Return period cyclonic wind hazard in the Australian region

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Introduction

A review commissioned by the Council of Australian Governments in 2001, *Natural Disasters in Australia: reforming mitigation, relief and recovery arrangements*, (COAG, 2002) recommended a fundamental shift in focus in relation to natural disasters; beyond relief and recovery towards cost-effective, evidence-based disaster mitigation.

The severe wind activity at Geoscience Australia is developing a tropical cyclone (TC) hazard model, one of the three components of an infrastructure risk model, to rigorously assess the risk around the Australian coastline posed by TCs. The other two models are infrastructure exposure and vulnerability models for different types of infrastructure (e.g. residential, industrial and commercial) and within infrastructure types (e.g. residential; solid brick, brick veneer, timber and fibro-cement).

The first stage in assessing the risk of tropical cyclones is to determine the level of hazard. The hazard model is a statistical model of tropical cyclone behaviour, similar to those of Powell *et al* (2005) and Hall and Jewson (2007). The model utilises distributions of tropical cyclone properties (speed, bearing, intensity), developed on a grid covering the regions of interest. Tropical cyclones are randomly initiated by sampling from a 2 dimensional probability density function (PDF) of tropical cyclone origins. Subsequent behaviour of the TC is determined by sampling from the prepared distributions.

The hazard model is designed to permit as much flexibility for the user as possible. To this end, users can select the form of PDF kernel used to calculate distributions of parameters; wind fields applied to each synthetic track are parametric and can test the sensitivity of hazard levels to the choice of radial wind profile or asymmetry model, for example.

As a preliminary validation exercise of the model, the hazard output is compared to the output from another statistical hazard model over northern Australia, and other existing estimates of the wind hazard. We compare the 0.2% annual exceedence probability (AEP) wind speed at selected locations and present a spatial estimate of this wind speed, incorporating the effects of shielding, terrain and topography where possible to arrive at a site-specific hazard estimate. The 0.2% AEP is chosen, as this is the standard which residential buildings are designed to survive. Some caveats on estimating the appropriate wind hazard across Australia are also highlighted, indicating the difficulties in correctly estimating the hazard levels in a changing climate.

Model structure

The Tropical Cyclone Risk Model (TCRM) is a modular software package being developed at Geoscience Australia for assessing the impacts and risk of tropical cyclones on the Australian community. Being a statistical model, it relies on historic tropical cyclone data as input. The TCRM hazard model is comprised of four main modules: a data processing module to ingest input data and format the data suitable for the other modules; a statistical analysis module; a synthetic track generation module; and a windfield calculation module. TCRM is written in a combination of Python and C and is being tested on a range of operating systems.

The data processing module simply converts input data into a single format that can be ingested by the other modules. The statistical analysis module generates distributions of TC parameters such as genesis location, speed, bearing, rate of intensification and (where available) size. It also calculates the autocorrelation coefficients and variances of the tropical cyclone behaviour parameters (speed, bearing, intensity, size). TCRM uses kernel density estimation to derive the distributions, both for one-dimensional parameters and two-dimensional parameters such as genesis. TC behaviour parameter distributions are calculated on a grid covering the region of interest. In areas with a low density of observations, the grid can be incrementally increased until sufficient observations are included in the analysis.

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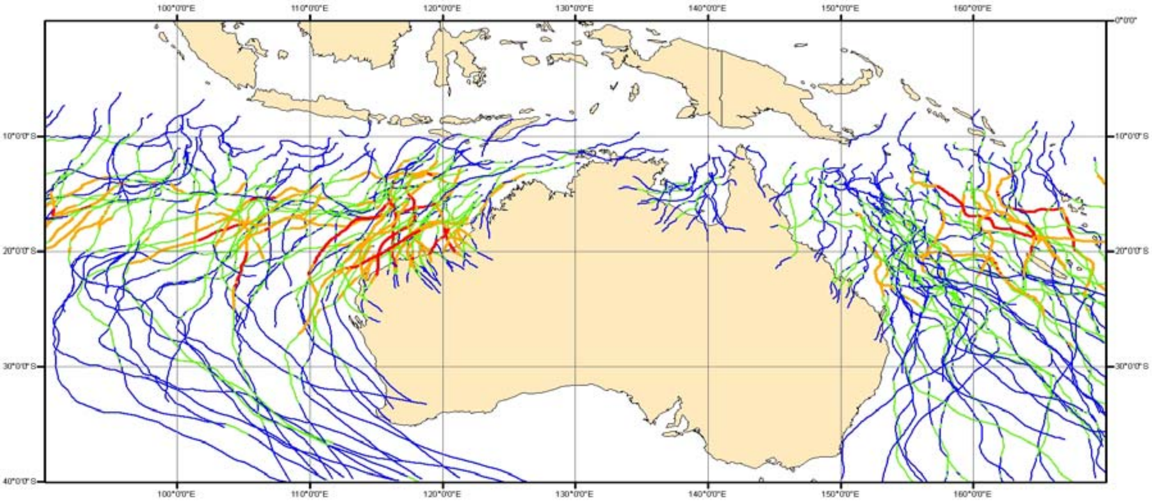

Figure 1: Synthetic TC tracks generated by TCRM, representing 10 years of activity in the Australian region, with 179 events.

The synthetic track generation module is based on the methodology described in Hall and Jewson (2007), where changes in TC speed and direction are modelled as an autoregressive process. This relies on having quality observations of TC behaviour in the region of interest. For our assessment, we have used the Australian historical tropical cyclone database (Holland, 1981) from 1970–2004. This does induce a bias towards low activity along the east coast (Arthur *et al.*, 2008a).

The windfield module can ingest historical or synthetic track information and estimate the wind swath using a 2-dimensional parametric wind field model to determine the spatial extent of the 'regional' wind field (of order 1 km resolution). The parametric wind field provides six radial profiles and three boundary layer models, each with several tuneable parameters, depending on the model chosen (e.g. peakedness parameter or gust factors). Each of the tuneable parameters can be randomly sampled from suitable distributions as part of a Monte-Carlo process to further increase the variability in simulations. This provides an efficient method to calculate the winds around a tropical cyclone while still retaining many of the intricate details.

Hazard assessment

To assess the hazard levels, we use the TCRM to synthesize many thousands of years of TC events and the maximum winds associated with them, and then use these events to derive statistics about the AEP.

Based on historical events, we generate a synthetic event set representing 5000 years of TC activity in the region of interest. The wind swath for each TC event is calculated and stored. Using the wind swaths, we can then calculate AEP wind speeds spatially, using a simple relation between the cumulative distribution function of wind speed and the AEP. The process is repeated numerous times and the results averaged (this also provides information on the upper and lower confidence limits of the estimated wind hazard).

Impact assessment

For detailed studies of TC risk from a specific event, TCRM can be applied to a small domain and incorporate the effects of terrain (land surface classification), topography and nearby structures (shielding) on regional wind speeds. An individual track can be ingested into TCRM, with a single wind swath generated. Using GIS software, we map the regional hazard to a 25 m resolution grid, where we use 'windfield multipliers' (AS/NZS, 2002) to incorporate site-specific influences on wind speed. At this level, we can then associate a site-specific wind speed with each building (or a mean wind speed over a statistical collection or 'meshblock' of tens to hundreds of buildings) extracted from Geoscience Australia's National Exposure Information System (NEXIS).

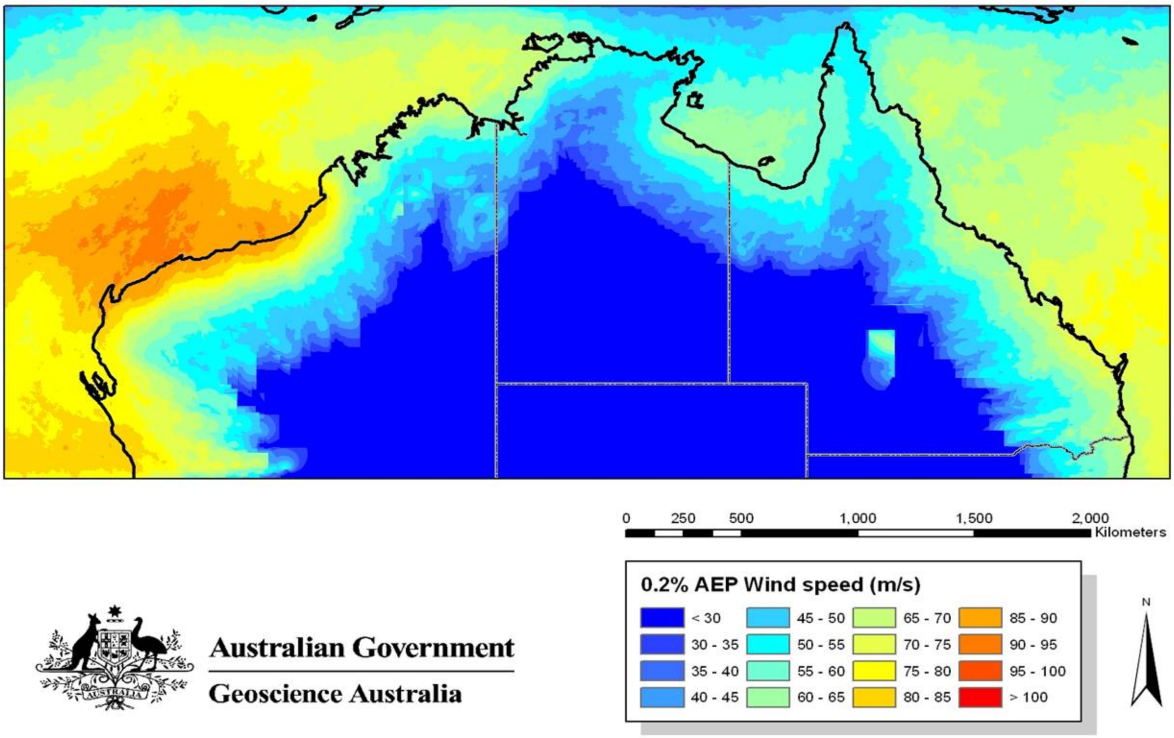

Figure 3: 0.2% AEP wind speeds generated by TCRM based on 5000 years of simulated tropical cyclone activity.

The site-specific wind speed is mapped to a vulnerability curve for the class of structure at each site (e.g. elevated, timber-framed fibre-board house) to determine the damage level (as a percentage of replacement cost). The loss can be aggregated over a community to determine the expected level of loss from an event.

Validation

The Australian wind loading standard (AS/NZS, 2002) is currently used as a reference for wind hazard in Australia. The hazard levels were determined by assessment at a set of discrete observation locations around the country – usually well-exposed sites such as aerodromes. The boundaries between different regions are somewhat arbitrarily set, and correspond to 50 km buffer zones around the coastline. The 0.2% AEP wind speed derived using TCRM is qualitatively similar, with highest values along the northwest Australian coastline and lower values along the eastern coastline and around the Gulf of Carpentaria. The results of TCRM have also been compared to the hazard estimates provided by insurance industry models, with encouraging results.

To validate the process of incorporating site-specific influences, we have analysed the impact of a high-profile historic event using the complete scope of the model process – that is

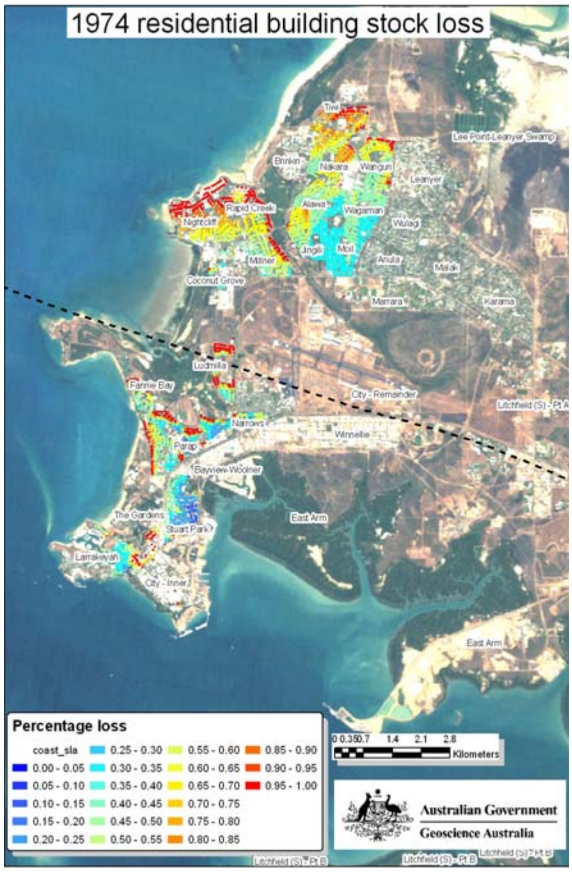

Figure 2: Estimated damage to residential building stock (1974 buildings) caused by TC *Tracy.*

to determine the loss (as a percentage of replacement cost) from an event (Arthur *et al.*, 2008b; Schofield *et al*., 2008).

Future work

Under the terms of the Disaster Mitigation Australia Package, the models are to be made publicly available through an open-source software release. Following a round of beta-testing, the TCRM will be made publicly available in the near future. It is hoped the model will provide a reference standard for future development of TC loss models and allow input and testing from researchers and practitioners alike.

The synthetic track generation module can be seeded with historical data, or alternatively the tracks of tropical cyclone-like vortices (TCLV's) extracted from climate simulations. In this way, the model can rapidly increase the catalogue of TC events under future climate regimes. Geoscience Australia's work program in the next year includes activities to determine the changes in hazard under a range of climate change scenarios using TCRM for the Australian region.

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