THOUGHTS ABOUT THE IMPACT OF CLIMATE CHANGE ON INSURANCE CLAIMS

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Summary

This paper focuses on the type of extreme event that is important to property insurers, and considers evidence on how those risks have been changing, and how they might move in future with climate change. In particular, evidence is drawn from UK, which has wide insurance coverage for weather perils and also much familiarity with international catastrophe insurance. The facts that UK weather is changing at an unprecedented rate, and that abnormal weather causes insurance claims, mean that climate change is already affecting the risks, though socioeconomic factors have also caused change. Further, the risk of extremes is changing very rapidly. However, because the costs of extreme events are heavily skewed towards the very rare ones and the pace of economic development has been so fast, it is difficult to discern a trend in the relatively short data series of economic costs. These hidden trends mean that we must expect frequent surprises. Hurricane Katrina showed how sensitive the global economic system is to climatic disruption, and this vulnerability will grow with the increasing reliance on regions that are prone to sealevel rise, tropical storms, and water shortages or floods. Private insurers may be able to limit the financial risk, as they did with Katrina, but then the cost spills over into wider society.

In this context, the question must be asked, whether it is right or prudent to take as the null hypothesis that damage is NOT increasing due to climate change rather than a Bayesian approach that damage should be increasing already.

1. Introduction

Potentially, the insurance industry is exposed to climate change in a number of ways, although the effects may vary greatly between jurisdictions, due to industry structure and practice, as well as climatic and geographical differences. The insurance industry is already encountering aggravated claims for insured property damage in extreme events, particularly flood, storm, and drought. As yet, the main causes of the rising trend in property claims in recent decades are socio-economic rather than climatic, but the contribution of climatic change will likely rise quickly, due to the strongly non-linear relationship between climatic variables and damage, and the fact that a small shift in mean conditions can create a large change in extremes. The pace of change regarding weather extremes is fast. The underlying rate of change can be 12% per year for very rare events, and in the range 2 to 4 % for extreme, but "insurable" events. This means that underwriting strategies are inadequate to the real risks. Already target regions are evident, on coasts and particularly on deltas. Likewise some sectors could be strongly affected, with greatly increased risks. For some hazards, like freeze and drought in UK, the risk may diminish, but this will be more than offset by increases in flood and storm risk.

A key source of evidence is UK, because of its wide insurance cover and good statistical database, as well as its familiarity with overseas markets, through its subsidiaries and also reinsurance of external markets. Next we look at global trends using data from Munich Re. Then we shall consider the literature as revealed by IPCC. Finally we look at European storm, from two studies not in the current IPCC draft.

2. UK Evidence[1]

2.1 The climate data

The UK has the longest series of scientific weather records in the world (1659 for monthly temperature, and 1766 for

[1] This section draws heavily on the technical annexes to Dlugolecki (2004) available at http://www.abi.org.uk.

precipitation - see Hadley Centre website. This gives us the ability to calculate long-term weather patterns with confidence. For insurers, it is the extremes that matter, since those are what cause property damage.

Any month in which the monthly temperature or rainfall fell in the top or bottom ten percent of the historical range will have experienced some rather extreme days, so this decile threshold can be used to identify the extreme-weather months (hot, cold, wet, and dry). Since we are using the decile level to pick the months, there ought to be twelve such months in every decade (10 % of 120 months).

The table shows the pattern of extreme months in recent decades in the UK (bold font indicates high and low values, as values outside the range 7 to 17 are statistically significant at the 5% confidence level).

Table 2.1 Recent UK weather: extreme months since 1960 (see Also Figure 2.1 below)

Number per decade (12 expected)	1960's	1970's	1980's	1990's	2000's (pro-rated to March 2004)
Hot	10	17	**18**	**34**	**33**
Cold	**5**	7	8	**3**	**0**
Wet	14	11	**19**	15	**26**
Dry	10	15	10	15	**2**

Note to Table 2.1. The figures for the 2000's decade are estimated by scaling up the observed occurrence of extreme months to March 2004, by the factor 120/51 to allow for the remaining months of the decade.

- For hot months, the 1960's were just below average, with only 10 hot months. Since then the frequency has risen dramatically, and it has been running at nearly 3 times the expected rate since 1989 in fact. This is the highest level since records began.
- Cold months however have been running well below the expected level since 1960, and have now disappeared. Again, this is unprecedented.
- Wet months have become steadily more frequent, now running at double the customary rate. This is particularly a winter phenomenon.
- Dry months seem to have receded for the moment. However, it is worth noting that what matters here from an insurance point of view is a succession of below-average months, rather than simply isolated very dry months. A prolonged dry period leads to shrinkage of clay soil, with consequent damage to the foundations of buildings and claims for subsidence.

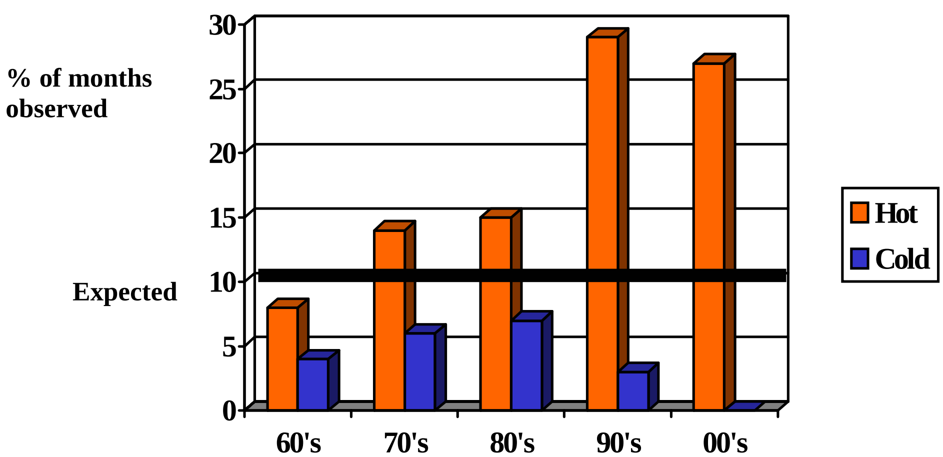


Figure 2.1 Recent patterns of hot and cold months in UK (Central England Temperature observation series)

2.1.1 Statistical significance of the recent observations

To test whether the data is generally consistent with the long-term average of 12 extremes per decade, we can use the standard χ^2 test, with 4 degrees of freedom. The test results are:

Hot $\chi^2 = 61.3$ Cold $\chi^2 = 15.6$ Wet $\chi^2 = 12.1$ Cold $\chi^2 = 5.5$

Since the significance levels at 98%= 11.7, and at 99% = 13.3, the test results confirm that, apart from cold months, the observed weather since 1960 has been abnormal.

Applying the standard normal distribution approximation test to the deviations from expected:

z= (observed-expected)/ ✓ (expected x probability of not occurring) for temperature after 1990 gives:

Hot z=7.75 Cold z=3.47

These values would be seen by chance 1 in a million and 1 in 4000 times respectively, confirming how very abnormal this weather is by historical standards.

2.1.2 Implications

This change to warmer winters is associated with more storms (the number of winter storms crossing the UK has doubled over the last 50 years), more rain, fewer frosts, and faster thaws. Warmer, drier summers mean more clay-soil subsidence. Significant weather events affecting the UK during this period include:

- The extended drought and heatwave of 1975/6
- The "hurricane" of October 1987
- The severe windstorms of January and February 1990
- Numerous severe local floods eg at Perth in January 1993 (see Annex 2 for more detail)
- The Shetland storm of 1993, probably the deepest ever depression in NW Europe, which wrecked the tanker Braer
- The drought and heatwave of 1995
- The Easter floods of 1998
- A close call - three storms devastated mainland Europe (December 1999)
- The Autumn floods of 2000
- The drought and heatwave of 2003
- Looming drought in 2006

2.1.3 Prolonged drought

Whereas individual dry months do not have a significant implication for insurers, longer periods do. In fact the seasonality of precipitation has shifted in the last 40 years, with more frequent dry months in Q3, and more frequent wet months in Q1 and Q4 (see Table 2.2). In those quarters, the months at the opposite end of the distribution have lessened. Q2 has seen a change to more variable precipitation, with an excess of wet and dry months.

Table 2.2 Seasonality of precipitation since 1965: occurrence of decile months
(12 expected for each quarter in 40 years)

	Q1	Q2	Q3	Q4
Wet	20	18	8	19
Dry	7	14	17	4

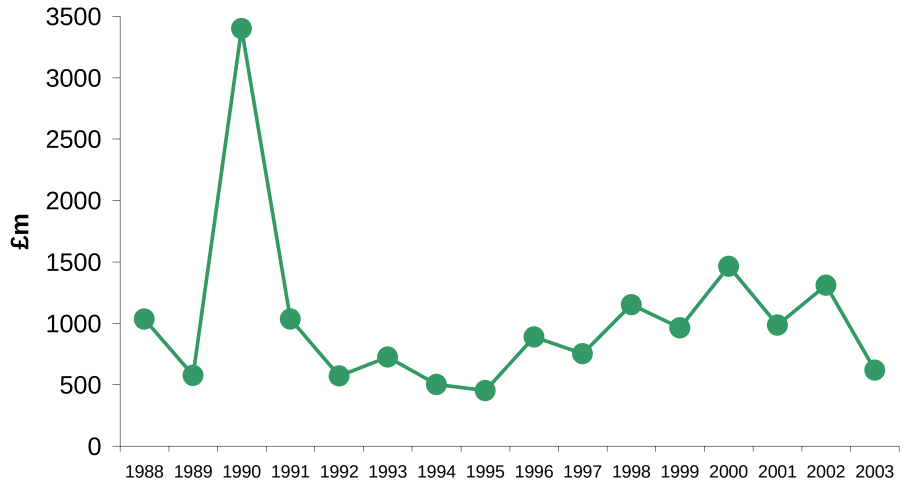
A relevant statistic for building damage is given by the following *drought index*: precipitation accumulated for 18 months to September. Using the historical data for precipitation (available from 1766), we can investigate whether there has been a shift in the behaviour of the drought index. For the period 1766-1965, the upper decile threshold is 1551mm, and the lower decile is 1151 mm. In the last 40 years (1966-2005), there have been five occurrences at the high end.

Although this is not statistically significant, one of the periods (2001) was a new record and was associated with high numbers of flood claims in 2000. At the other extreme, there have been six occurrences, of which two have been new lows (1976 and 1996), while three occurred in succession (1989, 1990, 1991). The sixth one occurred in 1997, adding to the effect of the 1996 low value. All of these lows have seen large numbers of subsidence claims (see Figure 2.3). The behaviour of the drought index is suggestive of a change to more erratic conditions, which is perhaps not surprising given the change in seasonality of the rainfall.

2.2 UK Insurance Data

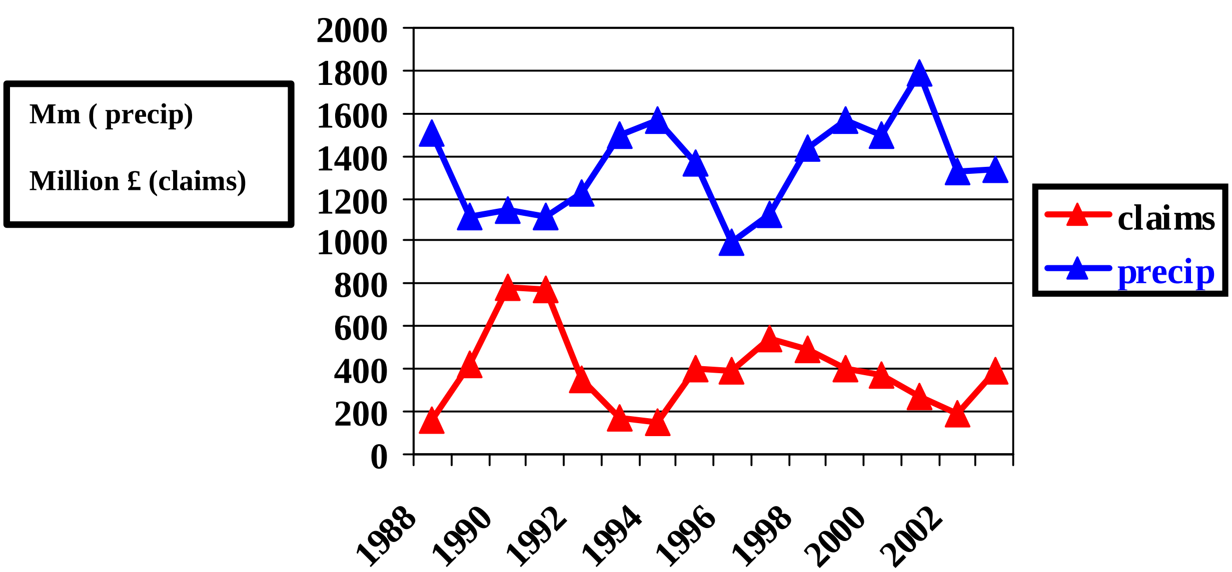
While it is true that insurance claims respond to abnormal weather conditions, it has to be borne in mind that the impacts develop unevenly when looked at on an annual basis, because of catastrophes. Figure 2.2 shows this for "weather" claims recorded by members of the Association of British insurers (ABI), excluding subsidence claims. The cost is measured in constant values, which demonstrates the scale of the 1990 peak. The massive spike in 1990 was due to a four-week period of storms commencing on Burns' Day. The fact that individual years have been lower since then does not mean the risk is diminishing, because of the random occurrence pattern. There was another great storm in 1987, a near-miss in 1993 and three near-misses in 1999!

Figure 2.2 ABI member companies' weather claims, 1988-2003 (excluding subsidence)



Subsidence claims respond strongly to drought (see Figure 2.3). There are of course other factors, such as the state of the housing market, and the relationship given here is only approximate because most claims arise in the clay belt of mid and SE England, whereas the data shown here relates to all UK for claims, and all England and Wales for precipitation. If anything, the data suggests a downward trend in subsidence claims. This is not surprising, given the trend to wetter winters seen in Table 2.2, which militates against prolonged droughts.

Figure 2.3 ABI member companies' subsidence claims 1988-2003 versus drought index for England and Wales.



2.3 Weather Risk Trends

The UK insurance industry has been willing to underwrite the broadest range of weather perils. However, the prospective increase in UK weather damage may make such risks unacceptable for insurers. Two approaches indicate that the risk is already rising quickly, so that this could soon become a significant issue for the industry and its customers. The first method is based on projections by the Foresight Programme[2] in their recent work on flooding while the second looks at the issue with an illustrative example for a reinsurer. It is important to remember that without reinsurance many risks would not be insured at all. For example, when reinsurers withdrew from the UK market for terrorism risk in 1993, the government had to create Pool Re as a backstop for primary insurers, who were about to withdraw in the absence of reinsurance.

2.3.1 The Foresight Programme's view of flooding in the 2080's

Table 2.2 shows the basic estimates of UK flood risk now and in the 2080's, as provided by the Foresight Programme. The costs in the 2080's are based on four scenarios of how society might develop, using a classic two-dimensional approach (scale and sustainability). It should be emphasised that these scenarios are non-interventionist ie they assume that no action is taken on account of climate change in flood defence or planning policy. Thus they give a true view of how the underlying risk will behave. Of course society will be able to take precautionary measures (at a cost) to control the future damage, but the inherent risk will still exist.

	Current	World markets	National Enterprise	Local Stewardship	Global Sustainability
Annual expected damage (£billion, constant value)	1.3	28.4	20.7	2.2	6.7

Table 2.3 Annual Expected Flood Damage in UK, present day and 2080's

The increase in flood damage for "local stewardship" is 69% over the 80-year period, but this scenario seems almost utopian in that it requires a reversal of current trends in consumption and globalisation, and the estimated damage lies well away from the other three projections. It has been ignored for the purposes of these calculations. The increase in flood damage between now and the "global sustainability" scenario is an increase of 415%. If the underlying process is uniformly continuous this implies an annual change of 2.1%, compounded for 80 years. The increase in damage between now and the "world markets" scenario is an increase of over twenty times the amount. To generate this would require an annual increase of just over 3.9%. The calculation for the "national enterprise" scenario is an annual increase of just over 3.5%.

Thus on the basis of the Foresight Programme view of future flood risk, the risk of flood damage is already increasing by between 2.1% and 3.9% per annum, or in round terms a range of <u>two to four percent per year</u>. As Annex 3 indicates, not all of this is due to climate change, but a very substantial part is. An alternative view is that the risk should be normalized according to the future exposure, since that gives a relative measure of riskiness after taking account of economic growth and other socio-economic factors. If that is done , then the two "growth" scenarios present a risk which is between two and four times higher than currently, while the two "sustainable" scenarios present a picture where the risk declines, because in those society pays more attention to risk. In the growth scenarios, the flood risk escalates at around one to two percent per annum, reflecting climate change and less risk aversion. It is well understood in the insurance industry, that when extreme events occur, in fact the costs increase far beyond the normal scale, due to the compounding effect on the capacity of the repair and recovery resources and processes. This was seen after Hurricane Katrina, and after recent European storms. For that reason, this author believes that it is appropriate to retain the risk escalation factor <u>at two to four percent per year</u>.

[2] *Future Flooding*, Foresight Programme, Office of Science and Technology, April 2004

2.3.2 Illustrative Reinsurance Example

Reinsurers tend to work on very focussed risk portfolios, because they are dealing with those risks which are unacceptable to primary insurers. The example below illustrates how this could escalate in future and become unacceptable. Suppose that in 2000 the reinsurer assessed there were three possible event outcomes, normality, an extreme event (defined as a 1-in-100 year probability), and a catastrophe (defined as having a 1000 year return period). Swiss Re's estimates for inland flood and windstorm in the UK in 2004 are shown in Table 2.4 below.

Event type	Normal	Extreme	Catastrophe
Return period (years)	Annual	100 yrs	1000 yrs
UK river flood	-	£1.7 bn	£3.9 bn
UK Storm	-	£10 bn	£24 bn

Table 2.4 Estimated event costs

If the reinsurer ignores the possibility of other events (ie slightly smaller than the 100 year flood, or between the 100- and 1000-year flood, or greater than the 1000 year event) then it would assess the annual expected claim cost, or risk premium due to inland flood as £20.9 million (1% of £1,700 million, and 0.1% of £3,900 million). Of course a reinsurer would not be presented with the risk for the entire UK, but would receive presentations from individual insurers for their share of the UK market. Thus for an insurer with a 5% market share the exposure for river flood is £85 million in the 100 year event, and £195 million in the 1000 year event.

However, the balance of these events will be disturbed by climate change. Judging what the change will be is problematic, because the current generation of climate models is not well-suited to dealing with extreme weather events like storms, which are, in climate-science terms, rather small-scale even though their impacts are large. However, for heatwaves and intense rainfall floods, there is a growing body of evidence that indicates that the frequency of today's extremes will be much higher in future, perhaps 4 times greater[3]. Furthermore, this escalation factor rises rapidly as one raises the definition of "extreme" due to the shape of the tail in statistical distributions (see section 2.3.3).

This might lead the reinsurer to assess that the typical distribution of events in 2050 will shift to 4% and 1%. (ie four times more frequent extremes, and ten times more frequent catastrophes, on today's definitions). This is the scale of change which UKCIP is suggesting for future flood risk[4]. On that basis the annual risk level rises to £107 million (4% of £1,700 million, and 1% of £3,900 million), an increase of 412% over a 45 year period, or roughly 3% per year, which is in the middle of the 2-4 % range based on the Foresight projections.

2.3.3 Potential Range of Increase in Risk Premium

The approaches above support a range of 2 % to 4% as an annual increase in risk premium, based on consideration of the potential weather hazard, and potential changes in exposure. However, experience has shown that riskiness increases for other reasons also, such as vulnerability of materials and behaviour. There are no reliable measurements of this factor, but it is significant that the cost of natural disasters had been rising rapidly for several decades (see Section 4) before the influence of climate change began to appear. Clearly therefore this factor is significantly greater than zero. We can conclude that a conservative estimate of the underlying increase in risk premium is **two to four percent per annum**.

An attitude which comes up repeatedly among underwriters is that recent extreme events are simply a feature of normal climatic variability. This is reinforced by the view that since property insurance policies are annually renewable, it would be easy to extricate oneself from a deteriorating risk situation before permanent damage was done to the balance sheet. But, we are in a dynamic situation, which produces very rapid change in the likelihood of extreme events.

[3] *Regional climate-model predictions of extreme rainfall for a changing climate*, Huntingford C et al, Quarterly Journal of Royal Meteorological Society, vol 129 pp1607-1621, 2003

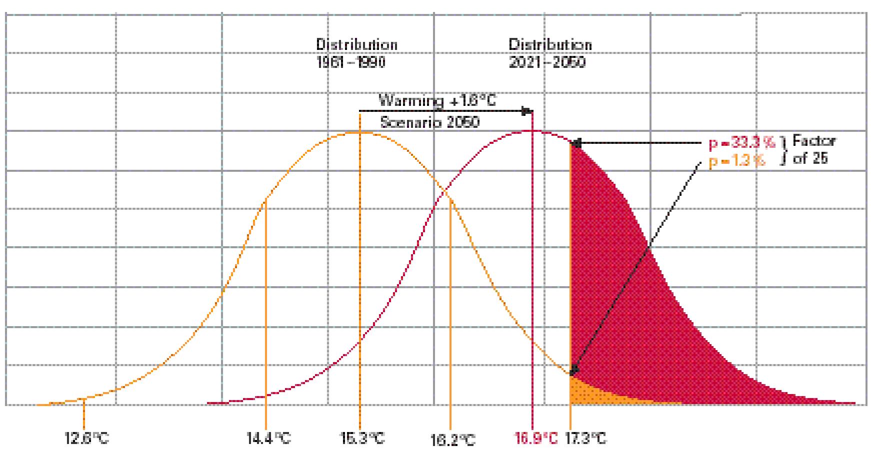
[4] *Climate Change Scenarios for the United Kingdom: the UKCIP02 Scientific Report*, Hulme M et al, Tyndall Centre for Climate Change Research, April 2002

The diagram below shows the expected change in temperature distribution for UK summers due to climate change. A hot summer, like that of 1995, with a temperature of 17.3 ºC was likely to occur about once in 75 years or 1.3% of the time on the climatic pattern of the period 1961-90, where the average was 15.3 ºC. For the period 2021-2050, centred on 2036, the average temperature will be 16.9 ºC. On that basis the chance of exceeding a temperature like 1995 will be 33.3% ie one year in three! This implies a change in return period of 25 times, and the rate of change will be faster still for less frequent events. Clearly this process is already under way, and it is reasonable to suppose that the rate of change is constant. It might be objected that temperature is not a critical variable for insurers- in fact recent evidence on hurricanes (see CERES report, 2005) shows that rapid increases of intensity have been occurring there, and are correlated with rising sea temperatures.

Taking the midpoint of the two periods as representative, gives a time span of 60 years between the two patterns. To produce a 25-fold change within 60 years implies an annual rate of change of about 4.5% per year. Such a rapid change, if ignored, soon accumulates into a significant error. In five years, it means that return period calculations for the event would be 25% too low. The only reason it is not noticed soon is that the probability of the event is still quite low for the initial part of the transition time. Similar calculations based on the estimated rate of change of the risk of extreme heatwaves in Europe following the 2003 event, produce an annual rate of change for very extreme events of 12%.

What it means is that one can expect "surprises" to start occurring: there are many potential low probability events, so that some of them do start to occur "too often". (Of course the reverse happens at the other end of the distribution, where events do not happen as often as they should- a phenomenon that is harder to notice obviously. Usually, we can assume that damage only happens at one side of the distribution.)

Figure 2.4 Change in distribution of UK summer temperatures: disjoint effect on extremes
(source Climate Change Impacts Review Group, 1991)



However, the position is really even more extreme, because we are dealing with a multi-dimensional, nonlinear system. The shifts can compound across more than one factor to produce very unexpected costs - for example inland and marine flooding at the same time eg Hurricane Katrina. Other factors which could raise costs are pressure to make ex gratia payments, repair price inflation due to scarcity of supplies, close repetition (eg Lothar and Martin 1999, or the 1990 European storms, or the 2004 hurricane and typhoon season), and denial of access or failure of utilities, as in New Orleans 2005. If events become more frequent, that will also increase the chance of coinciding with an uncorrelated event eg an earthquake, or an economic catastrophe, as happened in UK on October 17th 1987, when the 87J storm coincided with a global stockmarket crash.

The consequences for insurance companies could be serious:

- Risk assessment will be wrong, and prices consequently will also be wrong. If historical data is used to set prices, the error might be in the region of 25% for "average" weather risks, much more for catastrophic risks.
- Exposure accumulations will be too large.

- Reinsurance plans may be inaccurate, and reinsurers themselves may be taking on too much risk.
- Estimates of risk-based capital will be incorrect- eg the risk of .0007% failure for an AA rating will be too generous

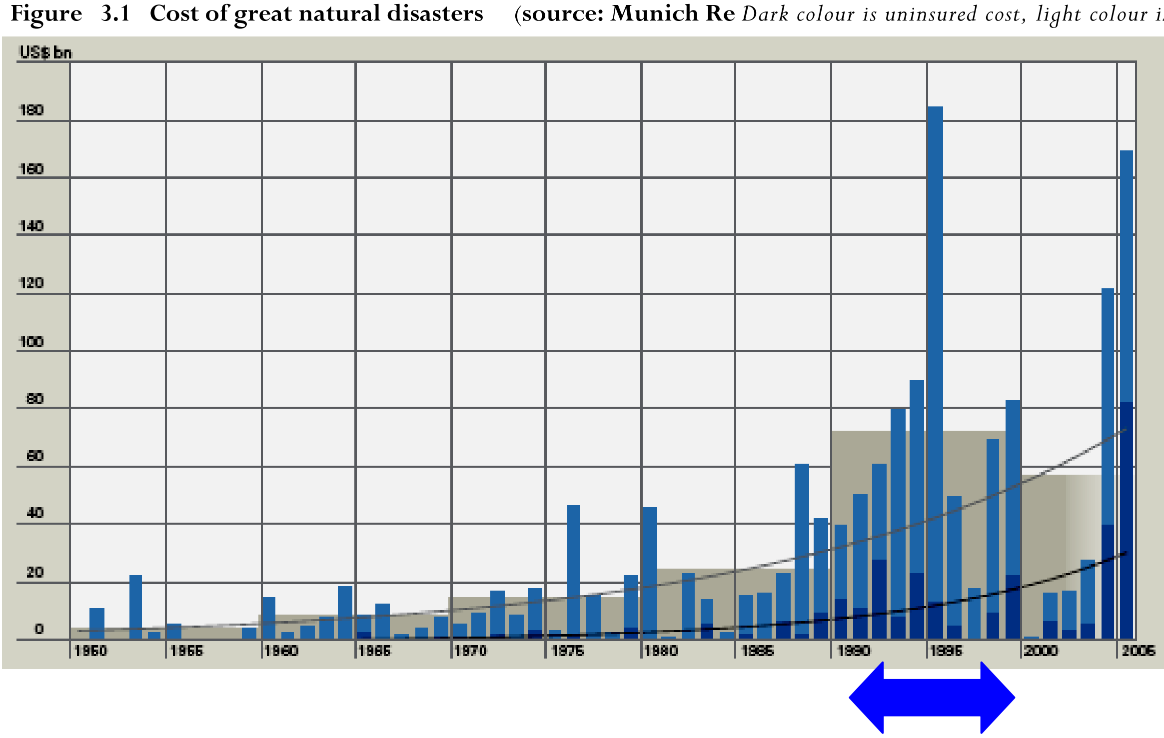
3. 2005 in Perspective

The 2005 hurricane season can be seen as an indicator of climate change, in the same way that the European heatwave of 2003 is now recognised to have been. Before Katrina, the statistical evidence was accumulating rapidly that global warming causes more intense hurricanes, and the records broken in 2005 confirm this:most storms (27) , most hurricanes (13), most strong US-landfalling hurricanes (4), costliest in total ($200billion+), single most expensive (Katrina), and strongest ever (Wilma). The season also had three of the six strongest hurricanes recorded (Wilma, Rita, Katrina) and continued a very active phase (most storms, hurricanes, and strong hurricanes ever in a two-year or three-year period). The hurricane season of 2005 may cost insurers $60 billion, more than double any previous year. The true cost is much greater – possibly $250 billion direct economic loss including uninsured losses and property blight, and even greater globally when higher oil prices and lost economic production is included- not to mention the over 1,300 dead and thousands of people traumatised. Post- Katrina issues include coverage disputes with Mississippi State, the cost and quality of the new levees, land zoning, business interruption, and long-term relief payments.

In terms of relevance to insurers, climate change will make tropical storms more intense (ie stronger winds, heavier rain, and higher sea-surges). In USA this will possibly be reinforced by natural cyclicity over the next two decades. This author is sceptical of this argument on cycles for two reasons. Firstly, the data required to estimate a cycle length is roughly ten times the cycle, and we don't have such a long timeseries for hurricanes. Secondly, there is a tendency to view climate change simplistically as a monotonic increase in temperatures. In fact we know that in the third quarter of 20th century, a cooling effect occurred due to the large amount of eg sulphur dioxide being emitted, which suppressed the longterm warming. This cooling therefore put a brake on various extreme events eg hurricanes, winter storms for some decades.

It could be argued that we have been here before. The insurance market reacted strongly to a series of great storms between 1987 and 1992, which were then followed by a lull. However, the magnitude and number of events this time is on a new level- see Figures 3.1 and 3.2.

Figure 3.1 Cost of great natural disasters (**source: Munich Re** *Dark colour is uninsured cost, light colour is insured*).



The time of the first insurance alarm at global warming

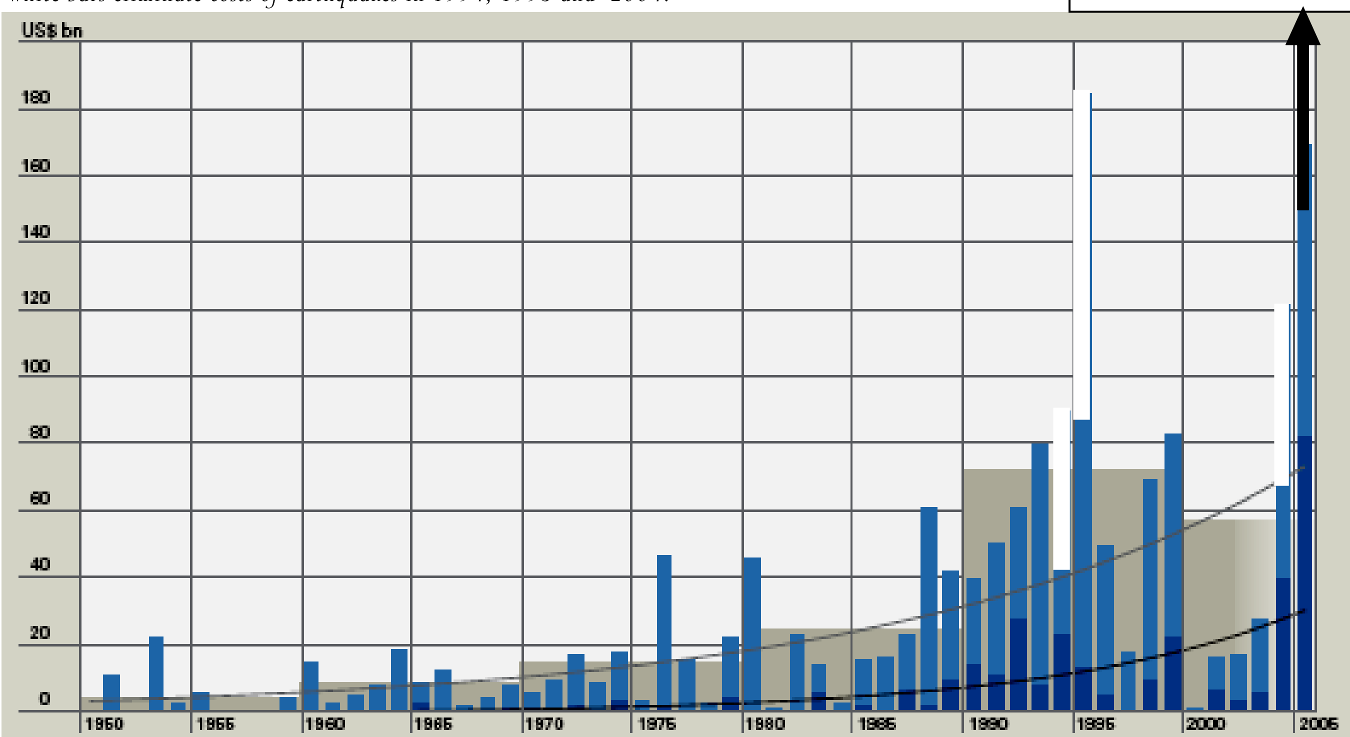
In fact, we shall focus on the economic losses, rather than insurance claims, because the latter are a rather variable proportion of the total, depending on the state of the insurance market and its interaction with other stakeholders. It can be argued that even without climate change or variability the total damage varies depending on such factors as risk awareness, preventive measures, and an efficiently prepared crisis management (Munich Re, 2006)

Also, Figure 3.1 presents a misleading impression, because it includes earthquakes and tsunamis as well as climatic disasters. Further, this author believes that the costs attributed to 2005 are too low, because Katrina and Rita caused massive disruption on global energy markets with harmful effects to many nations around the world. Figure 3.2 attempts to rectify these points by removing the largest earthquakes (1994, 1995, and 2004) and adding a speculative amount for global disruption to energy markets (see below). It is worth noting, that the effect of the hurricanes lingers on locally. New Orleans may never recover, (as happened to Galveston in 1900), and the defences will be weaker in 2006 than in 2005.

Figure 3.2 Adjusted cost of great natural disasters

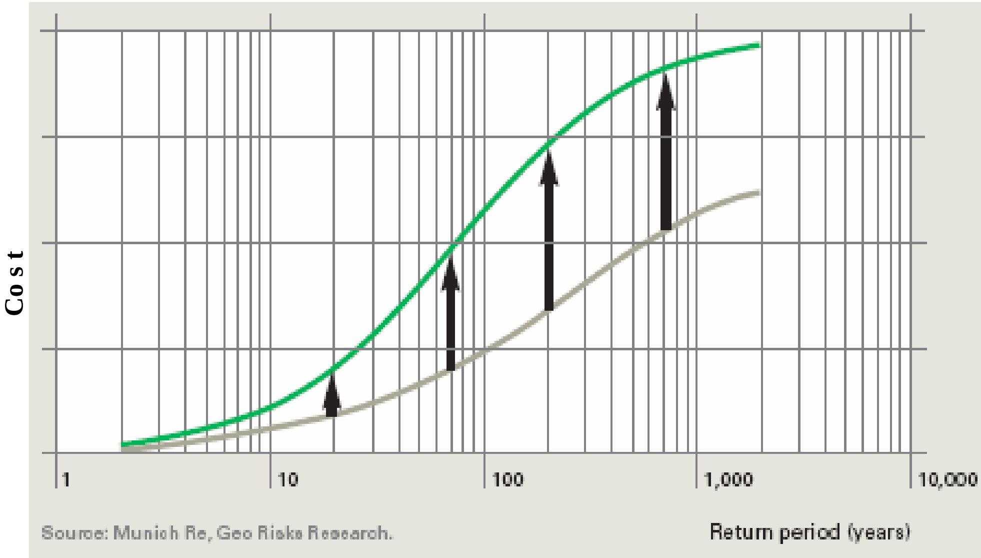
Source Munich Re *Dark colour is uninsured cost, light colour is insured. Supernormal cost of Katrina and Rita is shown by black arrow*

white bars eliminate costs of earthquakes in 1994, 1995 and 2004.



While Munich Re has a more conservative view regarding the economic costs, it does believe there is a watershed regarding insurable costs, following the 2004 and 2005 hurricane seasons. Figure 3.3 indicates that Munich Re now believes that the damage curves have shifted by almost a factor of two, for a number of reasons. Similar views are shared by many expert commentators (eg Tillinghast, RMS)

Figure 3.3 Shift in return period after 2005 season (Munich Re)



- Munich Re states that historical data understates the potential present-day risk by up to 60%
- The upper curve shows the adjustment of the loss distribution including the following factors:
  - Higher hurricane frequency
  - Higher intensities
  - Re-evaluation of the storm surge and flood risk (not including NFIP)
  - Loss-aggravating factors in connection with mega-catastrophes

- **The Munich Re curve gets relatively closer in % as the return period rises**
- **However, non-insured costs kick in then eg global shortages, labour unavailability, competitors - SUPERSATURATION**

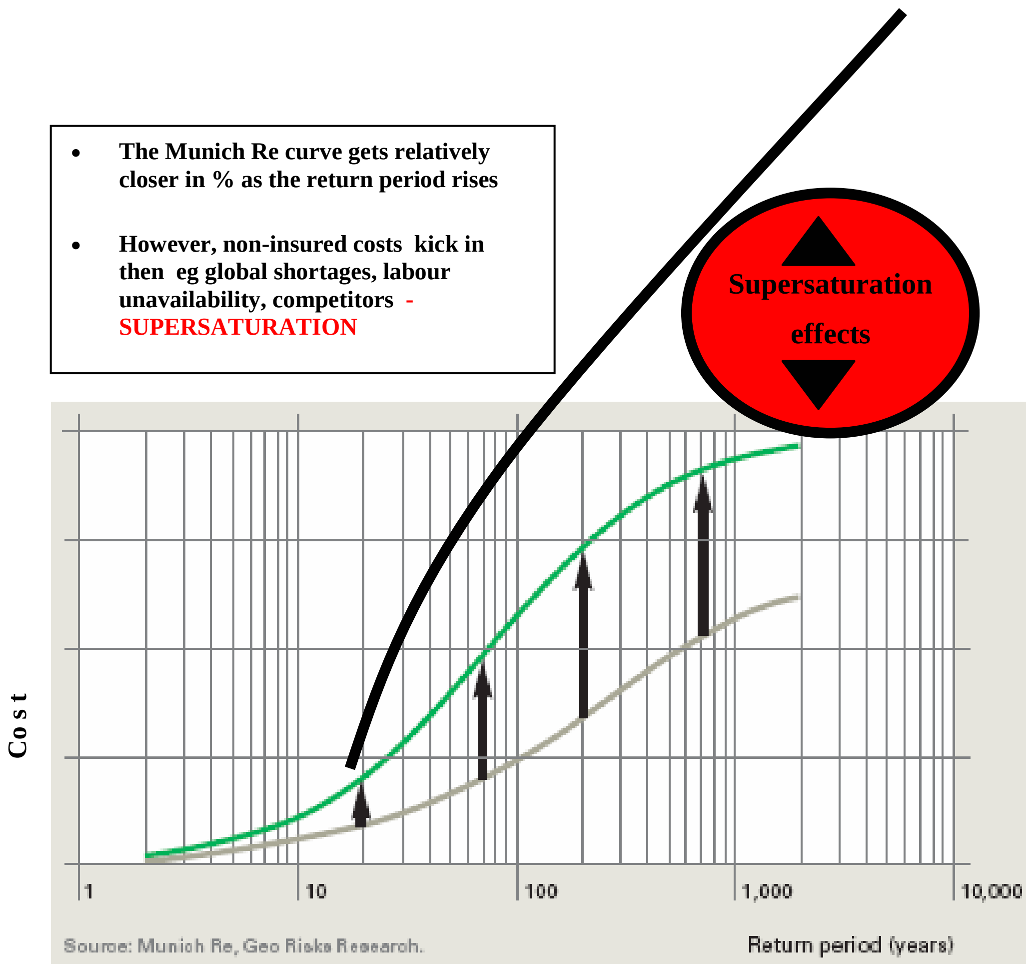


Figure 3.4 Supersaturation and damage curves

This author believes that once damage reaches a certain level , the effects escalate dramatically, due to firstly their longevity- the recovery is more extended, with consequent vulnerability and greater on-costs, while the geographic extent is much greater through effects like migration and global market disruption. We saw this happen in 2005. Some economists have dismissed the likely costs of climate impacts as acceptable, around 0.2 % or less of GDP by mid-century. In fact Katrina may have cost 2% of US GDP in 2005 already. For New Orleans it was a turning point; tens of thousands may never return, and new defences may cost $32 billion + for which there is no budget.

In Super Catastrophes like Katrina, losses become nonlinear, i.e., the scale of the event itself causes losses to increase further, through a variety of processes (see eg RMS, 2005). Indeed costs might have been even greater if Katrina had not weakened before landfall, or Rita and Wilma had not veered away. After Hugo in 1989, roughly a dozen insurers were financially overwhelmed. Generally, these were smaller regional insurers that had not purchased sufficient reinsurance. After Andrew, nine insurers failed. Even some very large carriers were stressed to the limit. There have been no reports of private insurance company failures after Katrina (Tower Perrins, 2005), but ironically two airlines filed for bankruptcy due to high fuel prices (RMS, 2005), and the government-funded National Flood Insurance Program is insolvent.

It was an accident waiting to happen. A classic deltaic city in the literature, slowly subsiding and threatened by sealevel rise and storm surge, it grew during the hurricane pause (1965-95). **Did climate change play a part in the cost of Katrina? The answer must be yes, but we cannot quantify the share precisely**. Sealevel rise contributed to the storm surge obviously. In addition, the sea was unusually warm, which is a classic symptom of climate change. Finally, there is strong statistical evidence (Emanuel, Webster, Munich Re) that once a storm starts it is now likely to become stronger. Some commentators put a range of 10 to 60% on the contribution of climate change.

4. Munich Re Climate-Related Losses

Munich Re has been compiling statistics of natural disasters for many years because they illustrate the need for risk management. Their definition of what are "major natural catastrophes" follows the criteria laid down by the United Nations - the affected region's ability to help itself is distinctly overtaxed, in that interregional or international assistance is necessary, thousands are killed, hundreds of thousands are made homeless, and there are substantial economic losses and/or considerable insured losses. In this section we exclude those disasters like earthquakes and volcanoes which are not weather-related.

Table 4.1 Great weather-related disasters 1950-2003: Munich Re, monetary data in constant 2003 values.

	1950's	1960's	1970's	1980's	1990's	1994-03
Number	13	16	29	44	74	47
Economic loss ($ bn)	41.8	54.8	82.8	130.5	439.1	288.8
Insured loss ($ bn)	-	6.1	12.1	23.9	101.2	58.8

Table 4.1 shows great weather-related disasters for the period 1950-2003. Clearly there has been a global increase in numbers and costs of weather disasters, paralleling the UK picture. Of course, there are many reasons for this trend, including increased volumes of assets located in more hazardous areas. It will be noted that the 1990's were the most costly decade, and that the moving 10-year figure figures have fallen since then. This partly reflects the fact that the early 90's witnessed major incidents in the USA (1992 Hurricane Andrew, 1993 Mississippi flood) where the concentration of assets is much greater than elsewhere. A more reliable indicator is the number of incidents which shows a strong upward trend.

Table 4.2 Great flood disasters 1950-2003: Munich Re, monetary data in constant 2003 values.

	1950's	1960's	1970's	1980's	1990's	1994-03
Number	6	6	8	18	26	16
Economic loss ($ bn)	31	22	20	28	234	163
Insured loss ($bn)	-	0.24	0.41	1.52	8.39	8.02

The number of flood events has stabilised at a level well above the mid-twentieth century level, but the costs have risen enormously, both in pure economic terms and in insured value, reflecting the incidence of flooding in wealthier countries like UK and Germany.

On the New Orleans flood of 2006, Munich Re notes that the levees were built in the 1960s and were designed to withstand Saffir-Simpson Category 3 hurricanes. They were also supposed to stand up to storm surges with wind speeds of up to 209 km/h. Why then did this catastrophe occur when Katrina only hit New Orleans with wind speeds of a Category 1 and 2 hurricane? Most of the levees are made of swamp peat with a high concentration of organic substances. They stand on a relatively thin layer of clay which lies on a natural layer of peat. In the centre of the levee is an impervious concrete wall which extends into the peat layer. Initial studies suggested that the impervious wall was not deep enough. Water probably flowed under the wall and saturated the subsoil, thus reducing its stability (Munich Re 2006)

New Orleans is by no means an isolated case. Munich Re has identified a number of other flood scenarios in the USA:

Storm surge in Texas (Galveston/Houston), Storm surge in Florida (Miami), Storm surge in the northeast (New York),

Mississippi-Missouri flood (St. Louis), Levee breach in the Central Valley, California (Sacramento), Flash floods in the west (Las Vegas, Denver).

Table 4.3 Great windstorm disasters 1950-2003: Munich Re, monetary data in constant 2003 values.

	1950's	1960's	1970's	1980's	1990's	1994-03
Number	7	10	19	21	42	26
Economic loss ($bn)	11.1	32.9	51.7	54.1	189.9	97.4
Insured loss ($ bn)	0	5.9	11.7	21.0	82.9	43.3

The number of windstorm events has trended strongly upward, with a peak in the early 90's. The costs have not risen quite as fast as for flood, but are still double the levels encountered in the 1980's for insured and total damage.

4.1 Parallels with UK

The increase in global economic losses from weather recorded by Munich Re is broadly consistent with the ABI data for UK only. (It is better to take the economic cost, rather than insured cost, for the global losses, because practice varies so widely in the use of insurance as a compensation vehicle). Between the 1980's and the ten-year period 1994-2003, the cost in constant currency rose from $130 billion to $289 billion, an annual rate of increase of 6% over fourteen years. During the same period in UK the annual increase was about 6.5% in the constant-value cost of climate-related claims.

It is interesting too that the global figures have recently exhibited a strong uplift in flood damage, as has happened in the UK. This indicates that the UK experience is part of a general pattern.

5. Loss trends and projections

Pielke and others argue that the upward trend in losses shown by Munich Re is just due to socioeconomic factors, not increases in climatic extremes. Recently RMS has been examining global loss trends. Preliminary results seem to show that climatic factors are important. The 1990's were much worse than previous decades, and this pattern has resumed again after a short lull in the early 2000's. This is not conclusive, since there are various factors that cloud the issue, such as the effectiveness of disaster preparations and the wealth of the affected regions (USA has a disproportionate effect on the total losses due to its wealth), but it does mean that one of the standard objections to using loss statistics as an indicator of climate change is weakening.

One example of a positive finding is that after correcting for wealth, population and location, **at the national level, a 1% increase in precipitation results in about a 2.8% increase in US catastrophic losses**.

Studies of the potential net losses to USA from climate change have produced estimated in the region of 0.1 to 0.2 % of GDP. **This seems much too low now- the 2005 hurricane season may cost two percent of US GDP, with international repercussions beyond that eg high winter fuel costs in UK**. Recent works by Mills in USA have not provided robust figures for future loss potential, but merely indicated that on the basis of current trends, the losses demand a coherent response from government and the private sector.

Results for 3 out of 4 climate scenarios for the UK imply an annual increase of 2 to 4% in the cost of flood damage, which will have a large impact on the medium and long-term planning of infrastructure (see above, section 2.3.1). A preliminary study by this author for Association of British Insurers (ABI) indicated that future climate-related insurance claims in UK might be two to three times higher than current levels by 2050 assuming no change in government policy on climate adaptation. (ABI, 2004). One of the main uncertainties in this calculation is the future frequency and severity of extreme climate events because climate models do not yet provide a consistent estimation of future storm tracks and intensity. This is a key weakness: in the UK, the cost of a 1000-year extreme climate event is roughly two-and-a-half times larger than the cost of a 100-year event. In Germany, insurance claims increase as the cube of maximum wind speed, or even a power relation of the fourth or fifth degree according to Munich Re, because of collateral damage from debris. A recent study of German storm losses estimated a 60% increase in insured losses in Germany by 2080 without adaptation.

ABI estimated the increased insurance cost of hurricanes (US), typhoons (Japan) and European winter storms due to climate change as around two-thirds by the 2080's, keeping other factors constant, to a new annual average of $27 billion. The extreme seasons would be worse, around 75% higher than currently due to the nonlinear damage curve as windspeeds increase. These calculations may now be regarded as on the low side, especially for USA, as they came before some of the more recent papers on observed increases in hurricane intensity. ABI also made a cursory estimate of future European flood costs, but it should be disregarded as it simply assumed they would parallel the UK trend (ABI, 2005).

ABI 2005 went on: under high emissions scenarios (where carbon dioxide levels double) insurers' capital requirements could increase by over 90% for US hurricanes, and by around 80% for Japanese typhoons. In total, an additional $76 bn could be needed to cover the gap between extreme and average losses resulting from tropical cyclones in the US and Japan. Higher capital costs combined with greater annual losses from windstorms alone could result in premium increases of around 60% in these markets. These loss estimates do not include likely increases in society's exposure to extreme storms, due to growing, wealthier populations, and increasing assets at risk. For example, if Hurricane Andrew had hit Florida in 2002 rather than 1992, the losses would have been double, due to increased coastal development and rising asset values.

Strong and properly enforced building codes have been shown to prevent and reduce losses from windstorms. If all properties in south Florida were built to meet the strongest local building code requirements, damages from a repeat of Hurricane Andrew would fall by nearly 45%. If design codes for buildings in the South East of the UK were upgraded by at least 10%, increases in climate-induced damage costs from windstorms could be reduced substantially.

In the UK, taking account of climate change in flood management policies, including controlling development in floodplains and increasing investment in flood defences, could limit the rising costs of flood damage to a possible four-fold increase (to $9.7 bn or £5.3 bn) rather than 10 – 20 fold by the 2080s.

6. Science of climate change[5]

There is high vulnerability in certain key areas with insurable infrastructure- particularly deltas, but most coastlines are sensitive to damaging events. Global figures are not relevant to local underwriting: the sea is not flat (!), and the rate of SLR (sea-level rise) is accelerated by subsidence in deltas, while storm surges are more damaging in the absence of sea-ice in northen latitudes, or due to the trend to more intense hurricanes (see later). The rates of change in risk are significant: for example in Los Angles area, the return period for severe flooding is decreasing at **between 2.5 and 4 % per year**.

At first sight trends on river flooding are contradictory, with the risk increasing in some regions, but decreasing in others. However, this reflects clear underlying trends in precipitation and warming. High-latitude regions are getting wetter, while low-latitude continents are experiencing droughts in the interior. At the same time, warmer weather is advancing the thaw dates for arctic regions. Thus most of USA, Russia and northern Europe are experiencing greater floods. This was reported by Milly in a study of mega-rivers which noted that the probability of such floods occurring at random was well below 5% ie there is a new factor- climate change. It has been argued that land-use and other human factors are intensifying the problem, but there is no doubt that the underlying risk has changed already. In some areas of Europe, the risk of severe flood is changing at over 3% per year (a current 100 year return period will be just 10 years for the Mosel by 2070 for example). Naturally, the higher the greenhouse gases, the stronger the risk will be. The effect will be seasonal- with much wetter winters in Northern Europe (20% more rain on average), and drier summers (as much as one-third less rain). Monsoons in Asia are also expected to be much wetter. (In fact the 2005 monsoon saw a record 994 mm of rain fall in 24 hours at Bombay).

Drought will be a major issue for the Mediterranean/ Maghrib regions. (Portugal currently has a rainfall deficit of 77% below normal, which would occur just once in 400 years randomly). The risk of severe heatwaves in Europe is rising rapidly- possibly at 12% per year, so that the 2003 drought will be the normal pattern of summer in 60 years.

Large-scale circulation changes like ENSO (El Nino Southern Oscillation) and NAO (North Atlantic Oscillation) are important for extreme events. Currently climate models (GCM's) cannot say what the future pattern of ENSO will be (one side benefit of more ENSO's would be a likely reduction in hurricane frequency, but there is no reason to plan for this). On the other hand, modellers do expect NAO to remain positive until mid-century, which means higher sea-levels for northwest Europe, stronger onshore winds, and more rain.

Regarding European storms, the most important feature is the steady intensification of the wind pattern "CP11" (previously called Wz), which means stronger, possibly clustered storms for northwest Europe, and heavy rain for southwest Europe. There is still disagreement among modellers, but a weak consensus for somewhat stronger European storms by late 21st century (an 8% increase in windspeed)- see section 7.

One of the most striking recent results is that intense tropical hurricanes have almost doubled in frequency in recent decades, at the same time that SST (sea surface temperature) has risen by about 0.5C. This is an unexpectedly strong relationship, indicating that the potential damage is rising at around 2% per year, according to Emanuel's Power Dispersion Index (PDI). Some have argued that the trend is exaggerated because older records are incomplete, or that there are natural cycles of regional activity. These points can be dismissed- the records have been well-validated, and the trends are global, not localised. Future results confirm this trend to more intense events. Some researchers believe that return periods could reduce by two-thirds or more in 50 years or so, due to warmer oceans. Even sceptics believe that we are in for a period of up to 30 years of more active hurricanes, so there is a consensus for the planning horizon! Most of the work has focussed on Atlantic hurricanes, but similar views have been expressed for typhoons also.

[5] with acknowledgements to IPCC WG II, in draft, for providing a convenient literature search.

While attention is drawn to the catastrophic events, attritional losses can also be expected to rise. A wide range of indicators of temperature and precipitation (known as Frich indices) are expected to become more extreme. Particular issues are heatwaves in northwest and northeast America, and regions adjoining the Mediterranean.

7. European Storm

Two studies are considered here, historical storms, and future climatology.

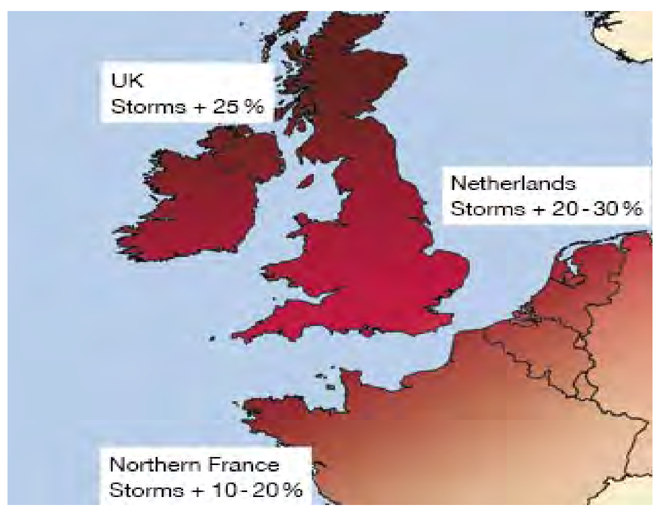
The author reported a striking correlation between winter temperature and the occurrence and strength of great European storms, using the CET as a proxy for temperature, and Lamb's record of great storms (Dlugolecki et al. 1994). This has been dismissed by some meteorologists as unscientific, since it relies on a subjective catalogue, rather than instrumental observations of storm strength. However, it is currently the only long time series, and the findings seem quite robust. Indded . Lamb himself did not notice this correlation, but did note that 1990 (which fell after his record formally ended) produced great storms, and that was a very warm winter indeed. Since then there was the great 1993 storm, probably the deepest European depression since records began, that destroyed the tanker Braer off Shetland, and the storms of 1999 and 2005. Therefore, it seems that this may be worthy of further investigation as a pointer to the future. (On the other hand, it has been argued that winter months are warm in terms of CET when the atmospheric flow is westerly, which is conducive to storms, rather than that warm temperatures cause storms ie the relationship may be correlation rather than causation).

Type of winter month	Storm frequency	Storm intensity
Warm	15%	2,568
Medium	7%	2,544
Cool	6%	1,075

Table 7.1 Great storms and winter temperatures
Temperatures from CET series, storms data from Lamb

WWF has recently carried out a scientific assessment of future storminess, with the results indicated in Figure 7.1. The map indicates that strong increases in storm frequency are expected by 2090 in NW Europe. Additionally, maximum windspeed could increase in the range 8 to 16%. The joint effect would be an increase of about 75% in storm costs, other things being equal, in a range 50% to 100% increase. If we then allow a margin for "saturation" effects eg lack of recovery capacity, the costs there could be well over 100% increase- making no allowance for economic growth in the meantime.

Figure 7.1 Late 21st century storm activity in Europe
Source "Stormy Europe" WWF 2006



8. Other Issues

Other property/casualty classes may be affected by shifts in extremes also e.g. business interruption, automobile, travel, but this author does not believe that the industry faces the prospect of a wave of climate-change –related liability claims.

Automobile In the USA, 16% of automobile accidents are attributed to adverse weather conditions as are one-third of the accidents in Canada. Vehicles also sustain insurance losses during natural disasters, amounting to $3.4 billion between 1996 and 2000 and averaging 10% of all disaster-related property losses. In some events, such as hailstorm, damage to automobiles can exceed 50% of total catastrophe losses (Mills, Roth and Lecomte, 2005). In Hurricane Katrina, one estimate reckoned that about half a million vehicles had been damaged, mainly by flood-water, with about half of them insured. The insured costs alone fell in the band $1.2 to 2.3 billion, or between three and four percent of the total insured losses (Towers Perrin, 2005). While this is normally a major loss, it was so dwarfed by the concurrent buildings damage that another estimate ignored automobile entirely (RMS, 2005).

In less severe climates, such as UK, automobile claims are correlated with meteorological conditions, with dry /warm weather seeing less accidents reported, and cold/wet being the opposite. The exception to this is that in very severe winters motorcycle claims diminish owing to their drivers' greater awareness of the dangerous conditions. However, the type of accidents also change, with many more minor "shunts" in icy conditions, so historically the UK is not exposed to major catastrophes in this class.

Agriculture another obvious impact area is agriculture, particularly crops, but the private market avoids this area, so it is hard to comment on trends.

Health/life The effects could extend into life and health and pensions also, albeit probably less strongly, for the private insurance industry isinceprivately insured people are wealthier than average and generally have better health and access to medical care. The latest estimate of excess deaths in the European heatwave of 2003 is around 50,000, but with minimal effect on insurance emarkets. Similarly, the 1300 deaths in Katrina had little effect on US insurers. In the USA there has been a major programme of research into climate change and human health. Five areas were examined: heat stress, extreme events, air pollution, water-borne/food-borne disease, and vector-borne/rodent-borne disease. Among the findings were that heavy precipitation is strongly linked to outbreaks of water-borne disease: 58% of outbreaks were preceded by a rainfall event in the top decile, and 68% of outbreaks by events in the top two deciles. Water contamination was also linked to extreme precipitation, but with a greater lag effect.

Insurance products have very low penetration in less developed countries, where the impacts of climate change are expected to be most acute, due to the greater vulnerability of those regions to extreme events. Consider Asia. Glaciers in the Himalaya are receding faster than in any other part of the world and many disappear by the year 2035, with catastrophic results for rivers in India, China, etc. Six mega cities in Asian deltaic regions will have population exceeding 10 millions by 2010. These deltas are shrinking due to sediment starvation eg the Changjiang sediment discharge will fall by 50% after construction of the Three-Gorges Dam. For a 1 m rise in sea level, half a million square hectares of Red river delta and up to 2 million square hectares of Mekong river delta is projected to be flooded. The deltas are also usually economically more developed. The GDP of the three metropolitans located in the Zhujiang delta, Changjiang delta and Huanghe delta will represent 80% of China's total GDP in 2050. The current rate of sea level rise in coastal areas of Asia is reported to be between 1 to 3 mm per year – marginally greater than the global average, and is accelerating gradually. Clearly, refugees from such regions would disrupt neighbouring regions also, besides placing a burden on global society.

8. Insurers will also be touched by climate change by government mitigation policy which will alter the economics of energy consumption, with effects on technologies offered for insurance, and on investment returns in a wide range of industries (beside being underwriters, insurers are also major investors, but that is beyond the remit of this paper.

9. The Right Null Hypothesis?

In the context of already evident rapid change in the climate, and the established high sensitivity of society to extreme weather, the question must be asked, whether it is right or prudent to take as the null hypothesis that damage is NOT increasing due to climate change rather than a Bayesian approach that damage should be increasing already. In the former case, it may be some time before "significant" deviations from past behaviour can be discerned, which could lead to delay in taking precautionary action. In the latter case, recent observations are surely "consistent with" a new trend toward higher weather-related damage caused by climate change.

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Annex 1 - ABI Climate-Related Claims

Year	Original values (£ million)			Constant values (2003 £ million)		
	Subsidence	Weather	Climate	Subsidence	Weather	Climate
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1988	91	605*	696*	157	1037*	1194*
1989	255	351	606	418	577	995
1990	506	2194	2700	784	3401	4185
1991	540	723	1263	772	1038	1810
1992	259	427	686	347	573	920
1993	134	566	700	172	727	899
1994	125	404	529	156	504	660
1995	326	373	699	398	455	853
1996	333	752	1085	393	891	1284
1997	472	656	1128	542	753	1295
1998	437	1030	1467	489	1153	1642
1999	364	885	1249	397	964	1361
2000	350	1377	1727	375	1467	1842
2001	265	945	1210	276	987	1263
2002	183	1285	1468	187	1312	1499
2003	390	621	1011	390	621	1011
1992-1997	1649	3178	4827	2008	3903	5911
1998-2003	1989	6143	8132	2114	6504	8618
Six-year increase	21%	93%	68%	5%	67%	46%

Table A.1 ABI climate-related claims costs

Notes to table A.1

*The 1988 figures have been calculated by estimating the cost of commercial weather claims, missing in the original data, from the ratio of such claims to domestic claims in other years.

1) motor and other non-property classes other than business interruption are excluded from these figures.

2) The constant value figures adjust for the effect of inflation, by scaling the figures using the government RPIX index of prices.

Table A.1 shows the total amount reported annually by ABI member companies in respect of weather-related (burst pipe, storm, flood) and subsidence claims for commercial and household property accounts, including the related business interruption figures for commercial business.

As can be seen, over the period 1998-2003, the claims for weather alone came to nearly £6.2 billion, which was an increase of 93% over the comparable six year period 1992-97, virtually double in original values. This is indicative of the underlying increase in "attritional" weather events, whereas most attention is caught by the spectacular events ie great storms or floods.

Preliminary Assessment of Future Costs

This section presents the current scale of insurance industry costs from climate-related incidents, based on ABI data, together with projections of the top-range potential costs under the UKCIP climate change scenarios. Table A.2 gives the historical data, in 2003 values, relating to claims paid by ABI member companies. They relate to the period from 1998 only, since figures split by cause are not available before then. In making the adjustments in the table as described in the footnotes, the author used quarterly data also (available back to 1991), and applied judgement based on extensive experience with insurance industry claims statistics.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Commercial of which flood	Business Interrup. of which flood	Domestic Pipes of which flood	Domestic Storm of which flood	Domestic Flood	Revised storm	Revised Flood
1998	286 188	32 21	239 0	457 317	139	249	665
1999	269 171	26 15	278 0	333 193	58	249	437*
2000	467 369	85 74	238 0	420 280	258	249	981
2001	178 80	14 3	354 102	278 138	163	249	486*
2002	270 172	27 16	420 168	479 339	117	249	812
2003	98 0	11 0	310 58	140 0	61	249	119*
Average						250	350

Table A.2 Base calculations of present-day weather claim costs (£million at 2003 values)

Column (1) Left-hand figures from ABI. Right-hand figure derived by assuming steady figure of around 2003 level is due to storm, nil for burst pipe claims, and that the residue is from flood.

Column (2) Same procedure as for column (1).

Column (3) Left-hand figure from ABI. Right-hand figure derived by assuming the true cause of these claims is mainly burst pipes (non-weather or frost) rather than flood and that this applied to all claims in 1998,1999, and 2000. This is based on the author's experience, and the remarkable stability of the quarterly loss figures for those years, all lying in the range £48m to £62m, apart from Q3 1999 at £79m, The average amount in these years came to £252 million, and this is subtracted from the left-hand figures for 2001-03 to derive hidden flood claims in those years.

Column (4) Left-hand figure from ABI. Right-hand figure by assuming 2003 figure was entirely storm, in the absence of any major events, applying the same correction to previous years.

Column (5) From ABI, with no adjustment.

Column (6) This is the sum of the residual amounts from columns (1), (2), and (4) after removing the amounts assumed to be flood. Effectively, it assumes that the 2003 figures in those columns were entirely due to storm, since 2003 was a very dry year, and that those figures were typical of earlier years, in the absence of any major reported incidents.

Column (7) Column (5) plus flood allocations in Columns (1)-(4). Since the years 1998, 2000, and 2002 were affected by major flood incidents, the cost of a "typical" year is taken buy averaging the values for 1999, 2001 and 2003, marked *.

Subsidence

Current levels

Subsidence claims have been fairly static in recent years, with a running 5-year total of around £1.6bn, or about £300m per year. The peak years were 1990 and 1991, with over £750m each in 2003 values (see Figure 3.2), but since then the worst year has been 1997 at £542m, suggesting that the current peak may lie around £600m.

Future levels

An unpublished study by a leading scientific agency for ABI derived a relationship between meteorological conditions and claims costs historically, based on insurance company data. The study then considered the implications of future climate scenarios up to the 2080s. The findings suggested a doubling of cost, i.e. £3.2bn over five years, or £600m per year. The peak might be £1.2bn in a year (double the average cost). This is less than twice the cost of the peak years 1990 and 1991. Although the general tendency is for climate change to exacerbate the peak costs, this is unlikely for subsidence, because wetter winters will prevent lengthy droughts like that in 1990/91. This is true even for the south-east with its drought-sensitive clay soils, where the above-average trend towards drier summers, could be largely offset by a contrary trend towards wetter winters.

Storm

Current levels

From above the background level is around £250m per year currently, since there were no major storms in the period 1998-2003. The cost of a major storm is around £1,500m on the basis of the 1987 storm and industry data on the individual 1990 events. Allowing for a return period of ten years, this would generate a further allowance of £150m per year for major storms, giving £400m annually for storm risk currently (background and major elements combined).

An extreme year in the UK might be seen as around £2,500m currently, taking 1990 as a base. The total weather cost in 1990 was 3,400M, while the average annual cost during the period 1988-2003 ran at 990m. Subtracting the "average" gives 3,400-990 = 2,410, or £2,500m rounded up. Note that this is considerably less than the 100-year storm estimate of £10bn in Table 5.1 from Swiss Re for UK. This is due primarily to the fact that we are looking at a shorter return period, of roughly ten years.

Future levels

Going by the UKCIP outlook, we should allow +50% for frequency in the more populated regions of UK. At the same time, it seems that there could be a 6% increase in wind strength. Figure A.1 shows a clear non-linear relationship between windspeed and damage, with a gearing of approximately 1:5 i.e. a 6% increase in windspeed would produce a 30% rise in damage. The compound effect on claims costs of the increases in frequency and windspeed are 1.5x1.3=1.95 i.e. about double. Therefore the future annual smoothed cost could be 2x£400m=£800m pa.

The peak loss in future might be equivalent to three major storms in one year. There were four major storms inside four weeks in northwest Europe in 1990, and three within three weeks in 1999. Since we are anticipating a general increase in winter depressions frequency of 50%, a figure of three in a severe year may even be on the low side. The cost of a major storm could rise by perhaps 30% due to faster windspeeds (as explained above). Additionally, future storms will be wetter, (on the basis that by 2050 winters will be about 15% wetter, with more intensive events), and so cause more damage, particularly in a multiple-event scenario, where damage cannot be repaired before the next storm arrives. Based on the author's unpublished analyses of company claims data, an allowance of 30% for these elements is required. This gives a peak year cost of £7.6bn=£1.5bnx3x1.3x1.3, or £7.5bn rounded.

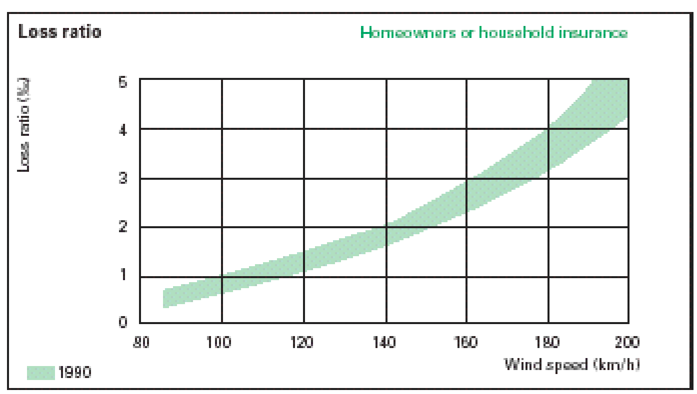


Figure A.1 Great Britain Household Insurance: damage versus windspeed, 1990 storms [Source Munich Re: Winter storms in Europe (II), 2002]

Inland Flood

Current levels

The background level for flood claims including commercial lies at around £350m per year. High years cost about £800m (i.e. an additional cost of £450m), so allowing for one every five years gives an additional £90m pa. This amounts to about £350m+£90m=£440m pa, or £400m rounded.

A recent ABI study of flood potential provided an estimate of about £1,500m as the likely worst case exposure. This compares closely with the estimate of £1,700m given by Swiss Re for a 100-year flood event.

Future levels

The Foresight study provides a very wide range, depending on the climate change scenario and response strategies. If responses are implemented, the range is much narrower, with a topside of double today's costs. Therefore, even with a substantial amount of action on flood risk management, the background level of flooding would rise from £400m to £800m.

Peak cost could be three times the current level. This reflects the trend towards heavier and more intense rainfall patterns (conservatively a doubling effect- Huntingford, 2003 estimates that return periods for extreme monthly rainfall could reduce by a factor of between four and seven times by late 21st century), and also the nonlinear nature of the damage response curve, whereby higher flood levels and longer flood durations produce disproportionate increases in damage (roughly a 50% effect). This gives an extreme-year cost of 3x£1.5bn = £4.5bn in a year.

Coastal flood

Current levels

Coastal flood is negligible in terms of insurance claims currently, largely thanks to the high quality of defences. The last significant incursion was in February 1990 at Towyn in North Wales, and cost under £100M.Therefore the background level has been set at nil. Since the Thames Barrier defence complex currently provides a very high level of security for London, the extreme cost would occur elsewhere e.g. East Anglia, and informal industry estimates indicate a potential value for such an event of around £5bn.

Future levels

For background levels, it is assumed that the Foresight recommendations are adopted, so that the risk of coastal flooding continues to be well-managed, with an absence of any significant incursions, and an annual cost of nil.

For the peak cost, it is assumed that the Thames Barrier defence complex fails, and that the event is compounded by other factors, for example up-river flooding due to heavy winter rains, and generally stormy conditions affecting the efficiency of the recovery process. Based on information from the Environment Agency, the London Climate Change Partnership puts £80bn assets at risk, and £30bn estimated economic loss from a major flood. Perhaps two-thirds of this would be insured because much of the infrastructure damage and business interruption costs would not be covered due to public policy and customer choice, giving a current exposure of £20bn insured damage. Allowing for the greater depth of water in future, and the compounding effect, an increased of two to four times can be envisaged, resulting in a cost of, conservatively, £40bn.

All the above estimates ignore the effects of socio-economic changes, such as the location and value of assets, and any substantial changes in Government policy.

Annex 2 Floods in Perth, Scotland

The UK has been hit almost annually since the early 1990's by severe local floods. The first significant one of these occurred in 1993 in Central Scotland, at the town of Perth, where the author lived and worked for the international insurer, General Accident, which had its world headquarters there. In January 1993, 45 cm equivalent rain fell in 18 days, but the effect was made worse by the accumulation of snow which then rapidly thawed (see Table below). 42 square kilometres were flooded and the total cost to insurers was £125 million, a very substantial figure considering that the town had only 40,000 inhabitants.

January 1993	Weather	Temperature (^{o}C)	Comments
11th	Gales, snow	1	Blizzard, roads cut
12t h	Gales, snow	2	Food runs out
13th	Snow showers	2	Rescue convoys
14th	Heavy rain	5	Local floods
15th	Thaw, rain	5	Head waters flood
16th	Heavy rain	7	Rivers rise
17th	Showers	4	Record flow on

Table A.3 Chronology of the Perth 1993 flood

The situation was extraordinary, because initially the problem was a surfeit of snow which resulted in Perth being cut off by road, rail and air. The Army was called out to attempt to break through with emergency supplies, either by special vehicles, or by helicopter if the weather cleared. Just as this started, a fast thaw arrived, with continuous rain. Soon the River Tay began to rise, reaching record flows on 17th January, and bursting through the flood defences in several places. Hundreds were evacuated, and some remained in temporary accommodation for nine months. Many of the losses were borne by insurers, though often under-insurance complicated matters.

The area was known as a flood hazard (as far back as 1210, when King William the Lion had to escape by boat from Perth Castle, which was built of wood and was destroyed utterly, and never rebuilt). The local flood defences were constructed in 1974 to a standard that could cope with any "normal" flood of the previous 200 years ie up to about 6.2 metres. (There had been one in 1814 which was 7 metres, but that was due to ice-blockages). The town deliberately permitted a major housing development in this floodplain, believing that the wall made it safe. In fact the 1993 flood reached 6.5 metres, and the wall broke, resulting in 1500 houses being flooded. This flood came on top of previous storms, so there were many other claims from houses which were not flooded, due to power cuts causing food spoilage, and also for damage to property stored at low-lying golf-courses.

Following the incident, insurers continued to provide flood cover to former clients, but naturally they adjusted their premium levels and deductibles. A key factor in this was the intentions of the public authorities. Perth was fortunate, in that it was the first major flood in Scotland for many years, and attracted great sympathy and political support for new defences. As a result, magnificent new flood defences including holding tanks, were commissioned and completed in 2001. However, that did not solve all the problems.

In 2002, wet weather in the spring filled the holding tanks. Unfortunately, a severe thunderstorm latched on to the town in July, and the ensuing cloudburst could not be contained. Localised flooding ensued, exacerbated by the flood walls. For the first time in its 100-year history, the two-day Perth Agricultural Show had to be cancelled and the central park was closed to visitors for the entire summer due to health fears from sewage. The Show had a lucky escape in 2004, when just after it ended torrential rain fell for three days from a decaying hurricane, causing the cancellation of the Perth Highland Games for the second time in three years.

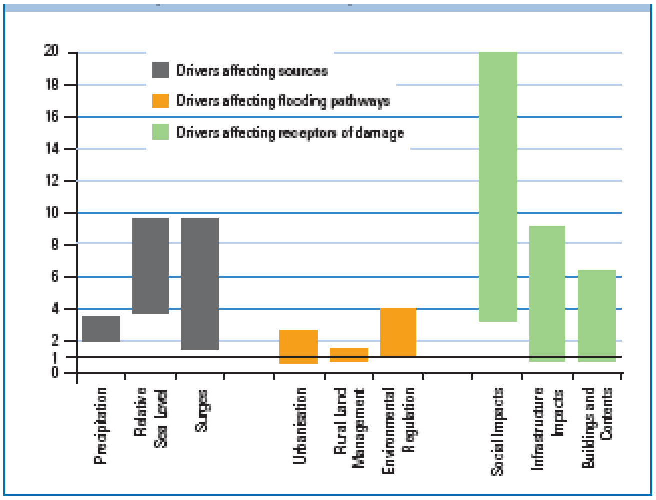
The floods of 1993 and 2002 are both events that are typical of climate change: a prolonged wet winter period with rapid thawing, and a violent summer thunderstorm. The 2004 flood was maybe bad luck- we do not know yet.

Annex 3 - Foresight -Executive Summary

Foresight evaluated the influence of 19 drivers on future flood risk for each of the four future scenarios (see Figure A2).

Figure A2 How key drivers might affect UK flood risk by the 2080's.

(Source Foresight Programme, bars represent range of possibilities dependent on scenarios)



- Climate change – has a high impact in every scenario. Risks at the coast will be particularly affected: relative sea-level rise could increase the risk of coastal flooding by 4 to 10 times. Precipitation will increase risks across the country by 2 to 4 times, although specific locations could experience changes well outside of this range.
- Urbanisation – particularly in flood-prone areas, could increase rainwater runoff, increasing flooding risk by up to times. At the same time, new developments and weak planning controls on the types, densities and numbers of new buildings could also increase risk.
- Environmental regulations – could be risk-neutral or could affect flood pathways by constraining maintenance and flood-risk management along rivers, estuaries and coasts, thereby raising risk. This argues for an integrated approach to decisions on flood management and environmental regulation in order to achieve multiple benefits for people and nature.
- Rural land management – a recent major study showed that there is substantial evidence that current land-management practices have led to increased surface runoff at the local scale. However, there is a general absence or uncertainty of evidence of the impacts at the catchment scale, or how small-scale impacts combine at larger scales.
- Increasing national wealth – will increase the value of the buildings and assets at risk and is therefore a strong driver of economic impacts. However, increases in flood damage as a proportion of national wealth will be much smaller and may even reduce in certain scenarios (see next Figure).
- Social impacts – these are difficult to quantify, but the analysis showed a large increase in social risks in all scenarios, by 3 to 20 times. Unless these risks are managed, significant sections of the population could be blighted. Many of the drivers that could have the most impact are also the most uncertain. Some of this uncertainty relates to scientific understanding – for example, uncertainties in how to model the climate. However, other sources of uncertainty are inescapable – such as the extent to which the international community will succeed in reducing greenhouse-gas emissions. It is therefore important to develop policies that can cope with a wide range of possible futures, and which can respond flexibly to an evolving world.

Figure A3 UK annual flood costs as a percentage of UK GDP in 2080's
(Source –Foresight Programme)

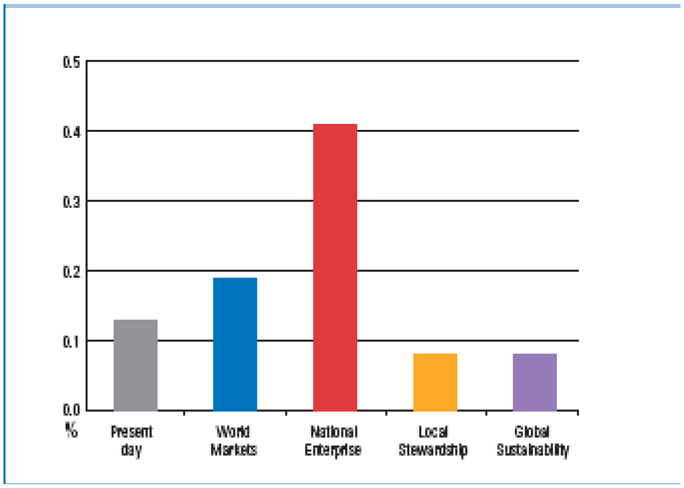


Figure A3 shows that whereas the future costs in monetary terms are many times greater than current levels, to a large extent this is explicable by socio-economic factors, because when the costs are normalised against future GDP, the impact varies from about two to four times current level under the World Market and National Enterprise scenarios, to a decrease under the more sustainable scenarios. However, the analysis did not incorporate the findings of recent events like the New Orleans flooding of 2005, when the severity of the event caused the costs to soar well above accustomed levels, and to extend far more widely than before. It may be expected that particularly for the two "growth" scenarios, Figure A3 underestimates the costs by a substantial factor.