ESG @TransRe™

U.S. Hurricane Risk Volatility Case Study

An Alternative to Current Climate Change Scenarios

DECEMBER 2021

- Analyzing the financial impact of climate change is a relatively new field of study
- TransRe has developed three alternative climate change scenarios for U.S. hurricanes
- Most frameworks have focused on the impact to the 'mean'
- Our framework looks at the impact on both mean and volatility

Contents

TransRe™
We value risk.

Executive Summary

The changing climate will affect weather events in different ways. Analyzing the impact of climate change is a relatively new field of study. Given a) the lack of certainty in long term model predictions, and b) the regulatory interest in an emerging risk to our business, (re)insurers need a clear framework to work within. **Most frameworks to date have focused on impact to the 'mean'. TransRe's research goes further, looking at the impact on volatility.**

This paper focuses on the impact of climate change on U.S. hurricane risk. Three alternative climate change stress scenarios are introduced, taking into account both best (RCP4.5) and worst (RCP8.5) climate projection pathways. TransRe's approach is similar to guidelines provided by the Prudential Regulation Authority (PRA) in June 2019. **These new alternative climate scenarios are developed including climatological patterns such as positive AMO and La Niña, which enable TransRe to capture climate change's impact on both mean frequency and risk variation.**

TransRe's climate scenarios (physical risk only) can also be mapped to the Climate Biennial Exploratory Scenarios (CBES) recently published by the Bank of England (June 2021).[1]

- TransRe Scenario A is comparable to the CBES Early/Late Action
- TransRe Scenarios B and C explore two possibilities if No Additional Action

***Table 1:** TransRe climate scenarios mapped to CBES and RCP projections*

TransRe Climate Scenario	CBES	RCP
Scenario A	Early/Late Action	RCP4.5 (SSP2-4.5)
Scenario B/C	No Additional Action	RCP8.5 (SSP5-8.5)

---

[1] https://www.bankofengland.co.uk/stress-testing/2021/key-elements-2021-biennial-exploratory-scenario-financial-risks-climate-change

While forward-looking, long-term time horizon projections allow management to analyze and act to mitigate risk exposures, future outcomes will be determined by external factors, including demographic and economic developments, government policies, technological changes and market sentiment. Even if such policies and actions were known, there is substantial modeling uncertainty regarding the feedback of them into future physical risks. Therefore, this analysis focuses on the short-term time horizon, which we define as the next 5 to 10 years. **These scenarios may therefore be considered as a proxy for short term climate change.**

Section 1 provides an overview of Representative Concentration Pathway (RCP) scenarios.

Section 2 includes a brief summary of PRA guidelines on climate change assessment and an introduction to the recent Bank of England report on CBES.

Section 3 introduces details of TransRe's alternative climate change scenarios for U.S. hurricane risk.

Section 4 shows that **the financial impact is more significant, especially in the tail, when considering both changes in mean and risk volatility together.**

Background

Significant insured losses from recent tropical cyclones and wildfires highlight the volatility inherent in weather-related catastrophe risk and raise questions about the potential impact of climate change on these and future events. The detrimental impact of global warming on natural and human systems is already visible today and without further international climate action, the global average temperature and associated physical risks will continue to increase.

Climate change is expected to have varying impacts on the frequency, severity, and distribution of different weather-related catastrophes. While the impact of climate change varies by event, region and timeframe, the expectation is generally for increasingly adverse effects, some of which can be observed today. This suggests increasing underwriting risk for (re)insurers, as well as possible asset value impairments and business strategy challenges.

The analysis of climate change risk is a relatively new field, in particular in relation to the financial sector, including (re)insurance. The (re)insurance industry, catastrophe model vendors as well as supervisory authorities recently started more formally and systematically exploring the effects of climate change. Considerable progress has been made to enhance understanding and to develop approaches in measuring exposures to climate change risk, but challenges remain. We recognize that the approaches to scenario analysis of climate change risk need to evolve over time as new methodologies become available and the industry gains additional experience.

At present, the scientific assessment of climate change impact on tropical cyclones (TC)[2] indicates:

- Strong evidence for acceleration of sea level rise leading to higher storm inundation and intensifying losses from storm surge;
- No clear consensus on potential impacts on TC overall frequency, but a growing confidence in an increase in very intense TC frequency (category 3-5);
- A general increase in storm intensity and precipitation; and
- A possibility of slowdown in TC forward speed. Due to the potential for data artifacts in observations and a lack of model consensus, the confidence in projections is low.

---

[2] https://journals.ametsoc.org/view/journals/bams/101/3/bams-d-18-0194.1.xml

One should also consider the demographic and economic trends that have led to concentrations of exposure in catastrophe-prone areas, which further complicate the picture and reinforce the potential impact of climate change on (re)insurance businesses.

Based on current scientific evidence, the inherent uncertainty of long-term climatic model predictions, the lack of data, and the limitations of existing tools, in this paper, we explore an approach in defining climate change stress scenarios tailored for the (re)insurance industry. These scenarios measure the physical risk associated with the changes in frequency and severity of U.S. hurricanes.

1 Representative Concentration Pathways (RCPs)

Climate models simulate the physics, chemistry and biology of the atmosphere, land, and oceans to provide a better understanding of how the climate has changed in the past and may change in the future. These models are constantly being updated to incorporate higher spatial resolution, new physical processes, and biogeochemical cycles. The updates to climate models are released according to the schedule of the Intergovernmental Panel on Climate Change (IPCC) assessment reports.

The IPCC 5th assessment report (AR5)[3] published in 2013 featured climate models from Coupled Model Intercomparison Projects (CMIP5). In the 2021 IPCC 6th assessment report (AR6) a new set of climate models were introduced (CMIP6). CMIP5 presented a standard set of RCPs from 2.6 to 8.5 W/m^2 based on greenhouse gas emissions (Table 2). The RCPs started in 2007 and provide projections of future climate change in the long-term (out to 2100 and beyond).

The CMIP6 combines social trends and climate policy assumptions – "Shared Socioeconomic Pathways" (SSPs) – with RCP scenarios (greenhouse gas emission scenarios) and it explores a much wider range of possible future outcomes than were included in CMIP5. In the CMIP6 version of climate models, the RCP2.6, RCP4.5, RCP6.0, and RCP8.5 scenarios are renamed SSP1-2.6, SSP2-4.5, SSP4-6.0, and SSP5-8.5. Similar to CMIP5, each of the SSPs are based on 2100 radiative forcing levels. In addition to renamed RCP scenarios, four additional scenarios are provided in IPCC AR6 (Table 2).

---

[3] https://www.ipcc.ch/assessment-report/ar5/

***Table 2:** SSP scenarios according to IPCC AR6 and CMIP6*

CMIP6 Scenario	CMIP5 Scenario	Description
SSP1-1.9		A "very stringent" pathway that limits global warming to below 1.5°C (relative to pre-industrial levels).
SSP1-2.6	RCP2.6	An immediate pathway to keep global temperature rise well below 2°C by 2100 that requires CO2 emissions start declining by 2020 and go to zero by 2100.
SSP4-3.4		An intermediate pathway between the RCP2.6 and more strict mitigation efforts than RCP4.5. A scenario that assesses the impacts of warming if societies rapidly reduce emissions, but fail to mitigate fast enough to limit warming to below 2°C.
SSP5-3.4OS		An overshoot scenario (OS) where emissions follow a worst-case RCP8.5 pathway until 2040, after which they decline extremely rapidly with a lot of late-century use of negative emissions.
SSP2-4.5	RCP4.5	An intermediate stabilization pathway that results in achieving a temperature increase being kept below 3°C. This pathway requires CO2 emissions start declining by approximately 2045 to reach roughly half of the levels of 2050 by 2100.
SSP4-6.0	RCP6.0	A stabilization pathway where emissions peak around 2080, then decline. It requires CO2 emissions start declining after 2080.
SSP3-7.0		More optimistic scenario compared to RCP8.5. This scenario is more of a baseline outcome rather than a mitigation target.
SSP5-8.5	RCP8.5	High-emissions scenario is frequently referred to as “business as usual” Fail to enact any climate policies and limit warming below 2°C.

Figure 1 compares the old RCP scenarios (dashed lines) and the new SSP scenarios (solid lines). There are some differences between the old and new scenarios, but there are no substantial changes in scenario emission outcomes. The SSP scenarios started in 2014 whereas RCPs started in 2007. Generally, the SSPs have a higher starting point than RCPs partly due to higher emissions between 2007 and 2014 than was expected based on original RCP predictions. Also, SSP scenarios have a more gradual decline in emissions than RCP scenarios.

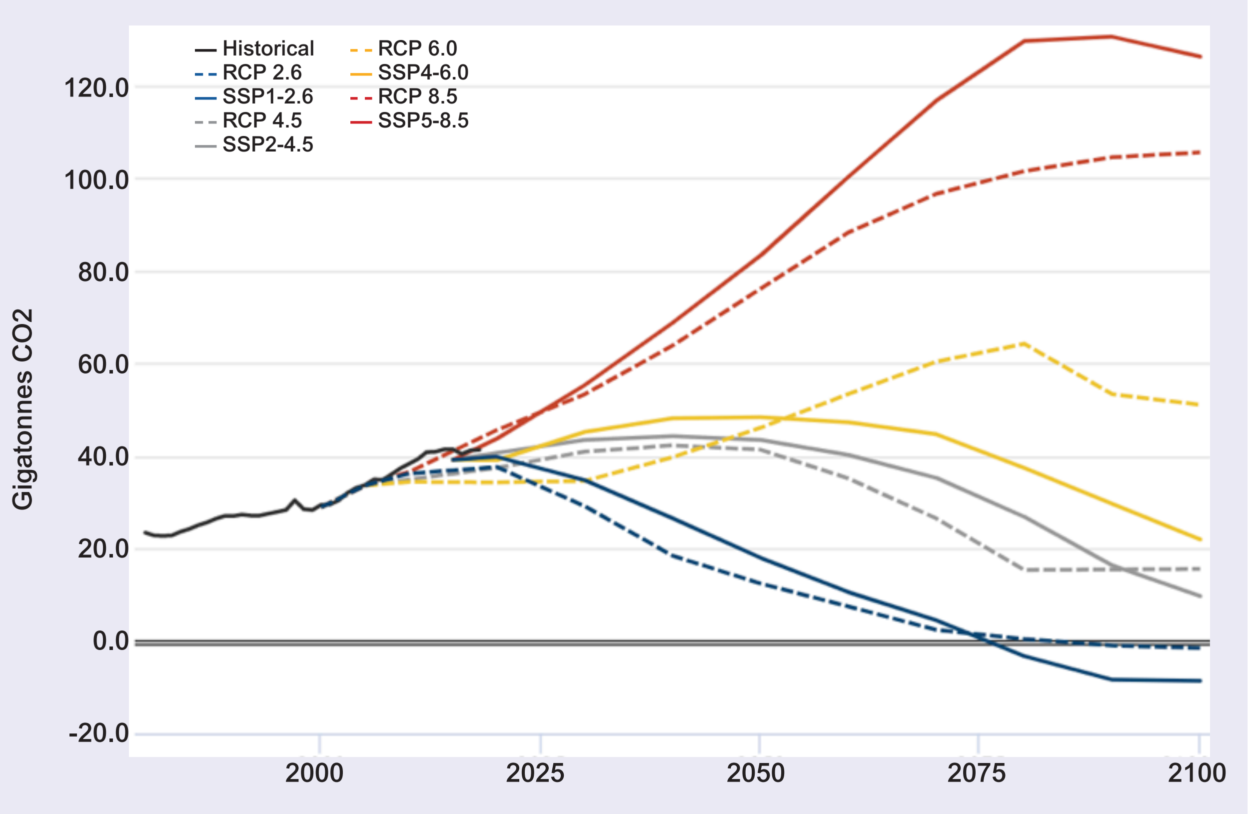

***Figure 1:** CO2 emissions comparison between CMIP5 and CMIP6 (Source: CarbonBrief)*

Table 3 provides the IPCC AR6 SSP (RCP) projections of global mean temperature change based on three time-scales: the near-, mid- and late 21st century relative to the reference period of 1850-1900.

***Table 3:** IPCC AR6 projected change in global mean surface air temperature for the near-, mid- and late 21st century relative to the reference period of 1850–1900*

Scenario	Near term, 2021-2040		Mid-term, 2041-2060		Long term, 2081-2100	
	Best estimate (°C)	Very likely range (°C)	Best estimate (°C)	Very likely range (°C)	Best estimate (°C)	Very likely range(°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

2 Regulatory Guidelines on Climate Change Assessment

In June 2019, the PRA provided a set of climate change scenarios as part of their General Insurance Stress Test (GIST) document.[4] The PRA introduced three hypothetical climate scenarios based on the IPCC AR5. Scenarios A and B assume that the Paris Agreement targets are broadly achieved, although through different means. Scenario C assumes that the targets are not met, resulting in a significant impact on the global climate.

- **Scenario A:** Rapid global action and policies that result in achieving the temperature increase being kept below 2°C (relative to pre-industrial levels) based on the IPCC AR5 disorderly transitions. Shock parameters illustrative of potential impact in 2022.
- **Scenario B:** A long-term orderly transition scenario based on the IPCC Special Report (2018) on Global Warming of 1.5°C assumption. This involves a maximum temperature increase being kept well below 2°C (relative to pre-industrial levels) with the economy transitioning in the next three decades to achieve carbon neutrality by 2050 and greenhouse-gas neutrality in the decades thereafter. Shock parameters illustrative of potential impact in 2050.
- **Scenario C:** A scenario with failed future improvements in climate policy resulting in a temperature increase in excess of 4°C (relative to pre-industrial levels) by 2100 assuming no transition and a continuation of current policy trends. Shock parameters illustrative of potential impact in 2100.

According to RCP definitions (Table 2), the PRA scenario A considers the RCP2.6 long-term (out to 2100 and beyond) projection. The PRA scenarios B and C correspond to RCP4.5 and RCP8.5 long-term projections, respectively. For each scenario, the PRA provided factors to assess the potential impact of climate change on the TC "mean" frequency and severity. Table 4 shows a set of PRA factors to assess the potential physical risk that may arise from the climate change impact on U.S. hurricanes.

---

[4] https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2019/general-insurance-stress-test-2019-scenario-specification-guidelines-and-instructions-draft.pdf

***Table 4:** The PRA's climate scenarios impacting U.S. hurricane risk*

Assumptions	Scenario A	Scenario B	Scenario C
Increase in frequency of major hurricane	5%	20%	60%
Uniform increase in wind speed of major hurricane	3%	7%	15%
Increase in surface run-off resulting from increased tropical cyclone-induced precipitation	5%	10%	40%
Increase in cm in average storm tide sea-levels for U.S. mainland coastline between TX and NC	10 cm	40 cm	60 cm

On June 8th, 2021, the Bank of England published a paper regarding the key elements of CBES which explores three different climate policy scenarios considering a range of possible future outcomes for global temperatures and the economy, each spanning 30 years. Early Action and Late Action scenarios consider two pathways to net zero greenhouse gas emissions. These scenarios primarily explore transition risks from climate change.

- **Early Action:** The transition to a net-zero emissions economy starts in 2021 so carbon taxes and other policies intensify relatively gradually over the scenario horizon. Global carbon dioxide emissions (and all greenhouse gas emissions in the UK) drop to net-zero around 2050.
- **Late Action:** The transition is delayed until 2031, at which point there is a sudden increase in the intensity of climate policy. In the UK, greenhouse gas emissions are successfully reduced to net-zero around 2050, but the transition required to achieve that is more abrupt and therefore more disorderly.
- The **No Additional Action** scenario primarily explores physical risks from climate change. In this scenario, no new climate policies are introduced beyond those already implemented prior to 2021.

Early Action and Late Action scenarios assume that by 2050 the global mean temperature increases 1.8°C from pre-industrial levels. The difference between these two scenarios results in different degrees of transition risks which drive differences in the impact. In the No Additional Action scenario, global warming relative to pre-industrial levels reaches 3.3°C by 2050.

3 TransRe Alternative Climate Change Scenarios

In this paper, TransRe climate scenarios are designed to measure the impact of the changes in frequency and severity of U.S. hurricanes. As mentioned earlier, the majority of publications in the financial sector that consider climate change impact on tropical cyclones have studied the changes in the mean and none explore the impact of climate change on volatility.

In this document, to capture the change in major hurricane frequency we are introducing a modified version of the PRA climate scenarios which not only provides an estimate of the change in "mean", it also approximates the change in volatility. TransRe climate scenarios are developed using historical data conditioned by weather-related anomalies that influence hurricane activities in the Atlantic Ocean. Whilst the past is not a good representation of future climate, a conditional history can be used as an approximation for future trends. We understand the limitations of this approach, especially considering the change in volatility. However, we believe these scenarios provide an estimate for the potential outcomes of future climate impact on risk uncertainty.

Although it is important to assess the long-term risks of climate change, the uncertainties will multiply when considering a longer time horizon. Therefore, TransRe climate scenarios are further modified to examine the financial impact of climate change in a shorter time horizon (5-10 years). These modified scenarios allow (re)insurance businesses to assess the short-term climate change risk, potentially fostering more realistic forward-looking risk management and governance. TransRe scenario A represents the short-term RCP4.5 assumption (best estimate). TransRe scenarios B and C are two representations of short-term RCP8.5. TransRe scenario B "mean" frequency assumption is similar to the work of Kerry Emanuel published in November 2020.[5] It could also be considered as a proxy for the climate change scenario under the medium-term (30-year time horizon) RCP4.5.

For each scenario, the increase in severity due to increase in wind speed is captured using TransRe's proprietary model risk framework. TransRe's model risk framework is developed based on an asymptotic power law methodology. A wide variety of physical phenomena that can occur over a wide range of magnitudes follow power law (e.g. volcanic eruptions, earthquake fault ruptures, avalanche). Most identified power laws in nature have exponents such that the mean is defined but the variance is not, implying

---

[5] https://journals.ametsoc.org/view/journals/clim/34/1/jcliD200367.xml

they are capable of “Black Swan” behavior. This behavior is what produces the linear relationship when logarithms are taken (generates a straight-line in log-log plot), a signature of a power law. However, the power law function is unbounded and allows for infinite large losses which can overstate the tail. Since exposed values are finite, building codes are designed to withstand minimum wind or shake loads, and limits are applied on (re)insurance contracts, damage is attenuated. Asymptotic power law function still mimics the signature behavior of power law, but it is bounded by asymptotic limit.

Scenario A: Active AMO

The Atlantic Multi-decadal Oscillation (AMO) is a natural variability in the North Atlantic Ocean associated with sea surface temperatures (SST) on multidecadal timescales (Figure 2). Hurricanes have periods of high and low activity linked to AMO (Figure 3).

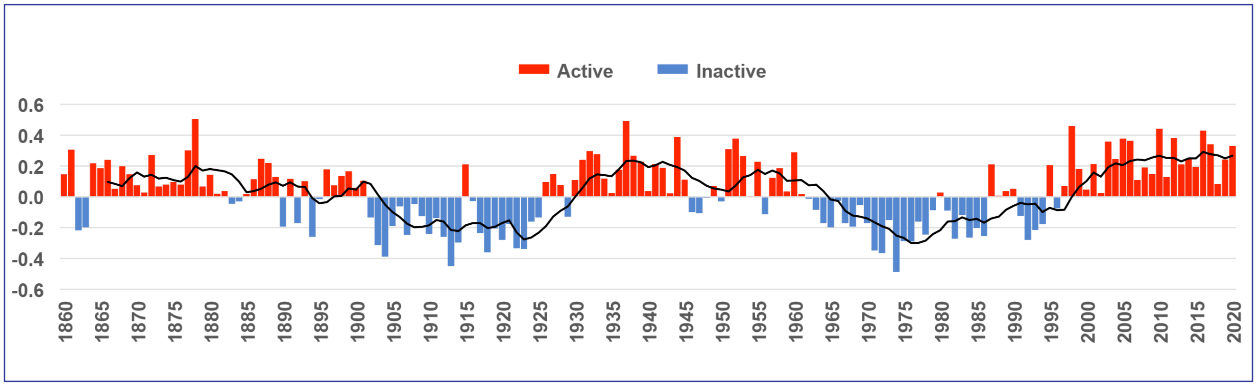

Figure 2: *AMO phases 1860 to 2020*

Research studies[6] show that the frequency of weak-category storms – tropical storms and minor hurricanes – is not much affected by the AMO. However, the number of weak storms that mature into major hurricanes is noticeably increased during the warm phase of the AMO (Active AMO). Thus, the intensity is affected, and clearly the frequency of major hurricanes is also affected. The current research studies on the impact of climate change on tropical storm activities suggest a similar behavior.

[6] https://www.aoml.noaa.gov/phod/faq/amo_faq.php#:~:text=top-,Does%20the%20AMO%20influence%20the%20intensity%20or%20the%20frequency%20of,much%20affected%20by%20the%20AMO.&text=Thus%2C%20the%20intensity%20is%20affected,major%20hurricanes%20is%20also%20affected

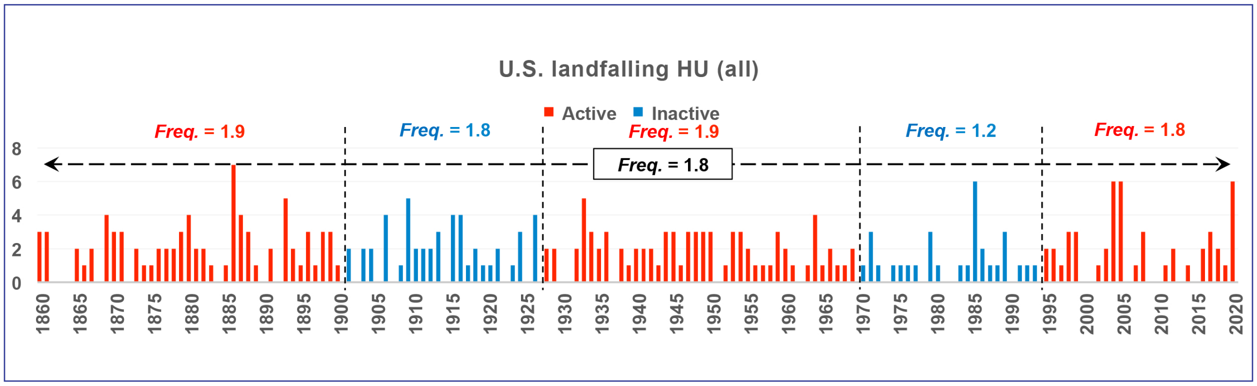

Figure 3: *U.S. hurricane landfalls (1860-2020) and the "mean" frequency variation due to AMO phases*

The analysis of the 160 years of history suggests a 6% increase in the frequency of U.S. landfalling hurricanes in Active AMO compared to the long-term average, whereas the increase in major hurricane category is 5%. During Active AMO the uncertainty around the mean increases approximately by 8%. A 5% increase in frequency of major hurricanes is similar to the PRA scenario A (Table 4).

As discussed in section 2, the IPCC AR6 for different SSP (RCP) temperature change projections are provided based on three time-scales relative to the reference period of 1850-1900. However, as shown in Figure 4, we can assume in the next 5 to 10 years the RCP2.6 and RCP4.5 projection trends on global temperature rise are very similar. TransRe's research team suggests using the "Active AMO" scenario as a proxy for the climate change impact under the short-term RCP4.5 projection.

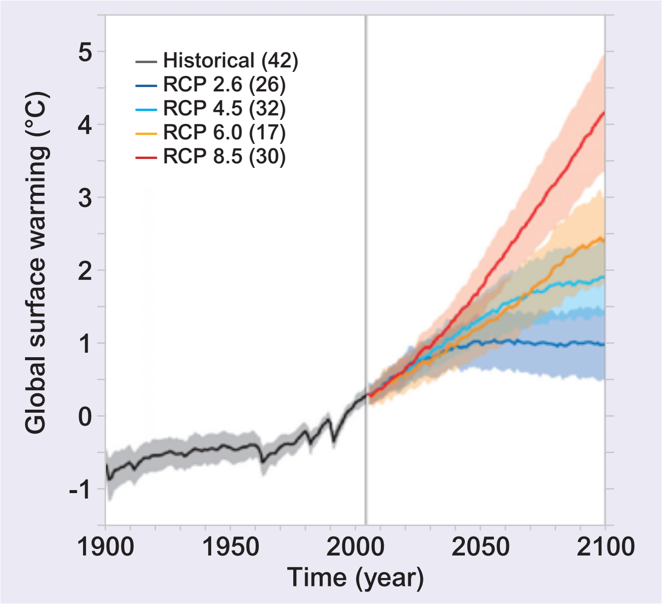

Figure 4: *Global temperature increase used in IPCC-AR5 presented by the RCPs. The values in parentheses represent the number of Global Climate Models (Source: Knutti and Sedlácek, 2013)*

Scenario B: La Niña

El Niño-Southern Oscillation (ENSO) is one of the large-scale climate systems that influence weather extremes globally (e.g. temperature and precipitation) which relates to the sea surface temperatures (SST), in the central and eastern tropical Pacific Ocean. It has three states/phases: two opposite phases of “El Niño” and “La Niña,” and a “Neutral” phase in the middle of the continuum. Arrival of an ENSO phase can often be predicted a few seasons in advance of its strongest impacts on weather and climate. La Niña enhances hurricane activity in the Atlantic and reduces typhoon activity in the Pacific whereas El Niño reduces hurricane activity in the Atlantic and enhances typhoon activity in the Pacific.

La Niña weakens the wind shear over the Caribbean Sea and tropical Atlantic Basin which provides a more suitable environment for storms to develop and intensify and increases hurricane activity in this Basin. Historical data (Figure 5) suggests that under La Niña condition mean landfall frequency increases by about 17% (27% for major hurricanes) compared to the long-term average landfall frequency (1950-2020). This scenario is similar to Kerry Emanuel’s analysis that suggests a 17% increase in global landfall frequency (26% for major hurricanes) under the assumption of doubling the carbon dioxide by the end of the century. Historical data also suggests that the uncertainty around the mean frequency increases by about 14% during La Niña.

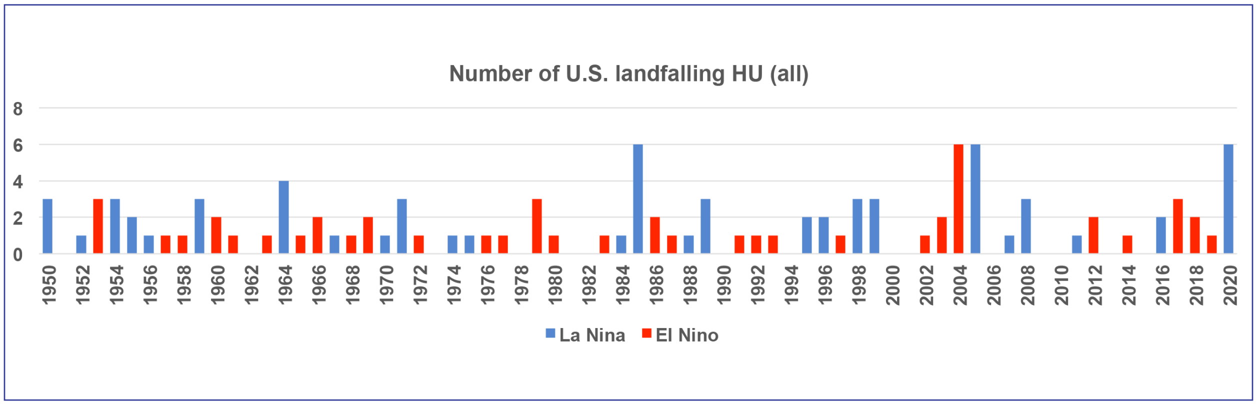

Figure 5: U.S. hurricane landfalls (1950-2020) and the "mean" frequency variation due to ENSO states

TransRe considers this scenario as an approximation for a short-term RCP8.5 or medium-term RCP4.5 projection that addresses the impact of mean frequency increase as well as considering the change in physical damage in relation to higher risk variation.

Scenario C: Active AMO and La Niña Combined

The third scenario considers a combined impact of Active AMO and La Niña on U.S. hurricane risk. Historical data (1950-2020) suggests that the mean frequency increases by 25% (35% for major hurricanes) when considering Active AMO combined with La Niña phase. With this assumption, increase in uncertainty is about 17%.

This scenario can be used as a proxy for short-term climate change impact under RCP8.5. The increase in major hurricane frequency is higher than the PRA scenario B (20% increase in mean frequency) and is lower than the PRA scenario C (60% increase in mean frequency). Similar to the other two scenarios, by using this scenario, one can capture the climate change impact on mean frequency and in relation to higher risk variation.

4 Discussion on Climate Change and Impact on Volatility

Commercial catastrophe models and conventional industry practices lean towards Poisson-like frequency distributions, which assume event occurrences are independent. For Poisson-distributed random variables, the mean (μ) and variance (σ^2) are equal. Therefore, the ratio of variance to mean is equal to one. Actual catastrophe frequency distributions are "fat-tailed" ($\sigma^2/\mu>1$) and for certain perils are considerably more fat-tailed than Poisson. The scientific assessment of climate change impact of TC suggests an increasing trend in very intense TC frequency (category 3-5). This means that TC frequency distribution is even more fat-tailed under the future climate conditions. Therefore, it is highly important to have a framework that captures the impact on both mean frequency and risk variation.

Table 5 provides the change on the industry losses from the baseline for each scenario. The figures in Table 5 only represents the frequency change. The increase in severity is not included in these figures. The analysis shows the comparison between considering the change in only "mean" frequency and looking at the impact on both mean and volatility. The financial impact is more significant, especially in the tail when the combined effect of "mean" and "volatility" is considered. As an example in scenario C, the impact on the tail losses (above 250-year return period) is two times higher when the effect of climate change on volatility is also included.

Table 5: Climate change impact on insured industry losses – increase in "mean only" versus increase in both "mean" & "volatility"

Return Period	Scenario A		Scenario B		Scenario C	
	Mean only	Mean & volatility	Mean only	Mean & volatility	Mean only	Mean & volatility
1,000	0%	5%	1%	10%	8%	19%
500	0%	5%	2%	8%	6%	16%
250	1%	5%	3%	7%	8%	13%
100	1%	5%	3%	9%	10%	12%
50	1%	4%	6%	7%	10%	15%
20	3%	4%	9%	11%	14%	24%
AAL	5%	7%	9%	12%	18%	29%

ESG
@TransRe™

Contact

To discuss any of the contents of this paper, please contact the author:

Maryam Haji, PhD
Vice President, Head of Catastrophe Research
T: 1 212 365 2347
E: mhaji@transre.com