The impact of land cover change on storms in the Sydney Basin

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It is now commonly believed that increasing carbon dioxide in the atmosphere will lead to more energetic meteorology and a likelihood of increased frequency and intensity of storms. The international insurance and re-insurance industries are wise to watch the on-going development of this science. However, while at the global scale there is little doubt that increasing carbon dioxide is the major driver or forcing component of change in the Earth System, at scales of relevance to an insurance company's risk portfolio, there are other components of global change that might be of similar importance at smaller that global scale.

Many overseas observationally-based and modeling-based studies have shown that urban surfaces can affect weather via the urban heat island effect, the initiation of mesoscale circulations and by affecting storm occurrence, storm initiation, intensity and motion. While studies of the impact of urbanization in many major overseas cities have occurred, we present the first study of the impact of urbanization on storms in Sydney. We used the Regional Atmospheric Modeling System (RAMS) at a 1 km resolution over the Sydney Basin to assess the impact of land cover change on storms simulated over Sydney. First, we present results from a randomly sampled selection of storms. We show that these simulated storms do not respond to the change in land cover consistently, but there is a suggestion that storms of similar types respond in comparable ways. All simulated synoptically forced storms (e.g. those triggered by cold fronts) were unresponsive to a changed land surface, while local convective storms were highly sensitive to the triggering mechanism associated with land surface influences. Storms travelling over the smoother agricultural land in the south west of the Sydney Basin experienced an increase in velocity.

In one simulation, a storm entirely absent under natural land cover formed under current land cover. It formed over the Sydney CBD as an intense thunderstorm generating intense rainfall and hail that is of order the intensity that would have led to major financial loss if it had occurred in reality. Figure 1 shows this core result with rainfall and wind vectors plotted.

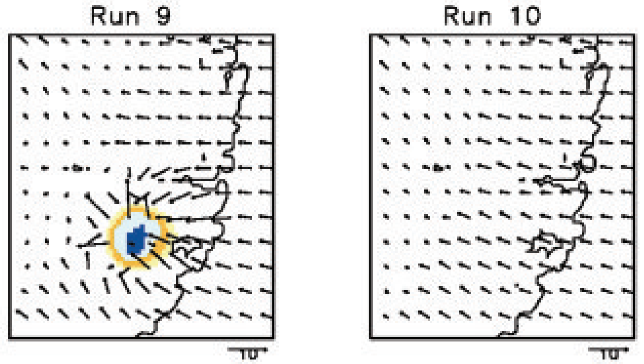

***Figure 1**: left shows a significant storm centered just to the west of the Sydney CBD, right shows this storm missing. The only difference between these simulations is the nature of the underlying surface.*

A tempting conclusion would be that this storm was *caused* by urbanization. Sadly (for us) we show that this storm had nothing to do with the presence of the CBD. The storm was causally related to the existence of agricultural land in western Sydney – demonstrated via a factorial experiment.

We will present the results and discuss the implications with suggestions on ways that our methodology might begin to have urban planners thinking about how to design mega-cities to minimize their impact on meteorological hazards.

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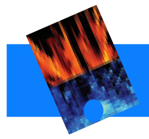

Risk Frontiers' Current Product List

This year marks an exciting milestone for those involved in the local insurance industry with the completion of Risk Frontiers suite of natural hazard loss models for all of the major perils afflicting residential buildings in Australia. Several of these models are already being upgraded to include commercial and industrial portfolios. These models represent the culmination of steady progress over a number of years. We also have a range of address-based databases for particular perils. All of these can be either licensed or purchased, or used by Risk Frontiers on behalf of clients. The list of our Australian-based products is as follows:

- ***CyclAUS*** – national tropical cyclone loss model.
- ***HailAUS*** – stochastic hail loss models for residential dwellings in Sydney, Wider Sydney (Wollongong – Newcastle), Brisbane.
- ***QuakeAUS*** – national stochastic earthquake loss model for residential dwellings.
- ***Bushfire PML*** – simulation model calculating national PMLs or Exceedance probabilities for bushfire losses based on the *PerilAUS* database.
- ***FloodAUS*** – address-by-address Risk Ratings for 1.2 million addresses down the eastern seaboard. The database can also be used in a stochastic mode for PML calculations for specific catchments.
- ***FireAUS database*** – national address-by-address bushfire risk ratings based on distance to the nearest area of extensive bushland.
- ***PerilAUS database*** – searchable natural perils database (1900-1999) with mapping functions and relative risk ratings at postcode and CRESTA zone levels.
- ***Coastal Vulnerability Database*** - national address-by-address database based on distance to the sea (or to estuaries, lagoons or rivers connected to the sea) and elevation.

For more information on any of these models or databases, please contact John McAneney or Carol Robertson - email: riskfrontiers@els.mq.edu.au

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Earthquake Forecasting

At present, there is no generally recognised capability for earthquake prediction, which seismologists define as specifying the time of occurrence, location and size of an earthquake within reasonably narrow uncertainty bands. However, it has long been recognized that there are periodicities in earthquake occurrence, and recently it has become clear that earthquake forecasting based on the preceding sequence of earthquakes in a region is feasible. One kind of forecasting relates mainly to the occurrence of aftershocks in the very short term (hours and days) following a mainshock, and is thus not of much interest to the insurance industry with its focus on an annual cycle. Another kind of forecasting, which is potentially of much more interest to the insurance industry, relates to the long term (years to decades) forecasting of mainshocks (which we define here as potentially damaging earthquakes) and is based on decades of prior seismicity.

It has been shown that a mainshock is preceded by an increase in the rate of occurrence of smaller earthquakes in the surrounding region. These smaller earthquakes appear to herald the reloading of the region to a level of stress that locally exceeds the strength of the crust. Equations have been developed that relate the magnitude of the impending earthquake to the duration of precursory seismicity and the size of the region in which it occurs. These equations provide the means to forecast the time-varying level of seismic activity throughout a region based on its preceding seismicity. This method does not predict specific earthquakes, but in hindsight specific earthquakes are found to have occurred in regions with high forecast levels of activity. To date, demonstrations of this capability have been done in New Zealand, California and Japan. Although it has not yet been tested in regions of low seismic activity such as Australia, it is expected to be also effective in such regions.

This development has important implications for the insurance industry. At present, the seismic hazard analyses on which earthquake loss estimates are based usually assume that earthquakes occur randomly in time (Poisson model). However, the accelerating seismicity model described above provides a much more accurate forecast of seismicity than the Poisson model. The use of a time-dependent method of analysis based on the accelerating seismicity model described above would potentially provide much more accurate estimates of earthquake loss in a given region during a given year. In a particular year, damaging earthquakes, if they occur at all, are likely to occur in locations that are identified as having an increased level of activity, while other such locations will not experience damaging earthquakes (but may do so in the future).

Adoption of this approach to seismic risk analysis would mark a radical departure from current practice. At a given location (say a major city), the level of hazard (and potential risk) could potentially fluctuate by a factor of two or more from year to year; this might tend to average out over a larger region (for example, a state). In some cases, the locations of regions identified as having high impending seismic activity levels may coincide with locations that have been active historically, and thus make intuitive sense, but in other cases they may not. A high level of confidence in the method may need to be developed to induce its adoption in the latter category of cases.

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CyclAUS - Risk Frontiers' Australian Tropical Cyclone Model

With the completion of *CyclAUS*, Risk Frontiers can now offer a complete suite of probabilistic loss models for natural perils afflicting Australian residential homes. *CyclAUS* is based on tropical cyclone (TC) events contained in the Bureau of Meteorology's TC database.

All post 1959 TC events with a central pressure $\leq$ 995hPa making landfall on the Australian continent have been individually analysed. This results in 163 TC's, and these are used to generate distributions of frequency as well as other parameters required to model the gradient wind field. Directionally-dependent wind adjustment factors for individual Census Collection Districts (CCD's) are then applied to the gradient wind field in order to obtain a localised gust wind value. This gust wind value is used to calculate the damage to residential buildings and/or contents.

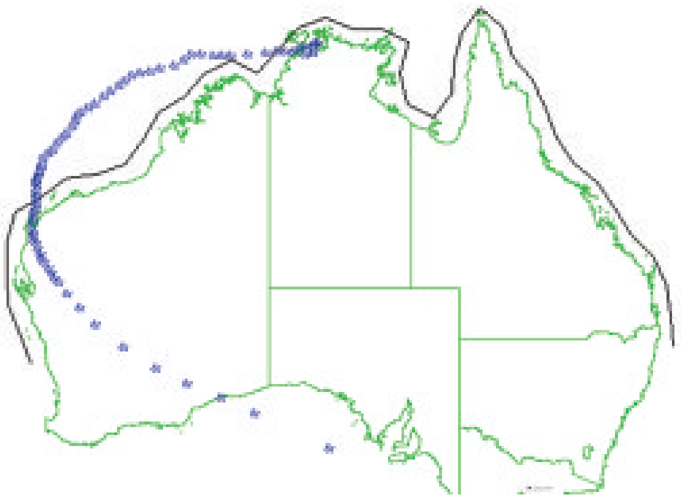

Figure 1. *TC Vance (17-24 March 1999)*

The model is based around a series of forty-one 200km long straight segments or gates positioned 100km off the coastline. These were used to both analyse the database, and as points of TC event generation in the simulation model. The segments extend as far as 30.4 degrees south; regions further south do not form part of the model.

CyclAUS generates a 50,000-year synthetic catalogue of tropical cyclones using Monte Carlo sampling. All wind speed and damage calculations are made at the CCD level, which in high density areas is as small as 0.03 km^2.

CyclAUS calculates loss at the CCD level for each simulated tropical cyclone based on the maximum gust wind speed experienced at each CCD, its proportion of pre & post-1980 construction, and its Wind Region (Wind Standard (AS/NZS 1170.2:2002)). The sum insured for each CCD is split based on the proportion (derived from Census Data) of pre- and post-1980 construction in each CCD. Having a spatially varying Wind Standard means that in more exposed regions, new buildings must be designed to withstand more intense wind speeds. The vulnerability functions in *CyclAUS* reflect these geographical differences.

Data input for *CyclAUS* can be provided at CRESTA zone or postcode levels. In either case, insured assets are disaggregated into CCD's assuming that these are distributed in the same proportion as Census Data. *CyclAUS* accepts a user-defined average deductible and produces annual aggregate as well as individual event losses.

Output from *CyclAUS* includes: comprehensive statistics summary (losses for various Average Recurrence Intervals, Annual Average Damage, minimum and maximum loss, standard deviation, etc), Annual Exceedance Probability plots, individual cyclone losses by postcode and building age, and more.

Risk Frontiers complete suite of catastrophe models makes an all hazard comparison in the Brisbane region possible. Which natural hazard will dominate the Probable Maximum Losses? All will be revealed at the Seminar.

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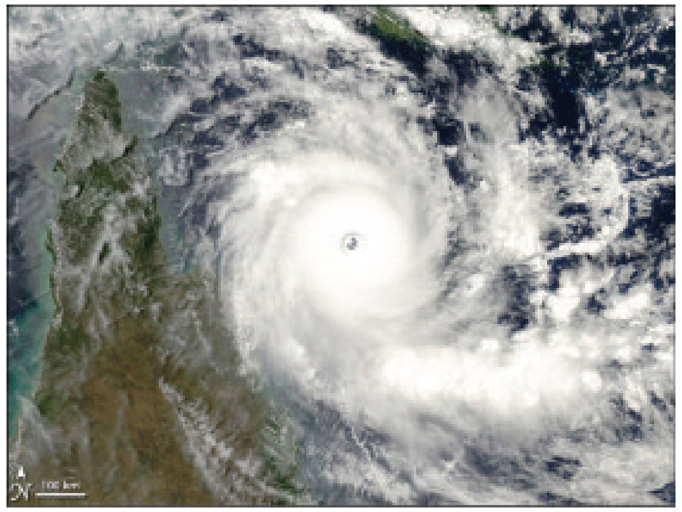

Figure 2: *Cyclone Ingrid - captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite, 8/3/05.*

Figure 3. *Double trouble - Still recovering from the effects of Hurricane Ivan in 2004 Pensacola Beach (Florida, USA) experiences the full force of Hurricane Dennis, July 2005.*

Quantifying at-risk Australian addresses vulnerable to sea level rise and tsunamis

The 26 December 2004 Sumatra-Andaman mega-thrust earthquake and the resulting tsunami, which caused enormous loss of life in coastal communities of the Indian Ocean, has once again focused attention on the vulnerability of populations living in low-lying coastal areas. In the worst affected areas in Sumatra, 10m high waves at the shoreline surged inland causing destruction at distances up to 3.5 to 4km. Clearly, there is a need to accurately quantify the number and spatial distribution of coastal populations at risk, not just to tsunami, but also to flooding, storm surge and sea-level rise.

Here we report on the first results of a project that sought to identify Australian addresses adjacent to the sea and at risk to a wide range of coastal hazards. The project provided answers to the following two important questions:

(1) How many Australian addresses are located within different distances from the shoreline?

(2) How many addresses within certain distance range categories are located in low-lying areas?

In order to examine how many addresses are in close proximity to shorelines, we first used GNAF (Geocoded National Address File) addresses, which have explicit location information in terms of latitude and longitude. After removing duplicates, a total of 9.6 million unique addresses (residential, commercial and industrial) were derived for the entire country as at the end of 2004. Nationally, 30% and 50% of them are located within 2km and 7km, and only 20% of all addresses are situated beyond 25km from the shoreline.

We also specifically examined the northwestern part of the country, which is more likely to suffer from future major subduction zone earthquakes in the Java Trench, Indonesia and resulting tsunamis. The area (see the dashed polygon in Figure 1) is bounded by latitudes 10.5S-23.5S and longitudes 113.5E-137.5E and is extremely sparsely populated; the total number of addresses is only 83,400. Within the first 1km off the shoreline 20,000 addresses are located and as distance to the shoreline increases, the absolute number drops off very quickly (Figure 2).

For the Greater Sydney region spanning from Newcastle to Wollongong, we also used a high quality DTM with a vertical accuracy better than 1m and located 46,000 addresses most at risk: those within 1km from the shoreline and with elevations less than 3m (see Figure 3). Examination of their spatial distribution reveals the majority of these vulnerable addresses to be located near sea-connected coastal waters – alongside lakes or lagoons, river banks and estuaries, rather than directly facing the open ocean. These findings will be useful in directing effective mitigation measures and looking at the vulnerability of critical assets.

To investigate a methodology for obtaining estimates like those given above for any region in the whole world, not just Australia, we undertook validation and up-scaling approaches that were based on relationships between the very fine-resolution Australian datasets and fine-resolution global datasets on population (LandScan at 30-arc-second resolution) and elevation (SRTM at 3-arc-second). A desktop-based software program with an easy-to-use interface is currently under development to enable the selection of any region of interest anywhere in the world and generate corresponding reports.

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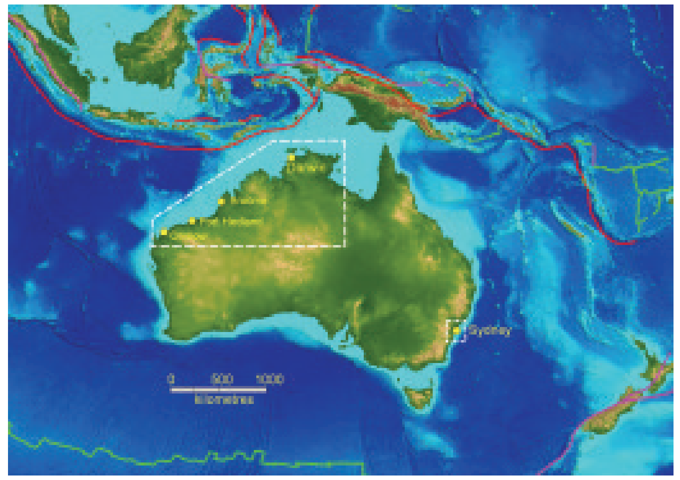

Figure 1: *Study area and plate boundaries in the region.*

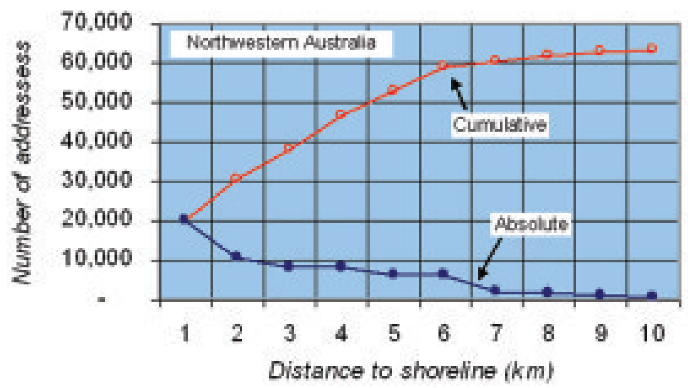

Figure 2: *The number of addresses as a function of distance to shorelines.*

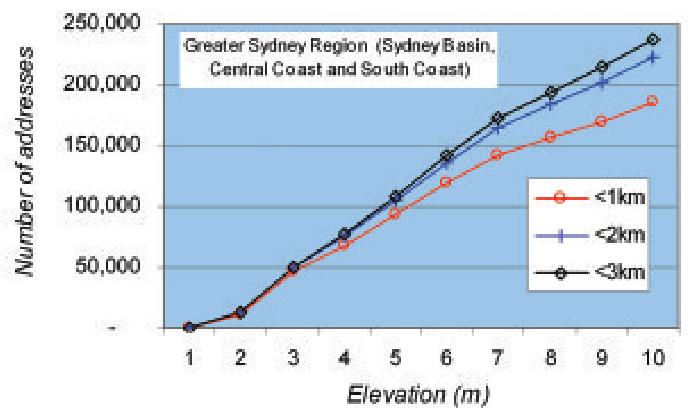

Figure 3: *The number of addresses as a function of distance to shorelines and elevation above the mean sea level.*