

Hail storm – one of the costliest natural hazards

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One of the costliest natural hazards?

Ascertaining the true financial impact of natural hazards when they occur is difficult; comparing the cost of events separated by many years is even harder. The quite high frequency of damaging hail storms in urban areas in Australia compared to other hazards such as earthquake, cyclone and flood makes us suspect that hail storms are a costly hazard. For people in Sydney the relatively fresh memory of the very damaging April 1999 storm reinforces the perception. But what about some evidence?

Figure 1 shows the proportion of all building damage attributable to various hazards for the period 1900 to 2003. The data is derived from Risk Frontiers' PerilAUS database. Destroyed and partially damaged non-residential buildings and partially damaged houses are converted to a common base equivalent to a single residential dwelling by considering factors such as construction costs per square metre and relative floor areas. The figure accounts for buildings damaged or destroyed - it doesn't include building contents, cars, machinery, aircraft or crops. (See Blong 1999 for more details)

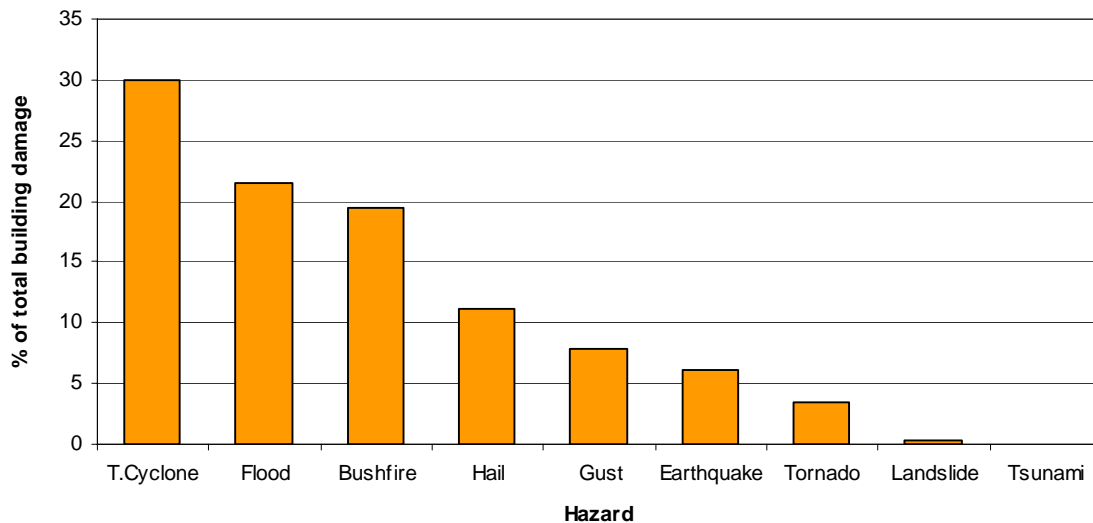


Figure 1: Normalised building damage for the period 1900 to 2003

By converting everything to an “equivalent house” we have avoided the issue of the changing value of property and the spending power of the dollar over time. However by excluding contents and motor vehicles we are likely to be underestimating the cost of hail compared to other hazards.

Another way to look at the relative cost of natural hazards is to interrogate the Insurance Council of Australia's natural disaster event list. This is a list of the total insurance payouts made for large events since 1967. It is one of the longest time series of natural hazard losses in the world and is a unique and valuable resource. An important feature is that it itemises the cost of damage to motor vehicles as well as commercial and domestic buildings and contents. Shortcomings are: 1) it lists “large” events only so many hailstorms have been excluded 2) the threshold for inclusion has changed a number of times 3) the losses are based on insurance payouts so uninsured property and

uninsured hazards are excluded (think flood) 4) hazard classifications are a bit woolly (this is a generic problem rather than a shortcoming of the list).

Risk Frontiers has recently re-indexed the losses in the list to estimate what the loss would be if the event under consideration were to recur today. A number of different indexation methodologies were explored and the preferred approach adjusts for increases in dwelling value and increase in dwelling numbers at the relevant locality. Important attributes of this preferred method are its relative simplicity; easy accessibility of the underpinning information; and the fact that it adjusts for only changes in building value and is thus independent of land value. Since damage to dwellings often makes up a major component of most catastrophe losses, this approach assures close alignment to insured losses. See Crompton (2006) for details of the method.

The “top 10” insured losses are shown in Table 1. It is immediately apparent that half of these involved hail. Figure 2 shows indexed losses summed over the whole list and broken down by hazard. This can be considered a proxy for average annual damage. So by insured loss data hail could be considered the most costly hazard. But it is notable that flood is not fully insured so is not as prominent on this list as it should be. Also a large damaging cyclone tomorrow would quickly put hail in second place. On the other hand this list does not include all hail losses but probably includes all cyclone losses.

Table 1: Top 10 losses ranked by indexed current loss

Rank	Year	Type	Location	Original loss (\$M)	Current loss as at 2006 (\$M)
1	1989	Earthquake	Newcastle	862	4300
2	1974	Cyclone	Darwin	200	4060
3	1999	Hail	Sydney	1700	3310
4	1974	Cyclone, Flood	Brisbane	68	1790
5	1983	Bushfire	VIC, SA	176	1610
6	1990	Hail	Sydney	319	1480
7	1985	Hail	Brisbane	180	1430
8	1976	Hail	Sydney	40	740
9	1986	Hail	Western Sydney	104	710
10	1984	Flood	Sydney	80	670

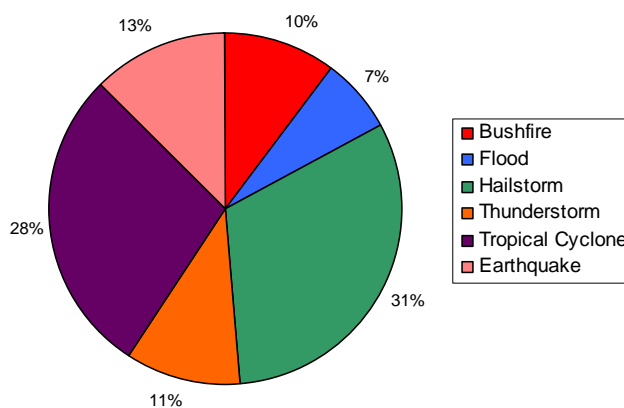


Figure 2: Percentage of total current loss classified by hazard type

What drives the cost?

The amount and cost of damage caused by a hailstorm depends on the physical characteristics of the storm and a range of factors relating to the vulnerability of the units at risk. Important physical characteristics of hailstorms include:

- Location
- Direction and path of the storm
- Areal extent
- Size and density of hailstones

Other important drivers are the size and spatial arrangement of the exposed units such as homes and cars and the vulnerability of these units or their components to damage.

Physical characteristics of the hazard

The magnitude of hailstorms can be defined in terms of both maximum hailstone size and area affected. Hailstone size is usually reported by comparison to objects of known or assumed size and is generally recorded as a maximum size within a given area such as postcode or suburb. Although maximum hailstone size does not completely describe the severity or damage potential of a hailstorm it is most commonly recorded and therefore used as a measure. This is generally considered appropriate for studies of damage to buildings based on studies in North America suggesting that damage to structures is more highly correlated to maximum hail size than to other characteristics (Summers and Wotjiw 1971; Changnon 1977). We are following convention by focussing on hail size and associated impact kinetic energies. However, we remain cognisant of the likelihood that motor vehicles are more sensitive to hail density than structures, and that large volumes of small hail can cause building damage by blocking roof gutters and drains.

Hailstorms tend to drop hail in hailstreaks so that the area affected is often discontinuous. The size of the total area affected also varies considerably. In Sydney for example, the available data indicates that about 40% of storms producing hail of diameter greater than or equal to 4 cm were recorded in only one postcode; only 20% were reported as falling in 6 or more postcodes. However some hailstorms have been very widespread: the March 1990 storm affected 83 postcodes and storms in 1976 and 1971 affected 167 and 139 postcodes respectively (Andrews, Blong and Byrnes 1996). It is difficult to estimate the occurrence and coverage of storms in non-urban areas because of the paucity of data.

Hailstone size varies between storms and within a storm, ranging from sleet-like graupel (hail with diameter less than 5mm) to large pieces of ice weighing hundreds of grams. The largest scientifically documented hailstone is usually taken to be one that fell in Aurora, Nebraska, USA in June 2003 weighing 500 grams with a maximum dimension of 18 cm (Knight and Knight 2005). A 14cm diameter stone is reported to have fallen near Kempsey in NSW on 21st December 1991.

The downward force due to gravity and the opposing (upward) force due to aerodynamic drag determine the motion of any falling object. The gravity force on a hailstone depends on its mass, while the drag force depends on its dimensions, shape and surface characteristics. When these two forces are balanced, the hailstone has zero acceleration, and therefore constant velocity. This velocity is the body's terminal velocity. A hailstone falling from a thundercloud will attain its terminal velocity well before reaching the ground (Paterson and Sankaran 1994).

For a spherical ice balls the theoretical terminal velocity may be represented by the equation :

$$V_t = 14.04(d)^{0.5} \quad (d \text{ in cm}) \quad (1)$$

It is generally accepted that for practical purposes, the simplification of assuming hailstones to be solid ice spheres of an equivalent spherical diameter is satisfactory.

A falling hailstone embodies an amount of kinetic energy that is proportional to its mass and the square of its velocity ($KE = 0.5mv^2$). The impact velocity of the hailstone is critical with respect to damage potential and is likely to have both a vertical component due to gravity (terminal velocity described above) and a horizontal component due to wind effects. Figure 3 indicates the terminal (vertical) velocity and impact kinetic energy for a range of hailstone sizes based on standard conditions and a constant spherical hailstone drag coefficient of 0.55. Note that the kinetic energy axis has a logarithmic scale, indicating that the damage potential increases dramatically with diameter. Small hail can fall more slowly than predicted by Eqn. (1) because it can be less dense than bulk ice and have a larger drag co-efficient (Knight and Heymsfield 1983). Large hailstones can exceed the critical velocity at which the airflow in the boundary layer adjacent to the stone can change from laminar to turbulent; this results in a lower drag co-efficient and therefore a higher velocity than predicted by Eqn. (1). (Bilham and Relf 1937; Willis et al. 1964; Doswell 1985).

Compared to other natural hazards damaging hail storms occur relatively frequently in urban areas in Australia. The structure of insurance and reinsurance contracts mean that the number of losses in a given year, the largest loss in a year and the sum of losses in a year, are all interesting parameters – hence the annual frequency of hail storms is also interesting. The best available information is for the Sydney metropolitan area; Figure 4 shows the number of annual recorded hail storms for the period 1935 to 2002. The large interannual variability is apparent. The average annual frequency for the 50-year period 1953 to 2002 is about 10. Schuster et al. (2005) stratified the data for this period and found that there was a statistically significant decrease in frequency for the last 14 years when compared with the previous 36 years.

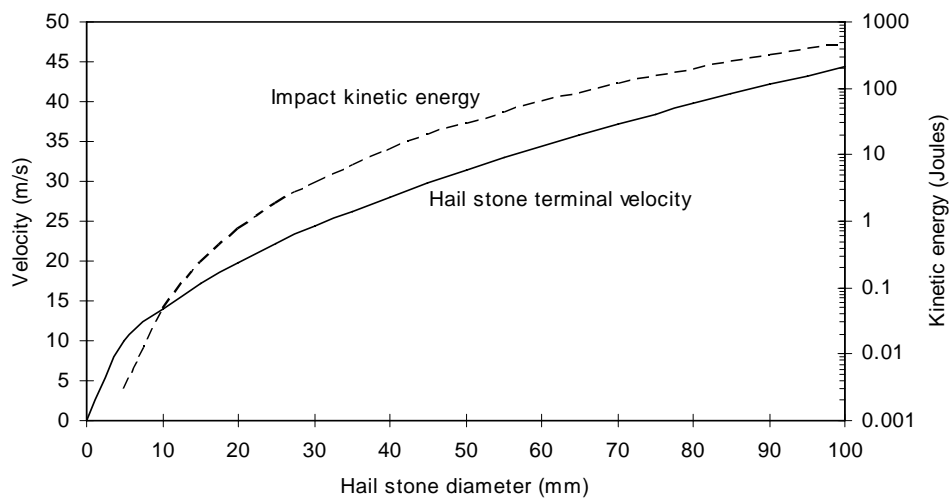


Figure 3: Theoretical relationships between terminal velocity, kinetic energy and hailstone size.

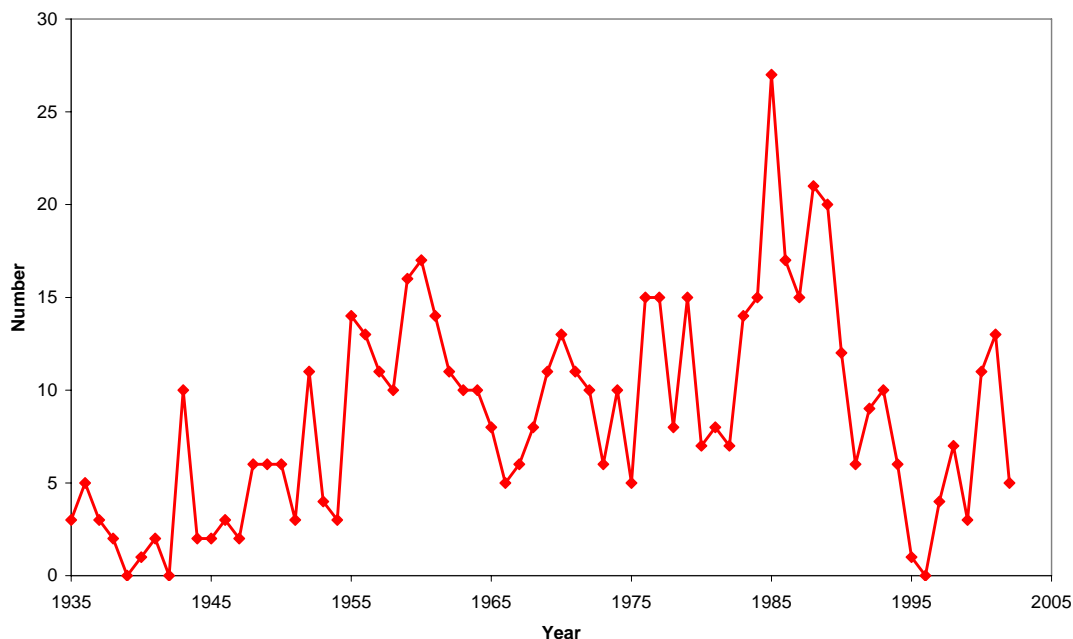


Figure 4: Annual number of recorded hail storms in Sydney (ICA zones 41 to 43). (after Schuster et al. 2005)

Exposure

The number of vehicles exposed to the impact of a particular storm (and hence the cost of the damage) simply depends on the number of vehicles in the affected region and how many of those vehicles are not protected from the hailstones (i.e. under shelter). Both these factors vary with the time of day, the day of the week and the time of year. A good starting point for estimating the number of vehicles in a region is the number of vehicles registered in the region.

Most cars are only at their garaging address for a small part of their lives. The rest of the time they are parked elsewhere – place of work, shopping centres, other peoples' homes etc – or are on the road. Quantifying the exposure involves adjusting the baseline data to capture these movements in vehicles to build a picture of the vehicle populations in different areas throughout the day and for a range of types of days.

To arrive at the number of vehicles exposed to hail, the number of vehicles located in storm affected areas must be adjusted by a factor representing the proportion of vehicles under shelter in that area. This 'shelter factor' will also vary temporally and spatially. On a Statistical Local Area basis, the proportion of vehicles parked on the street after their journey to home range from less than 2% (Baulkham Hills) to 78% (Leichhardt). Such information provides a "first cut" estimate of the effect on hail losses of parking under shelter. The third main exposure issue for motor vehicles is aggregations of unsheltered vehicles at sportsgrounds, shopping centres, railway stations, airports, universities etc. These will also vary temporally and spatially.

Defining commercial, industrial and residential building exposure is considerably less complicated than for vehicles – mainly because buildings don't move. In the case of residential buildings the key issue is density of dwellings and the value of dwellings, and consequently the density of exposed value. The Australian Census of Population and Housing is a good source of residential dwelling counts. Baseline commercial and industrial building exposure is more problematic – to date there is no readily available inventory of commercial and industrial buildings in Australia.

Vulnerability

Estimating the cost of damage sustained by a group of cars or houses exposed to hail depends on being able to relate the damage cost to some characteristic of a hail fall, such as hail size or impact kinetic energy. For the same storm, the cost of the damage in dollar terms will be different for different cars and for different dwelling types and constructions. Some cars dent more easily than others and some are more costly to repair; similarly dwellings with slate roofs, tile roofs and iron roofs have different damage and failure thresholds and different repair costs.

When a hailstone hits a car panel or roof tile its approach kinetic energy is converted to heat, noise, elastic and plastic deformation of the impacted component, fracturing energy of the hailstone and rebound kinetic energy of the hailstone (or pieces thereof). The most significant effect from a cost perspective is of course plastic deformation (for steel) or in the case of windscreens, plastic components and roof tiles, failure by cracking.

The hailstone impact energy (assumed to be proportional to hailstone diameter) at which dents become visible and windscreens or tiles start to crack is important. Information on the relationship between hail intensity and the amount of damage can be deduced from the effects of real hailstorms or through theoretical and experimental simulations. Data are only available for a small range of automotive steels, glass types and building materials. Some data is based on field work and some is based on tests using steel strikers or spherical ice balls; it is worth noting that the resulting dent for equal impact energies could be quite different for each of these data sources.

Results of a survey conducted by Risk Frontiers following the April 1999 hail storm in Sydney are shown on Figures 5 and 6. More than 350 responses were received providing details of hailstone size and descriptions of damage at the address of each respondent (Yeo et al. 1999). Some form of damage to roofs was reported by 62% of respondents. Figure 5 shows the distribution of three classes of roof damage – none, few broken tiles, and many broken tiles – according to the size of the largest hailstone. No tiles were broken by hailstones smaller than 3 cm. No houses were without roof damage for hail sizes of 7 cm or more. The most common type of roof damage for hailstone sizes less than 5 cm was a few broken tiles. Hailstones larger than 5 cm often caused substantial damage. Damage to cars was reported by 53% of respondents. A significant proportion of the cars that did not sustain damage – even for hailstone sizes ≥ 7 cm – would have been garaged. Some respondents reduced the degree of damage by putting their cars under-cover at the outset of the storm, or by covering their cars with doonas. Figure 6 shows that hailstones smaller than 3 cm caused little damage. Damage was more common for hailstones between 3 and 5 cm in diameter, but most damage was slight. Severe damage was common for hailstones larger than 5 cm.

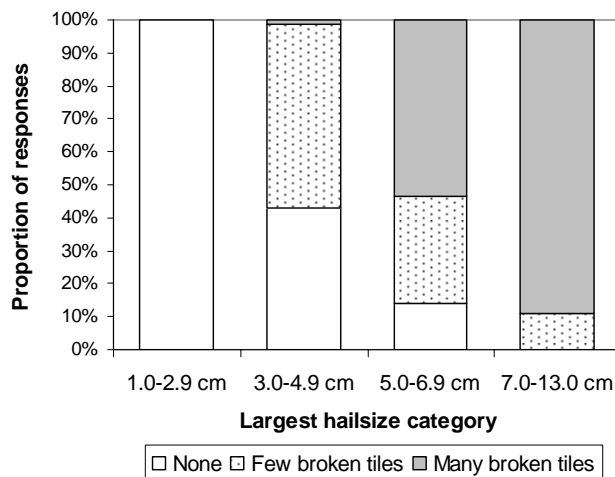


Figure 5: Largest hail size and roof damage

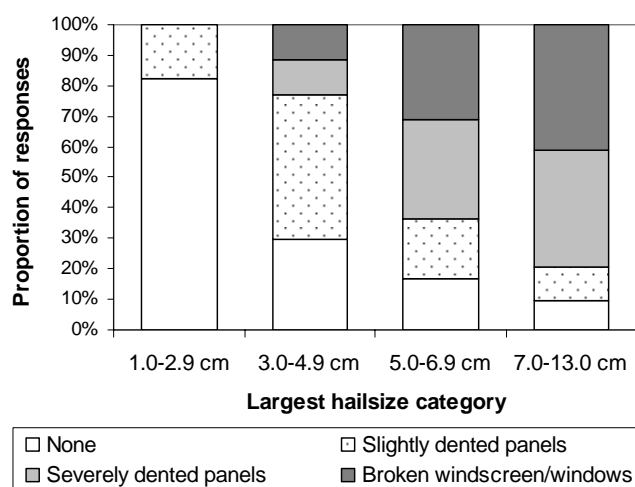


Figure 6: Largest hail size and car damage

Damage mitigation

There are limited ways in which the damage caused by hail can be reduced:

- Modify the hazard so it is less damaging
- Relocate or physically protect units at risk (either in accordance with forecasts or all the time)
- Use more resilient building materials

Although rarely used to reduce property losses, weather modification is still used in many places to attempt to reduce crop losses. The theory behind hail cannon and hail rockets is that shock waves generated from cannon on the ground or exploding rockets in the cloud will weaken or destroy hailstones in the air. Notwithstanding the manufacturers’ claims there seems to be very little scientific evidence that these methods work (Wieringa and Holleman 2006). In the words of the World Meteorological Organisation “In recent years anti-hail activities using cannons to produce loud noises have re-emerged. There is neither scientific basis nor a credible hypothesis to support such activities.” (WMO 2001)

Cloud seeding on the other hand, does have a credible hypothesis – called beneficial competition. Beneficial competition relies on the assumption that the water volume in a cloud is limited, and that if water is divided equally over a larger number of precipitation elements then the radius of the elements - i.e. hailstones - will be smaller. So injecting excess seeding particles at the correct time and location should reduce the average size of fully grown hailstones. Numerous experiments suggest that seeding does reduce the risk of damaging hail, but there are many practical difficulties to deal with – see Weiriga and Holleman (2006) for details.

Timely and accurate warnings of hail storms are valuable, particularly for life safety and emergency management planning reasons. There is probably little that homeowners can do to reduce the damage from hail given a one or two hour warning, but there is certainly scope for reducing motor vehicle damage by finding shelter or covering the vehicles. However, forecasting the evolution and movement of small scale intense weather phenomena such as hail storms is much more difficult than forecasting larger-scale weather systems and still involves many technical challenges for the Bureau of Meteorology.

It was apparent after the Aril 1999 storm in Sydney that corrugated steel roofs are not penetrated as readily as tile roofs. They are therefore better from the perspective that a hail damaged steel

roof will rarely lead to significant contents claims from large amounts of water permeating building fabric leading to collapsed ceilings etc. From a building claims perspective the benefit of steel roofs really depends on whether the insurance company decides to replace dented, but still structurally sound, steel roofs. Slate tiles may not be much more susceptible to failure than terracotta but they are a special case because they are so expensive to replace.

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