

Managing US Hurricane Landfall Risk in a Changing Climate

November 2022

Executive summary

- US hurricanes are by far the largest exposure of any Insurance-Linked Securities (ILS) portfolio. A profound understanding of the impact of climate change on the risk of ILS portfolio is crucial for attractive long term investment returns.
- Twelve Capital, through its cooperation with climate-tech expert reask, expects a modest increase in North Atlantic Hurricane risk over the coming decades as a consequence of climate change.
- Future projected global climate model simulations, suggest that increased risk will not be felt uniformly across the US coastline with the East Coast (north of South Carolina) potentially seeing larger increases in landfall risk relative to the Florida and Gulf coastlines.
- Forward looking views of landfall risk under possible future climates provide much needed insights into how to potentially assess longer term risk-adjusted price movements or how risk can be managed through portfolio diversification.
- Climate variability will likely continue to drive US hurricane risk premia with increased demand for ILS capital to help the (re)insurance industry manage capital-intensive peak peril US Hurricane exposure.
- Climate change research allows Twelve Capital an increased understanding of the climate variability associated with both the current and future climate, helping to continuously improve its investment process to build well-balanced Cat Bond and Private ILS portfolios.

Background

This research extends the North Atlantic hurricane seasonal forecast and climate change methodology, produced by Twelve Capital and machine learning climate-tech firm reask, to assess the possible impacts of climate change on North Atlantic hurricane activity and landfalls. Twelve Capital and reask have worked closely together, since June 2018, to develop hurricane forecasting tools using reask's proprietary machine learning algorithm.

Assessing climate change impacts on North Atlantic hurricane

The forecast methodology moves beyond traditional basin-wide hurricane activity metrics, such as hurricane count, towards a more complete insurance risk assessment framework that

incorporates a measure of regional hurricane landfall risk.

The original reask algorithm used machine learning techniques to estimate conditional landfall risk distributions considering three geographical regions of genesis (Rodney and Loridan, 2019): the Main Development Region (MDR), the East Coast Region, and the Gulf region (see Figure 1). The updated model now generates a machine learning driven stochastic set that directly simulates storm characteristics and landfall locations given a certain state of the climate. This direct simulation allows for the calculation of landfall risk along a more granular coastline and is consistent with simulation techniques used to develop catastrophe models. Figure 2 shows the landfall regions, split into three segments of coastline: the Gulf, Florida and the East Coast.

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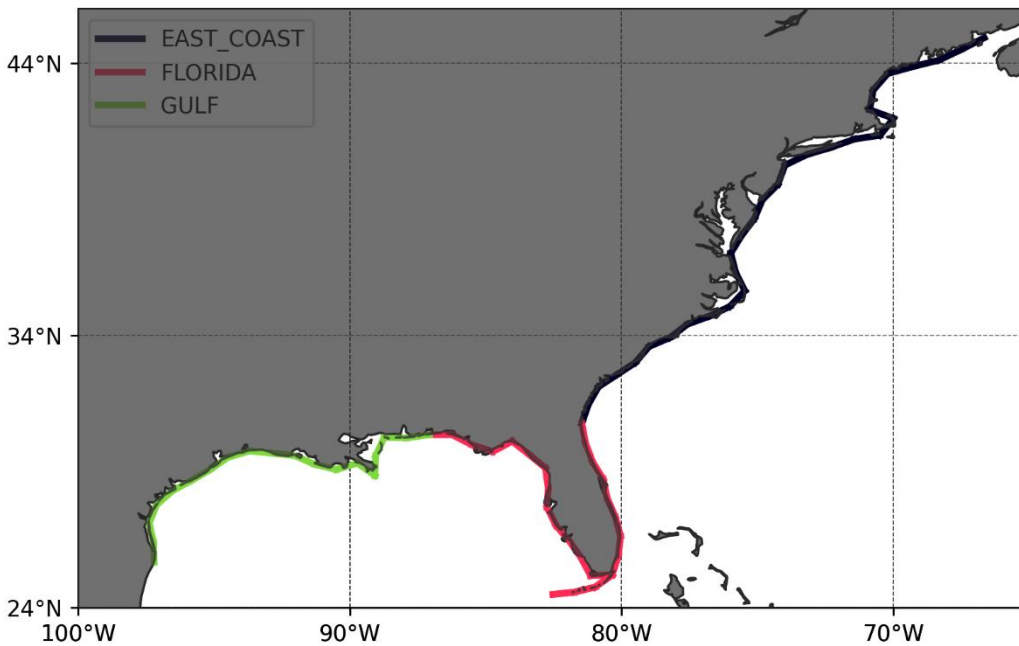
Figure 1: Model region classifications from the previous model



Source: reask and Twelve Capital.

The Community Earth System Model Large Ensemble climate database (“LENS2”, Rodgers et al., 2021) under CMIP6 historical and SSP370 future radiative forcing scenarios is used to generate stochastic event sets of the North Atlantic hurricanes for present and future periods.

Figure 2: Coastline landfall locations for the updated model



Source: reask and Twelve Capital.

Using the climate LENS2 model outputs, the approach consists of a range of machine learning techniques to isolate climate modes of variability known to drive hurricane activity, as well as to drive each tropical cyclone of the event set based on the knowledge of the climate.

The variability in hurricane risk is then assessed from (i) the variability in the climate state as captured by these drivers and (ii) the variability in hurricane risk given a certain state of the climate.

The algorithm relies on a set of 50 different model simulations to ensure the uncertainty in the climate

itself is being sampled and generates around 900k years of synthetic hurricane risk.

This study is designed to quantify the variability in projected landfall risk, focusing on trends between 1990-2020 (the control period), 2020-2040 and 2040-2060.

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How might the landfall risk distribution shift under a warming climate?

The simulated risk distributions over the periods 1990-2020, 2020-2040, and 2040-2060 are projected to possible future climates using the CESM2 SSP3.7.0 scenario¹.

Table 1 and Figure 3 show the results of the expected modelled shift in hurricane risk incorporating the future climate SSP3.7.0 scenario.

There is a clear trend of increasing risk for the number of hurricanes in the basin between control period and projecting to 2020-2040 and 2040-2060 with the simulated risk distribution visibly skewed towards higher risk levels (Figure 4).

Table 1: Expected risk for periods 2020-2040, 2040-2060 relative to 1990-2020 control period

Metric	1990-2020	2020-2040	2040-2060
Basin Activity	7.52	8.88 (+18%)	9.58 (+27%)
US Landfalls	1.68	2.13 (+26%)	2.32 (+37%)
Gulf Landfalls	0.74	0.89 (+19%)	0.91 (+22%)
FL Landfalls	0.59	0.74 (+26%)	0.81 (+38%)
East Coast Landfalls	0.49	0.68 (+38%)	0.80 (+64%)

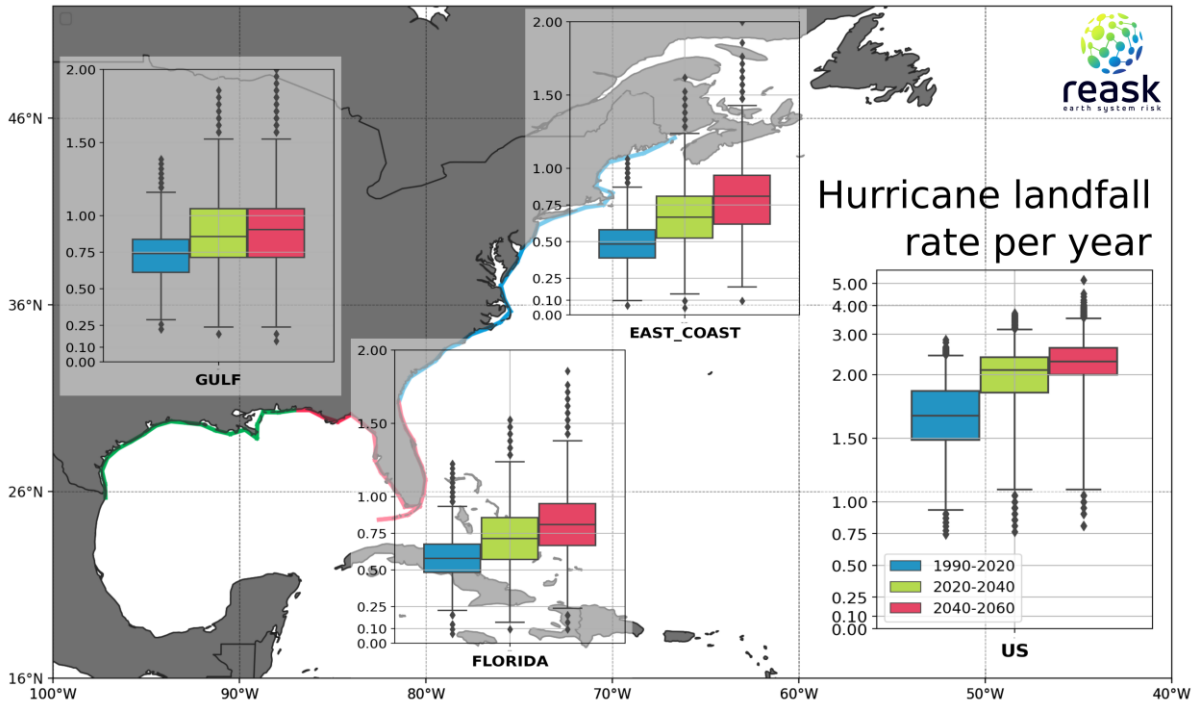
Source: reask.

¹ The CESM2 Shared Socio-economic pathway (SSP) 3.7.0 represents a high greenhouse gas emission scenario where CO2 emissions double by 2100 and estimated warming

between 1941-2060 increases by approximately 2.1°C. The SSP3.7.0 was used as one of the scenarios to produce the IPCC 6th assessment report on climate change.

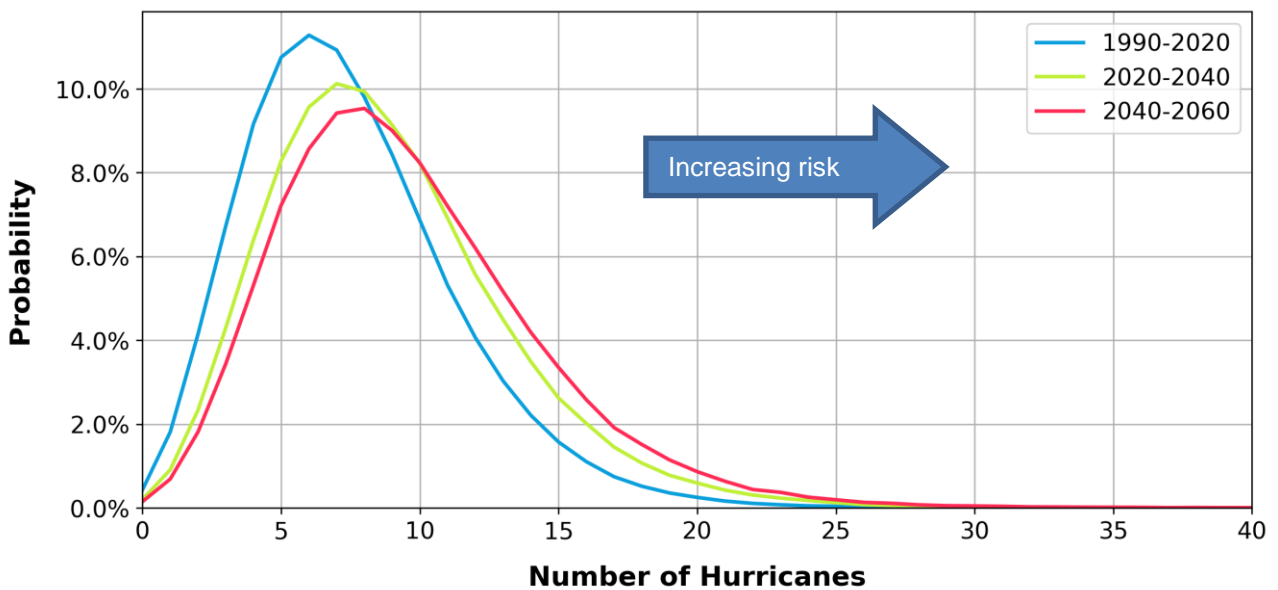
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Figure 3: Geographical distribution of landfall risk between the periods 1990-2020, 2020-2040, 2040-2060



Source: reask.

Figure 4: Simulated Basin wide activity for periods 1990-2020, 2020-2040 and 2040-2060



Source: reask.

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Breaking the analysis out further, it can be seen in Table 2 and Table 3 that the increase is not uniform i.e., the East Coast is having a much larger relative increase in major hurricanes compared to Cat 1-3 hurricanes.

Table 2: Cat 1 to 3, expected risk for periods 2020-2040, 2040-2060 relative to 1990-2020 control period

Metric	1990-2020	2020-2040	2040-2060
Basin Activity	5.30	5.70 (+7%)	5.70 (+7%)
US Landfalls	1.43	1.73 (+21%)	1.81 (+27%)
Gulf Landfalls	0.62	0.72 (+16%)	0.72 (+16%)
FL Landfalls	0.47	0.56 (+20%)	0.58 (+23%)
East Coast Landfalls	0.46	0.62 (+33%)	0.71 (+52%)

Source: reask.

Table 3: Cat 4 and 5, expected risk for periods 2020-2040, 2040-2060 relative to 1990-2020 control period.

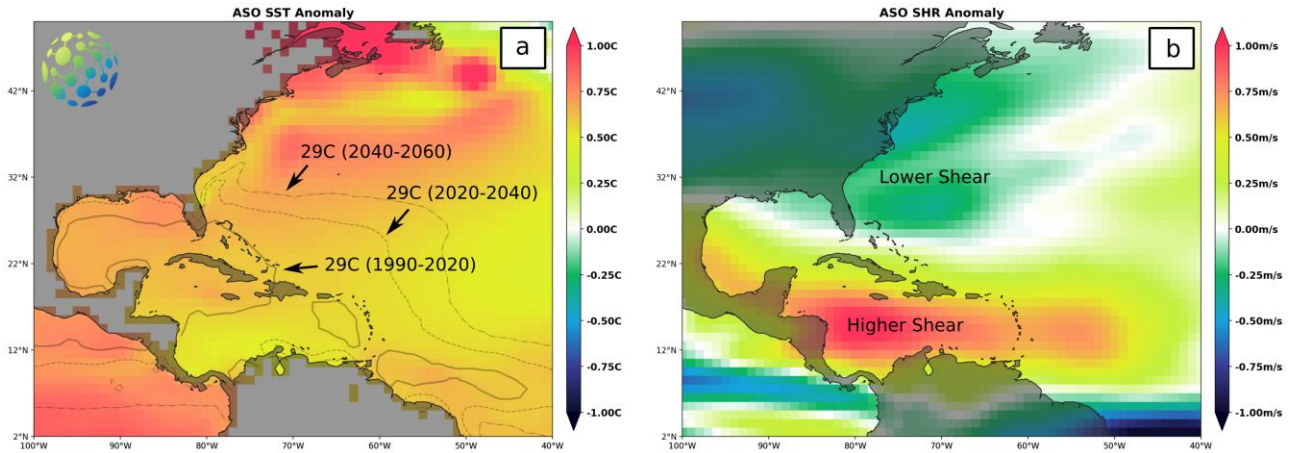
Metric	1990-2020	2020-2040	2040-2060
Basin Activity	2.22	3.17 (+43%)	3.90 (+76%)
US Landfalls	0.26	0.39 (+51%)	0.51 (+95%)
Gulf Landfalls	0.12	0.17 (+38%)	0.20 (+58%)
FL Landfalls	0.12	0.18 (+51%)	0.23 (+98%)
East Coast Landfalls	0.03	0.06 (+100%)	0.09 (+200%)

Source: reask.

Landfall risk is expected to increase across the basin marginally more than the increase in activity with the largest increase observed along the East Coast segment of coastline, landfall probabilities

increasing by upwards of 100% out to 2040-2060. This marked increase along the East Coast relative to the Gulf and Florida is primarily driven by two factors.

Figure 5: a) Sea Surface Temperature anomalies and b) wind shear anomaly between 2020-2040 and the control period 1990-2020.



Source: reask.

The first physical driver is a result of dominant Sea Surface Temperature (SST) patterns favouring hurricane formation. Figure 5a shows the Sea Surface Temperature anomaly patterns during the peak of the hurricane season in August / September / October (ASO) between 2020-2040 and the control period 1990-2020. The East Coast shows an increase in SSTs shifting to more favourable conditions for Hurricane formation further North. The contour lines show where the control period is 29°C which corresponds to an approximate level above which increases in temperature have less effect on hurricane activity. However, we see how this 29°C region stretches further North in future periods. This in part

describes the higher impact along the East Coast relative to Florida and Gulf.

The second physical driver is a result of contrasting wind shear patterns along the East Coast and the Gulf and Florida coastlines. Figure 5b shows the wind shear anomaly patterns in ASO between 2020-2040 and the control period 1990-2020. Higher wind shear is clearly visible (in yellow and red) in the Gulf and Caribbean with weaker wind shear visible (in green) offshore of the East Coast creating more favourable conditions for hurricane formation and intensification.

References:

Rodney, J.; Lordinan, T. Machine Learning for US Hurricane Forecasting - New Signals for ILS Investment Management. Clear Path Analysis: Insurance Linked Securities for Institutional Investors, 2019. www.clearpathanalysis.com

Rodgers et al. Ubiquity of human-induced changes in climate variability. Earth Syst. Dynam., 12, 1393–1411, 2021. <https://doi.org/10.5194/esd-12-1393-2021>

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Twelve Capital and reask – co-operation

Since June 2018, Twelve Capital and reask have worked closely together to further the development of hurricane forecasting tools by using machine learning. Both parties believe that advancements in technology and computing power can enhance ILS investment management.

reask is a catastrophe analytics specialist providing global solutions for tropical cyclone risk management and forecasting. reask is based in Sydney with its team of experts in risk analysis, machine learning and high performance computing. Their team has vast experience in natural catastrophe modelling having developed their expertise from previous engagements at RMS, Willis Re and other specialised firms.

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