to navigate the challenges of natural disasters and safeguard your interests.

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