Natural Perils: Tropical Cyclones, Extra-tropical Cyclones and Wildfire

Natural perils are key contributors to the risks that we face as a (re)insurer. The hazards they present are prevalent all over the world, but their impacts are felt only in specific geographic regions, as it is the amalgamation of localised climatic and weather conditions, exposures and vulnerabilities that combine to create risk. AXA XL has carried out extensive research into the possible effects of climate change on the intensity and frequency of future climate peril systems, yet our ability to quantify the contributions from exposure and vulnerability remains a challenge. In the following sections we highlight some of the insights we have thus far gained into weather and climate hazards and point to areas of scientific and engineering research where AXA XL is progressing work on exposure and vulnerability.

Tropical Cyclones (TCs)

In terms of average annual losses, TCs are the costliest peril to the global (re)insurance industry. More widely, they are regularly devastating to human life, particularly in communities that struggle to incentivise disaster mitigation and resilience. Although TCs are given different names in different basins, they all form from the same physical processes and, once established, maintain a similar axisymmetric structure of rainbands which spiral inwards to an intense eyewall and an area of calm within the eye. Although formation is largely confined to the tropics, TCs regularly track into the mid-latitudes (i.e. poleward of 30°) and impact coastlines there as sub-tropical, post-tropical, transitioning or extra-tropical cyclones. The broad impact that TCs have had on society has led to significant research on the topic, and academic literature is rife with theorized impacts of climate change on global TC activity.

The following sub-sections outline a few of the aspects of TC hazard as it pertains to catastrophe modelling, and which of them AXA XL believes will play a crucial role in understanding TC risks under a changing climate.

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By John Wardman

Figure 1: Expected changes to frequency and intensity characteristics of tropical cyclones in the scenario where global temperatures increase by 2°C (the blue line shows the median increase and the bars the 5th and 95th percentile ranges) (from Knutson et al., 2020).

Average Frequency & Intensity

Knutson et al. (2020)[1] provided a comprehensive synthesis of modelling studies that look at basin-wide changes under a 2°C climate change warming scenario. A summary of their results can be seen in Figure 1, and the findings suggest that, on average, the frequency of TCs globally are projected to decrease by a median of 14%, while average intensities are projected to increase by a median of 5%. Knutson et al. also found the proportion of category 4 and 5 storms within the resultant frequency-intensity distribution increases by ~13% under this 2°C warming scenario, and that the rain rate of TCs is also likely to increase by ~14%. While such scenario tests offer valuable insight into the possible impacts of climate warming on global TC hazard, it is important to acknowledge the large uncertainty ranges around these projections, and note that for almost all regions, the uncertainty straddles the zero % change line, indicating low confidence in the exact magnitude of the changes, and also considerable uncertainty regarding the direction of the changes.

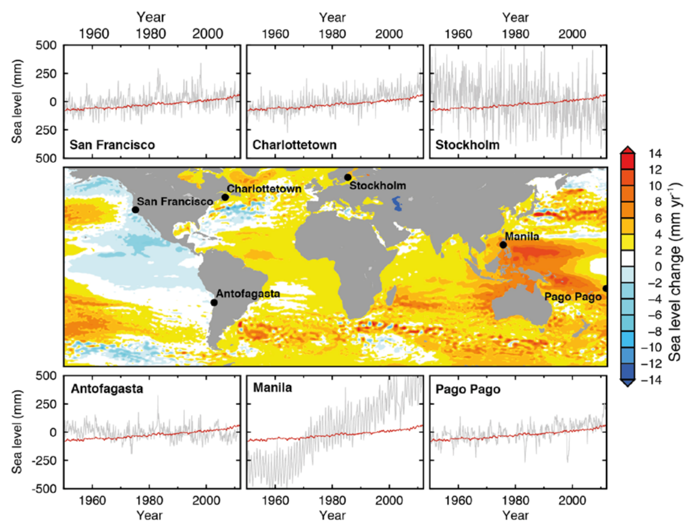

Figure 2: Global sea level changes relative to land since ~1950 with trends shown for certain places (grey lines = local change, red line = globally averaged trend)(from IPCC, 2013)

Sea Surface Height

It is well understood that sea level rise will, on average, increase the impact from TC storm surge. However, this picture becomes much more complex when we begin to disaggregate the global average to instead look at local impacts. At a local level, it is much more appropriate to use the term sea level change, because land is almost always in motion – either upward or downwards – but on extremely slow (i.e. geological) time scales; importantly, timescales between different parts of the land differ. Thus, in some areas land may be rising at a faster rate than sea level (e.g. from isostatic rebound, which is the gradual rise of land masses in response to the receding of heavy ice sheets emplaced during the last glacial period), and thus risk from storm surges would actually be decreasing. Figure 2 (from the IPCC AR5, 2013)[2] shows how sea level relative to land is changing around the world, along with trends in select locations (grey lines = local change, red line = globally averaged trend). For instance, while Manila is quickly becoming more susceptible to storm surge impacts, places like Stockholm seem to be on a slightly decreasing trend.

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Translation/ Forward Speed

Translation speed (defined as the speed at which a TC shifts from one point in space to another) is an important feature because the slower TCs move, the longer their influence time, and the greater the potential societal impact of associated hazards such as heavy rain and strong winds. However, there is much debate around the changes that have been observed in translation speeds for global TCs. Recent research has shown that there was a 10% slowdown in global tropical-cyclone translation speed over the 68 years between 1949 and 2016 (Kossin, 2018)[3], in part due to the weakening of tropical circulation brought about by anthropogenic-induced climate change. However, this claim is refuted when analysing data from the period of satellite observation (i.e. from the 1970s), which is considered more accurate and reliable (Lanzante, 2019)[4]. The relationship between the slowdown of TCs and anthropogenic warming, is therefore, not clear, and the relevant potential increase in local rainfall totals under a future warming climate is also not clear. This contradiction highlights the uncertainty that exists within the science and the need to remain objective when developing our view of TC risk.

The abovementioned aspects of TC hazard are not novel concepts and represent the findings from decades of in-depth and intense analysis by industry and academic experts alike. Generally speaking, the (re)insurance industry has a much weaker understanding of TC vulnerability and exposure, and ongoing analysis at AXA XL suggests that, in the short-term (i.e. next 10 years), we believe the biggest driver of change in TC risk will be from continued accumulation of wealth and assets in areas with pre-existent material hazard. We are focused on strengthening our understanding of exposures by enhancing our data, whilst exploring how future exposures and vulnerabilities might evolve in response to the changes in the hazard we expect to see.

Extra-Tropical Cyclones (ETCs)

ETCs are the scientific terms for EU windstorm, US winter storms and other synoptic scale-scale (~100km) storms that occur at the mid-latitudes. Although similar to TCs in that they (i) see large scale cyclonic flow that spirals in towards a centre and (ii) are associated with extreme winds, precipitation and, in some regions, storm surges, there are fundamental differences in their formation mechanisms and structure that make them very distinct from TCs. While TCs form from atmospheric instability that is usually the result of a pre-existing convective disturbance at the surface and mid-levels of the troposphere, ETCs form from a type of upper-level instability called baroclinic instability. This is where disturbances in the atmosphere are created that ETCs can feed off. Typically, you can think of them as areas where you see clashes of poleward and equatorial air masses. Although theoretically they can form at any time of the year, they tend to form most often during winter seasons as the gradients between poleward and equatorward air masses tend be at their strongest. There is less literature when it comes to impacts of a changing climate on ETCs, but work that has been done to date has focused on the frequency and intensity changes across the mid-latitudes. Work done by Catto et al. (2011)[5] looked at three different climate scenarios to investigate the impacts that these might have on future ETC activity. Their findings were inconclusive as irregular changes were apparent across the entirety of the northern hemisphere and there did not appear to be an overall clear average increase or decrease of storm activity under either scenario (rather, it was the patterns which seemed to shift). In a later study, Catto et al. (2019)[6] attempted to synthesize some additional research on ETCs and concluded that results from future modelling of the peril remain inconsistent and therefore difficult to infer reliable information from the studies. They hint, however, that the models point to a change, but that predicting precisely how that will happen is beyond contemporary science at the moment.

As with TCs, vulnerability and exposure are the components of the ETC risk equation which have received the least amount of research focus to date. Rather than hinder our work on quantifying climate change impacts, near-term focus on exposure and vulnerability will more readily help us to constrain the hazard impacts that we may see in a changing climate. AXA XL has initiated this research roadmap and is engaging with leading experts to fill crucial knowledge gaps.

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Wildfire

Wildfire, like most climatically linked hazards, is highly episodic in many parts of the world. However, unprecedented insured losses from catastrophic wildfires in California during 2017/18/20 and the substantial area of burned land during the 2019-20 Australia bushfires raise the question of whether we are entering a new phase of heightened wildfire activity. As the sophistication of contemporary wildfire risk models lags behind that for more frequent and material perils such as North Atlantic windstorm, it is essential that we propel independent research and forge partnerships with leading experts on the topic. Recent incentives at AXA XL seek to do just this: to better understand the key drivers of wildfire hazard, vulnerability and exposure.

On Hazard

Sparse global fire-climate projections suggest there will be spatially variable responses in fire activity, including strong increases and decreases (Figure 3) due to regional variations in the climate–fire relationship, and anthropogenic interference (Moritz et al., 2012)[7].

These findings propose that populated areas of the US, Europe, Australia, and the western side of the Andes in South America will see substantial increases in fire danger and fire activity (i.e. hazard). However, the diversity of modelling approaches and failure to incorporate the influence of vulnerability and exposure on the risk equation confounds efforts to synthesise how changes might occur globally. Thus, we must always look locally when estimating likely changes to wildfire hazard. As a recent collaboration between AXA XL and wildfire experts from the University of California at Merced highlights, future wildfire regimes will be affected differently in different biomes, and changes in hazard from climate change is but one of several equally important factors driving future wildfire risk.

On Exposure

Rapid growth in the wildland-urban interface (WUI) has increased the risk to vulnerable populations. The largest insured losses consistently occur in the WUI, and a study by Kramer et al. (2018)[8] found 82% of all US buildings destroyed by wildfire between 1985–2013 were in this zone. Population and associated infrastructure growth introduce more sources of ignition and lead to suppressed fires, allowing the build-up of excess fuels. The result has been a change in the frequency of large fires (the hazard), demonstrating that the impacts from increasing exposure on overall wildfire risk are far reaching.

Recent work by Alexandra Syphard (2020)[9] looked at the change in urban development and wildfires over 60 years in San Diego County, California (Figure 9). Whereas no homes were destroyed during the 1940s, more than 5,000 were destroyed in this same area during the 2000s despite similar levels of fire frequency. An 871% increase in development between these time periods is further evidence that human expansion into an already flammable landscape is a primary driver of losses. Future research in this space at AXA XL will therefore look to quantify the impact that population growth has had on overall wildfire risk, and to develop strategies to further manage exposure in an evolving risk landscape.

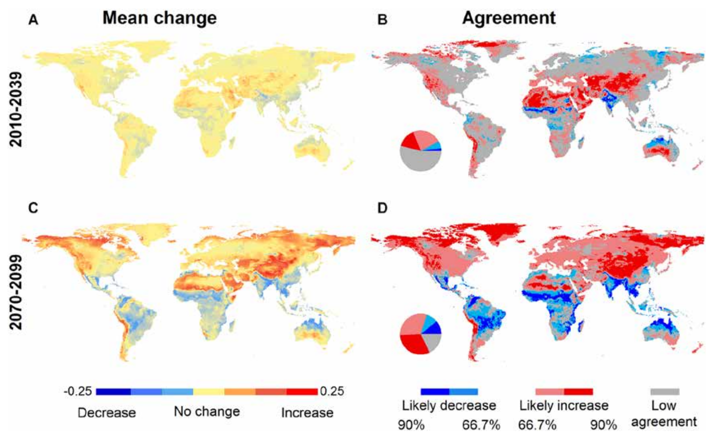

Figure 3: Ensemble mean change (A, C) and degree of model agreement (B,D) in predicted fire probability for 2010-2039 and 2070-2099. Pie charts indicate global proportions in each agreement class: likely decrease, likely increase and low agreement correspond to 8.1% and 54.1% for the 2010-2039 period, and to 20.2%, 61.9% and 17.9% for the 2070-2099 period (from Moritz et al., 2012)[7].

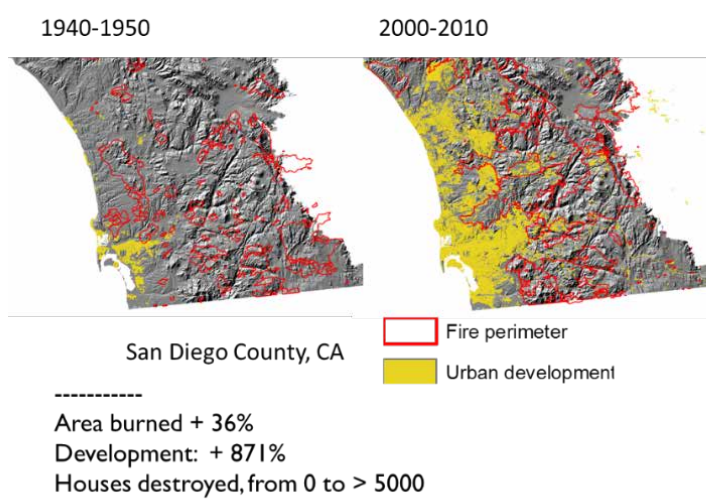

Figure 4: Changes in fire activity and urban development over a sixty-year period in San Diego County, California. While no homes were destroyed in the 1940s, more than 5000 were destroyed in the 2000s, as development grew by 871% Syphard (2020)[9]. This contrasts with the moderate change in area burned (+36%) over this same period.

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On Vulnerability

From 2005 to 2020, wildfires have destroyed more than 89,000 structures across the United States (Barrett, 2020)[10]. Many of the conditions which facilitate large and high-intensity wildfires are not necessarily conducive to structure (i.e. insured) loss. The vast majority of wildfire prediction modelling to-date has focused on predicting ignition, fire spread, and basic fire behaviour across vegetation, with very little to no prior research on how vegetation fire quantitatively transitions from the landscape to structures and subsequently destroys them. AXA XL regularly communicates with third-party vulnerability experts such as the Insurance Institute for Business and Home Safety (IBHS) to obtain insight into the best practices for reducing wildfire risk to homes in suburban areas and/or the WUI.

Considering the binary nature of observed structure damage from fire (i.e. wildfire damage to structures tends to be either minimal or a complete loss), AXA XL is working to identify the key drivers of structure vulnerability to support clients in mitigating their wildfire risk, either through hardening of structures using fire-resistant material and/or reducing the intensity of a potential fire around the structure. Improving data capture and the quality thereof from our clients will further augment our efforts to develop robust wildfire risk prevention strategies.

Conclusions

TCs: TC impacts are a primary driver of annual losses within the (re)insurance industry. AXA XL stays abreast of the science to ensure that we are objectively factoring in the latest views into our views of risk. Although there is some evidence to suggest that some aspects of TC hazard may increase in the future (e.g. precipitation, wind), other aspects of it may decrease (e.g. frequency). The slow speed with which these signals will become clearer means that our focus in the short-term should be around the exposure and vulnerability when thinking about the risk we face as (re) insurers.

ETCs: Historical statistics of ETCs show that there have been no reliable/ detectable climate change trends at all in frequency and intensity of ETCs in the recent past. However, the scientific community is largely in agreement that climate change will cause a change to frequency and intensity patterns of ETCs going forward, but it is far beyond reliable science to say exactly how and at what timescales. Given this uncertainty in ETC hazard, we aim to continue our focus on aspects of exposure and vulnerability to ensure we understand holistically the risks we face from ETCs.

Wildfire: AXA XL actively engages with leading experts in the field of wildfire science and engineering to develop robust views of risk. Ongoing work focuses on understanding the relative contribution to risk from the three components of hazard, vulnerability and exposure. Working closely with leading experts from each of these fields, we intend to expand our understanding of this hazard in order to provide greater insights for ourselves and our clients.

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