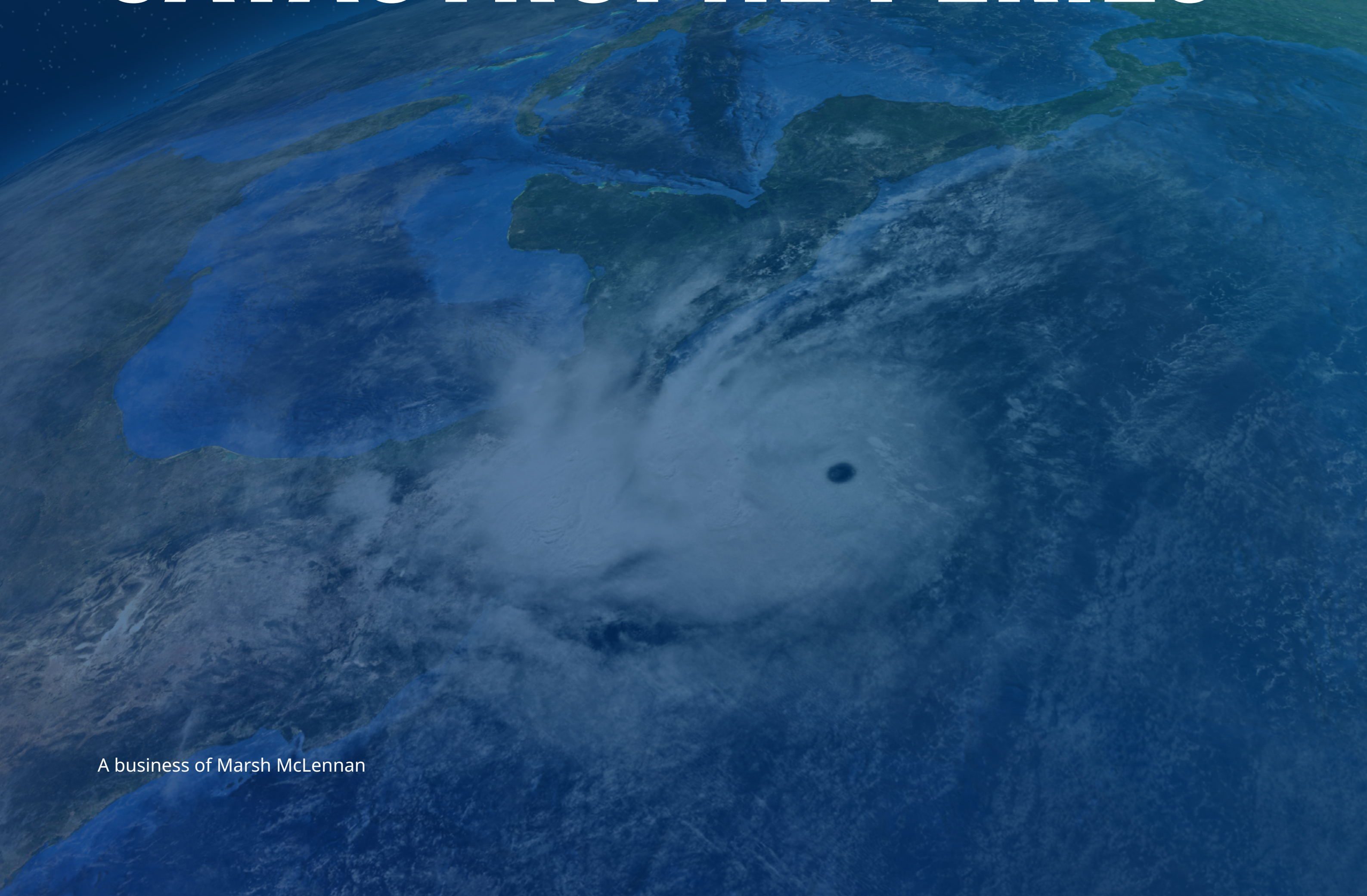
GuyCarpenter

GC BRIEFING

CLIMATE CHANGE IMPACTS ON NORTH AMERICA CATASTROPHE PERILS



A business of Marsh McLennan

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EXECUTIVE SUMMARY

Climate change and connections to extreme weather are of growing interest after multiple years of elevated insured losses globally. More concerning for society is the growing disparity between insured and economic losses, commonly referred to as the protection gap. Increasing industry sentiment of quantifying and taking action on climate change, illustrated prominently in the World Economic Forum Global Risk Report 2020 (Franco, 2020), builds on well-established research about the human impact on climate change. The Fourth National Climate Assessment (NCA4), published in 2017 by the U.S. Global Change Research Program, concluded that it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the clear observed trend of both surface and ocean warming since the mid-20th century. Natural cycles in our planet ocean/atmosphere system, inclusive of investigation of solar output changes, only contribute marginally to observed changes in climate over the last century. Slight shifts in the means of temperatures over a period of years to decades have a magnifying impact on the tails of outcomes. Yet, on shorter time scales, natural variability of ocean and atmospheric processes can, and indeed do, have a pronounced influence on shorter time scales of months, seasons, to the span of several years. The NCA4 assessment builds upon the fifth assessment report (AR5) from the International Panel on Climate Change (IPCC) published in 2014.

Figure 1: Top 5 Global Risks in terms of Likelihood

Economic | Environmental | Geopolitical | Societal | Technological

	1st	2nd	3rd	4th	5th
2010	Asset Price Collapse	China economic slowdown	Chronic disease	Fiscal crises	Global governance gaps
2011	Storms and cyclones	Flooding	Corruption	Biodiversity loss	Climate change
2012	Income disparity	Fiscal imbalances	Greenhouse gas emissions	Cyberattacks	Water crisis
2013	Income disparity	Fiscal imbalances	Greenhouse gas emissions	Water Crisis	Population ageing
2014	Income disparity	Extreme weather	Unemployment	Climate action failure	Cyberattacks
2015	Interstate conflict	Extreme weather	Failure of national governance	State collapse or crisis	Unemployment
2016	Involuntary migration	Extreme weather	Climate action failure	Interstate conflict	Natural catastrophes
2017	Extreme weather	Involuntary migration	Natural disasters	Terrorist attacks	Data fraud or theft
2018	Extreme weather	Natural disasters	Cyberattacks	Data fraud or theft	Climate action failure
2019	Extreme weather	Climate action failure	Natural disasters	Data fraud or theft	Cyberattacks
2020	Extreme weather	Climate action failure	Natural disasters	Biodiversity loss	Human-made environment disasters
2021	Extreme weather	Climate action failure	Human environment damages	Infectious diseases	Biodiversity loss

Figure 1: The top five global risks to the world economy progressing from 2010 to 2021. As noted in the World Economic Forum 2020 Global Risks Report, "respondents to the Global Risk Perception Survey are sounding the alarm, ranking climate change and related environmental issues as the top five risks in terms of likelihood – the first time in the survey's history that one category has occupied all five of the top spots."

A number of key conclusions compiled across numerous government and academic institutions provide strong evidence and high consensus on the following aspects of our changing climate:

Peril	Theoretical Impact	Historical Observations	Future Projections
Atlantic hurricane	Warmer ocean temperatures provide more energy for hurricanes to develop and intensify. Wind shear may counter impact.	Any statistically significant trend in the Atlantic basin is masked by natural cycles of the Atlantic Multidecadal Oscillation, ENSO and interannual variability.	Increasing rainfall due to slower moving landfalling hurricanes. Potential increase in most severe category 4-5 events. Frequency projections indeterminate.
Sea Level Rise	Loss of ice from glaciers, polar ice caps and warming ocean temperatures via thermal expansion cause sea level rise.	Global sea levels have increased by 7-8 inches since 1900. Local or regional variations occur where land is sinking or rising concurrently.	The 2020s will transition to more frequent 'sunny day high tide flooding' in certain locales. Severe flooding from storm surge will increase.
Wildfire	Longer and hotter dry season with favorable spring vegetation growth increasing fuel risk. Stalling weather patterns may prolong duration of wet periods to promote fuel growth, and also of hot, dry periods to promote fuel curing & potential ignition.	Heat waves and droughts are increasing in frequency, intensity and duration. Wet periods are wetter, dry periods drier.	Snow pack melts earlier/faster and precipitation more likely to be rain increases risk. Southwestern US prevalence of drought.
Flood	A warmer atmosphere has the ability to hold more moisture. Warmer oceans further increase precipitation rates due to increased evaporation. Stalling weather patterns may prolong duration of rainfall events.	Increase in annual rainfall (north and east) while decrease southern and western US. Increases in frequency and intensity of heavy rain events.	Urban development exacer bates higher precipitation trends due to increased runoff. Regional shifts in seasonal rainfall activity.
Hail, Wind, Tornado, Lightning	Increased surface temperature and moisture increases the risk. Upper air patterns may decrease the risk. A potentially longer SCS season may increase the risk on an annual basis.	Possible increase in large outbreak days, downward trend in total number tornado days.	Probable increase in large hail days. Increase in season length. Enhanced year to year volatility in tornado counts.
Winterstorm	Warmer winter days increase potential for rain instead of snow. Decrease in severe cold and nighttime minimum temperatures. Stalling weather patterns may prolong periods of cold, snow.	Significant increase in large eastern US snowstorms in 2010s, inconclusive if this trend will continue in subsequent decades.	Projected decrease in frequency, increase in severity, with a poleward shift with expectation of increasing sea surface temperatures. Potential linkage to jet stream and Arctic sea ice loss.
Heatwaves	A warming planet should decrease cold temperature extremes, increase warm extremes, with an overall increase in global temperature.	Average number of US heatwaves has tripled since 1960s in largest 50 cities, lasting longer in duration.	Significant increase in very hot days will drive significant decreases in life quality and economic disruption of labor and agriculture. Mortality rate increases due to excessively high nighttime temperatures. Potential impacts on energy demands and strain on energy systems.

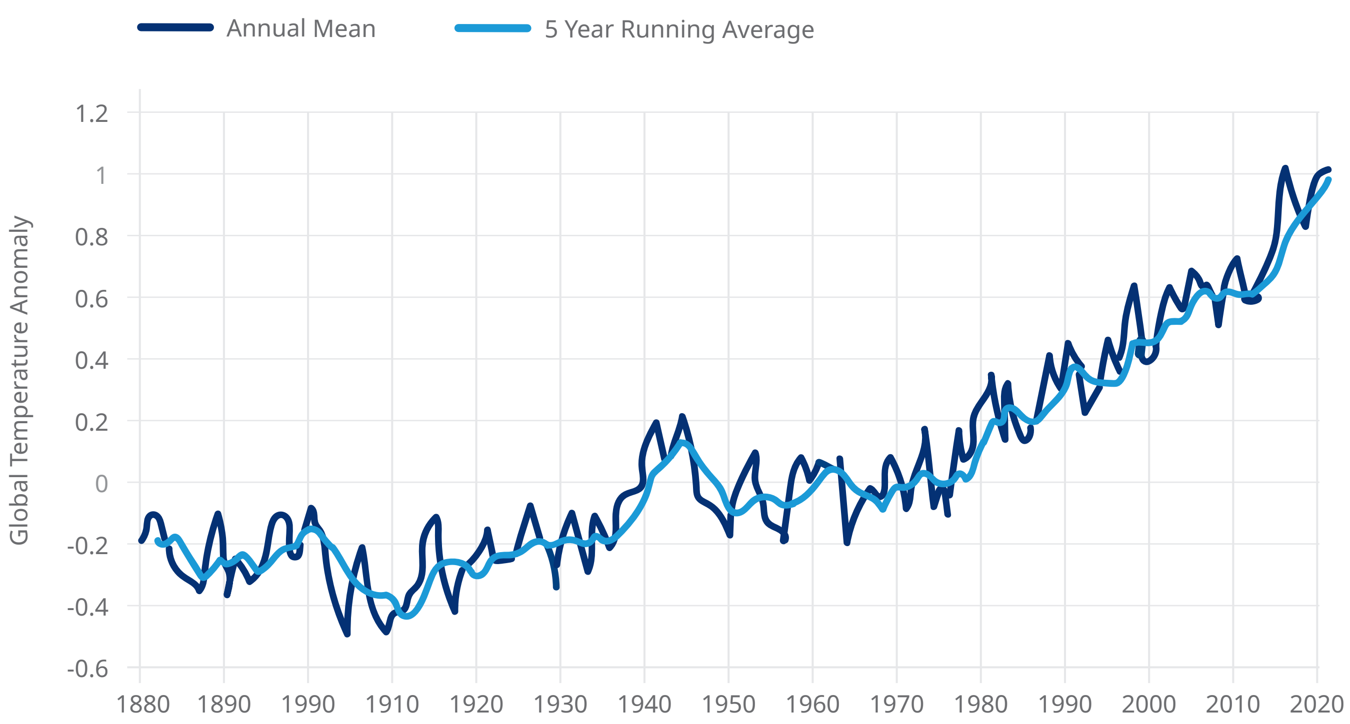
Table 1: An assessment of the changing climate impact on specific perils across the theory, historical trend analysis and expectation of future projections of change in frequency, severity and regionality where appropriate.

The assessments put forth in the aforementioned table compile seminal scientific literature on climate change trends and extreme weather found in observational datasets, attribution studies, and climate models simulating future trends. The most complete sources of information are governmental studies such as the assessment reports released by the IPCC or the United States 4th National Climate Assessment. These documents are subject to a rigorous review process by multiple authors and represent the best available consensus at the time of publication; however, they are released infrequently and may not reflect the most up-to-date science. Official findings from the NCA and IPCC are augmented with the best available scientific literature, where the scientific consensus has evolved among a cohort of respected scientists. A single scientific finding should be considered in the context of a bigger picture derived from multiple publications, with a view to the best scientific consensus among respected authors in the field.

THE RISING CONSENSUS ON CHANGING CLIMATE

The growing interest of risk managers, regulators, investors and the general public in climate change is increasing the need among insurers to understand its impacts. At the time of the last Intergovernmental Panel on Climate Change's (IPCC) assessment report, global temperatures had increased by 0.85°C over the period 1880-2012, with warming becoming more rapid in more recent decades (IPCC, 2013). Since that report, temperatures jumped an additional 25 percent over the period 2014-2016, adding another 0.24°C to the global mean (Yin et al., 2018). Figure 2 illustrates a report from the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) on the annual surface temperature anomalies since 1880 through 2020, where the latest global temperature in 2020 was 1.27 °C above the pre-industrial era'.

Figure 2: Global Ocean-Land Surface Temperature Anomaly (°C)



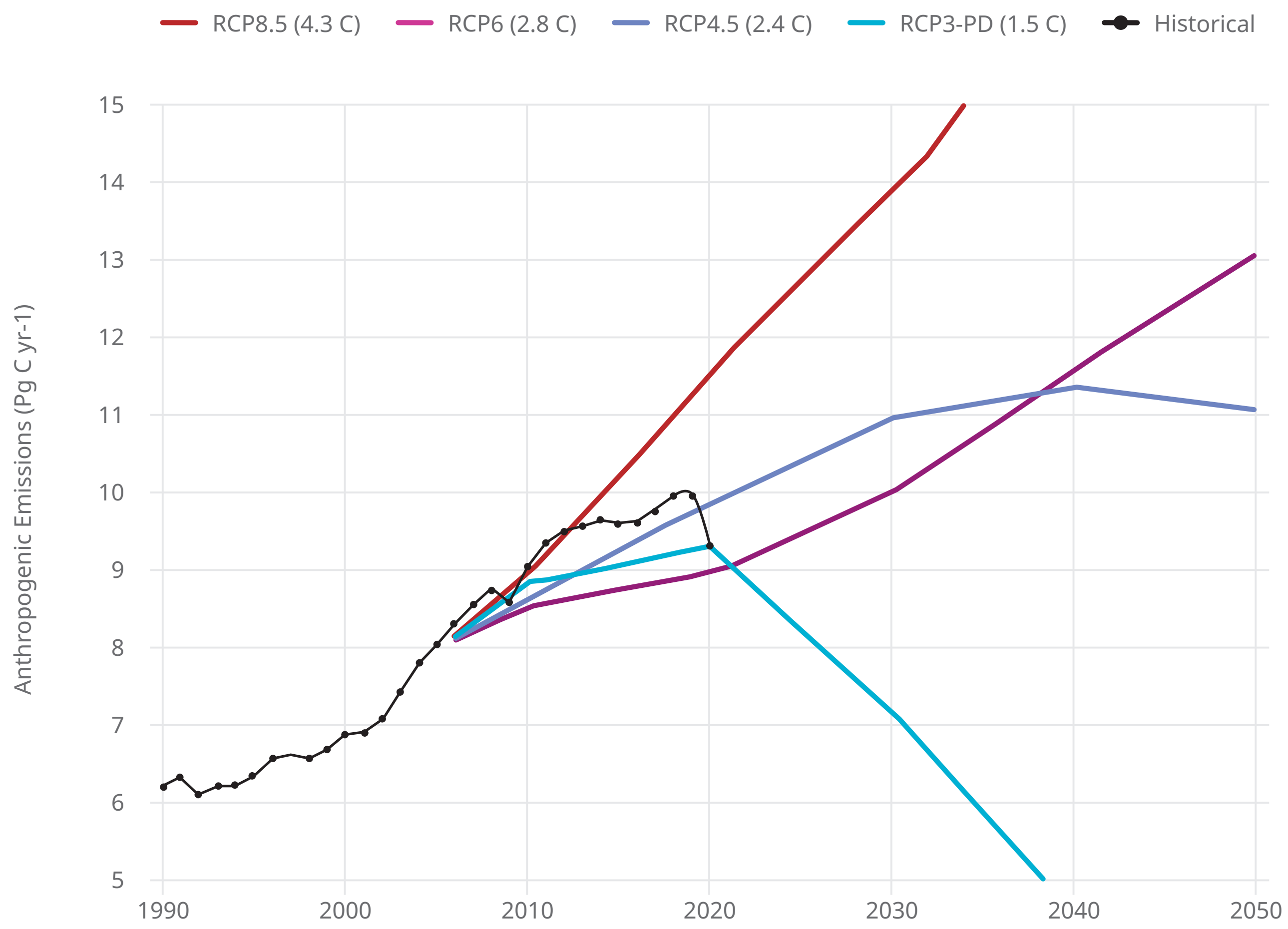
Source NASA GISS Baseline temperatures: 1951-1980

Figure 2: Land-ocean temperature index, 1880 to present, with base period 1951-1980. The solid dark blue line is the global annual mean, and the solid light blue line is the five-year running average.

Scientists use a collection of global climate models (GCMs) to estimate the implications of global warming through the end of the century. While any single model demonstrates considerable error, the collection or ensemble of models has reasonably captured the climate change history of the past century. The same models issue forward projections through the end of the century, under a range of greenhouse gas concentrations.

Global climate model ensembles project a best estimate of a further two to four degree Celsius increase in the mean temperature of the Earth by the end of the century. This seems minor on an intuitive level. However, the resulting impacts are of significant concern, especially concerning increased variability of extreme events, and begin to rapidly accelerate between a global temperature rise of 1.5°C to 2.0°C. Extrapolating recent trends, the period of 2032 – 2045 is the best projection of when the planet will cross this critical threshold. Future projections, outlined in the executive summary, become highly probable outcomes when the planet crosses this threshold of warming. (IPCC, 2018)

Figure 3: Global Ocean-Land Surface Temperature

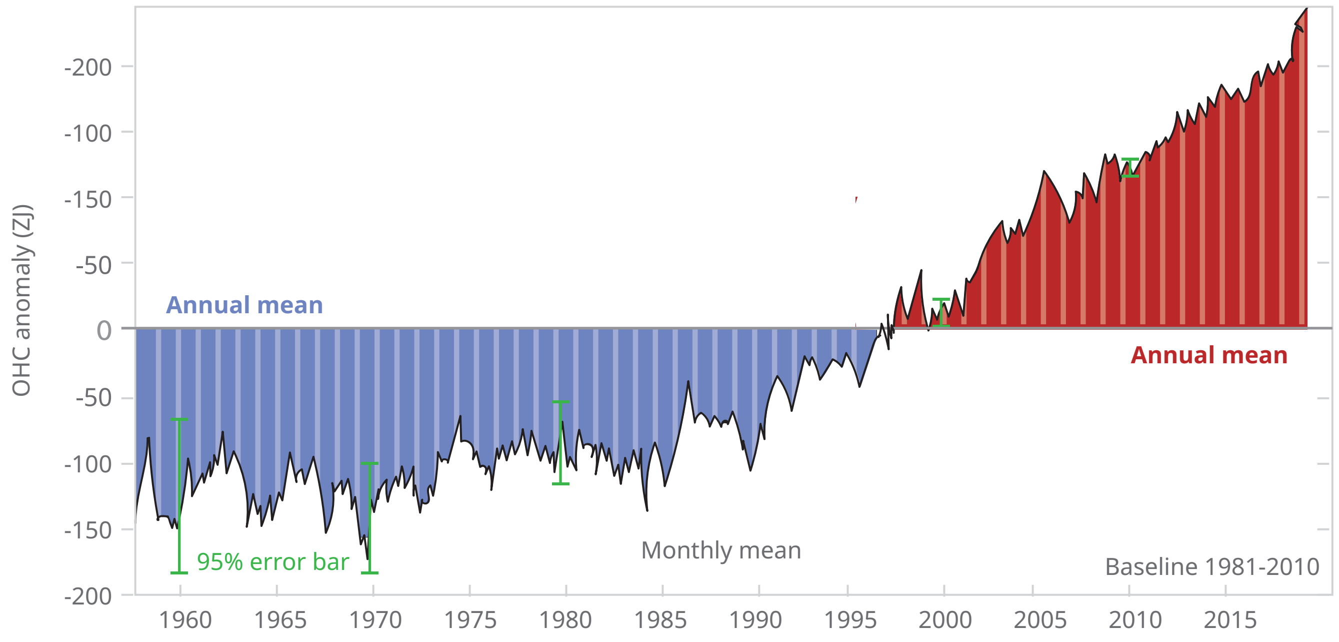


Emissions Source: Global Carbon Project and IPCC; Global Temperature Anomalies Source: NOAA GISS

Figure 3: Annual anthropogenic carbon emissions relative to global temperature anomalies (black dotted line) from 1990-2020. Colored lines represent various climate models Representative Concentration Pathways (RCP) of additional carbon emission into the future on various levels. With the initiation of climate models in 2005, the verification of the last 15 years illustrates that our current trajectory lies on the more aggressive carbon concentration pathways. Notwithstanding the 7% drop due to COVID-19 related reductions during the course of 2020.

From a property-catastrophe perspective, sea-level rise presents the most significant threat for coastal areas because of melting glaciers and thermal expansion of ocean waters. In turn, 90 percent of excess heat produced by global carbon emissions is absorbed into the ocean, rather than the atmosphere. The combination of rising atmospheric temperatures and excess heat content in global oceans influences the intensity of weather patterns. Changing jet stream regimes will continue to impose drought and inland flood threats for many areas. As a general principle of climate change, some modification to the mean of meteorological extreme value distributions can be expected, but with a more concerning increase in tail thickness (or variability). This change could amplify the effects of existing natural variability modes such as the El Niño Southern Oscillation (ENSO), which already cause severe disruption due to flood, drought, wildfire and hurricane frequency (Fasullo et al, 2018). Other key modes of variability that influence North America include the Atlantic Multidecadal Oscillation, Pacific North America pattern, the Arctic Oscillation and North Atlantic Oscillation (Moore et. al, 2017, Liu et. al, 2017, Overland et. al, 2019). The meteorological consequences of global warming are expected to be most severe in high latitudes and particularly in the Polar Regions (Screen, 2018).

Figure 4: Global Ocean heat content change in the upper 2000 m



Source: National Climate Assessment

Figure 4: Global ocean heat content anomaly in the upper 200 meters of the global ocean. In the fourth National Climate Assessment, 90 percent of excess heat produced by global carbon emissions is absorbed into the ocean, rather than the atmosphere. As the oceans absorb and balance the excess heat disproportionately relative to the atmosphere, it is estimated even with the 7% drop in carbon emissions in 2020, the planet's atmosphere would still continue to warm for at least 10 years as a result of the transfer of excess ocean heat content back into the atmosphere.

ECONOMIC OUTCOMES OF EXTREME WEATHER FROM A CHANGING CLIMATE

The dynamics of a changing climate will challenge the insurance industry to manage capital, evaluate and execute growth plans while adapting to shifts in volatility. Understanding climate change, quantifying the financial impact and proactive management of a peril impacted by a changing climate will take a myriad of forms of execution. Climate scientists and global policymakers have simplified the multitude of risks associated with global warming into the following three major categories for financial institution risk assessment: physical risks to assets and property, transition risks to investments stemming from a rapid switch to a low-carbon economy and liability risks from individuals or organizations who issue claims for damages. While physical risk is uniquely positioned to be answered on the back of a catastrophe modeling framework, additional tools are required to assess transition and liability risk. Additional information on estimating transition risk can be found in the joint Mercer, Oliver Wyman and the United Nations Environment Program (UNEP) paper Extending Our Horizons, as well as a Mercer 2019 report Investing in a Time of Climate Change.

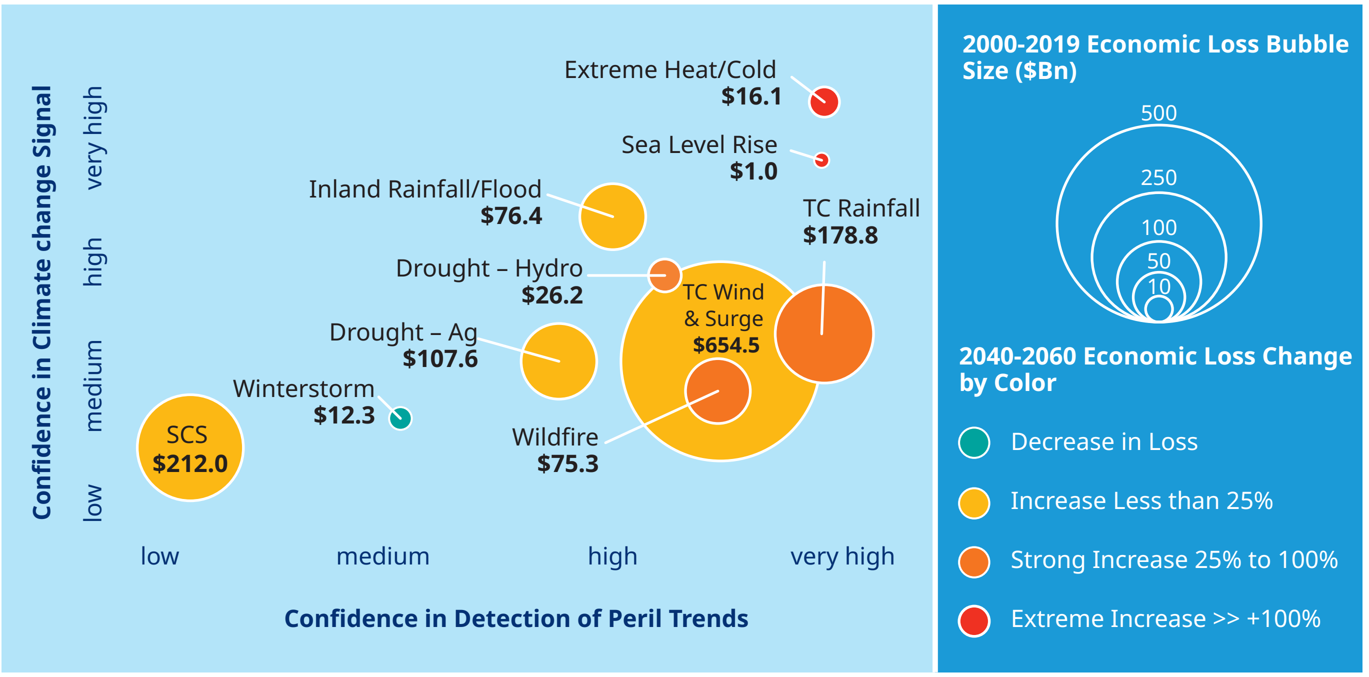
The flexible nature of the insurance business, with short-term contracts and ability to change premiums and coverage over time, ensures some resilience of the sector to climate change impacts (Botzen et al., 2013, Erhardt et al., 2019). However, there is evolving concern about the potential of climate change to significantly impact long-term business sustainability and investment decisions – key questions from a strategic perspective. The possibility also exists for specific region/peril combinations that the catastrophe models insurers use to assess risk from weather perils do not offer a timely view of the current climate. Latency in the data leveraged to calibrate models on longer-term observational records assume stationarity, whereas for some perils, recent years show emerging trends in frequency and/or severity.

The magnitude of estimated trends in extremes found in the observational period can differ across methodologies and reliability of underlying datasets. In addition, due to the inherently chaotic nature of the weather, referred to as internal variability, any signal from a climate change trend can be hidden. The underlying integrity of a historical dataset is an important point of consideration for issuing confidence on future outcomes. For example, changes in data collection methods, station density and derived second datasets all pose a variety of challenges. Furthermore, some datasets are inherently more uncertain because they rely on proxy relationships rather than direct measurements, such as is the case with satellite methods.

The confidence in projections and expectations of future impacts of climate change are illustrated in the chart below. Two key attributes summarize the scientific literature to provide a comparative assessment of confidence across perils:

- **Confidence in Climate Change Signal**
  How likely is the discernable trend of an individual peril attributable to human induced climate change?
- **Confidence in Detection of Peril Trends**
  Does the body of published scientific research conclude that recent trends in peril risk have a meaningful trend due to a changing climate?

Figure 5: Global Ocean heat content change in the upper 2000 m



Source: NAS, NOAA, Guy Carpenter

Figure 5: Each US catastrophe peril is ranked on a four-category confidence scale (low, medium, high, very high) based on the scientific consensus of the IPCC, the US Fourth National Climate Assessment, and an extreme weather assessment of climate change from the National Academy of Sciences (NAS, 2016). The size of the bubble represents the economic loss level measured by NOAA from 2000-2019, while the color is the projected percentage change in economic loss in the middle 20 years of the 21st century.

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