Senate Standing Committee on Environment & Communications

Inquiry into Recent Trends in and Preparedness for Extreme Weather Events

Submission by Risk Frontiers

Macquarie University

RISK FRONTIERS

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Credentials

Professor John McAneney is the Director of Risk Frontiers and a Professorial Fellow in the Department of Geography and Environment at Macquarie University. Ryan Crompton is a Catastrophe Risk Scientist with Risk Frontiers. Ryan recently completed a PhD entitled “Natural hazards, impacts and climate change”. Both authors have expertise in assessing natural hazards risks and more generally in quantitative risk analysis.

Risk Frontiers is an independent research centre sponsored by the insurance industry to aid better understanding and pricing of natural hazard risks in the Asia-Pacific region. It was founded in 1994 to service the specialised needs of its sponsors in the local insurance and international reinsurance markets. Its aims were to:

- undertake risk assessment and research into natural hazards,
- develop databases of natural hazards and their impacts on communities and insured assets, and
- develop loss models to improve the pricing of natural hazard catastrophe risks.

These activities remain the core business of Risk Frontiers today, although we now undertake studies on a much wider range of risk-related problems and for a client base that extends well beyond the insurance sector. For example, Risk Frontiers is the preferred provider of research to the NSW State Emergency Service, and also has interests in public policy in respect to the management of natural hazard risks.

Risk Frontiers’ research and model developments are geared towards providing:

- databases and tools to promote risk-informed insurance underwriting in relation to natural perils,
- applications of advanced geospatial and image analysis tools,
- multi-peril Probable Maximum Loss (PML) modelling, and
- promoting risk-informed decision-making and the responsible management of risk.

Risk Frontiers is based at Macquarie University where it enjoys close collaborative links with a number of key academics. The Centre is self-funded and its staff are devoted to research, real-world problem solving and software development; it has no formal teaching commitments although the Centre does train post-graduate students who undertake research to advance our understanding of natural perils and their impacts on communities.

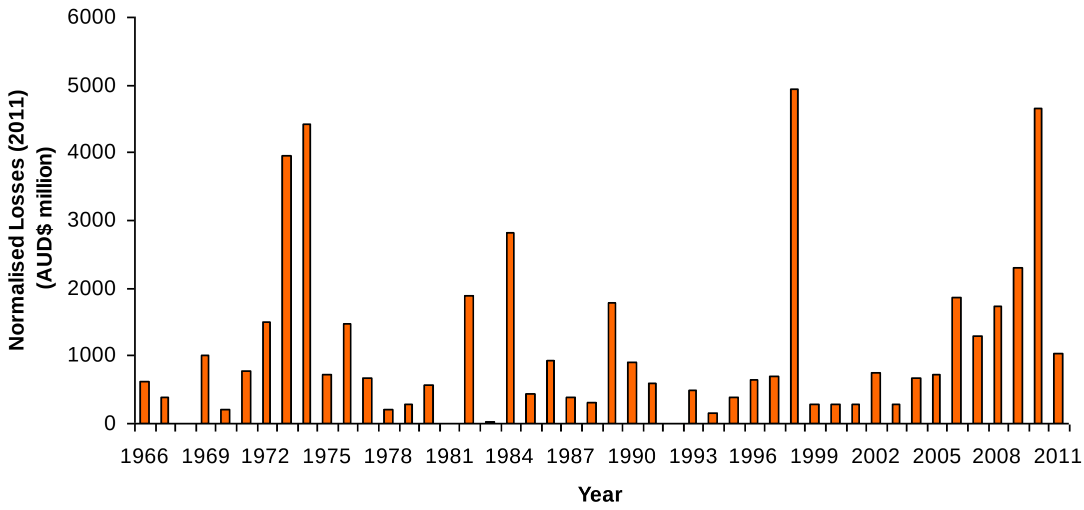
Brief summaries of some recent assignments and research activities undertaken by Risk Frontiers can be found in the Appendix.

Summary

In Australia as elsewhere loss of life from natural disasters is falling relative to the increasing scale and cost of economic and insurance losses. Thus our primary interest here will be disaster losses from extreme weather-related events likely to cause property damage – tropical cyclones, storms including hailstorms, floods and bushfires. Other submissions have dealt with increases in temperature.

A wealth of peer-reviewed research has shown that the economic cost of weather-related natural disasters is rising in concert with growing concentrations of population and wealth in disaster-prone regions. No role can yet be attributed to anthropogenic climate change. This is the case for multiple natural perils and across different jurisdictions. And recent studies suggest that we may be centuries away from being able to detect an anthropogenic climate change signal in US tropical cyclone loss data.

The figure below shows annual aggregate insurance industry losses due to Australian weather-related natural disasters. The losses have been normalised to 2011/12 societal conditions following the methodology described in Crompton (2011). Importantly, the time series of losses exhibits no significant trend over time but there is some general correspondence with El Niño-Southern Oscillation phases.



Recent catastrophes have highlighted many challenges, including how best to organise systems to pay for the damage caused by natural disasters and how to mitigate their effects. Insurance (public and private) plays a critical role in developed countries for providing funds for economic recovery after a catastrophe but has a limited supply. Purchasing insurance merely transfers risk, it does not reduce it.

The insurance system can also provide incentives for loss mitigation by sending price signals reflecting risk. In some parts of the world, government-subsidised insurance premiums effectively encourage development in hazard prone areas.

Hazard-resilient construction standards, defence measures and risk-informed land use planning are key elements to reducing the toll of natural disasters. Cost-benefit analyses of such measures must include the expected change in cost of risk transfer over the lifetime of buildings to reflect the current and potential future impact of large disaster losses on the overall economy. Since this cost is affected by the aggregate level of risk in an area it will increase if the surrounding area is subject to significant exposure growth or adverse anthropogenic climate change effects.

The potential economic damage from natural disasters can become very significant at a macroeconomic level as exposure grows disproportionately in areas of high risk. More consideration of large loss scenarios is needed to guide policy and raise awareness of the issues; the tools to do this already exist.

While it is difficult to influence the likelihood of extreme weather events, i.e. the hazard, we can decide where and how we build.

Conflating disaster losses with anthropogenic climate change is to look in the wrong direction and ask the wrong questions: reducing the vulnerability of people and property to disasters makes sense regardless of whether increasing losses can be linked to anthropogenic climate change. Vulnerability reduction is particularly important in the short term as greenhouse gas emission policies cannot decrease weather-related hazard risks for many decades (Bouwer et al. 2007). And doing this will afford economic and social benefits under any future climate.

The authors are happy to meet with the parliamentary committee to discuss any aspect of this submission.

(Some of the material presented here formed part of a report to the National Climate Change Adaption Research Facility Project SD11-17 (Crompton et al. 2012).)

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1. Introduction

The increase in natural disaster losses has led to a concern that anthropogenic climate change is contributing to this trend. In response to this concern, numerous studies have examined the factors responsible for this increase. This report summarises the peer-reviewed literature in this area as well as more recent efforts to estimate the timescale at which an anthropogenic climate change signal might be detectable in the case of US hurricane losses.

Figures 1a and b show the declining Australian death rate from natural disasters as recorded in Risk Frontiers' PerilAUS database (Coates 1996; Haynes et al. 2010; Crompton et al. 2010). Coates (1996) also shows that heatwaves cause more loss of life in Australia than any other natural peril. Our main focus here however will be disaster losses from extreme weather-related events likely to cause property damage – tropical cyclones, storms including hailstorms, floods and bushfires.

US hurricanes receive special attention because (1) they impact the global insurance market through the supply of and demand for reinsurance (2) the availability of long-term normalised economic loss history from land-falling hurricanes and (3) high quality modelling of the impact of global warming on basin-wide hurricane activity in the North Atlantic.

We take a risk-based perspective where *risk* is considered a function of three variables, the:

- *hazard* as expressed by the intensity and frequency of the peril,
- *exposure* -- the spatial distribution of assets and their value,
- *vulnerability* of assets to the intensity of the peril.

(There are also behavioural dimensions to risk (Slovic 1999). These are important in helping to explain why 173 deaths occurred in the 2009 Victorian bushfires despite near perfect predictions of fire weather.)

We will argue that there is much to be gained in both the short- and long-term from reducing societal vulnerability to natural disasters. Governments can address vulnerability through measures such as more resilient construction standards, risk-informed land-use planning practices and protective infrastructure. Implementing these would offer immediate benefits.

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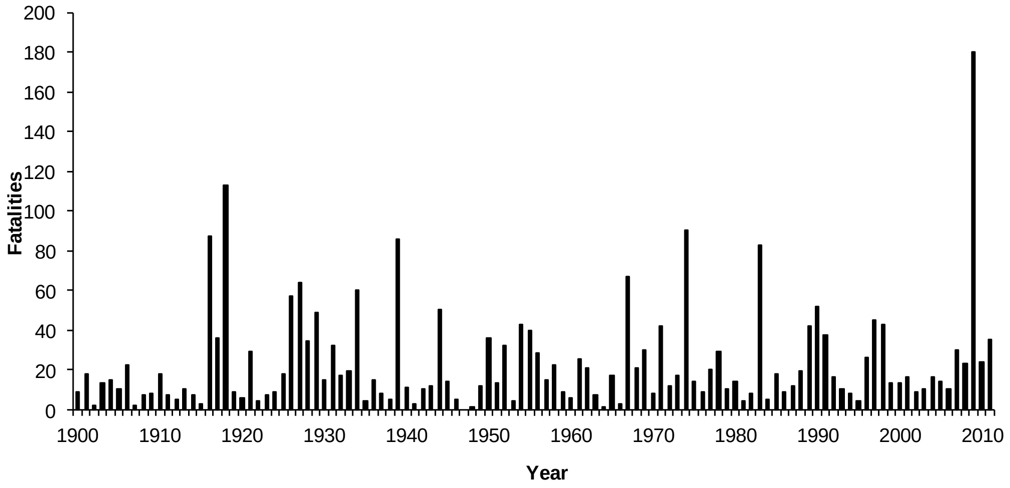

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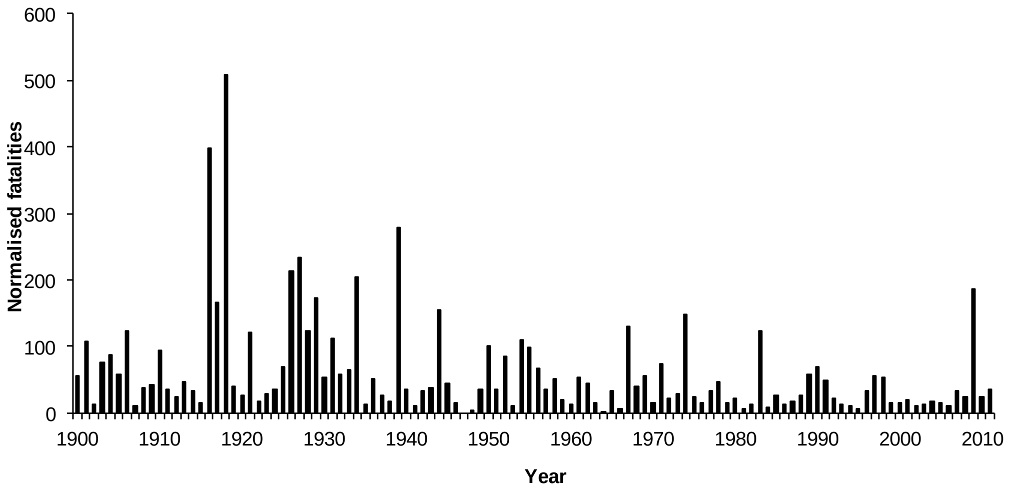


Figure 1: (a) number of fatalities arising from natural perils in Australia since 1900; (b) as for (a) but with numbers of fatalities normalised by population. Natural perils include, in alphabetical order: bushfires, earthquake, flood, grassfire, wind gust, hail, landslide, lightening, rain, tornado and tropical cyclone (Source: PerilAUS, Risk Frontiers (L. Coates)).

2. Loss normalisation studies

Normalisation

Before comparisons between the impacts of past and recent natural hazard events can be made, various societal factors known to influence the magnitude of losses over time must be accounted for. This adjustment process has become known as *loss normalisation* (Pielke and Landsea 1998).

Normalising losses to a common base year is undertaken primarily to: (1) estimate the losses sustained if historic events were to recur under current societal conditions, and (2) examine long-term trends in disaster loss records with a view to exploring what if any trend remains after taking societal factors into account.

Climate-related influences stem from changes in the frequency and/or intensity of natural perils – tropical cyclones, storms including hailstorms, floods, bushfires – whereas socio-economic factors comprise changes in the vulnerability and exposure to the natural hazard. Socio-economic adjustments have largely been limited to accounting for changes in exposure, although Crompton and McAneney (2008) adjusted Australian tropical cyclone losses for the influence of improved building standards introduced around the early 1980s following the destruction of Darwin by Tropical Cyclone Tracy in 1974 (Mason et al. 2012).

Global studies

Bouwer (2011) provides a comprehensive review of loss normalisation studies. The key conclusions from the 21 weather-related disaster loss studies are that economic losses have increased around the globe, but no trends in losses adjusted for changes in population and wealth can be attributed to anthropogenic climate change.

Studies published since the review of Bouwer (2011) provide yet further support for his findings. Two of these - Neumayer and Barthel (2011) and Barthel and Neumayer (2012) – were funded by the global reinsurer Munich Re and utilise their NatCatSERVICE natural disaster loss database. Neumayer and Barthel (2011) found substantial increases in economic losses from natural disasters during 1980-2009. However, no significant upward trends were found once these losses were normalised: this was the case globally, for specific disasters or for specific disasters in specific regions.

Barthel and Neumayer (2012) undertook trend analyses of normalised insured losses due to different natural perils at the global scale over the period 1990 to 2008, for West Germany for 1980 to 2008 and for the US from 1973 to 2008. Within these limited time frames, they found *no significant trends* at the global level, but claimed *statistical* significance for upward trends for all non-geophysical hazards as well as for certain specific disaster types in the US and West Germany. However, the authors *expressly warn against* taking their findings for the US and Germany as evidence that climate change has already caused more frequent and/or more intensive natural disasters in these countries. They refer to now well-documented issues confounding the statistical analysis of loss data over short time periods (Bouwer et al. 2007) and suggest that the findings reported could reflect natural climate variability that has nothing to do with anthropogenic climate change.

Importantly, and echoing many other studies, Barthel and Neumayer (2012) conclude:

> *Climate change neither is nor should be the main concern for the insurance industry. Accumulation of wealth in disaster prone areas is and will always remain by far the most important driver of future economic disaster damage.*

Other recent analyses that report no trend in normalised losses that could be attributed to anthropogenic climate change include: Zhang et al. (2011) – tropical cyclone economic losses in China over the period 1984-2008; Barredo et al. (2012) – insured losses from floods in Spain between 1971 and 2008, and Simmons et al. (2012) – US tornado economic damage from 1950-2011.

The recently released Special Report of the Intergovernmental Panel on Climate Change (IPCC) 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation' (SREX) (IPCC 2012) offers the most up-to-date consensus on the science of extreme events and disasters. As expected, it supports the findings previously discussed:

> *Increasing exposure of people and economic assets has been the major cause of long-term increases in economic losses from weather- and climate-related disasters (high confidence). Long-term trends in economic disaster losses adjusted for wealth and population increases have not been attributed to climate change, but a role for climate change has not been excluded (high agreement, medium evidence) (IPCC 2012).*

Australian-specific studies

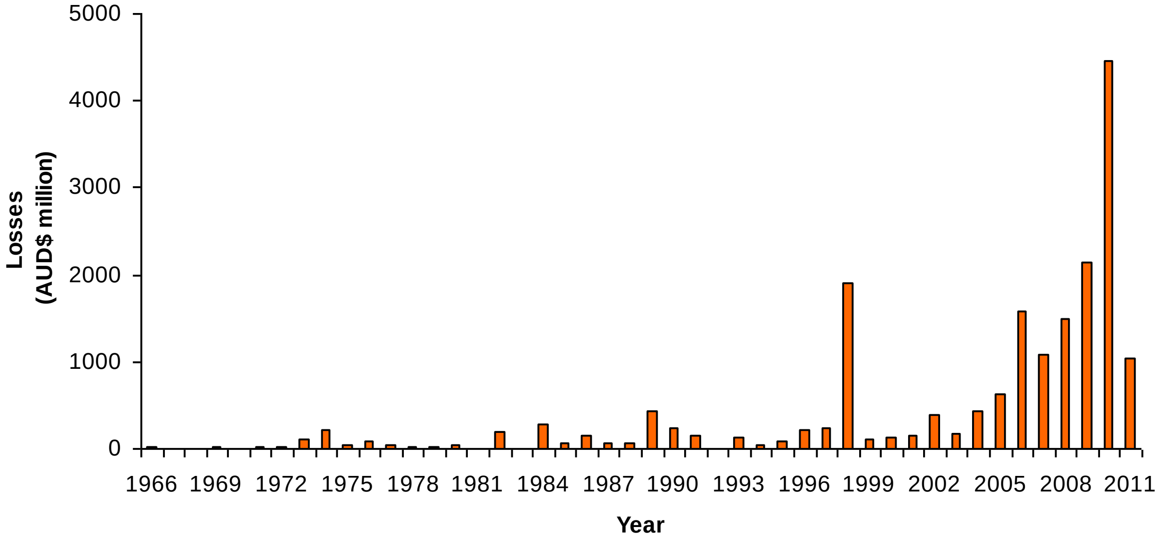
Crompton and McAneney (2008) normalised Australian weather-related insured losses over the period 1967-2006 to 2006 values. Insured loss data were obtained from the Insurance Council of Australia (ICA) (http://www.insurancecouncil.com.au/). The methodology adjusted for changes in dwelling numbers and nominal dwelling values (excluding land value). In a marked point of departure from previous normalisation studies, the authors applied an additional adjustment for tropical cyclone losses to account for improvements in construction standards mandated for new construction in tropical cyclone-prone parts of the country (Mason et al. 2012). They emphasise the success of improved building standards in reducing building vulnerability and thus tropical cyclone wind-induced losses.

Figures 2a and b show the annual aggregate losses and the annual aggregate normalised losses (2011/12 values) for weather-related events in the ICA Disaster List. These figures are updated from Crompton and McAneney (2008) and Crompton (2011) using the refined methodology described in Crompton (2011).

Following the large loss of life and property damage in the 2009 bushfire in Victoria, Crompton et al. (2010) examined the history of fatalities and building damage since 1925. Once the building damage was adjusted for increases in dwelling numbers, there was no discernible evidence that it was being influenced by anthropogenic climate change.

Crompton et al. (2010) emphasise the large proportion of buildings destroyed in Kinglake and Marysville during the 2009 fires that either lay within bushland or at very small distances from it (<10 m) and the role that poor land use planning policies in bushfire-prone parts of Australia have played in increasing the risk that bushfires pose to the public and the built environment. (The probability of home destruction within 10 m of bushlands and under the prevailing weather conditions on Black Saturday was in excess of 90%.) These same observations were made by Chen and McAneney (2010) in an invited submission to the 2009 Victorian Bushfire Royal Commission.

a)



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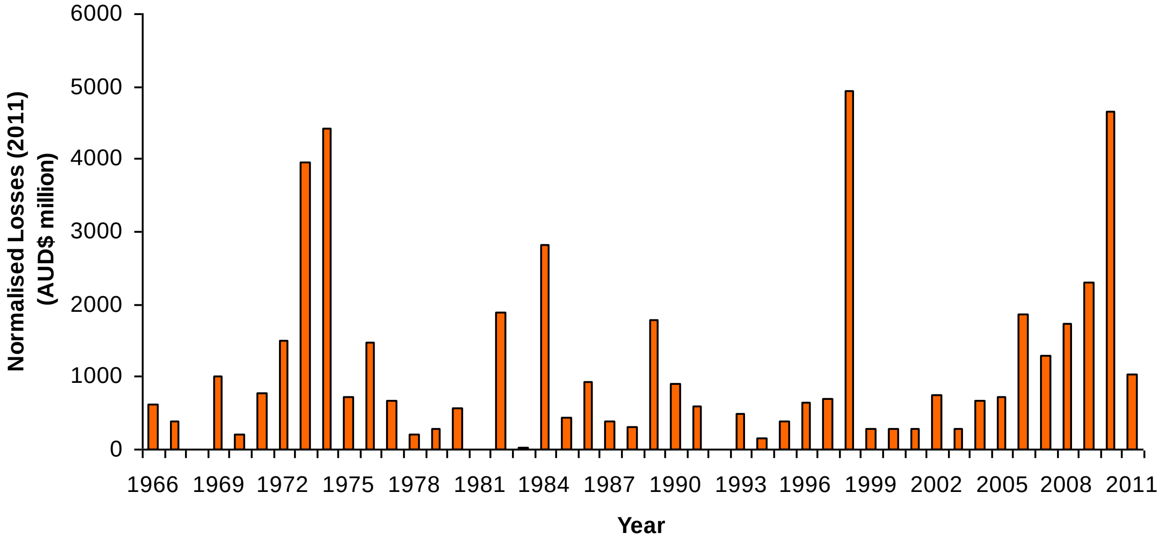

Figure 2: (a) annual aggregate insured losses (AUD$ million) for weather-related events in the ICA Disaster List for years beginning 1 July; (b) as in (a) but with losses normalised to 2011/12 values. These updated datasets are an extension of the normalisation analysis described in Crompton (2011) to 30 June 2012.

Other relevant studies

Although not normalisation studies, those by Di Baldassarre et al. (2010), van der Vink et al. (1998), Weinkle et al. (2012) and Chen et al. (2009) are also relevant to our discussion in pointing to societal factors being the driving forces behind rising disaster losses. Based on the results of both continental and site analyses, Di Baldassarre et al. (2010) found that the magnitude of African floods has not significantly increased during the 20th Century, and that climate has not been a consequential factor in the observed increase in flood damage. They conclude that:

> *. . . the intensive and unplanned urbanization in Africa and the related increase of people living in floodplains has led to an increase in the potential adverse consequences of floods and, in particular, of the most serious and irreversible type of consequence, namely the loss of human lives . . . It can be seen that most of the recent deadly floods have happened where the population has increased more.*

Much earlier van der Vink et al. (1998) had concluded that the US was becoming more vulnerable to natural disasters because more property was being placed in harm's way. They stated that:

> *In many ways the trends [in losses] seem paradoxical. After all, most natural disasters occur in areas of known high risk such as barrier islands, flood plains, and fault lines. Over time, one would expect that the costs of natural disasters would create economic pressures to encourage responsible land use in such areas.*
>
> *. . And while there will always be great political pressure to provide economic relief after a disaster, there has been little political interest in requiring pre-disaster mitigation.*

Many of the above observations hold true for Australia.

The results of Weinkle et al. (2012) add yet further confidence to the findings of tropical cyclone loss normalisation studies. They created a homogenised dataset of global tropical cyclone landfalls and found no long-period global or individual basin trends in the frequency or intensity of landfalling tropical cyclones of minor or major hurricane strength. This supports the conclusion that increasing tropical cyclone losses around the globe can be explained by increasing populations and wealth, as concluded earlier by Pielke and Landsea (1998), Chen et al. (2009) and others for US landfalling hurricanes.

3. Timescale at which an anthropogenic climate change signal might be observed in US tropical cyclone loss data

While it has not yet been possible to detect an anthropogenic climate change influence on normalised weather-related disaster loss data across a range of perils and locations around the world, we would be naïve to imagine that this will not occur at some point in the future under a warmer climate. This being the case, Crompton et al. (2011) asked the following question in relation to US tropical cyclones: if changes in storm characteristics occur as projected, then on what timescale might we expect to detect the effects of those changes in economic loss data?

The starting point for Crompton et al. (2011) was a study by Bender et al. (2010) from the NOAA Geophysical Fluid Dynamics Laboratory on Atlantic storm projections and published in the journal *Science*. Combining these projections together with the Pielke et al. (2008) normalised loss data, Crompton et al. (2011) showed that anthropogenic signals are very unlikely to emerge in a time series of normalised US tropical cyclone economic losses at timescales of less than a century. Their results are dependent on the global climate model(s) underpinning the projection with emergence timescales ranging between 120 and 550 years for individual models. It took 260 years for an 18-model ensemble-based signal to emerge, at which time losses are expected to approximately double.

The main message, from the projections analysed, is that it will be quite some time, perhaps centuries, before it can be said with any level of confidence that anthropogenic climate change is influencing US tropical cyclone losses. Crompton et al. (2011) extended this caution more generally to global weather-related natural disaster losses to the extent that they are correlated with US tropical cyclone losses.

Crompton et al. (2011) further point out that short-term variability is not 'climate change', which the IPCC defines on timescales of 30-50 years or longer, and that their results argue very strongly against using abnormally large losses from individual Atlantic hurricanes or seasons as evidence of anthropogenic climate change.

They also note that their results confirm that it is far more efficient to seek to detect anthropogenic signals in hurricane activity data directly rather than in hurricane loss data. This is because there is a large amount of variability in loss data - two events of the same intensity can hit different areas and generate very different losses depending on a number of factors such as the strength of buildings and the economic wealth in those areas. Moreover, annual loss data can comprise losses from different Saffir-Simpson category events and the projected changes in frequency of events for these categories under a warming climate can have different magnitudes and directions.

Emanuel (2011) implemented an alternative methodology to Crompton et al. (2011) to assess when the signal of anthropogenic climate change would be detectable in the damage record of Atlantic hurricanes. He looked at four different models, three of which showed increasing losses and one a small decrease. Of the three models that showed increasing losses, the time until detection is 40, 113 and 170 years. The decreasing signal in the fourth model did not emerge within the 200-year period analysed. This time to detection is shorter than that which Crompton et al. (2011) determined and there are a number of possible reasons for this. Regardless of these differences, both studies are in agreement that the time to detection of a signal of anthropogenic climate change, assuming that recent projections are correct, is a very long time, perhaps even centuries.

Lastly and returning to the fallacy of linking individual weather-related disaster losses to anthropogenic climate change, we note this is a temptation that sections of the media and some politicians find impossible to resist.

4. The disaster mitigation challenge

Recent catastrophes have highlighted many challenges, including how best to organise systems to pay for the damage caused by natural disasters and how to mitigate their effects. Insurance (public and private) plays a critical role in providing funds for economic recovery after a catastrophe. But simply purchasing insurance does not reduce the risk: insurance is a means of transferring risks to others with a broader diversification capacity.

In principle the insurance system can play an important role in providing incentives for loss mitigation by sending price signals reflecting risk (Roche et al. 2010) but regulatory efforts to limit premium increases in high risk areas, as has occurred in some parts of the US, can diminish the insurance system's ability to perform this function (Crompton et al. 2012).

Disaster mitigation measures can offset some of the upward pressure demographic and economic drivers (as discussed in previous sections) exert on natural disaster losses. In a study for the Australian Building Codes Board, McAneney et al. (2007) estimated that the introduction of building code regulations requiring houses to be structurally designed to resist wind loads had reduced average annual property losses from tropical cyclones in Australia by some two-thirds. Their estimate was based on the likely losses had the building code regulations never been implemented or had they always been in place.

Kunreuther and Michel-Kerjan (2011) at the Wharton School also examined this question by analysing the impact that disaster mitigation would have had on reducing losses from hurricanes in four states in 2005: Florida, New York, South Carolina, and Texas. They considered two extreme cases: one in which no one invested in mitigation and the other in which everyone invested in predefined mitigation measures. A US hurricane catastrophe loss model developed by Risk Management Solutions (RMS) was used to calculate losses for each scenario. The analyses revealed that mitigation has the potential to significantly reduce losses from future hurricanes with reductions ranging from 61% in Florida for a 100-year return period loss to 31% in Texas for a 500-year return period loss. In Florida alone, mitigation was estimated to reduce losses by $51 billion for a 100-year event and $83 billion for a 500-year event.

The magnitude of the destruction following a catastrophe often leads governmental agencies to provide disaster relief to victims – even if prior to the event the government claimed that it would not do so. This phenomenon has been termed the 'natural disaster syndrome' (Kunreuther 1996). This combination of underinvestment in protection prior to a catastrophic event and taxpayer financing of part of the recovery following can be critiqued on both efficiency and equity grounds.

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Without regulations, the challenge lies in encouraging residents in hazard-prone areas to invest in mitigation measures as has been highlighted by many recent extreme events. This is difficult: even after the devastating 2004 and 2005 US hurricane seasons, a large number of residents in high-risk areas still had not invested in relatively inexpensive loss-reduction measures, nor had they undertaken emergency preparedness measures. A survey of 1,100 residents living along the Atlantic and Gulf Coasts undertaken in May 2006 revealed that 83% had taken no steps to fortify their home, 68% had no hurricane survival kit and 60% had no family disaster plan (Goodnough 2006).

In fact it is a common observation that despite the reductions in risk that could be achieved, many homeowners, private businesses, and public-sector organisations fail to voluntarily adopt cost-effective loss-reduction measures, particularly if regulatory actions inhibit the insurance system from providing sufficient economic incentives to do so.

This theme was echoed in the results obtained in NCCARF-funded surveys of victims of the 2011 Queensland and Victorian floods, many of whom indicated a preference to use monies from state and federal disaster relief or insurance to build back the same or better, but with no thought of reducing future risk (Bird et al. 2012).

Musulin et al. (2009) identify an additional factor that must be considered to correctly assess the proper level of investment in loss mitigation – the current and future potential for large disaster losses in the area where policy applies.

The destruction of a single building can be easily absorbed into the normal building capacity of an economy but the destruction of hundreds of thousands of homes by a major tropical cyclone say cannot – the required diversion of material and labour to post-event reconstruction from other activities would cause massive stress and disruption. The potential economic damage from disasters can become very significant at a macroeconomic level as exposure grows disproportionately in high risk areas (Musulin et al. 2009).

Musulin et al. (2009) conclude that the economic value of loss mitigation must reflect the expected cost of risk transfer over the lifetime of the building. Since the cost of risk transfer is affected by the aggregate level of risk in an area it can change if the surrounding area is subject to significant population growth, wealth accumulation or adverse anthropogenic climate change effects. Loss mitigation should therefore also target areas of high potential future growth.

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5. Conclusions

Research into the economic impacts from natural disasters now spans many parts of the world. What is evident from studies to date is an *increasing trend in the cost of natural disasters* over time. The main drivers of the increasing trend are demonstrably socio-economic factors. No study has yet been able to detect an anthropogenic climate change influence. Anyone asserting the contrary now has a mountain of peer-reviewed literature to climb over.

This does not rule out a climate change influence; but it does suggest that its influence, if any, is currently minimal in the context of societal change and large year-to-year variation in impacts.

Research into future disaster losses highlights increasing socio-economic factors as having an equal or greater effect than anthropogenic climate change for the period until 2040 (Bouwer 2012). Moreover, it will be a very long time before the influence of anthropogenic climate change becomes detectable in loss data, at least for US tropical cyclones.

The collective research considered here suggests that there is much to be gained from reducing societal vulnerability to natural disasters. Without efforts to address this, the economic impacts from natural perils will continue to rise on the back of an ever increasing exposure.

Vulnerability reduction should be encouraged in an effort to minimise future losses and to improve the resilience of society from threats posed by *both* the current climate and any future one.

While it is difficult to influence the likelihood of extreme weather events, i.e. the hazard, the exposure and vulnerability components of risk lie within our control. We can decide where and how we build.

It should also be borne in mind that given the relatively short recorded history we have probably not seen the worst that the current climate has to throw at us.

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Appendix:

Recent Relevant Assignments by Risk Frontiers

1. Development of a Flood Exclusion Database (FEZ™) database identifying Australian addresses that lie beyond the extent of the Probable Maximum Flood (Australian Innovation Patent Application 2012100867 and an Australian Provisional Patent Application 2012902377).
2. Street-address natural hazard profiles for all addresses in Australia — bushfire vulnerability, frequency of damaging hail, flood status, earthquake peak ground acceleration and seismic soil conditions, peak wind gust speeds, distance to coast, etc.
3. Development of an Australian Multi-Peril Loss modelling platform to allow insurers and reinsurers to price risks due to riverine flood, hail, bushfire, tropical cyclone and earthquake, either individually or in combination. Some corporate clients are finding these tools useful.
4. Post-event reconnaissance surveys and interviews with victims after the 2004 Sumatran earthquake and tsunami, 2003 Canberra and 2009 Victorian bushfires, the 2010 and 2011 Christchurch earthquakes, the 2011 Queensland and Victorian floods and 2011 Cyclone Yasi.
5. Joint development (with Willis Re Australia[1]) of the National Flood Information Database (NFID) for the Insurance Council of Australia.
6. Nationally consistent database of coastal vulnerability of population by distance and elevation from the coast (Chen and McAneney 2006).
7. Normalising the Insurance Council of Australia's (ICA) Natural Disaster Database of insured market losses for changes in inflation, wealth and population, and in tropical cyclone-prone parts of the country, changes in construction standards in order to estimate likely losses if historical disaster events were to recur under today's societal conditions (Crompton and McAneney 2008; Crompton 2011).
8. Cost benefit investment analysis and risk assessment of remedial engineering works related to flood levee failure in an Australian city.
9. Valuing the benefits arising from regulations mandating improvements in construction standards for residential dwellings in cyclone-prone areas of Australia (McAneney et al. 2007).
10. Estimating the timescale at which an anthropogenic climate change signal may emerge in US hurricane loss data and implications of this for other disaster databases (Crompton et al. 2011).

[1] Willis Re is an international reinsurance intermediary with skills is assessing flood risk.

11. Normalised bushfire building damage and fatalities from 1925 – 2009 and implications for land-use planning (Crompton et al. 2010).
12. Invited submissions to the Royal Commission into the 2009 Victorian bushfires in respect to (a) circumstances surrounding all bushfire-related deaths since 1900 (Haynes et al. 2009) and (b) the vulnerability of homes as a function of their distance from bushland (Chen and McAneney 2004 and 2010).
13. Invited submission to the Productivity Commission in relation to “Barriers to Effective Climate Change Adaption”.
14. Representation on the Australian Building Codes Board Flood Committee.
15. Database of historic heat wave fatalities.