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ESTIMATING THE IMPACTS OF NATURAL HAZARDS ON FATALITIES AND BUILDING LOSSES

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ABSTRACT

This paper is a first pass at quantifying the impacts of natural hazards on fatalities and building losses in Australia over the past century. The emphasis is on developing a methodology which allows the effects of societal changes (population and wealth) across time to be taken into consideration. This process, termed normalisation, effectively estimates the building losses or fatalities from an event as if the event were to impact present-day society, thus allowing a comparison of the most damaging natural hazard events, even if they occurred many years apart. *PerilAUS*, a database of natural hazard events in Australia and virtually complete since 1900, is described. Future research into losses from natural hazards in Australia is documented.

INTRODUCTION

The Bushfire and Natural Hazards Cooperative Research Centre (www.bnhcrc.com.au) has been set up to explore the causes, consequences and mitigation of natural disasters.The *Scenarios and Loss Analysis* cluster project entitled "*An analysis of building losses and human fatalities from natural disasters*"[1] aims to measure and understand the impacts of natural hazards in terms of the toll on human life and the built environment. This examination is a fundamental first step to providing an evidence base for future emergency management policy, practice and resource allocation and to enable efficient and strategic risk reduction strategies. The analysis underpinning the project will be based on an examination of the historical record of losses caused by natural hazards in Australia since 1900.

The project has two distinct focuses:

- An analysis of building damage, by hazard, across time and by state/territory due to natural hazards, and
- A longitudinal analysis of the social and environmental circumstances in respect of fatalities, injuries and near-misses. This will include an examination of trends over time in terms of exposure and vulnerability. It is envisaged that these trends will be interpreted in the context of emerging issues (e.g. an ageing population, spatial population shifts, climate change etc) and how these issues might influence vulnerability and exposure trends in the future.

Key to this project will be the collection of set of data relating to losses (human and building) from natural disasters, in particular flood, cyclone, bushfire, severe storm, heatwave and earthquake. Some data exists (see the description of *PerilAUS*, below): the objective is to make this data set as complete as possible, given the resources made available through the BNHCRC project.

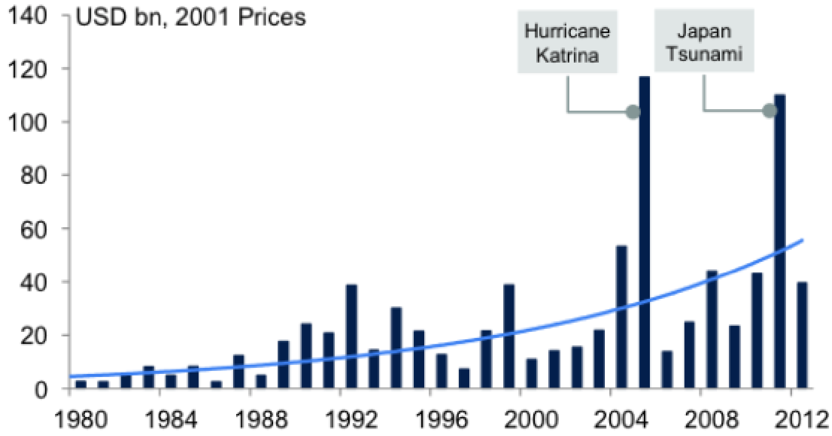
This paper will concentrate on the first of these focuses, and will describe and justify the approach to be taken. It will touch on human fatalities from natural hazards, and describe next steps in the project to expand and explore this data. Some very preliminary results are provided.

BUILDING LOSSES FROM NATURAL DISASTERS

Insured losses caused by natural disaster events have increased rapidly in recent years. Figure 1 shows global insured disaster loss data from Swiss Re, Munich Re and Deutsche Bank Research.

[1] http://www.bnhcrc.com.au/research/economics-policy-and-decision-making/235

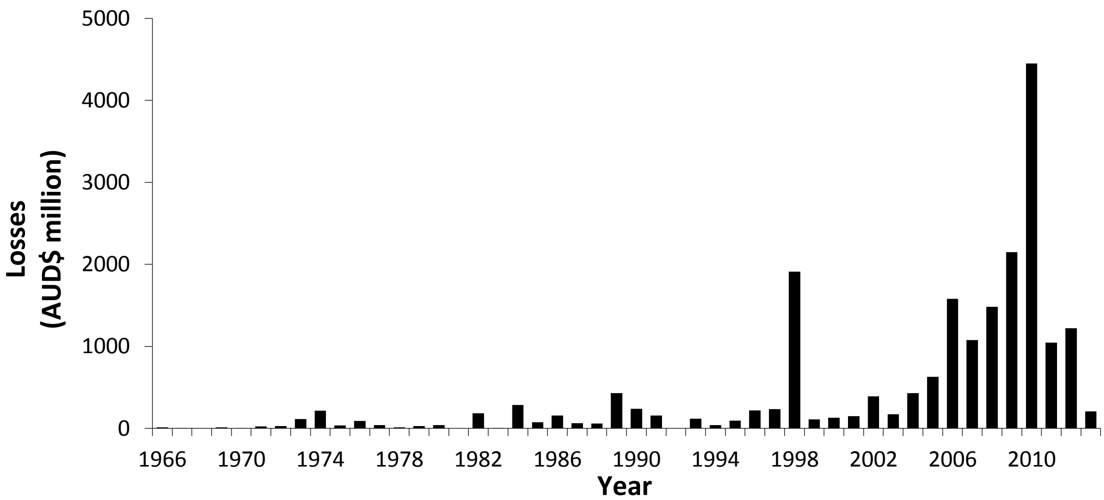
Figure 1. Global natural disaster losses, 1980-2012 (Source: Business Insider Australia, 2012)



Whilst the insured real losses are rising, the losses are seen to fluctuate wildly from year to year.

Although geographically far from other countries, Australia is not immune to these rising costs. Figure 2 displays data from the Insurance Council of Australia's historical Disaster Statistics list (ICA, 2014), composed of insurance industry losses from weather-related natural hazards (e.g. hail, floods, cyclones, etc) in Australia since 1967. This data closely mirrors the trend in Figure 1.

Figure 2. Australian weather-related natural disaster insurance industry losses, 1967-2013 (Data source: ICA, 2014)



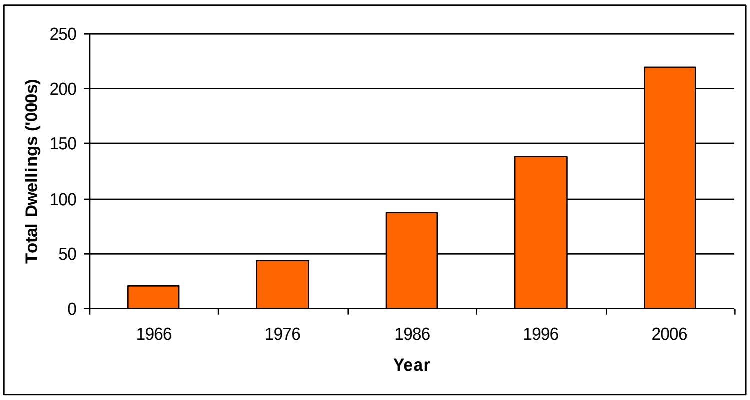
A linear regression function of the form losses (in $) = a + b (year) shows a statistically very significant increasing trend in this data ($p<0.0001$), implying increasing insured losses across time. The losses are increasing at an annual average rate of $32 million per year.

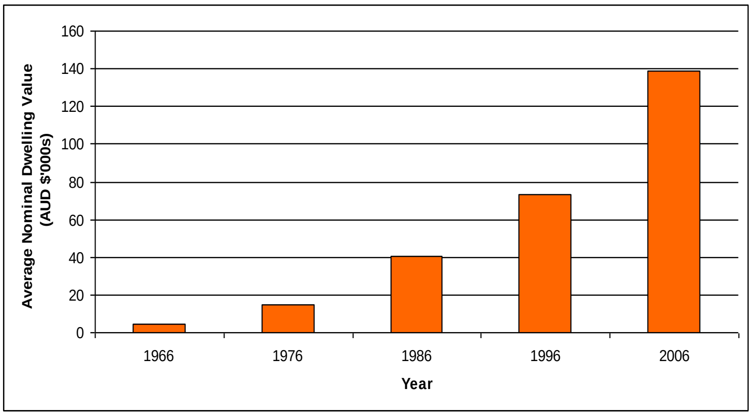
What might be causing this increase in losses? Over recent years there have been societal changes: for example significant population growth and movements of some of this population to areas susceptible to natural hazards (such as river floodplains and coastal or bushland fringes). Furthermore, with this increase in population has come an increase in wealth in hazard-prone areas – homes are costing more in dollar terms and are getting bigger. To illustrate, the two photographs in Figure 3 depict the Gold Coast/Surfers Paradise beachfront area, around 1970 and again in about 2003.

Figure 3. Gold Coast, around 1970 (left) and around 2003 (right). (Source: Local Studies Library, Gold Coast City Council)

Immediately noticeable is the proliferation of high-rise buildings in more recent times – more people and more wealth have become established here. Figure 4 quantifies these increases: an increase in population (proxied by the increase in the total number of dwellings) and an increase in wealth (proxied by the average dwelling value).

Figure 4. Gold Coast/Tweed Heads, 1966-2006. Total number of dwellings (above) and average dwelling value (below). (Source: ABS, 2014)



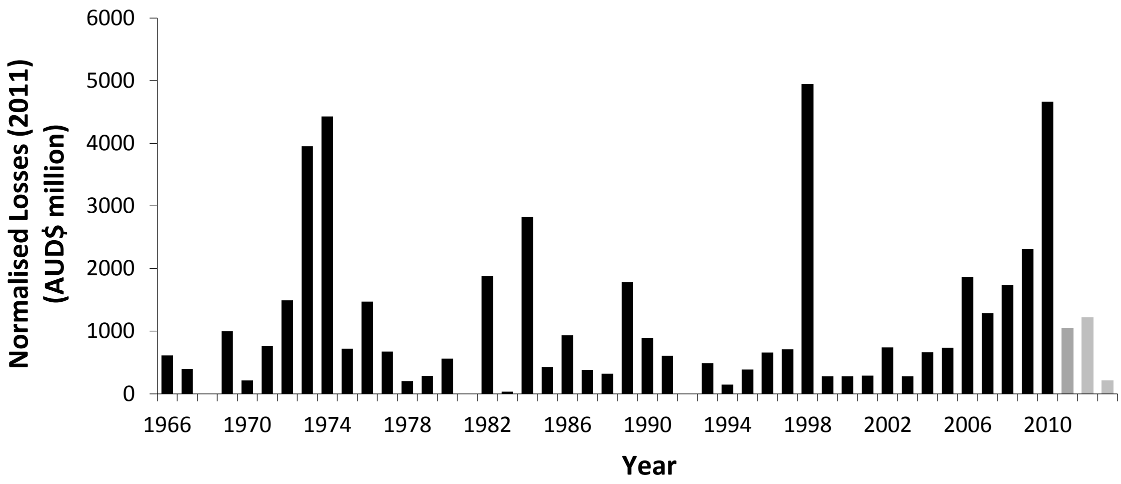


This is just one example of what has been happening in many places across Australia.

These societal changes offer a clue to the increase in insured losses from natural hazards, as observed in Figures 1 and 2. Normalisation refers to the process of adjusting historical losses for known societal changes (e.g. numbers of homes, the value of these homes and improvements in building codes and construction). Normalised losses effectively estimate the losses as if past events were to impact present-day society (i.e. an 'apples-versus-apples' comparison of event losses over time).

After normalisation the loss data shows a different picture (Figure 5). Whilst there is substantial variability across time there is now *no* statistically significant upward trend ($p>0.50$). This result implies that no signal has yet been detected to indicate that insured losses from causes other than societal changes (such as population changes and wealth growth) are increasing.

Figure 5. Australian weather-related natural disaster losses, 1996-2013, normalised to 2011 dollars. (Data from 2011-2013 have not been normalised.) (Data source: ICA, 2014)



MAJOR AUSTRALIAN DISASTER LOSSES

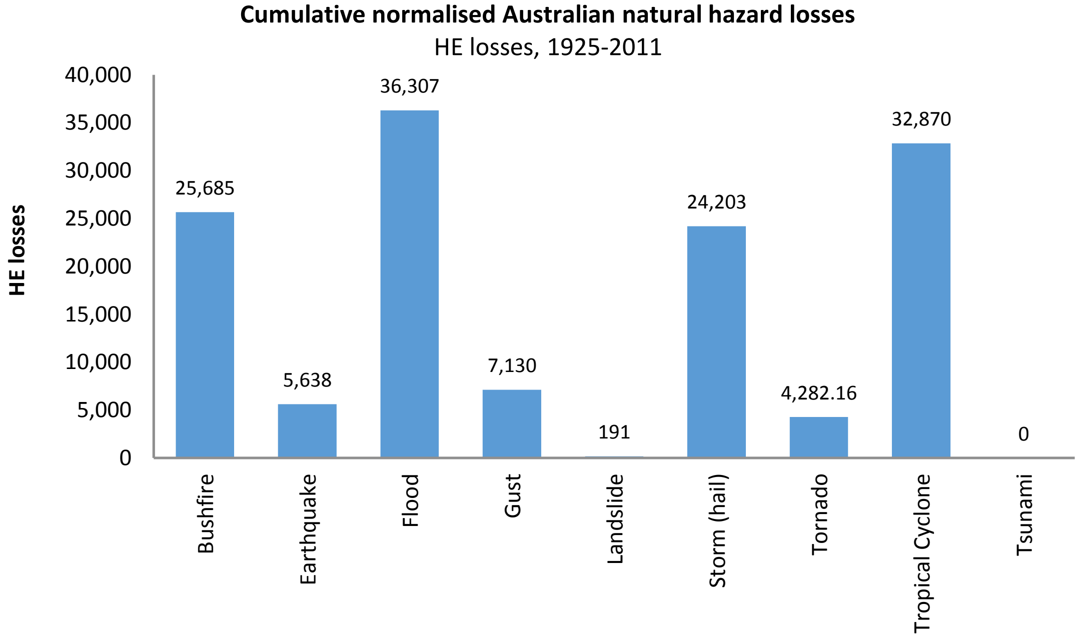
Normalisation allows a comparison of the most damaging natural hazard events, even if they occurred many years apart (Table 1).

Table 1. The largest Australian natural disasters (in terms of normalised insurance losses) of each peril type, 1967-2013, normalised to 2011 dollars (Source: Crompton, 2011; Data source: ICA, 2014)

Event	Ranking	Year	Normalised cost
Sydney Hailstorm	1	1999	4.3 Billion AU$
Tropical Cyclone Tracy	2	1974	4.1 Billion AU$
Newcastle Earthquake	3	1989	3.2 Billion AU$
QLD Floods	5	2011	2.5 Billion AU$
Ash Wednesday Bushfires	7	1983	1.8 Billion AU$

Table 1 shows that, after removal of the impact of population and wealth, no single peril dominates or is responsible for most insured building losses - damaging hailstorms, tropical cyclones, floods, earthquakes and bushfires all feature in the top seven most damaging events in Australia. This means that mitigation against natural hazards cannot be limited to one peril alone. Indeed, Figure 6 shows the cumulative normalised losses from 1925 to 2011 from the natural hazards that have caused most damage, with flooding, tropical cyclone, bushfire and storms (mostly hail) all prominent.

Figure 6. Australian natural losses, 1925-2011, measured in House Equivalent[2] (HE) (Data source: PerilAUS database, Risk Frontiers)



Major earthquakes are arguably the most damaging of all natural hazards. Over the decade 1992-2001 major earthquakes were cumulatively the costliest of all natural disasters (Alexander, 2004). The 1989 Newcastle earthquake remains the third most damaging disaster in Australia in terms of normalised insured losses. Earthquakes are rare in Australia and so, on a cumulative basis, losses from earthquakes have been relatively small.

FATALITIES FROM NATURAL HAZARDS

A glimpse at human fatalities caused by natural hazards is revealing.

In a similar vein to building loss data, an analysis of the number of human fatalities per year should be normalised to take into account population growth. Figure 7 displays fatalities from bushfires, earthquakes, floods, wind gust, hail, landslides, lightning, rain, tornadoes and tropical cyclones in Australia from 1900 to 2010. A linear regression on the raw data (Figure 7a) shows no significant trend, i.e. the fatality rate has been constant across time, whilst a regression on the normalised data (Figure 7b) shows a highly significant *decreasing* trend, amounting to around 0.7 deaths per year over the last 110 years ($p<0.001$). This is in line with research on global natural disasters (Alexander, 2004), which indicates that human fatalities are constant or decreasing.

[2] House Equivalents, a measure of building damage, is best described in the section "PerilAUS – *a database of natural hazards in Australia*".

Figure 7a. Australian natural disaster fatalities, 1900-2010 – raw data (Data source: PerilAus database, Risk Frontiers)

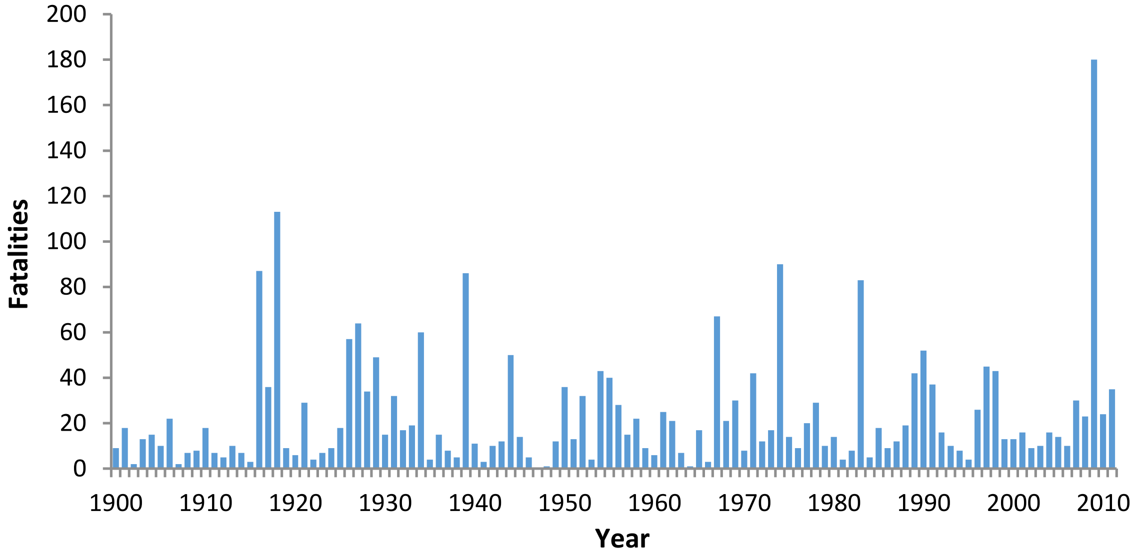
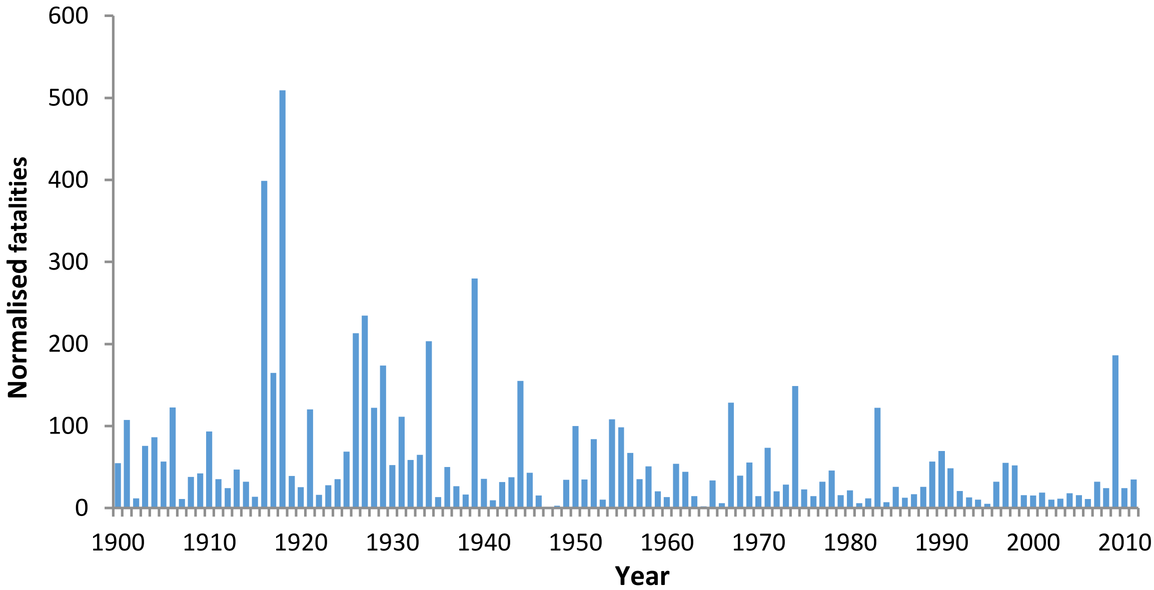


Figure 7b. Australian natural disaster fatalities, 1900-2010 – data normalised to 2010 numbers (Data source: PerilAUS database, Risk Frontiers)



Natural hazard fatalities from 1900 to 2011 as recorded in *PerilAUS* are displayed Table 2. Coates *et al.* (2014) found that the effects of extreme heat have killed more people in Australia since 1900 than as a result of all other natural hazards combined. Alexander (2004), reporting on a global scale, also concluded that heatwaves (and droughts) were the most lethal of all natural hazards.

Table 2. Natural hazard fatalities in Australia, 1900-2011 (Data source: Coates et al., 2014)

Natural hazard	Deaths 1900–2011	% total natural hazard deaths 1900–2011
Extreme heat	4,555	55.2
Flood	1,221	14.8
Tropical cyclone	1,285	15.6
Bush/grassfire	866	10.5
Lightning	85	1
Landslide	88	1.1
Wind storm	68	0.8
Tornado	42	0.5
Hail storm	16	0.2
Earthquake	16	0.2
Rain storm	14	0.2

PERILAUS – A DATABASE OF NATURAL HAZARDS IN AUSTRALIA

The *"An analysis of building losses and human fatalities from natural disasters"* project will be utilizing a unique database of natural hazard impacts.

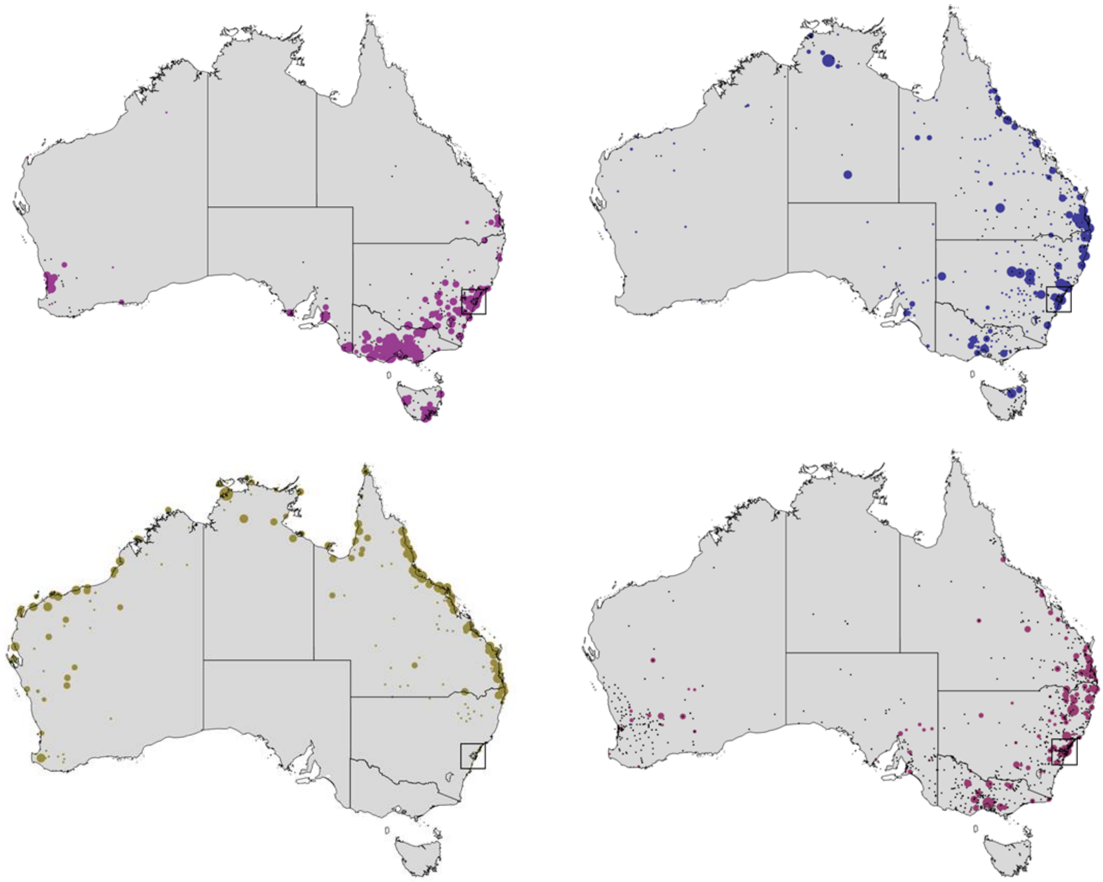
Over the last 20 years Risk Frontiers (Macquarie University, NSW) has been compiling a comprehensive database of natural hazard events in Australia from European settlement that have caused fatalities and/or damage to buildings, agriculture, infrastructure and lifelines. Where available, data has also been collected on the economic, social and environmental impacts of the event and on the number of people injured, evacuated and/or rendered homeless. The focus has been on natural hazard incidence, consequences and insurance losses, including event analyses, damage indices, insurable tangible damage and risk assessments.

Hazards covered in *PerilAUS* include bushfires, earthquakes, floods, wind storms, hail storms, heatwaves, landslides, lightning strikes, rain events, tornadoes, tropical cyclones and tsunamis. The record is complete for all major events from 1900 to December 2013. *PerilAUS* is distinguished from other such databases by the wealth of descriptive detail concerning the hazard impact and the inclusion of data about any built environment damage and/ or fatalities caused by that hazard. The damage information, especially the unique "housing equivalent" calculator, has been utilized in comparisons of particular hazard types, locations or years of record by a variety of insurance and specialist hazard-related organizations.

Data in *PerilAUS* has been collected from major and local newspapers and government and other official reports (including publications by the Australian Bureau of Statistics, the Bureau of Meteorology, the Registry of Births, Deaths and Marriages, Coroners' reports and Geoscience Australia).

PerilAUS has over 16,000 event reports dating from the European settlement of Australia to the current time. From 1900 there are almost 14,500 event reports. These event reports are supported by over 18,000 references. Figure 8 displays the geographic location of specific bushfire, flooding, tropical cyclone and hail events contained in *PerilAUS*.

Figure 8. Australian natural disasters recorded in Peril AUS, 1926-2013. Bushfires (top left), floods (top right), tropical cyclones (bottom left), and hail (bottom right) (Data source: PerilAUS database, Risk Frontiers)



An important attribute of PerilAUS is its use of House Equivalents (HE) as a means of comparing and/ or summing damage caused to buildings by natural hazard events of various types, in various locations and from at times. HE is based on buildings damaged or destroyed, and the unique damage index created from it, are described in detail by Blong (2003). In summary, an average house is assigned a Replacement Ratio (RR) of 1.00. Other building types are assigned ratios of greater (generally) or lesser value depending upon the area, amongst other factors. Replacement Ratios are estimates indicating how the costs of replacing the building in question compare with the cost of replacing a median-sized house. In effect, RR is the multiple required to express the cost of a building as a number of houses. A Central Damage Value (CDV) ranging from 0 to 1.0 (complete destruction) is then assigned and the damage to buildings of a specific type with the same amount of damage is then:

Damage [HE] = RR x CDV x Number of Buildings

This result is summed for differing building types and damage values to arrive at a total HE for a particular location, which can then be summed for all affected locations to determine the HE of a natural hazard event.

It should be noted that, as Risk Frontiers' House Equivalents considers only building damage with other important forms of damage excluded, a close parallel between HE values and records of insured losses is not expected. For example, in the April 1999 hailstorm in Sydney about 38% of the insured damage bill was for motor vehicles and aviation hulls. Neither of these losses are considered in the calculation of HE.

WHAT MORE CAN BE LEARNED ABOUT LOSSES CAUSED BY NATURAL HAZARDS? – FUTURE WORK

From the building loss perspective, the starting point will be updating and improving existing data contained in *PerilAUS*. Thereafter, temporal and spatial analyses of the data will be undertaken for each hazard, thus providing a natural priority ranking of hazard risks for each state. An analysis of changes to frequency of occurrence of hazards will be undertaken.

From the human fatalities and injuries perspective, updating *PerilAUS* with mortality data (from various coronial archives, the National Coroners' Information System, the Australian Bureau of Statistics and the Bureau of Meteorology) and morbidity data (from health departments (hospital attendance and admission records) and the Australian Institute of Health and Welfare) will be the initial outcome of the project. Further injury, "near miss" and rescue data will be collected from relevant emergency management agencies, where available.

A thorough statistical analysis will then be undertaken on the fatality/injury/rescue data in order to examine the relationship between demographics, social circumstances (warnings received, preparation, reasons behind actions, activities at the time of death etc) and the environmental circumstances at the time of the onset of the disaster (location, weather, hazard details etc). Past vulnerability and exposure trends will be interpreted in the context of emerging issues (e.g. ageing population, population shifts, climate change etc) in order to determine potential future vulnerability and exposure trends.

It is envisaged that a case-control study (details to be decided in collaboration with project end-users) will be conducted involving a survey of people who successfully reduced their risks and received little impact from a hazard event and those who did not reduce their risk and consequently received fatalities or injuries, or required rescues. This will offer insights into resilience in practice.

It is hoped that interviews with key senior emergency management practitioners and government policy makers will be undertaken to identify the policy and procedural changes that have been implemented over the years to reduce risks to people and property. A comparison of this with key trends within the fatality, injury and property loss data will enable an analysis of the impact that various changes to policy and procedures have had.

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