WHY NATURAL CATASTROPHE FREQUENCY-SEVERITY ADJUSTMENTS **UNDERESTIMATE TAIL RISKS FROM CLIMATE CHANGE**

BY **CAMERON RYE**

Climate scenario analysis has advanced significantly in recent years, with many insurers now adjusting natural catastrophe models to explore how physical risks could change over the coming decades. Extreme weather events – such as windstorms, floods, and wildfires – are projected to become more frequent and severe in many parts of the world. As a result, actuaries, catastrophe modellers, and regulators have focused their attention on methods for modifying frequency-severity relationships.

While these adjustments have provided valuable insights, there has been insufficient attention placed on scenario completeness, particularly in the tail of the distribution where some of the most severe impacts are expected to materialise. With the Institute and Faculty of Actuaries recently publishing a paper on how climate scenarios currently used in financial services could be significantly underestimating the risk[1], it is time to place increased focus on whether the adjustments we are making are consistent with expectations.

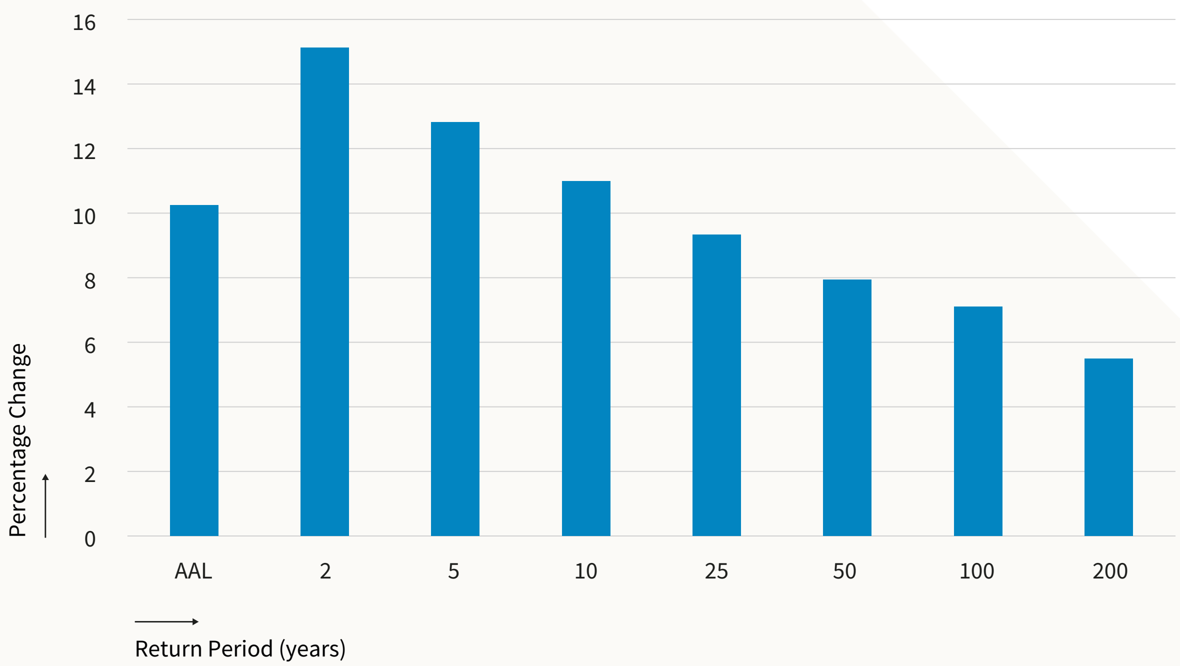
LARGER INCREASES AT SHORTER RETURN PERIODS

Tropical cyclones are one of the largest loss drivers for the insurance sector globally. Building scenarios to understand how the risk from these storms may evolve in the future is therefore important for informing decision-making, risk management, and resilience.

Most insurers currently base their tropical cyclone scenarios on a research paper by Knutson *et al.* (2020), which presented a synthesis of the expected changes in global tropical cyclone activity for a 2°C warming[2]. One of the key outcomes of this paper is that the frequency of very intense cyclones (Category 4-5) is expected to increase. This and other findings from Knutson et al. have been utilised by insurers to resample catastrophe model event sets.

As an example, *Figure 1* shows the impact of a hypothetical 20% increase in the number of Category 4 and 5 landfalling storms in a U.S. tropical cyclone model. The largest effect is seen near the bottom of the exceedance probability curve, with a 15% increase at the 1-in-2-year return period loss. In comparison, tail losses around the 1-in-200-year return period increase by 5.5%. >

FIGURE 1: The percentage change in losses for a hypothetical 20% increase in the number of Category 4 and 5 landfalling hurricanes in a U.S. tropical cyclone model. Selected return periods and the Average Annual Loss (AAL) are shown. The adjustment was applied by randomly resampling a 100,000-year simulation, based on the storm intensity at landfall.



The larger increase at shorter return periods seems counterintuitive at first. This is because many of us associate an increase in severe tropical cyclones with an increase in tail risk from events like Hurricane Andrew, which hit Miami in 1992. If a Category 5 storm made landfall in Miami today, the insured loss would likely be in the region of $150 billion. But there are many strong storms that also occur at shorter return periods. For example, in 2018 Hurricane Michael made landfall as a Category 5 storm on the Florida panhandle, resulting in only around $10 billion in insured losses at the time.

In the historical record, the annual rate of a Category 4-5 landfalling storm in the U.S. is 0.24. In a 100,000-year simulation, we would therefore expect approximately 24,000 Category 4-5 events. Given that the tail of the distribution beyond the 1-in-200-year return period accounts for just 500 years of the simulation, the vast majority of these storms will occur at shorter return periods. This means that when an event set is resampled to include more Category 4 and 5 hurricanes, the number of small and mid-sized losses will be increased the most, which pushes shorter return periods up higher percentage-wise than the tail.

This is surprising given that the tail of the distribution is expected to contain some of the most severe physical effects of climate change, particularly under higher emission scenarios. As a result, we must ask, *'Where is the tail risk from climate change?'*.

UNQUANTIFIED TAIL RISKS

Traditional models do not handle fat-tailed events well, as Nassim Taleb has written about in relation to financial markets[3]. This means that crucial aspects of the risk are likely to be overlooked. The same is true for traditional catastrophe models in terms of climate change: while frequency-severity distributions can be conditioned for various climate states, they underestimate the true tail risk because a number of direct and indirect effects are missing. >

For example, there is the possibility that climate change could result in an increase in serial clustering for some perils, which is when multiple events impact a region in close succession. This would mean that we witness more instances as in 2017, when three hurricanes - Irma, Jose, and Katia - threatened land concurrently in the North Atlantic. An increase in event clustering would lead to an increase in tail losses. But most scenarios do not consider this possibility, with insurers often assuming that historical clustering behaviour is unchanged in the future.

Another important example is climate tipping points, which many insurers exclude from their thinking because they view such outcomes as far-off problems. However, there is growing evidence that some tipping points, for example, the rapid collapse of ice sheets or the melting of Arctic permafrost, may be triggered once we pass 1.5°C of warming. The world is expected to reach 1.5°C at some point in the 2030s, meaning some of these fat tail consequences could be closer than many realise.

In addition to direct physical risks, there are multiple indirect effects that are frequently overlooked, including supply chain disruption, food insecurity, geopolitical conflict, and infrastructure failure. All of these have the potential to manifest as systemic risks, increasing the tail of the loss distribution.

SCENARIO COMPLETENESS

This is not to discount the value of catastrophe models. They bring together detailed information on hazard, vulnerability, and exposures in ways that other tools, such as climate models, cannot. However, just as insurers analyse and quantify non-modelled risks today (for example, under Solvency II), they must apply the same thinking and techniques to climate change adjustments and scenarios.

The breadth and complexity of climate change tail risks mean that careful consideration is required when incorporating them into our modelling. In some situations, it will be possible to explicitly simulate the effects – such as serial clustering – within existing modelling frameworks. But it will be more challenging for other risks, particularly those with socio-economic and systemic components. These more intricate risks may require tail loadings, similar to how post-event loss amplification is applied today to account for difficult-to-model factors such as demand surge and mass evacuations.

All of this means that when you next think about building or updating your climate change scenarios, it is vital to consider not only how to best adjust frequencies and severities, but also how comprehensive and complete your risk assessment is. <

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[1] Trust, S *et al.*, *The Emperor's New Climate Scenarios: Limitations and assumptions of commonly used climate-change scenarios in financial services*, The Institute and Faculty of Actuaries (2023).

[2] Knutson T. et al, *Tropical cyclones and climate change assessment: Part II: projected response to anthropogenic warming*, BAMS 101(3):E303–E322 (2020).

[3] Taleb, N., Statistical Consequences of Fat Tails: *Real World Preasymptotics, Epistemology, and Applications (Technical Incerto)*, STEM Academic Press, ISBN-10 1544508050 (2022).