Chapter 4

Climate change and its implications for catastrophe modelling

4.1 Introduction

The combination of catastrophe losses and inadequate risk management can reduce insurance company profitability, or can even cause insolvency. Assessing the potential losses from these events to ensure adequate risk transfer and appropriate pricing is, therefore, important to insurers' business survival.

Since catastrophic events are infrequent and extreme, there is little information about the characteristics of events themselves, or the losses caused. Traditional techniques, including actuarial analysis of historical loss information may not, therefore, be particularly successful in assessing this risk.

Catastrophe models (cat models for short) have been developed to address this need for risk assessment. These mathematical models simulate hazardous events (caused by both natural and man-made perils) and estimate the associated potential damage and insured loss. Most catastrophe models currently in use within the insurance industry analyse the loss from natural perils such as earthquakes, windstorm and floods, but models also exist for other types of peril, such as terrorism. In this chapter, we will consider only catastrophe models related to natural events.

Section 4.2 describes the general structure and development of catastrophe models. Section 4.3 reviews the major difficulties in using them, before Section 4.4 examines the particular difficulties associated with climate change. US hurricane risk is the focus of considerable attention, because of the scale of the loss potential for insurers from that peril. Section 4.5 therefore uses this peril to compare and contrast modelling approaches from the major software companies. The implications of climate change for catastrophe modelling are discussed in Section 4.6. Finally Section 4.7 draws conclusions and makes recommendations.

4.2 Catastrophe models

History of catastrophe models and recent developments

Catastrophe modelling originated from spatial modelling in the 1970s. Insurance companies developed so-called "deterministic loss models" to determine the losses associated with particular events, e.g. to test worst-case scenarios for a portfolio or simulate the losses expected if a particular historical loss were to reoccur. This kind of model made no judgement about the frequency of the events, but helped to understand the severity. These relatively simple models could nonetheless be powerful tools in communicating loss potential.

However, since it is useful to know how likely a loss could be, as well as how bad it could be, these deterministic models were combined with the probabilistic risk assessment techniques used by engineers to produce catastrophe loss models. The three main software providers then were founded to meet this need: AIR in 1987, RMS in 1988 and EQECAT in 1994 (the year of the Northridge Earthquake). However, at first, the insurance industry largely disregarded the models. The market was relatively benign and reinsurance cover was readily available.

A series of large catastrophes starting with Hurricane Hugo in 1989 and culminating in 1992 with Hurricane Andrew – the largest insured event at that time, with losses estimated by Property Claim Services (PCS) at $15.5bn (1992 values) completely changed this. Reinsurance capacity became very scarce, with several insurance companies becoming insolvent. The importance of risk assessment and the discipline it provided, led to widespread adoption of catastrophe modelling, particularly in newer "more technical" parts of the (re)insurance market, i.e. where the reinsurer does not rely on client relationships to give the opportunity to balance out losses in some years with profit in others, but only participates in risks that are expected to be profitable.

The wider financial markets have also increased demand for this software. Trading of Cat bonds and Industry Loss Warranties (see Chapter 6) began in 1995 as financial markets saw the attraction of combining the uncorrelated risk of natural catastrophes with their own portfolios to produce a less variable return on investments. Catastrophe modelling also has applications beyond the insurance industry. Capital markets have adopted the technique to price some catastrophe bonds. Governments have also utilised catastrophe modelling for emergency management and disaster response planning (Grossi et al 2005, p28).

The years since 2001 have encouraged a dramatic shift regarding the way insurance and reinsurance companies perceive the world in which they do business. The World Trade Center attack demonstrated the destructive power of man-made

catastrophes whilst more recently the 2004/2005 hurricane seasons demonstrated the frequency and severity of nature. Both events caused catastrophe modelling companies to respond. The first resulted in a new variation of a probabilistic model – terrorism (out of the scope of this report). The second has sparked continued debate over whether climate change (and in particular the anthropogenic influences of man on climate change) can be the reason behind the most recent increase in hurricane activity.

The insurance market has adapted to the new environment within which insurance business is conducted. More companies have set up in Bermuda after 2001 to take advantage of the hard market conditions. More recent hurricane losses, in particular Katrina, Rita and Wilma in 2005 have prompted a further wave of start-ups to begin writing business in Bermuda. These events have served to highlight the importance of aggregate management and the ability to understand the potential catastrophic loss within each company's portfolio and how this is changing over time.

Demand for the models continues to grow as they and their users become more sophisticated: models are no longer a rudimentary reporting tool that assists in pricing and portfolio management but are now an integral part of any organisation that deals with catastrophe risk. Rating agencies rely upon them when they assign credit ratings to insurers and reinsurers or individual risk transfer contracts, and insurance market regulators have started to insist on their adoption, though not always in a rational manner. The models may be used to improve response times to disasters. The process of collecting exposure data for catastrophe modelling, especially what is insured and where it is located, improves insurers' knowledge of their portfolio. Once an event is forecast, they can alert staff, intermediaries and policyholders in the threatened or affected areas.
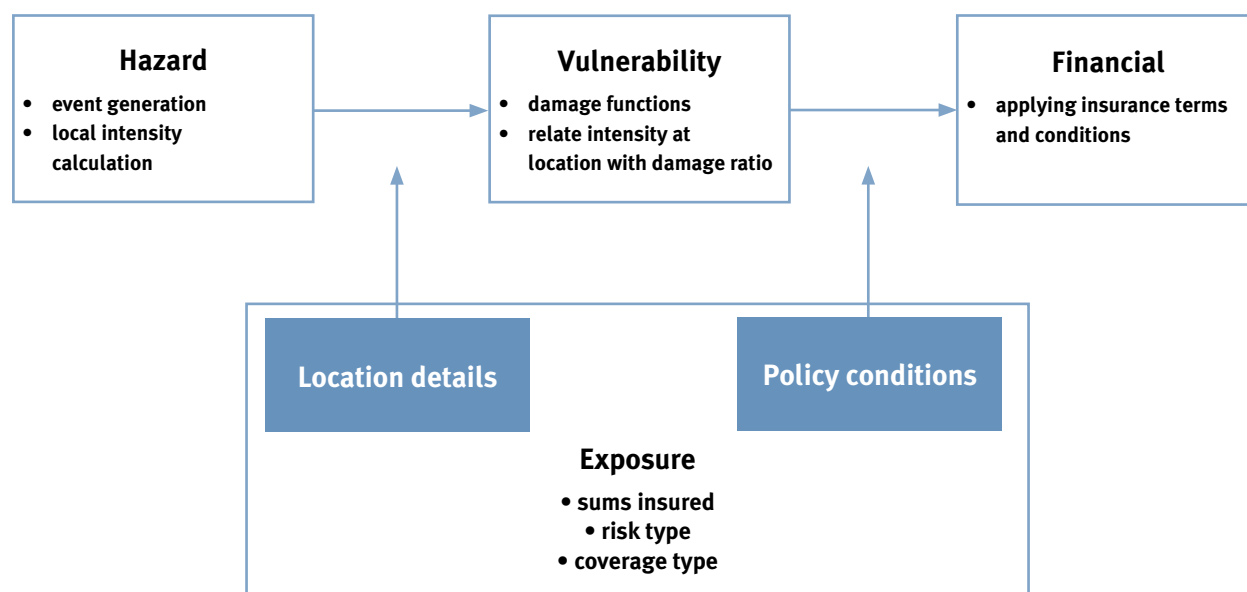
What is a catastrophe model?

Catastrophe modelling is used within the insurance industry to quantify the risk posed by catastrophic events and hence to improve risk management decisions (Grossi et al 2005, p27). The information produced by catastrophe models (i.e. estimates of potential losses) can be applied for a variety of risk management purposes, such as:

- Determining the appropriate levels of insurance and reinsurance protection;
- Informing underwriting decisions;
- Pricing insurance and reinsurance contracts;
- Portfolio optimisation and management;
- Provision of information to rating agencies;
- Design of triggers for alternative risk transfer mechanisms.

Although variations exist between different catastrophe models, most are constructed of four basic components (see Figure 1).

Figure 1: Key elements of a catastrophe model

- Hazard module – this describes the frequency, severity (referred to as the 'intensity') and geographic location of the event. In most catastrophe models, the events are structured into catalogues of 'synthetic' (i.e. imaginary, but realistic) events, which represent the expected range of events across the modelled area by frequency and intensity. The selection of synthetic events that make up the catalogue is usually based upon a set of key distributions that relate to fundamental characteristics of the events in question.
- Vulnerability – this component describes the expected damage, or more appropriately for this use, insured loss. They are usually based on observed relationships between the intensity measure (such as wind speed or flood depth) and the level of expected insured loss, as a ratio to the total insured value. This component will also describe how this damage will vary for different types of property or other asset.
- Exposure – this component will describe the geographical and physical property characteristics, for example its location, its type and construction, and its value.
- Loss – once the potential damage to the property has been estimated using the first three components, the modelling software can apply policy conditions (such as deductibles) in order to estimate the value of the claims which insurance companies will be liable to pay.

The model produces probabilistic loss estimates of a number of financial perspectives. These can be at different resolutions: site level, policy level or book level. The method of displaying this output depends on the application. Exceedance Probability (EP) Curves are a widely used output from a catastrophe loss model. An EP curve shows the probability of exceeding a monetary loss threshold. At the 1-in-100 year return period, there is a 99% probability that losses will not exceed this level.

However sophisticated, catastrophe models cannot capture the full spectrum of risks that exist in the real world and are a mathematical tool to help decision-makers quantify the potential for loss. Loss estimates for the same modelled peril and region can diverge between the software providers. Catastrophe modelling is complex and depends on many assumptions and to some degree, the divergence is a measure of the uncertainty in this process. Rating agencies are aware of these model differences and also question why models may not consider particular loss-generating factors, e.g. demand surge and secondary perils such as storm-surge and fire-following that may be ignored or under-assessed. This can be considered a form of 'epistemic uncertainty', i.e. the uncertainty arising from incomplete knowledge of the processes involved in loss generation.

Before introducing climate change, it is important to realise that loss estimates produced by catastrophe models contain considerable uncertainty, and this uncertainty comes from a wide range of sources and affects all components of the catastrophe model. The user needs to understand these in order to take a balanced view of the outputs. Box 1 illustrates this for flood modelling. (Flood risk in the UK is discussed in more detail in Chapter 7). Similar considerations apply to storm modelling. One unpublished survey found significant differences between proprietary models in their estimates of exposure, surface friction due to urban/rural roughness, and storm track patterns.

BOX 1
Sources of uncertainty within the components of a flood model.

Hazard

- the resolution of the terrain data used within the model
- whether flood defences are included
- the quality of the flow data
- the availability of historical data for calibration and validation
- the method used to 'propagate' floods in the model

Vulnerability

- the building inventory used
- the number of different vulnerability functions
- availability of data for calibrating the vulnerability functions

Exposure

- accuracy and resolution of exposure data entered into the models
- location of the risk, in particular accuracy of elevation
- characteristics of the risk (such as construction type, occupancy type)
- value of the risk
- policy terms and conditions (such as limits and deductibles)

4.3 Challenges in interpreting catastrophe model outputs

The first area of difficulty is the climate system itself, which is very complicated; the second area is the exposure at risk, and the third is establishing the vulnerability of those assets to damage.

Complexities within the climate system

The frequency and severity of hazards are systematically influenced by natural climatic patterns. Study has also shown that they may not occur independently of each other; rather there are correlations, which is important for reinsurers. Finally, there are 'feedback' mechanisms which can affect the situation.

Lack of observations

By definition, extreme events are rare. This means that there are few if any scientific observations of very extreme events (the inner structure of the 250 year storm for example). There is also the danger that catastrophe models have been 'overfitted' to describe the relatively few recent events that have been observed, with the result that further events will give rise to surprises when they do not behave exactly like the previous ones.

Natural climate patterns

The climate system is extremely complicated. Modes of natural climate variability operate over a timescale of months to decades. Examples of these phenomena include the Atlantic Multi-decadal Oscillation (AMO) and the El Niño Southern Oscillation (ENSO). These phenomena can have an impact on severe weather events in different parts of the world. For example in El Niño years there is an increased chance of drought in Australia and Brazil, and increased chance of flooding in Southern USA and Peru. As these phenomena vary over time, they can complicate the identification of trends in frequency and severity of extreme events. Box 2 describes the prominent weather patterns which influence Atlantic hurricane behaviour.

BOX 2

Climatic Patterns Commonly Used by Hurricane Modellers

AMO (Atlantic Multi-decadal Oscillation) is a cycle of sea-surface temperature (SST) changes that may last from 20-40 years. It is suggested that a correlation exists between warmer periods and heightened hurricane activity (Goldenberg et al. ,Science, 2001). As a warm phase is reached, then warmer SSTs, reduced vertical wind shear over the Atlantic and an African Easterly Jet (AEJ) are all conducive to tropical cyclone activity. Although it is the least regular pattern, many scientists have used the AMO signal as the focus of their research.

ENSO (El Niño Southern Oscillation) measures temperature anomalies off the coast of Peru. The warm, El Niño phase of ENSO lasts from 12-18 months, during which wind shear over the tropical Atlantic serves to reduce the chances of hurricane activity, whilst the opposite signal called La Niña brings lower than average wind shear to potentially increase hurricane activity. Between the warm and cool phases there are lengthy neutral periods.

QBO (Quasi Biennial Oscillation) is the most regular and therefore easiest to forecast. It is a measure of the equatorial winds in the stratosphere (12-13 miles above the ocean surface); blowing from east to west has a negative impact on hurricane formation, but it has the weakest correlation with hurricane activity.
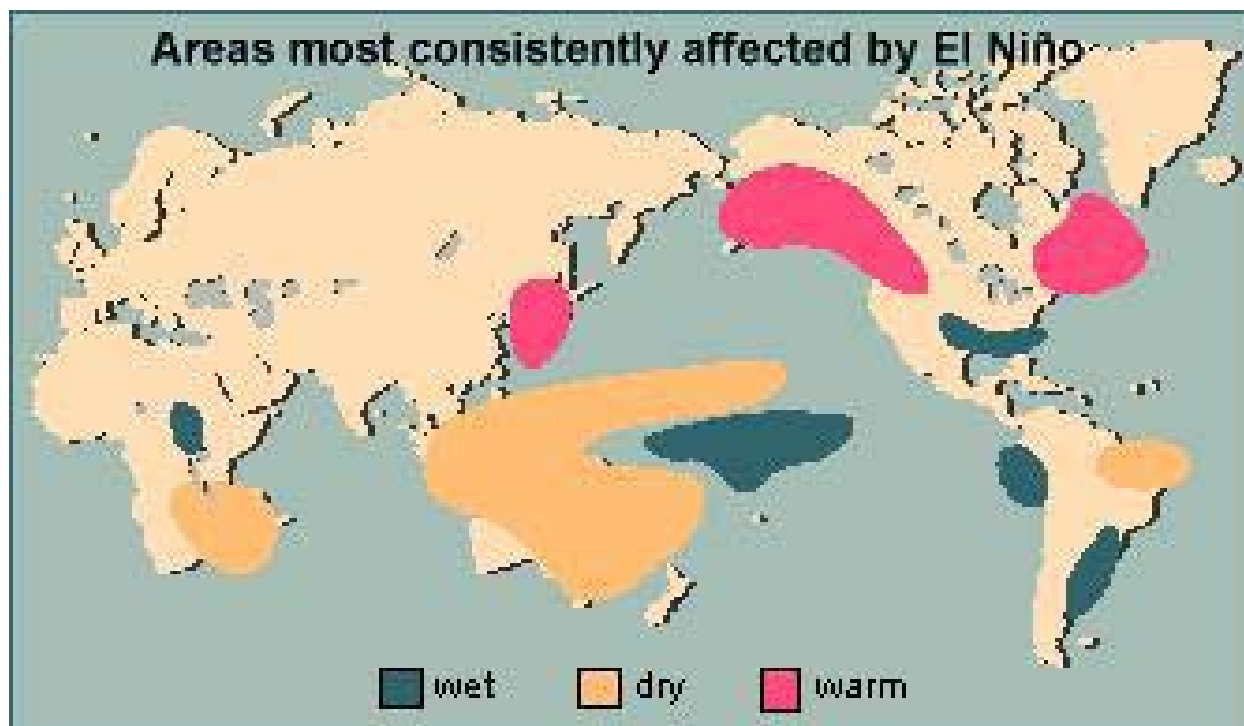
NAO (North Atlantic Oscillation) is a factor that helps explain annual variations in hurricane landfalls. (Elsner, J.B., Tracking Hurricanes, BAMS, 2003). A negative NAO results is more likely to steer storms towards a U.S. landfall (Texas to S. Carolina). The NAO is hard to predict more than a few months in advance as it varies in response to the atmospheric pressure distribution across the Atlantic, therefore limiting the value that can be gained from longer-term hurricane forecasting.

As one observer notes, hurricanes may be gaining more energy, but they have not been making land-all (Pielke, 2007). If they begin to track landward, then losses will really escalate.

Correlation between regions

Patterns of natural variability can lead to correlated changes in the weather in geographically disparate regions. For example, El Niño causes 'teleconnections' between regions (see Figure 2).

Figure 2: Teleconnections due to El Niño

Source: Bureau of Meteorology Australia http://www.bom.gov.au/lam/climate/levelthree/analclim/elnino.htm#three

This issue is likely to be of concern to (re)insurers with global portfolios. They may face the possibility of worsening risk of catastrophic losses in more than one country at time. Where there is an established teleconnection pattern, this can be planned for, but there may be surprises. For example, 2004 saw record breaking numbers of tropical storms in both the Atlantic basin and Japan. Whilst this cannot be attributed to climate change, it demonstrates the possibility of multiple catastrophic events in different countries within a relatively short time period. These patterns of natural climate variability can lead to an accumulation of seemingly unrelated risk.

Feedback mechanisms

Feedback mechanisms occur when a change in one variable within a system, through interaction with other variables in the system, either reinforces the original process (positive feedback) or suppresses the process (negative feedback). When modelling any system, it is important that all feedback mechanisms are fully understood and incorporated, as they will affect the rate and magnitude of any changes that occur.

In catastrophe modelling feedbacks with a short timescale can be important. For example, after prolonged periods of rain, ground becomes waterlogged, so that a further 'normal' period of precipitation can trigger flooding. Again, the longer a drought lasts, the more likely it is that a forest fire will break out.

Socio-economic factors

As discussed in Chapter 2, losses from natural disasters, both economic and insured, appear to have increased over recent years. This increase is often attributed to climate change, but in reality many other factors contribute to the increase in economic and insured losses. This means that historical loss data cannot be used to explore future exposure without considerable analysis.

Munich Re identifies six major reasons for the increase in insured losses in recent years:

- Population growth (a key driver of economic growth)
- Population shifts – more people living in vulnerable areas (coasts, floodplains), increased concentrations (mega cities)
- Increased values – people and firms have more assets, and individual assets are worth more
- Modern society is more vulnerable (more interconnectedness , and less stock-in-trade)
- Increasing insurance penetration (insurance is a 'luxury good' in some senses)
- Changes in local environmental conditions (faster run-off)

Keeping track of these variables is a major exercise in itself. Demographic shifts in the US hurricane belt provide a good example.

Demographic shifts in the US hurricane belt

Between 1980 and 2003, the population of coastal US counties grew by 33 million people, or 28 percent. Florida grew 75 percent, Texas 52 percent and Virginia 48 percent. More growth is expected with the highest growth expected in the southernmost part of Florida, the region most exposed to hurricanes. Coastal counties in the Carolinas and Georgia are also expected to see considerable population increases. Large increases are forecast for the Houston, Texas area and Florida's central Gulf Coast. According to population growth projections by the US Census Bureau, by 2030 more than 12 million additional people will be living in Florida and Texas.

Exposure to windstorms and high property values combine to make Florida the state with the highest potential for losses, and New York's Long Island the second highest. A 2007 study by AIR Worldwide put the value of insured coastal property in hurricane-prone states—states bordering on the Atlantic Ocean and Gulf of Mexico—at $8.89 trillion. The value of residential and commercial coastal property in Florida alone was almost $2.46 trillion. This represented 79 percent of the state's total insured property values. In New York it was $2.38 trillion, representing 62 percent of the total. Other states where insured coastal property values exceeded 50 percent of the state's total are Connecticut, Maine and Massachusetts (Insurance Information institute, 2008).

The effect of this is to overturn historical statistics on hurricane losses, because of the enormous changes in exposure that have occurred. Table 1 re-estimates insured hurricane losses up to 2005, against today's number and value of exposed properties.

Table 1: Re-estimated insured losses for hurricanes based on 2005 exposures

Date	Event Name	Insured Loss Were it to Recur in 2005
September 18, 1926	Miami Hurricane	$80 billion
August 24, 1992	Hurricane Andrew	$42 billion
August 29, 2005	Hurricane Katrina	$41 billion*
September 21, 1938	'Long Island Express'	$35 billion
September 9, 1965	Hurricane Betsy	$34 billion
September 9, 1900	Galveston	$33 billion
September 17, 1928	Great Okeechobee Hurricane	$33 billion
September 10, 1960	Hurricane Donna	$26 billion
September 17, 1947	Fort Lauderdale Hurricane	$24 billion
September 16, 1945	Homestead Hurricane (#9)	$20 billion

*Current PCS estimate.

Source: http://www.air-worldwide.com/_public/html/air_currentsitem.asp?ID=1031

Modelled loss to property, contents and direct business interruption and additional living expenses for residential, mobile home, commercial, and auto exposures as of December 31, 2005. Losses include demand surge, but not flood losses.

The most costly loss is the unnamed 1926 Miami hurricane. The figures require some caution, since they exclude flood losses, which would considerably increase the costs of both Katrina and the Galveston 2000 storm. However, the message is clear. Recent decades did not experience particularly savage hurricanes; the main driver of losses has been the increased exposure, and a return to more frequent storms. If climate change compounds that by making storms stronger, the outlook is grim.

Vulnerability to risk

Feedback mechanisms occur when a change in one variable within a system, through interaction with other variables in the system, either reinforces the original process (positive feedback) or suppresses the process (negative feedback). When modelling any system, it is important that feedback mechanisms are incorporated, as they will affect the rate and magnitude of any changes that occur.

Feedback mechanisms also exist within the insurance industry. For example, the relationship between the frequency and severity of severe weather events, the damage they cause and the translation of damage into insured losses is complex and affected by a wide range of factors. Consequently, it is not possible to assume that an increase in either frequency or severity of events will automatically result in a simple increase in insured losses.

This can be illustrated by looking at possible changes to future levels of flood risk. It has been proposed that climate change may increase the threat from flooding in some parts of the UK. Whilst this may lead to an increase in insured losses caused by flood, there may be feedback mechanisms which will cause the impact of an increase in flood risk to be opposite to that which might be expected. For example, increased risk of flooding could lead to:

- people moving away from flood prone areas;
- a higher price of flood insurance in flood-prone areas, and decreased insurance penetration;
- enforced planning guidelines preventing further development in flood prone areas;
- more flood defences being built.
- increased awareness of flood risk in affected areas, which in turn may lead to the adoption of loss mitigation techniques by local people (e.g. flood proofing their houses);
- a tendency to understate sums insured (59% of US homes are undervalued, (relative to what it would cost to rebuild, by an average of 22 percent). (Marshall & Swift/Boeckh, 2008.)

These factors would all act to reduce insured losses from flooding, even though the frequency and severity with which flooding occurs may increase.

At the same time, other feedback mechanisms may act to increase insured losses disproportionately. For example, if flooding comes more often, insurers may be under pressure to upgrade flood-affected homes with more costly building techniques to ensure future flood events have less impact. In Australia, insurers have paid out on flood damage even where the cover is excluded. Again, the damage done by floodwater in Hurricane Katrina was exacerbated by a mandatory evacuation, due to pollution and the failure of public utilities.

The above examples are far from an exhaustive list. They serve only to illustrate that the complexities of determining how changes in potential future flood risk will affect future insured losses. The challenge for catastrophe modelling is how to incorporate such factors and relationships into quantified expressions of uncertainty which can be used in a catastrophe model.

4.4 Climate change and catastrophe modelling

The frequency and severity of extreme events is determined primarily by the prevailing climate. If the world's climate changes, the behaviour of these extreme events will probably change. Chapter 3 discussed in some depth what might happen. In this section, we consider some of the challenges in using climate science predictions to assist catastrophe modelling, in particular relating to the coarse-grained scale of climate modelling, and uncertainties relating to frequency and severity of events.
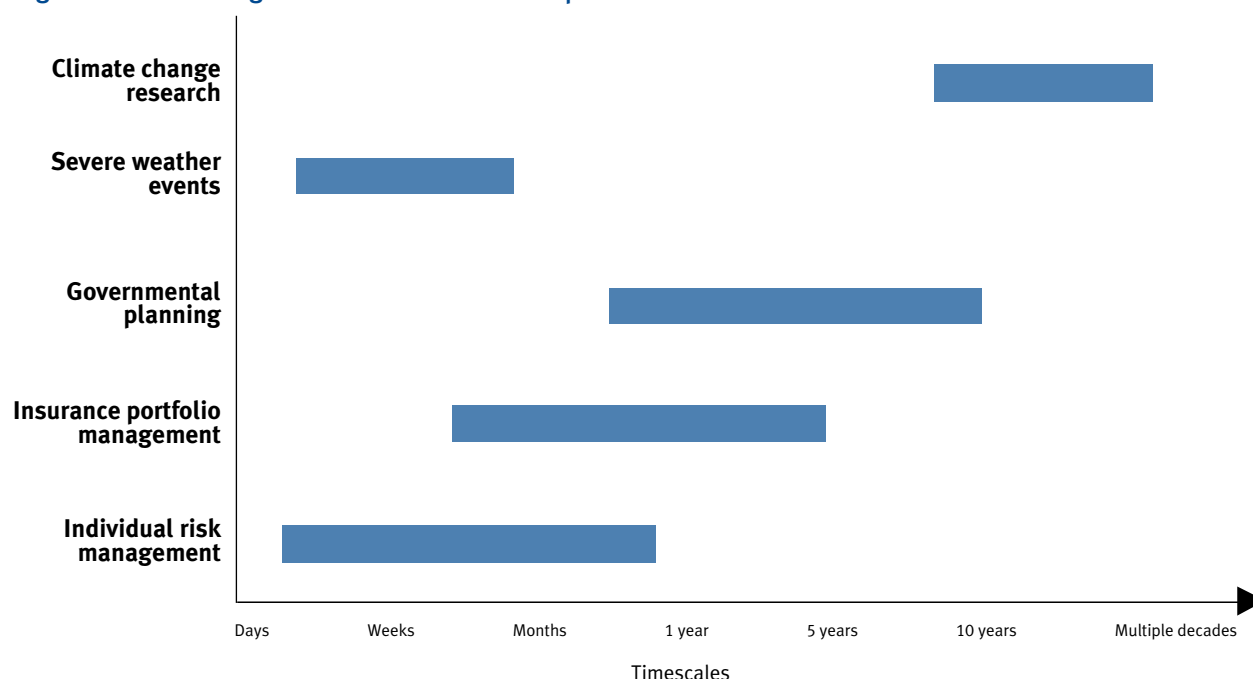
Questions of scale

There are fundamental differences between the scales on which climate change is considered and those at which the insurance industry operates, both in terms of timescale and geographical extent.

Temporal Scales

Figure 3 illustrates the different time scales that affect climate change and the insurance industry.

Figure 3: Contrasting Timescales in Climate Impacts

Individuals think about risk management over short timescales. Individual householders consider the immediate risks to their property, such as flooding and make decisions about how to deal with that risk. This may include wet- and dry-proofing; for example, fitting water resistant flooring in ground floor rooms to reduce damage in the event of a flood. For many people, risk management will simply involve the purchase of insurance.

Commercial enterprises will also have a risk management strategy, which is likely to involve the purchase of insurance, in addition to other mitigation techniques. As with individual householders, the potential for loss is considered over relatively short timescales – generally, the financial planning horizon. Industries with major infrastructure may also consider multi-annual time periods. Most property insurance policies are purchased on an annual basis, although there is usually an option to renew the policy each year.

Insurance and reinsurance companies may consider longer timescales, such as 3-5 years when thinking about the future growth and development of the business, a major concern will be the performance of the portfolio over the current year. Consequently the factors which could influence their results in that year will be the key interest of many insurers. These factors will be wide ranging, not limited to concerns over weather risks. They could include anything from general economic performance to actions by competitors or regulators.

In contrast climate change is normally considered over much longer timescales. Much climate change research, for example that carried out by the Hadley Centre, is based around the idea of using emissions scenarios. This involves setting emissions at a certain level (e.g. based on a projection of the how the global economy might develop) and modelling the potential impacts that these emissions will have on the mean global temperature over time. Most projections of future climate are for a number of decades from now. For example, the United Kingdom Climate Impacts Programme (UKCIP) report which looks at potential impacts of climate change in the UK includes projections at 30 year intervals, starting in the 2020s and continuing to the 2080s (UKCIP).

Although climate change science is considered over long timescales, the impacts of climate change will be felt at much shorter timescales – most severe weather events last only a few days or weeks at the most (although there are some exceptions such as heatwaves and droughts). This contrast in timescales raises a number of issues for the insurance industry:

• How can the differences in timescales between climate change research and risk management be resolved?
• How can the long term projections of future climate be used to understand the potential impacts in the next 3-5 years?

Catastrophe models are essentially tools for determining the probability of a loss of certain size or greater occurring within the next year. The question that needs to be answered is: how will climate change alter the probability of a severe weather event happening next year? This will be difficult to answer whilst climate change research is focused on the potential impacts in 2020 and beyond.

The practical answer is to select a scientific view of the distant future pattern, calculate the difference from the recent historical pattern, and then express the difference as an annual rate of change. For example, in 1996, the UK Department of the Environment published a report on climate change in the UK (CCIRG, 1996). This showed that within six decades the expected frequency of summers with an average temperature of 17.3C, such as that of the preceding year, would rise from 1.3% (a return period of 77 years) to 33.3% (a return period of three years) by the 2030s. Such a shift means the risk of the event would increase by 2,500% within 60 years. Expressed as an annual rate of change, this is a 5.5% change per year. This annual factor can be used to calculate the expected risk for any year up to the mid-21st century. (Dlugolecki, 2006.)

Geographical scales

The mismatch between the scales of risk management and climate change research exists geographically as well as temporally. GCMs operate on a fairly coarse grid, with prediction points typically a few hundred kilometres apart. The British Isles might be represented by just two or three predictions. However, weather varies systematically at a much smaller scale; there is a great difference in precipitation between east and west Scotland for example. Extreme events also happen locally, and indeed the current generation of GCMs does not succeed in generating tropical storms. As noted in Chapter 3, scientists attempt to get round this by downscaling, as in the UKCIP project, but such output is not available for all countries, and often places reliance on a single GCM, whereas there are significant differences among GCMs.

Even though the change in precipitation may be estimated at a regional level, the impact of this will still vary at a local level. For example, an increase in precipitation across a region will not cause a uniform increase in the risk of flooding across that region. The impact of that increase in precipitation on the flood risk will depend on a number of other factors such as land use, topography and location of property in relation to rivers and streams, all of which will vary locally. This raises several issues for insurers who have to operate at a number of geographical scales.

The individual underwriters within an insurance company need to consider risk at a local level. At the most basic level, the question is should they insure the particular property with which they have been presented? To answer this question, the underwriter needs to consider what the possibility of having a loss at that particular location, and how climate change may affect this possibility. A sophisticated catastrophe model with topographical detail can translate downscaled GCM predictions into localised effects, but that still leaves considerable uncertainty. The practical answer is to seek to identify 'risky' features, such as unoccupancy or prior weather damage, for more rigorous attention, while ensuring a geographical spread of risks at the portfolio level.

Additionally insurers need to consider not only each property individually, but must also monitor the portfolio as a whole to ensure that they maintain a well-diversified book and do not expose themselves to unexpected accumulations of risk. For many insurers, this will involve taking a regional and global view of their portfolio. Climate change impacts at this scale are better understood than localised changes, but information is still sparse on extreme events.
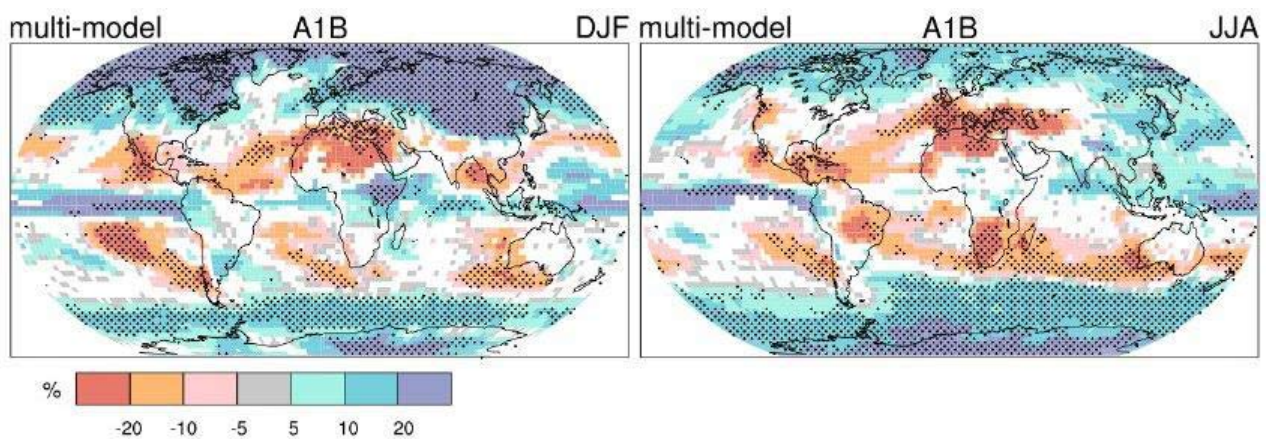
Uncertainty in climate change science

This section considers how much confidence can be placed in climate change findings about extreme events, as regards their likelihood, their future variability, and whether trends are emerging already.

Statistical significance and uncertainty of trends

One approach to address the lack of historical data is to use the output from GCMs to identify future trends in the frequency and severity of extreme events. However, this approach also comes with its own set of challenges. Climate models contain considerable uncertainty within their outputs. Figure 4 shows potential changes in precipitation by the end of the 21st century. (IPCC, 2007) The stippled areas show where more than 90 per cent of models agree on the sign of the change, though they still vary about the actual amount. In those areas the map shows the average of the predictions. The areas which are shaded but not stippled are where between 66 and 90 per cent of the models agree on the sign of the change; again, the shade shows the average change that is predicted. The blank areas are where less than 66 per cent of models agree on the sign of the change. Although for many parts of the world there is good agreement regarding the change in precipitation patterns, there are still large areas such as Africa, parts of Asia and the Americas where there is no clear signal from the climate models.

There are many reasons why GCMs differ. It is enough to note here that while the differences tend to magnify over time, due to the treatment of such factors as climatic feedback mechanisms, the models vary significantly even in their replication of recent history at regional level. Chapter 3 discusses these uncertainties in more detail.

Figure 4: Consistency between GCMs on precipitation: Emissions scenario A1B, for winter (DJF) and summer (JJA) , late 21st Century
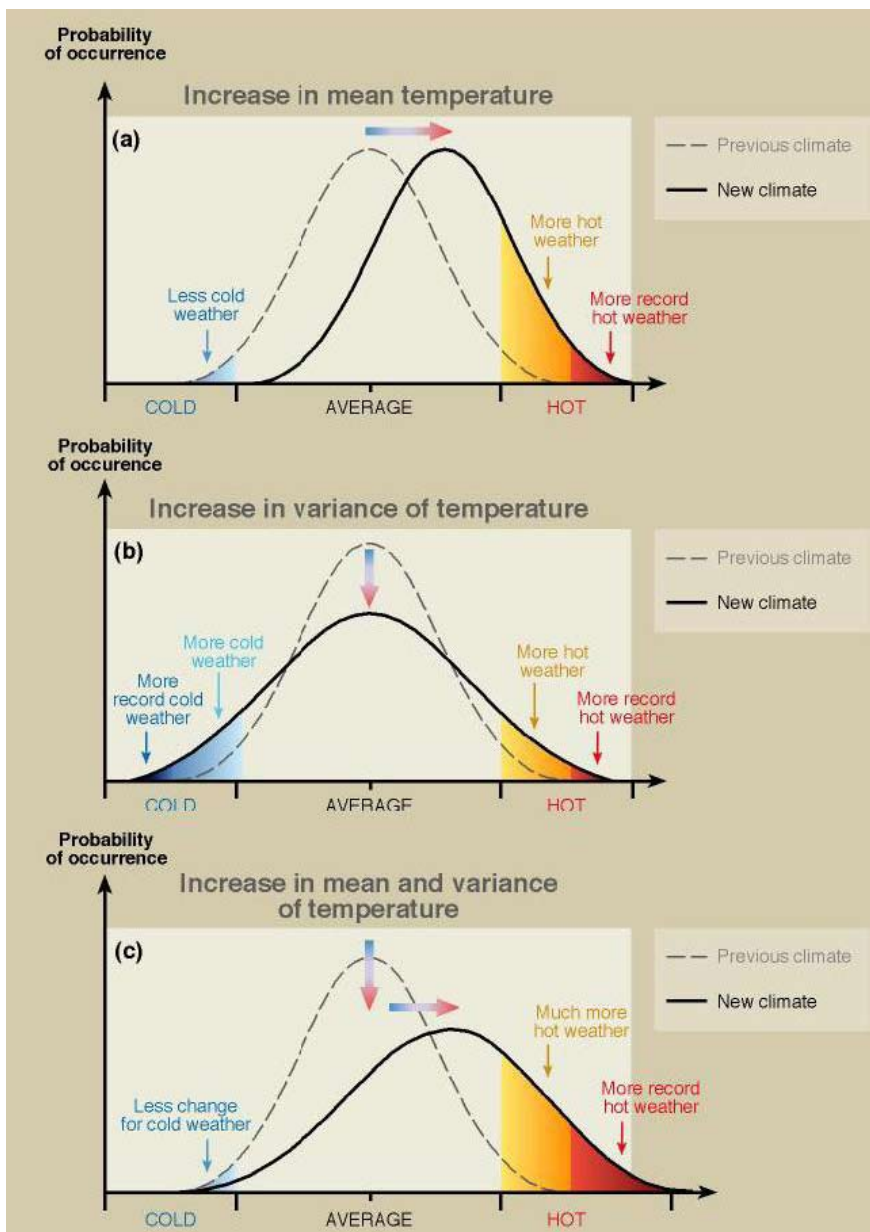

Source: IPCC AR4

Thus the first conclusion is that one should not rely on just one GCM, without checking how much it accords with other models for the problem that is under consideration.

Too much focus on changes in the mean

When assessing the potential for catastrophic loss, it is more important to understand extreme events rather than the average. This involves looking at events which occur in the tails of the distribution and how these are affected not only by changes in the mean, but also changes in the variance (which helps determine the shape of the distribution curve). Increases in extreme events can be caused by both increases in the mean and the variance (see Figure 5).

Figure 5: Different ways that probability distributions may alter under climate change

GCMs have just begun to examine the issue of variance, because the first priority has been to achieve a consensus on the average. Also, to assess the variance necessitates more runs and more data retention..

The Hadley Centre has produced some worrying conclusions in this field: "at many locations, extreme temperatures are predicted to increase more than the seasonal average. At some locations, seasonal average rainfall is predicted to decrease, while the intensity of extreme rainfall will increase."

(Hadley Centre, 2004)

Source: IPCC 2001 working group 1 chapter 2

Identification of trends

There are also a number of challenges to clearly identify the trends in the frequency and severity of extreme weather events. Firstly, there is relatively little reliable historical data available for severe weather events. Although for some perils, such as flooding, and in some regions, such as Europe or China, information about the frequency and severity may go back hundreds of years, for most regions and perils, it will be less than 100 years. Further, one can query the usefulness of historical impact-related statistics such as flood levels, since there have been enormous changes in land-use and those also affect flood levels.

There are also concerns over the quality of the data record. For example, the record of tropical cyclone activity in the North Atlantic basin is about 150 years long, but high quality data from satellite observation has only been available since around 1970 (IPCC 4AR, 2007).
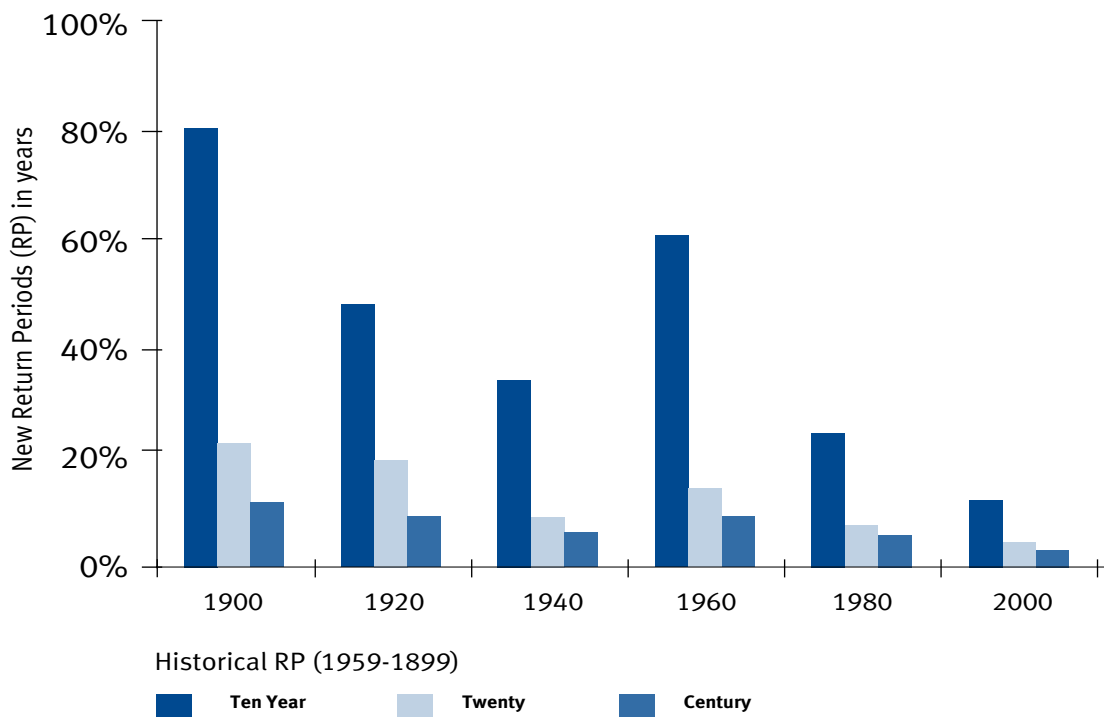
Thirdly, even if trends can be identified within the available data, it may not be clear whether these changes are a result of human induced climate change. Any increase in frequency and severity of severe weather events may be due to natural variability within the climate system or periodic fluctuations in the climate system that operate over longer timescales than the period for which data exists. The patterns observed could simply disappear or even reverse.

Scientists are therefore more confident when observed trends appear to behave as their GCMs predict. They have noted (IPCC AR4) the following trends in severe weather events:

• Strengthening of mid-latitude westerly winds since the 1960s
• More intense and longer droughts over wider areas since the 1970s in the tropics and subtropics
• Increased frequency of heavy precipitation over most land areas
• Increased frequency of intense tropical cyclone activity in the North Atlantic basin, but the GCMs cannot confirm this is an expected trend.
• "insufficient evidence to determine whether trends exist …in small scale phenomena such as tornadoes, hail, lightning and dust storms".

A good example is provided by UK temperatures. These are expected to become higher, but there is no indication that there will be any change in the variance. This is Case (a) in Figure 5, so one still expects to find an increase in more extreme values.

Figure 6: Actual Return Period for different levels of hot months in Central England

Raw data from the Hadley Centre. Processed by Andrew Dlugolecki.

Figure 6 shows that the return period of hot months has been dropping. Months that used to be 'century' events in Victorian times, now happen once every 14 years, a seven-fold increase, while 20-year events happen every five years, and 10-year events recur every three years. In other words, the more extreme the event, the greater the relative change in its frequency. By extension, the return period for a 1,000 year event is now around 83 years.

How important is this for insurers? This evidence relates to temperatures, whereas precipitation and storms are the real destroyers of property. However, hot temperatures are closely correlated with aggressive storm patterns. Recent research shows that intense hurricanes have become more frequent as tropical seas have warmed, while European winter storms are stronger and more frequent in warm winters. In addition, warm air can carry more water, so that winter storms are more likely to produce flooding, and summer thunderstorms are more intense. And, of course, subsidence claims shoot up in hot dry summers (Dlugolecki, 2006).

Scientists look for 'significant' change from the past before declaring a change has happened, i.e. a consistent and very strong change in observations is needed to overturn the 'null hypothesis' of no change. Typically, this means that they set a target of a 5% chance that 'no change' will be rejected when it is true. This outcome of deciding there is a change when in fact conditions are unchanged, is known as the Type I error.

However, this approach tends to play down the opposite (Type II) error, i.e. that 'no change' will be accepted as true, when in fact the world has changed. This focus on "Type I error" does not matter much if Type I error is more expensive than Type II, or even roughly the same. However, when the consequences of missing a shift in the real world like climate change are so great, then "Type II" error needs to be given more weight when balancing the evidence.

This is even truer if there is ample circumstantial evidence that changes are likely, so that the assumption of no change as the starting point is suspect. For weather patterns, the fact that global average temperatures have been rising for more than a century makes it unlikely that the world is going to repeat previous behaviour. However, in practice the high degree of natural variability in weather patterns means that most scientists say that climatic effects are not yet evident in the pattern of events.

One method of combatting this bias to the status quo is Bayesian statistics: essentially one alters the probability of expected events to align them with recent experience and model predictions, and uses the altered probability as the 'null hypothesis' which is tested.

4.5 Hurricane risk – current approaches by proprietary catastrophe modellers

Since hurricane modelling is well established and has been the focus of much attention, it provides a suitable case study to examine differences in modelling approach. As noted in Chapter 3, hurricane patterns are still the subject of intense scientific debate, or even dispute. From a practical point of view, fortunately, there is consensus about the outlook for the next few years regarding hurricanes. If such findings are not factored in, catastrophe models may well be underestimating the potential risk.

The approach here is to examine the recent approaches taken by the 'Big Three' catastrophe modeling companies: AIR, EQECAT and RMS. (There are of course other models, either independent or developed from the Big Three models, run by reinsurance companies, brokers and insurers.)

AIR Worldwide Corporation

AIR Worldwide's US hurricane model includes two views of potential hurricane activity: the standard catalogue, which is based on more than 100 years of historical data, and a warm-sea surface temperature (SST) catalogue, which represents hurricane risk under warmer than average sea-surface temperature conditions. The research that went into creating this alternative view of hurricane risk will be published in the Journal of Applied Meteorology and Climatology.

As a result, the inclusion of one additional season of hurricane landfall experience will not significantly change estimates of near term risk and the Warm SST catalogue will yield more stable results going forward. In Version 10.0 the difference in mean frequency between the near-term and standard catalogues is between five and ten per cent for the US, with the largest relative increase in the southeast. However AIR cautions that uncertainty in near-term estimates of landfall frequency remains significant and secondary factors can mitigate the elevated SSTs, e.g. as happened in the 2006 and 2007 season.

EQECAT

EQE's own research "indicates strongly that the risk for insured losses from the hurricanes in the US during the next decade – the 'near-term' – will be higher than the long-term average derived from more than 100 years of data," according to a recent press release from Rick Clinton, EQE president.
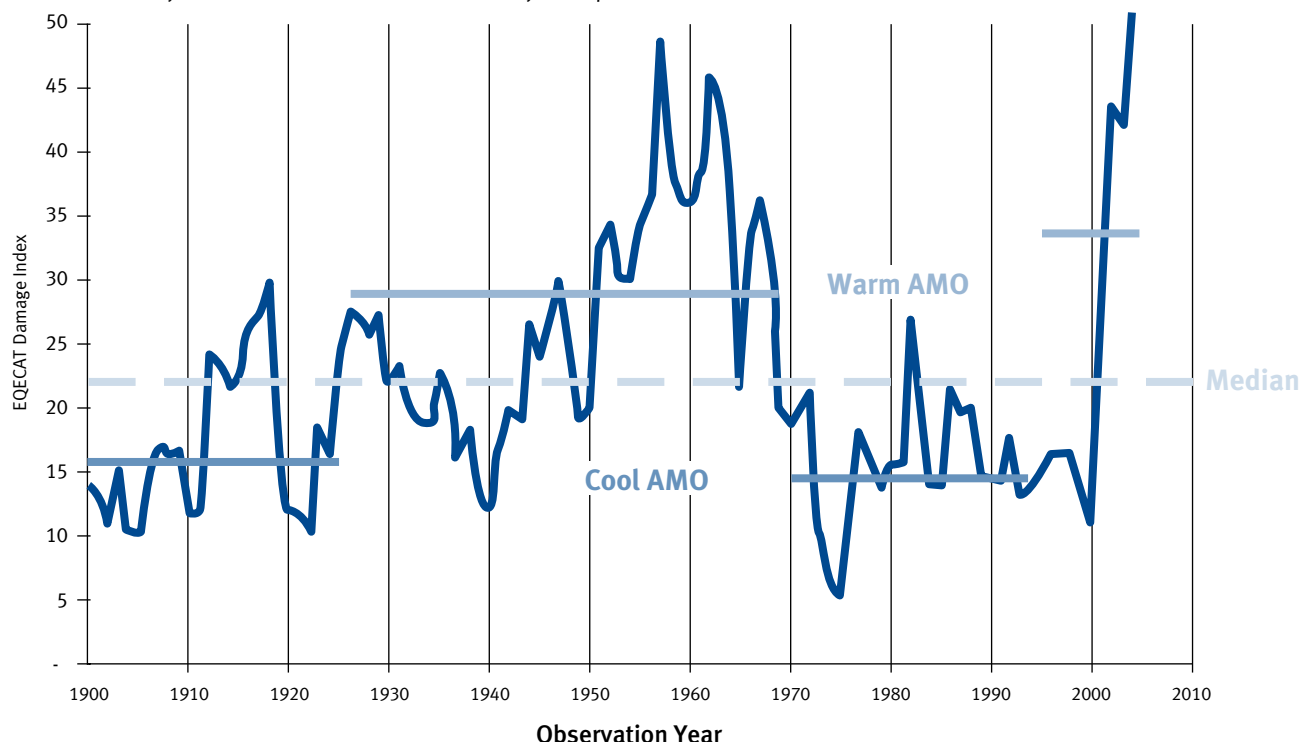
Having reviewed the AMO cycle and modelling losses based on the 2004 market portfolio, EQE noted a 40% increase in AAL (average annual loss) during the warm periods. In order to remove the potential bias in the land falling storms (urban area hits and misses) EQE developed a Trended Insurance Risk Index based upon "the damage to a 'portfolio' of uniformly

spaced residential buildings throughout all of the US":

Figure 7: Trended EQECAT Damage Index by year (seven-year averaging)

EQE believe that the AMO trend strongly indicates that we are in a period of heightened hurricane activity that could last between 10-15 years. It is with this in mind that they have produced a model based on the events that have occurred

during the warm AMO cycle (54 years of data) and assigning an annual frequency of 1.54. The 40% increase in AAL has particularly affected Florida where a 50% increase in AAL can be seen. When this is put into context with increasing flooding, temperature extremes and other perils, the need for insurers to ascertain the real (heightened) level of risk they are taking on becomes essential.

Risk Management Solutions (RMS)

RMS has taken the lead in recommending that the long-term historical average is no longer an appropriate basis upon which to make risk management decisions, given the undisputed fact that we are in a period of elevated activity compared to this long term average, and have in fact been so since 1995. The question is, how long will this last? To answer this, RMS has pioneered the use of an Expert Elicitation process involving several leading hurricane climatologists to overcome the problem of sparse historical data. (This technique is similar to the Delphi Method, a system of interactive forecasting which relies on a panel of independent experts. The experts answer questionnaires in two or more rounds, and after each round, the participants are encouraged to revise their earlier answers in light of the replies of other members of the group).

The first expert elicitation session to assess the medium term risk of land-falling hurricanes was conducted in 2005, with a second in October 2006. There are two theories (one cyclical and one trended) that serve to explain the current period of high activity. "With insufficient evidence to confirm either theory, and the potential for the reality being a hybrid of both, the theoretical underpinning of what determines current hurricane activity cannot be settled from historical observations alone."

Since the 2005 roundtable, there has been as increase in the number of experts participating and an increase in the range of statistical tools. The main conclusion reached by the experts is that over the next 5 years, Atlantic hurricane activity is

expected to be consistent with the average of the past 11 years. There is only a small probability of this activity returning to the long term baseline over the next five years. It is with this in mind that RMS sought the near-term model approval from the FCHLPM (Florida Commission on Hurricane Loss Projection Methodology) for 2007 but were denied. Their historical model has since been approved, but this does not incorporate the near-term event set. RMS firmly believes their new model to be superior for assessing potential loss over the near-term. If the FCHLPM had approved this near-term model, it could have major implications for rate making as insurers would use the near-term view of risk (substantially higher) as opposed to the historical view. Under guidance from RMS, many clients incorporate the near-term view as their primary view of risk (using the historical view when required).

RMS used the information provided by the panel of experts to implement the five-year view of activity rates in both the US and Caribbean hurricane models. Hurricane patterns in the near future (2007-2011), would result in severe hurricanes striking land 36% more often than in the past century, whilst cat 1-2 hurricanes are 21% more likely (RMS, 2006).

Postscript

The 2006 and 2007 hurricane seasons were relatively quiet, which cast some doubt on the consensus for increased activity. However, hurricane season 2008 saw a return to numerous damaging and deadly US and Caribbean storms and hurricanes.

Sixteen named storms formed, of which 8 became hurricanes including 5 major hurricanes. These numbers are very close to the 1995 to 2008 average of 15, 8 and 4, rounded to the nearest whole number, but continuing the bias towards stronger storms. The season was prolonged, with a major hurricane in five different months for the first time.

It was fortunate for insurers that both of the strongest hurricanes of the season (Gustav and Ike, both Category 4) struck other land areas and weakened before striking the US, but unfortunately in the process Ike greatly expanded in size, and is currently estimated as the fifth largest insured loss.

4.6 Future developments and synergies between climate science and catastrophe modelling

Historically, global climate modelling undertaken in academia and probabilistic catastrophe modelling within the risk and insurance industry have developed relatively independently. The challenges of modelling extreme events under a changing climate are bringing these disciplines together. Dynamical modelling[1] of the global climate system, at sufficiently high-resolution to begin simulating regional weather events, holds a wealth of information for risk assessment. In particular, the use of dynamical, high resolution GCMs, to complement and substitute inadequate historical observational data, could provide a powerful means to tackle some of the key challenges to climate variability and extreme event modelling identified above.

The IPCC-AR4 states that a GCM resolution of less that 100km is required to begin to simulate tropical cyclones. Recently improved models and computational resources have allowed GCMs to be developed with the detail able to simulate the evolution of small scale events, such as tropical cyclone-like circulations.

'High resolution' GCMs with improved detail in terms of the grid-points and equations can also help to assess the impact of climate variability. As indicated above, natural climate variability, such as the El Niño-Southern Oscillation, has been shown to have an impact of tropical cyclone activity.

Recent research at the Walker Institute, University of Reading, as part of the Willis Research Network (WRN), is applying state of the art methods such as a feature identification and tracking algorithm developed at the University of Reading (e.g. Bengtsson et al. 2007). In fact, the WRN is now the largest collaboration between insurance and academia in the world, boasting over 16 of the world's top universities and research institutions as members and funding a post-doctorate Willis Research Fellow scientist at each member organisation.

Using the output of advanced GCMs, it is possible to calculate the full life-cycle of the tropical cyclone, including transformation into extra-tropical cyclones, an important aspect of cyclone activity for the insurance industry. With higher and higher resolution, it will be possible to begin to resolve the processes that influence precipitation and windspeed in storms.

Downscaling techniques combine the benefits of a high resolution weather model with the coarse resolution GCM by embedding the weather model within the GCM over regions of interest. In addition to providing information on the frequency and locations of tropical cyclones, this approach can provide information on their intensities and land-falling

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[1]   i.e. attempting to show its development over time

wind 'footprints' (Done, 2008). Current research using this method is investigating hurricane changes over the next 50 years using a variety of greenhouse gas scenarios and horizontal resolutions of 36, 12 and 4 km. The huge volume of computations means that the 12 km simulations can only be achieved in three 11-year slices: 1995-2005, 2020-2030 and 2045-2055, and the 4 km for specific studies, such as landfall of Category 5 hurricanes. However, this will change with future computing and modelling advances.

The resultant databases of storm tracks and associated windfield and other hazard parameters can be structured to replicate the event catalogues of catastrophe models, and can explicitly include the impact of large scale climate drivers and global climate anomalies on the frequency and distribution of extreme weather features such as tropical cyclones. Whilst this application of latest high resolution, weather resolving GCM outputs is in its infancy and there are many areas still to be properly represented (particularly the correct representation of intensity, precipitation and other weather features), it is expected that preliminary event catalogues compatible with those generated by catastrophe models will become available soon.

An alternative view from RMS advocates a combination of Numerical Weather Prediction techniques for certain aspects of storms, such as strength at the time of landfall, and decay thereafter, but combined with statistical techniques for storm formation and direction. This has the added benefits of less reliance on one suite of GCMs, and also far less computational requirements.

One exciting development is the potential to provide accurate seasonal catastrophe forecasts, e.g. a prediction relating to next year's hurricanes. This means that risk assessment can be tailored to the likely hazards, rather than simply based on a generic average, either historical or based on expected long-term trends. Seasonal forecasts are already being used for agricultural purposes because rainfall can be predicted with some accuracy in some regions due to the dominant influence of large-scale atmospheric patterns such as El Niño. Various institutions already provide seasonal forecasts for tropical cyclones, but their success has been patchy. This could change with the advent of more powerful models, and might lead to a very active market in short-term risk transfer products.

4.7 Conclusions and recommendations

Climate change means the assumption that past losses are a reliable way of estimating future losses may no longer hold true. In this situation, it becomes even more important to adopt modelling based on scientific principles to assess the potential risk.

However, the previous sections have demonstrated that the incorporation of climate change impacts into catastrophe modelling is very challenging for a variety of reasons, including differences in the scale of scientific and insurance models, differences between GCMs themselves, lack of data and natural variability in the weather which makes it difficult to identify trends.

Climate change simply reinforces the need to remember the limitations and uncertainties inherent in any model. Catastrophe modelling is a relatively new field and is constantly changing (this is demonstrated by the major commercial catastrophe modelling companies releasing new models and upgrades frequently). Catastrophe models are one tool which should be used in conjunction with other risk assessment techniques to make informed risk management decisions. Given the uncertainties surrounding climate change impacts, exposure management and good underwriting are likely to become ever more important. Catastrophe modelling can help with this, but only when used as part of an overall strategy for assessing and managing risk.

As climate change occurs there will be a need to develop new models – for different perils and in different regions. However, this process could be hampered by a lack of hazard and vulnerability data to build those models. As previously described, catastrophe models have often relied on historical data for either their construction or calibration and validation. With many new perils and regions, there will be no historical data available.

Conclusions

Loss potential

Insured losses from severe weather events have been increasing over recent years. Socio-economic factors are a huge influence (wealth, location, vulnerability, and societal feedback), although climate change is becoming a factor. If premiums were risk-based, then the growth of values would be dealt with automatically by the additional premium that is generated on the new sums insured. However, the lack of adequate data, and competitive pressure, mean that often the rates charged are inadequate, sometimes knowingly, sometimes in ignorance. The real threat is that climate change may start to come

through rapidly, which would compound the socio-economic trend effect.

Hurricanes

Whether one believes global warming is the cause or it is part of a natural cycle, it would be prudent to prepare for some years of heightened hurricane activity.

Use of scientific evidence

Traditional scientific evidence may be biased against recognising new trends. The high variability of weather data means it is difficult to conclusively identify a new trend.

Because there are often large differences between them at regional level, it is advisable to use outputs from more than one GCM if possible. Additionally, downscaling will help to make results more granular.

Long-term predictions can be converted into annual rates of change, which is more relevant to catastrophe modeling and risk assessment.

Since damage is produced by extreme events, it is important to translate predictions about changes in the mean into terms of extremes, because of the disproportionate effect on the tails of a probability distribution. This could be compounded if the variance is also changing, but usually such information is missing.

Use of catastrophe models

It is important not to rely on just one model if possible. Models differ for many valid reasons, not least because of the lack of data to fit them. This means catastrophe modeling is more an art than a science, with different experts emphasising different aspects of hazard, vulnerability, and even exposure.

Users need to learn as much as they can about how a model works before using any outputs from it. For example, has enough use been made of recent knowledge, e.g. the state of ENSO, or recent rainfall (to allow for natural cycles, teleconnections, and feedback effects). How are event catalogues generated? What factors are used to model hazards and vulnerability?

The way ahead is dynamical modelling, using the current climatic status to initialise predictions. This will enable more accurate short-term and seasonal forecasting, but will require far more computational power.

Recommendations

The insurance industry

Insurers at all levels who are involved with catastrophic risk should strive to remain up to date with the current state of knowledge. The conclusions in this chapter give a very thumbnail sketch of the key principles.

Insurers should collaborate with the academic, scientific and modelling communities to develop a better understanding of the uncertainties involved in climate change and how these impacts can be quantified. This can be done by sponsoring research, publicising reports, supplying data on claims, and seconding staff for example. Progress has been made in this area with a number of initiatives such as the Willis Research Network and Lighthill Risk Network which bring together academic institutions and the insurance industry to address the research needs of insurers.

Insurance companies need to have data available at sufficiently high resolution to utilise improved catastrophe and risk models, e.g. for flash flooding. It may take a long time to get systems in place to capture this data – so insurers need to start considering this now.

Insurers should consider using catastrophe models for managing claims events. The policy database can be combined with event predictions in real time to target the vulnerable areas, which will improve customer support and reduce costs.

Re/insurers should adopt a conservative approach to loss retentions in view of the many uncertainties in catastrophe modeling, and the likelihood that climate change will compound the underlying trend in exposure.

A complementary strategy is to ensure a spread and diversity of risk, allowing for the possibilities of teleconnections.

Insurers should encourage clients to implement loss reduction measures, and reward them through improved terms. In the absence of accurate information, the quality of the risk portfolio gains more importance and can be improved in this way.

Government agencies

Those concerned with civil defence and financial regulation should make full use of catastrophe models to give them a realistic view of the risks.

Regulators should permit insurers to charge prices for catastrophe risks that are based on prospective rating with catastrophe models.

Developing countries should enlist catastrophe modeling as a key technique to manage the risks of climate change. This will need a major programme of data acquisition.

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UKCIP = UK Climate Impacts Programme

Biography

Kevin Bermingham

Kevin Bermingham is a Specialty Analyst in the Aon Benfield Analytics team. He has over 7 years experience in cat modelling, having started his career at XL London Market pricing Facultative business for XL Re and XLIGR before moving to Brit to manage the D&F Portfolio. At Brit, he soon transitioned to the Treaty Portfolio Manager and was involved with company-wide portfolio analysis, retro reinsurance placements and Property Treaty pricing. He has gained invaluable experience in catastrophe pricing with a focus on the London Market.

Kevin graduated with a BA(Hons) in Business Economics from Liverpool University and is ACII qualified.

Claire Crerar

Claire has 7 years' experience working as catastrophe modeller, using computer models to analyse the risk to insurers and reinsurers from catastrophic events such as windstorms, earthquakes and floods.

After 6 years as a catastrophe risk analyst at Willis, Claire now works for Aspen where she leads the London catastrophe modelling team which responsible for international treaty modelling and monitoring accumulations of catastrophe risk.

Claire's interest in climate change first developed whilst studying for a degree in geography at Cambridge University. In particular, she is interested in the impact of climate change on the frequency and severity of extreme events, and the different ways in which the risks associated with climate change are perceived by different groups of people.

Biography

Dr Andrew Dlugolecki

Andrew spent his salaried career with General Accident (now part of Aviva Group), starting in 1973 as a statistical analyst. Early projects included the effect of weather on motor and property claims. There followed a variety of interesting jobs at senior level, including managing the UK branches, and then emerging countries. A merger in 2000 led to a change in corporate direction, and departure for him.

When scientists started to investigate the economic implications of climate change in 1988, they asked various industry associations to identify experts to work with them. The British Insurance Association nominated Andrew, and he continued this "sideline" even as he worked in other areas, and then as a second career after he left Aviva.

Andrew's work on climate change covers three major aspects. Firstly, advice to politicians: he has been the chief author on insurance and financial services in major studies of climate change commissioned by the UK government, the EU, and of course the Intergovernmental Panel on Climate Change.

Secondly, in education, he has chaired three major studies of climate change by the UK Chartered Insurance Institute (1994, 2001 and 2009). He prepared and mentored modules of an e-learning training package on climate change and finance for financial institution executives, under the auspices of UNEP Finance Initiative (UNEPFI). He often gives talks and writes articles.

Thirdly, he continues to be active with business clients. He has been an advisor to the Carbon Disclosure Project and the UNEP Finance Initiative since 2000.

Andrew's qualifications include degrees in pure and applied mathematics, and a doctorate in applied economics. Among his affiliations he is a Fellow of Chartered Insurance Institute, and a visiting Fellow at Norwich University's Climate Research Unit. When IPCC received the Nobel Peace Prize in 2007, Andrew was one of those cited who had "contributed substantially" to their work.