6A.7 PROJECTED CHANGES IN CYCLONIC WIND HAZARD IN THE AUSTRALIAN REGION

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1. INTRODUCTION

Tropical cyclones pose a significant threat to life and property around Australia's northern coastline, with average annual losses estimated at around AU$260 million (BTE 2001). Nearly 80% of the nation's population reside within 25 km of the coastline (Chen and McAneney 2006) and continued rapid growth in the northern parts of the country is increasing the population exposed to tropical cyclones. For residential structures, the existing Australian/New Zealand Wind Loading Standard (AS/NZS 1170.2 2002) specifies the regional return period wind speed (hazard) over Australia. The Standard is based on anemograph records at a discrete number of aerodromes around the country, with significant caveats and concerns surrounding the validity of the records. Furthermore, the existing Standard provides no guidance on how wind hazard may change under global climate change, or how to estimate the potential changes. Given the estimated design lifetime of residential structures is 50 years in the Standard, there is potential for changes in cyclonic hazard to impact structures being built today. Understandably, it is of critical importance to ensure that structures built today will continue to be resilient to wind hazard as they approach the end of their design life.

2. MODEL DESCRIPTION

To make a useful interpretation of the historical record, risk researchers look to statistically-based hazard models of tropical cyclones (Vickery et al. 2009; Watson and Johnson 2004). Geoscience Australia has developed a statistical-parametric model of tropical cyclones called the Tropical Cyclone Risk Model (TCRM) to evaluate cyclonic wind impacts and risk. TCRM allows users to generate synthetic tropical cyclone records equivalent to many thousands of years of activity, which is statistically similar to the input record.

The track model is similar to Hall and Jewson (2007) and Rumpf et al. (2009) in that cyclone speed, bearing, size and intensity are modelled using an autoregressive process. Genesis is controlled by randomly sampling a 2-D probability distribution, generated from the genesis points in the input dataset. The initial speed, bearing, intensity and size are sampled from distributions of the initial (historic) values of these parameters. Autocorrelation coefficients are calculated for each parameter based on input data in the vicinity of the current cyclone position (x_i, y_i). Annual frequency of events is modelled as a Poisson process around the mean annual frequency of tropical cyclone events in the region of interest.

The swath of destructive winds surrounding each tropical cyclone is modelled using a radial profile to determine a gradient level vortex wind field and a boundary layer model to incorporate the effects of cyclone motion and surface drag. There are six radial profiles available in the model and three boundary layer models which can be selected at run time. The resulting wind fields are estimated 3-second gust wind speeds based on gust wind speed conversion factors for over-land conditions (Harper et al. 2008).

3. DATA

To estimate the current levels of cyclonic wind hazard in the Australian region, we used the Bureau of Meteorology's revised 'best-track' historical record (Kuleshov et al. 2010). This best-track record does contain some limitations, notably the lack of estimated tropical cyclone size (either radius to maximum wind R_{mw}, eye radius or radius to outermost closed isobar R_{oci}). The annual frequency of events in the Australian region (90°E–180°E, 0°S–40°S) in this period was 15.3 tropical cyclones per year. For estimating cyclonic wind hazard under future climate regimes, we obtained synthetic event sets produced by a statistical-dynamical downscaling approach (Emanuel et al. 2006). This provided 1000 events across the Australian region for the B1 and A1FI SRES Emission scenarios (Nakicenovic and Swart 2000) based on mean conditions spanning 2061–2080, as well as current climate simulations (1981–2000) to provide a baseline estimate of the hazard. Event sets for two GCMs were used in the analysis - the NCAR CCSM 3 and the GFDL CM2.1. The models were chosen due to their superior performance in representing the mean climate of temperature, mean sea level pressure and precipitation in the Australian region (Suppiah et al. 2007). Results presented here are based on the mean projections from the two models.

4. CURRENT LEVELS OF HAZARD

TCRM was first run using a high-quality tropical cyclone record for the Australian region, spanning 1981 to 2006 (Figure 1 — Kuleshov et al. 2010). This period was chosen as the quality of the record is much better than that of earlier years due to advances in technology and analysis methodology. To account for the lack of R_{mw} information in the historical record, we used a lognormal distribution with mean 47 km and logarithmic standard deviation of 0.6, after Willoughby and Rahn (2004). R_{mw} was held constant for the lifetime of each simulated tropical cyclone. Landfall decay was modelled using the same parameters as those applied in Vickery and Twisdale (1995).

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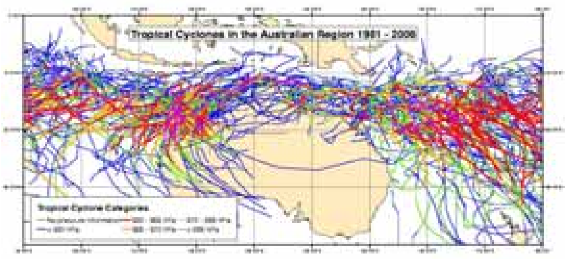

Figure 1. Historic tropical cyclones in the Australian region 1981-2006.

Over land, the hazard estimate from TCRM matches the existing Regional Wind Speeds specified in AS/NZS 1170.2 (2002) closely in the cyclonic regions. The poleward extent of return period wind speeds in excess of 70 m s^{-1} along the west coast is much greater than in AS/NZS 1170.2. In part, this arises due to the poor performance of the linear boundary layer model used when the translation speed of the simulated cyclone becomes comparable with the tangential wind speed. Along the east coast, the return period wind speeds remain almost constant along the full length of the coast (Figure 2).

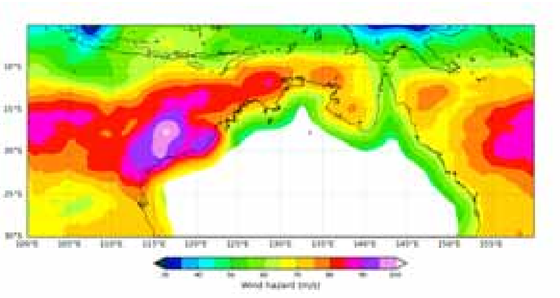

Figure 2. 500-year return period gust wind speed (m s^{-1}) calculated from the Bureau of Meteorology's best-track database (1981-2006). Areas more than 250 km from the coast have been masked.

The frequency of landfalling tropical cyclones along the Queensland coast was significantly lower in the period used to initiate TCRM (1981–2005), compared to the full historical record. From the mid-1970's onwards, there has been a significant reduction in the frequency of tropical cyclones in the Coral Sea (J. Callaghan, personal communication). As such, the return period wind speeds presented here may be lower than the hazard determined from a much longer historical record.

5. INFLUENCE OF CLIMATE CHANGE

We provide an estimate of potential changes in cyclonic wind hazard, based on the output of one statistical-dynamical downscaling approach (Emanuel et al. 2006). We first compare the results of running TCRM with the historical record against those based on simulations using GCM output for the climate of the 20th Century (C20C). The frequencies of events in the C20C simulations were adjusted such that the simulated frequency matched the observed frequency (15.3 cyclones per season). Future climate simulations were corrected such that the relative change in frequency was conserved. The equivalent of 50,000 years of events was generated and the resulting wind fields aggregated to provide return period wind speed estimates (Figure 3).

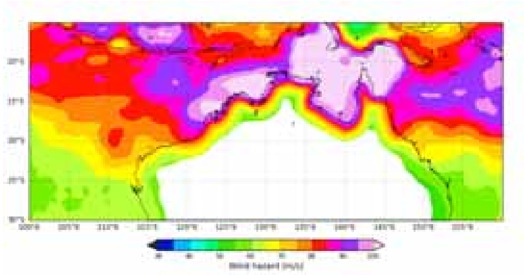

Figure 3. Mean 500-year return period gust wind speed (m s^{-1}) estimated from GCM-based event set for the Climate of the 20th Century simulation. Areas more than 250 km from the coast have been masked.

The GCM-based event set results in very high return wind speeds at low latitudes (Figure 3) compared to the historically-based estimate. Most areas equatorward of 15°S have 500-year return period wind speeds more than 25 percent higher than the corresponding historically-based estimate, while higher latitude regions are around 15 percent lower.

B1 2070:

Figure 4 presents the percentage change in cyclonic wind hazard for the B1 scenario at 2070 (the change in mean hazard for 2070 relative to the mean hazard derived from GCM-based event sets for the Climate of the 20th Century). These results indicate an increase in hazard of 5–10 percent for areas poleward of 20°S on both the east and west coast. Along the northern Queensland coast, there is a decrease of 10–15 percent, while along the Kimberly coast there is a decrease of around 10 percent.

A1FI 2070:

For the A1FI scenario (Figure 5), there is an increase in cyclonic wind gust hazard of 10–20% along the northern and northwest coast to around 25°S, south of which there is little change. Around the Gulf of Carpentaria and along the east coast to around 20°S, there is a decrease in hazard of 10–15%. South of this there is again little change in hazard (between ± 5%).

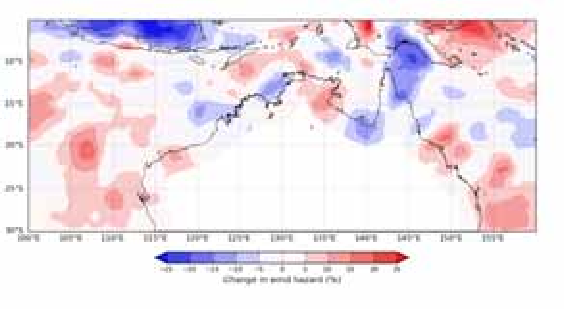

Figure 4. Percentage change in cyclonic gust wind gust hazard derived from GCM-based event sets for the B1 scenario at 2070.

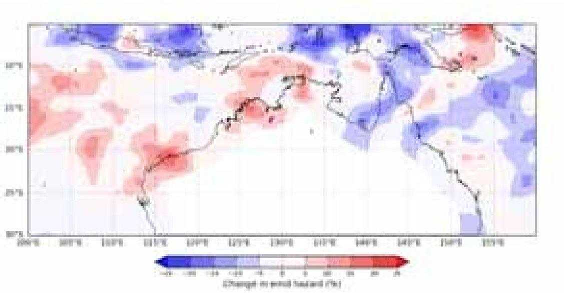

Figure 5. Percentage change in cyclonic gust wind gust hazard derived from GCM-based event sets for the A1FI scenario at 2070.

6. DISCUSSION

Examination of the cyclonic wind hazard estimated from the synthetic event sets highlights an equatorward shift and increase in hazard levels compared to the hazard estimated from the historical record. This may be in part attributed to a shift in the distribution of peak intensity (Figure 6).

It is also likely there is some level of decadal variability influencing resulting cyclonic hazard levels, arising from the variability present in GCMs (Delworth and Mann 2000; Emanuel et al. 2008). This may go some way to accounting for the localised fluctuations in cyclonic hazard.

7. CONCLUSION

We have spatially estimated cyclonic wind hazard under current and future climate regimes in the Australian region. The technique used allows the estimation of cyclonic wind hazard over large areas where observations of cyclonic gust wind speeds are sparse. Using historical tropical cyclone records, TCRM reproduces the existing understanding of cyclonic wind hazard, providing reasonable confidence that, given representative input data, TCRM is able to provide estimates of changes in cyclonic wind hazard. Reliant on the results of downscaling general circulation models, TCRM can provide guidance on the likely spatial and intensity

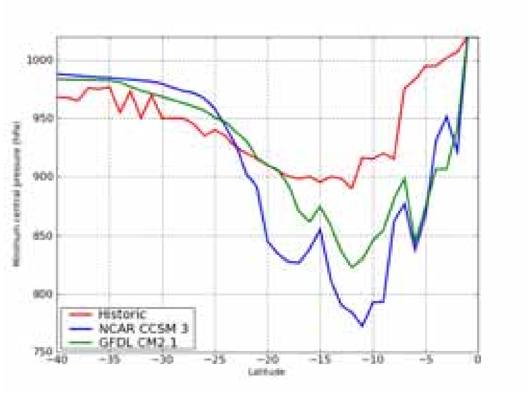

Figure 6. Minimum central pressure of tropical cyclones by latitude for the historical record (red) and from the C20C-based synthetic event sets for NCAR CCSM 3 (blue) and GFDL CM2.1 (green).

changes in cyclonic hazard arising due to projected changes in cyclone activity.

Initial results using downscaled results using two GCMs give no clear indication on the direction of the trend in cyclonic wind hazard under future climate scenarios. Further simulations using the output from other GCMs and different downscaling techniques will be essential to quantify the uncertainty surrounding these cyclonic wind hazard projections.

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