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Global Warming Statistical Analysis

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Abstract

This paper will investigate global warming and its effects on natural disasters. I will review the historic movements of climate change and activism, as well as the current discussions surrounding global warming. Secondly, I will examine various datasets, paying attention to the severity and frequency of specific natural disasters. I will then touch briefly on the topic of catastrophe modeling as it relates to the increased risk and losses associated with the discussed natural disasters and how those put the problem of global warming in a framework which financial and government institutions can grasp. I will also be analyzing economic impact of natural disasters to encapsulate the entire breadth of such disasters. Finally, I will summarize the output and give an overview of where statistical analysis will be leading the fight for climate activism.

Keywords: global warming, natural disaster, drought, hurricane, flooding, time series analysis, regression, catastrophe modeling

Introduction

Global warming is a hot topic speculated about today in media and social channels. However, discussions concerning the Earth's atmosphere and climate have been discussed within the scientific community for decades. The new buzz surrounding climate change and the looming threat of catastrophic collapse of ecosystems has pushed large amounts of people to the streets in protest. However, there are many skeptics as well, who have swept the notion aside and believe the current change in the climate is nothing to fear. They believe that because Earth's climate has changed for centuries that the current change is nothing significant and we should have no need for concern. With the wealth of data pertaining to natural disasters and our climate there may be truth behind both sides of the discussion.

History and Current Discussion

On September 27th, 1988 the social movement for climate change commenced. Margaret Thatcher, as the Prime Minister of the United Kingdom, addressed the Royal Society. Her speech to the Royal Society was about the apparent rise in greenhouse gases in the ozone. Thatcher, herself, had a background in the sciences, having graduated with a chemistry degree. Her talk that day set a precedent for future talks about social change and its impact on the climate (Nulman, 2015). The climate wasn't suddenly under scrutiny after Thatcher's talk though. Years prior, scientists and researchers were analyzing the data surrounding the climate. In 1983 the United States Environmental Protection Agency (EPA) gave a report on greenhouse gases and their effect on the atmosphere (Nulman, 2015). Slowly over the next decade international talk was stirring surrounding climate change and its possible effects on society. With negotiations taking place among politicians and world leaders, environmentalists stepped up to the plate and decided to take initiative. In 1989 European and United States environmentalist groups formed a network known as the Climate Action Network (CAN) (Nulman, 2015). This loose network of organizations was focused on pushing awareness of climate change and its potential impact on society to the public, while also advocating on the global stage in front of policy makers to create environmentally friendly decisions. CAN facilitated the formation of the United Nations Framework Convention on Climate Change (UNFCCC), a committed assembly aimed to stabilize greenhouse gas emissions by the turn of the century.

Following UNFCCC's success at the 1992 Earth Summit, the next goal was to negotiate similar emissions regulations within the developing nations or countries with 'developing economies' (Nulman, 2015). The first meeting to address the issue was called the Conference of the Parties and was organized in 1995. Negotiations did not go well at COP1 due to reservations from the U.S., which spread to the European Union, and many members left feeling dissatisfied. However, many Japanese NGO's (non-governmental organizations) organized quickly to create workshops and petitions that garnered considerable global attention. Because of this, during COP3, held in Kyoto, Japan, an agreement, later to be known as the Kyoto Protocol, between the major parties (namely the U.S. and European Union), was reached (Nulman, 2015). The terms agreed upon at the convention were much lower than originally desired by the environmental organizations. The pursuing annual COP's were aimed to set the rules and regulations that would hopefully lead the nations to the agreed upon reduction targets.

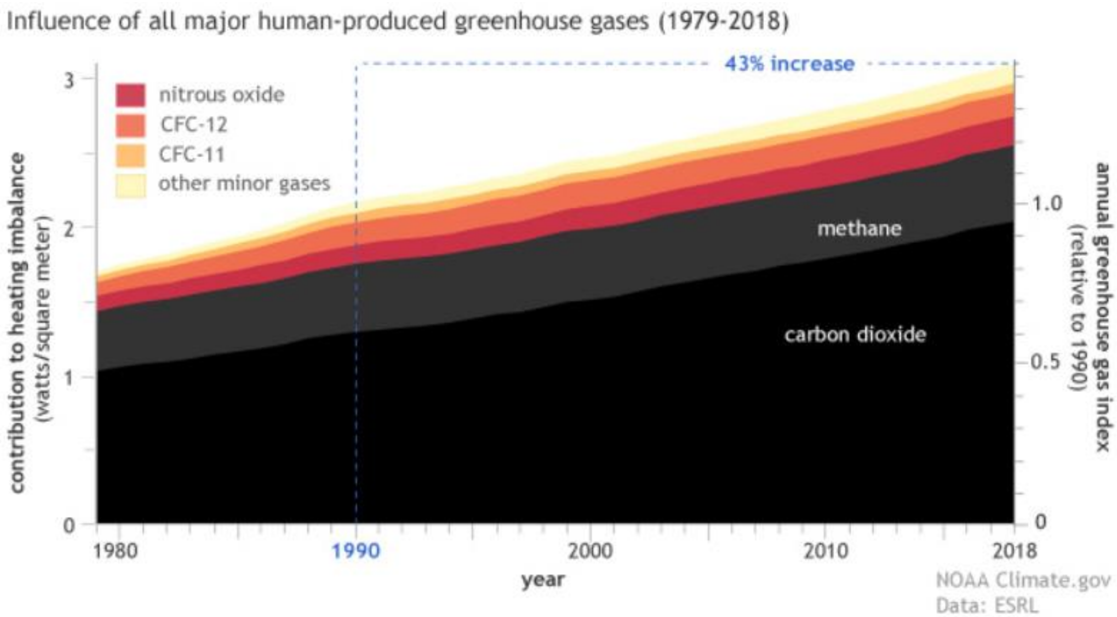
A devastating blow to the Kyoto Protocol occurred in 2001 when the United States, under the presidency of George W. Bush, announced their rejection of the agreement. With the departure of a major power, the agreement now required more countries to ratify it. This led to the eventual ratification from Russia, under Vladimir Putin's leadership, and the agreement was officially in affect by February 2005 (Nulman, 2015). Another important meeting of the Conference of Parties took place in Copenhagen (COP15) in 2009. This was the year that the emissions targets for each country would be extended into the next period. Almost 100, 000 demonstrators organized outside the conference pushing for the countries to extend their agreement (Nulman, 2015). The conference ended with the countries signing a non-binding agreement to extend their commit to the Kyoto Protocol.

A recent major meeting of COP, COP25, took place in Paris where the united parties agreed upon what's called the Paris Agreement. The agreement "aims is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels" (UNFCCC, 2019). The United States originally agreed to meet the terms of the agreement in 2015, however as of today the nation has formally withdrawn from the agreement.

Analysis of Current Climate Changes

Throughout the fight for climate change scientists have been doing research to try and display the significance of its impact on society. The accumulated knowledge of greenhouse gases and collection of data needed to be translated into a tangible argument when presented to political figures. That's how statistics has become such an important component to global warming debates. As I'll demonstrate, based off a few datasets I've collected and reports such as the Fourth National Climate Assessment, there has been significant impacts of global warming on our local and national communities.

The leading factor believed to cause or accelerate global warming is greenhouse gases. Among the many gases classified as a greenhouse gas the biggest contributor is carbon dioxide, CO_2. It is debated the most because it has the single largest contribution to global warming among other greenhouse gases. Other greenhouse gases include Methane (CH_4), Nitrous Oxide (N_2O), tropospheric ozone, Chlorofluorocarbons, and water vapor (EPA, 2016). A graph provided by NOAA demonstrates the fact that carbon dioxide and other greenhouse gases have contributed to warming the globe.



Additionally, within the National Climate Assessment, which is a U.S. government agency responsible for mandatory reports that summarize the impact of climate change, they display how these increases caused from gases leads to increases in national temperatures. The graph compares two different scenarios as well. One pair shows how temperatures would look under the RCP 4.5 and the other RCP 8.5. They are based on the Representative Concentration Pathways set by the IRCC in 2014 and are specific referred to as RCP 4.5 (stabilization) and RCP 8.5 (greenhouse gas emissions increase).

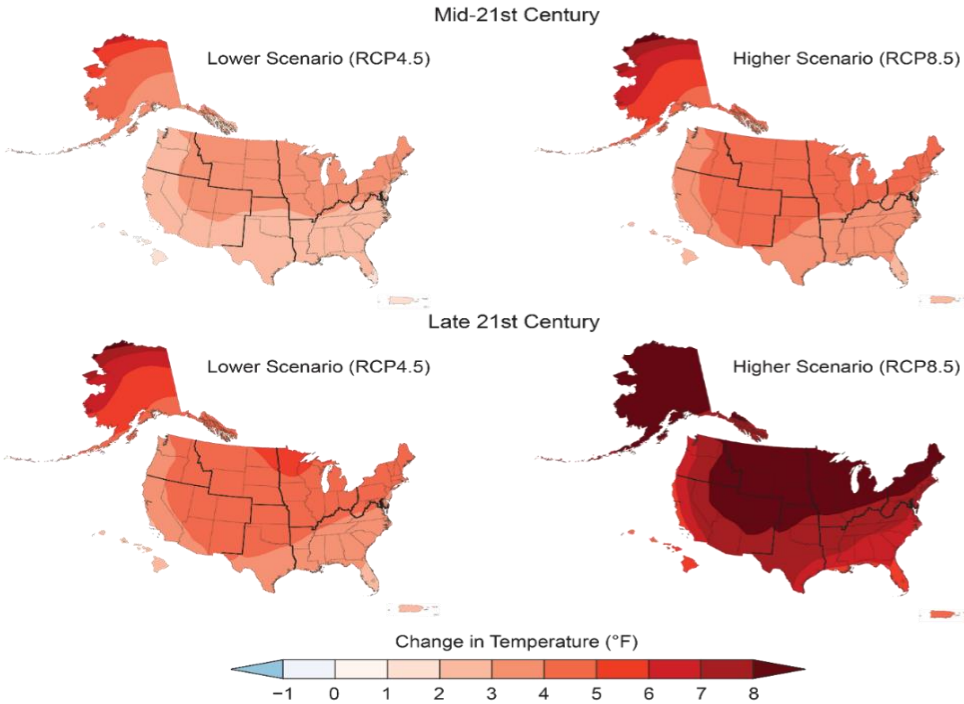
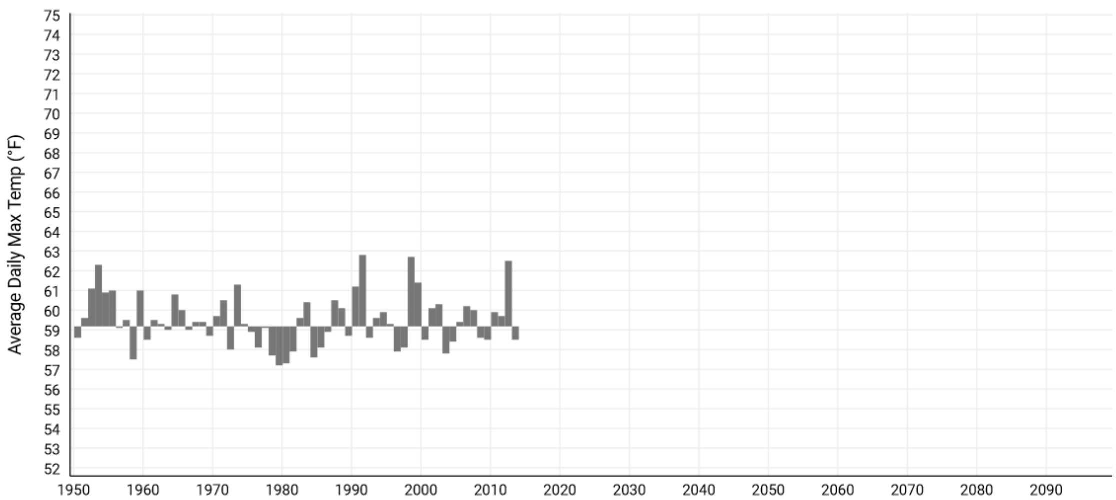
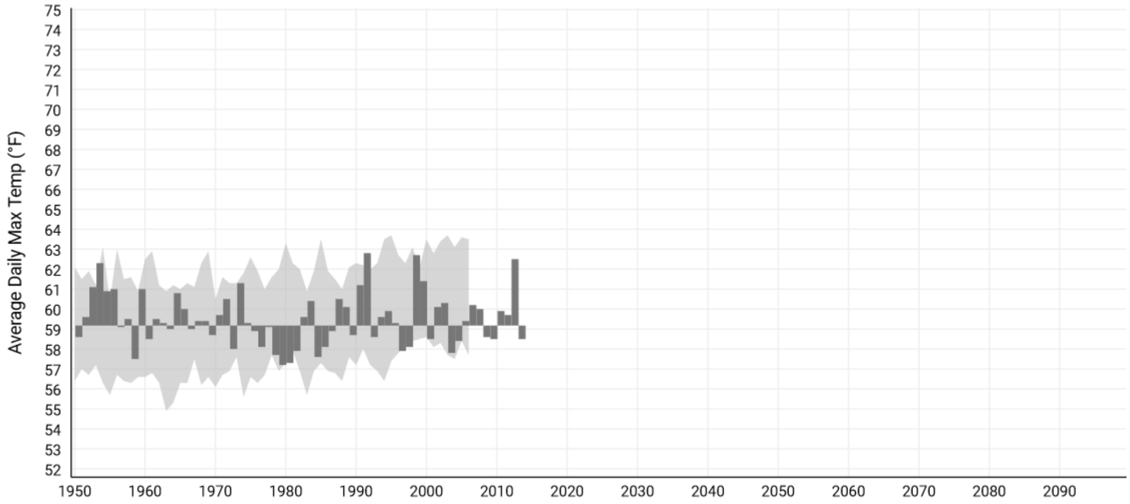


Figure provided by the NCA4 Report on Climate change

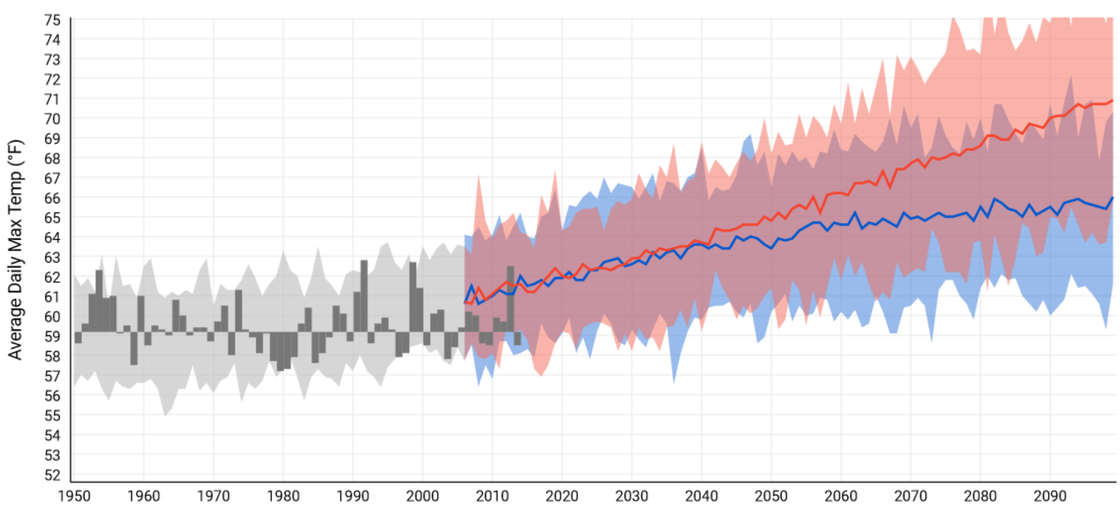
To get a deeper understanding, I looked at the average daily highest temperatures in Summit county between the years 1950 and 2013.



The graph above plots the annual average temperatures. The horizontal line from which each bar is extending is the average temperature between the years 1961 and 1990. The average between this period is the standard comparison used during meetings and debates. It was this average that was used in the Kyoto Protocol and Paris agreements. The emission rates and reduction estimates are also from that periods average. A bar which extends upward means it is above the average and a bar extending downwards fell below the average.



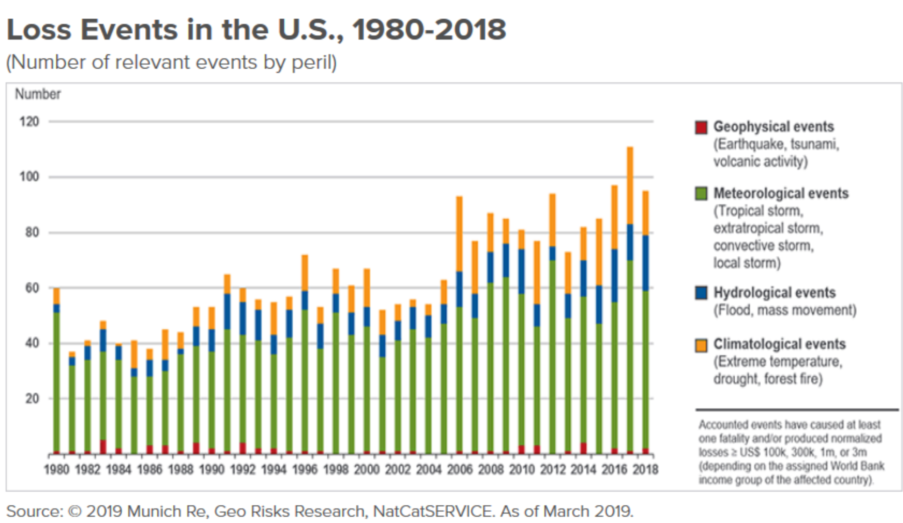
Afterwards an interval for temperatures is created based on the annual averages, that is used to test or model. The interval is represented by the light grey shaded region. Because the annual temperature bars fall within those regions closely it is an indicator that our model is decently fitted. The years between 2005 and 2013 are excluded because they will be used during the predictive model creation.

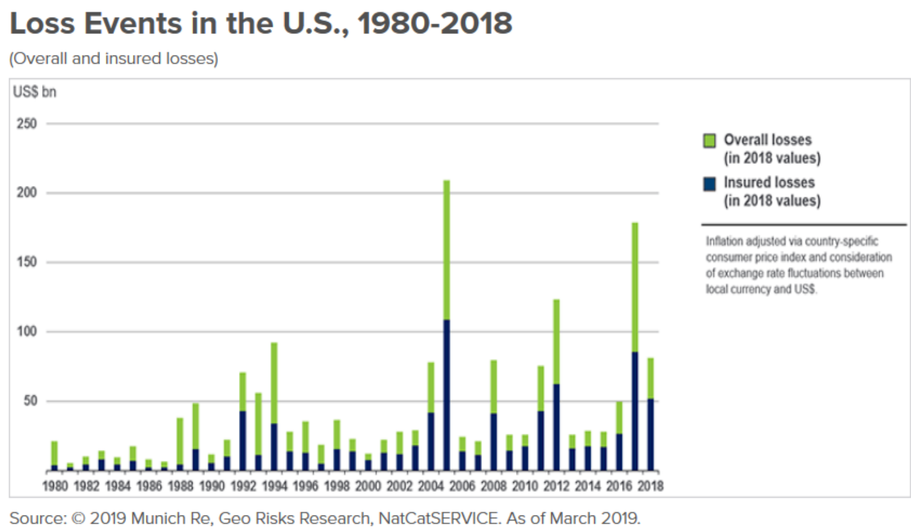


The shaded red and blue area depicted in the predictive model above distinguish between two possible scenarios. The red path represents a future with higher emissions of CO2 (RCP 8.5), while the blue path represents a future with stabilized emission outputs (RCP 4.5). Either scenario still shows that an overall increase in temperatures are going to take place in Summit County in the future. With increased temperatures natural disasters are bound to worsen as well (USGS, n.d.).

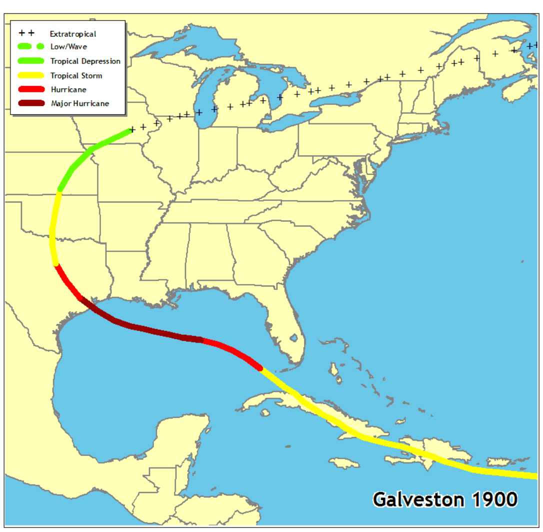
Catastrophe Modeling for Financial Impact of Global Warming

With the threat of more and more extreme weather occurring and the access to large data pools it has led to the development of catastrophe modeling. The core of what catastrophe modeling is all about is predicting the severity and frequency of any catastrophe, whether it be a large natural disaster or human-made catastrophe, such as acts of terrorism, or liability claims within the insurance industry, in order to better prepare financially for those costly events. The two graphs below show this has becoming increasingly more important as both the loss amounts per catastrophic event and the frequency of catastrophic losses have increased.





Catastrophe models are a progression because they provide better predictions then previously used models based off historical data - and have shown to be more accurate, flexible, and stable (CAS, 2010). It achieves this by simulating hundreds and thousands of scenarios of plausible events. The simulations that are run are generated using stochastic processes based off the historic data. Shown below is a simplified example of how a single hurricane track can be used to randomly create hundreds of other plausible hurricane tracks. Once simulations have been run a sample loss distribution is created and then predictions can be made based off the sample.

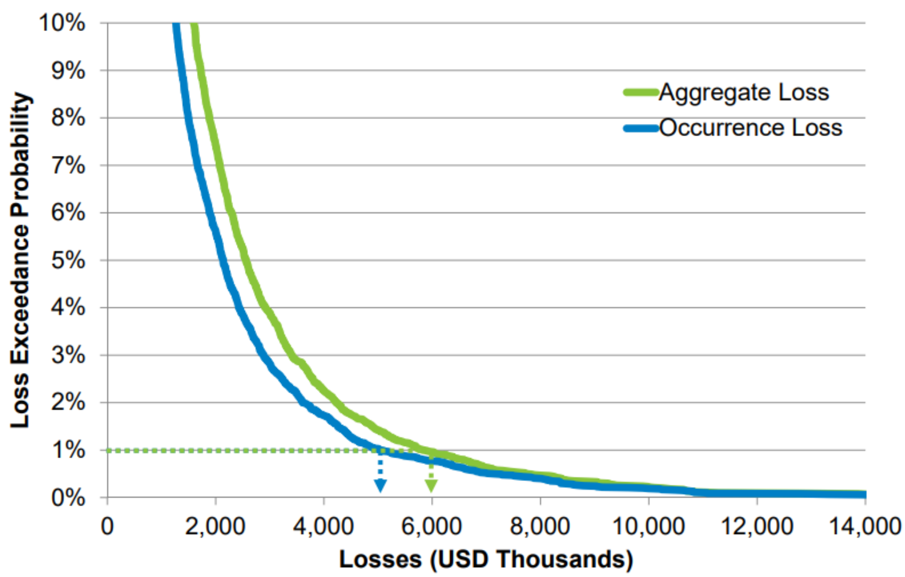


Images provided by the NOAA

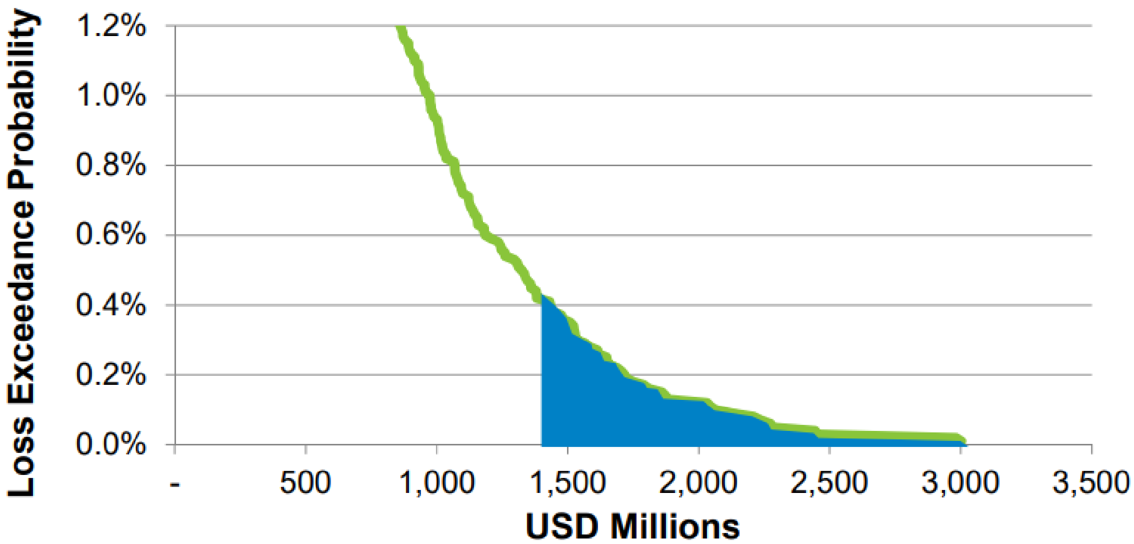
Catastrophe models provide four distinct statistics that are useful in translating the level of risk an event has associated with it; They are the exceedance probability, probable maximum loss, and tail value at risk (AIR Worldwide). The exceedance probability is the probability that a certain loss, at or above a specified threshold, will occur, and the probable maximum loss is the largest potential loss for a given exposure, often defined in terms of a specific exceedance probability. Lastly, the tail value at risk measurement is a widely used measure by the insurance industry to evaluate risk. It measures the probability-weighted average, or expected value, of a loss occurring at or above a specified exceedance probability. The calculation for the tail risk at value (TVaR) is:

$$TVaR_p = E\left[X\middle|X \geq \pi_p\right] = \left(\sum_{i=pN}^{N} \frac{1}{N} L_i\right) = (1-p)\left(\sum_{i=pN}^{N} L_i\right)$$

Where N is the number of event years, L_i is the individual probability of an event i, and p is a specified exceedance probability.



The outputs are summarized in graphs as shown. The exceedance probability curve is simple and straight forward. As an example, based on the graph above, it can be said that the probability of an event with a loss amount greater than $6 million in a single year is about 1.0%. Additionally, the TVaR curve interpretation builds upon the exceedance probability. For example, based on the graph below, if there was a .4% chance of a loss equaling 1.5$ and the TVaR associated with that was $2.3 million, we could say, ‘given that at least a $1.5 million loss occurs the average severity will be $2.3 million’.



With these outputs and interpretations, a risk manager is able to translate the risks and drawbacks of certain events and prepare others or themselves to handle them. If methods like catastrophe modeling are implemented into global warming impact models the likelihood of positive action from governing bodies would probably rise because they are more swayed by financial implications than purely environmental ones.

Conclusion

Statistics and the fight for climate change will forever be interlocked due to the nature of science and the necessity to translate scientific findings to the general public and policy makers.

With the idea of catastrophe modeling still relatively new it hasn't reached its full potential yet either. Insurers are using catastrophe models to predict the next 1-5 years, however with the growing knowledge that global warming may impact financial investments and loss factors farther into the future, a need for catastrophe models to be able to extend a decade or further is becoming highly desirable. Additionally, being able to transform and combine global warming impact models with catastrophe models is vital in communicating to risk analysts and government bodies in a language which they more understand, financials. With the ceiling for potential high it may be possible to direct world leaders in a direction that protects Earth and ourselves from catastrophe.

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