Wind hazard derived using climate model data - Methodology

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1 INTRODUCTION

Regional and local wind gust hazard estimates are utilised in the Australian building codes through the Australia/New Zealand Wind Loadings Standard [1]. The wind engineering community relies to a significant extent on the peak gust wind speed estimates derived from observations collected over more than 70 years by the Australian Bureau of Meteorology (BoM). The current wind loading code and the performance of our infrastructure (residential, commercial, industrial and critical infrastructure) is based primarily on hazard estimates from a small dataset, consisting of mainly airport sites. In this paper we present an alternative method for the calculation of gust wind hazard using climate-simulated data. Currently we deal only with gusts associated with synoptic winds as the climate model only provides mean winds at a resolution of 14 km, which does not resolve thunderstorms.

The methodology involves three computationally demanding processes:

- Calculation of return period (RP) for gust wind speed using a statistical model;
- Extraction of wind speeds from a high resolution climate model; and
- A Monte Carlo method to generate synthetic gust speeds by performing a numerical convolution of mean wind speeds and regional *gust factors*.

Results of applying the methodology to assess severe wind hazard in Tasmania under current and future climate are shown in a poster also presented at this workshop [2]. In this paper we present the methodology.

2 MODEL DESCRIPTION

2.1 Extreme value distributions

The core of the statistical model is the fitting of Extreme Value (EV) distributions to a dataset of wind speeds. EV distributions allow wind analysts to make inferences about the magnitude and frequency of extreme events beyond the range of years available in the observed record. Wind hazard is quantified by calculating Return Periods (RP). The model uses the Generalised Pareto Distribution (GPD) to calculate the return period of maximum daily wind speeds, employing an automatic algorithm to calculate the appropriate threshold to fit the GDP to datasets [3].

2.2 Monte Carlo (MC) generation of gust wind speeds

In the MC process the physics of wind gust generation is simulated. Surface wind gusts originate from the deflection of air parcels flowing higher in the boundary layer, which are brought down by turbulent eddies [4]. The method separately takes into account the mean wind and the turbulent structure of the atmosphere. Turbulence is represented by the gust to mean ratio, referred to as the gust factor in wind engineering terms. The process consists of the numerical convolution of daily maximum mean wind speed and the gust factor to produce synoptic gust wind speeds.

As explained in [3] the implementation of the MC process involves three steps:

1. Calculation of a representative regional gust factor;
2. Extraction of mean wind speeds in each cell of the grid; and
3. Calculation of corresponding gust wind speeds by numerical convolution of the mean wind speeds and the gust factor.

2.2.1 Gust factor (GF)

The Gust Factor (GF) is defined as the ratio of maximum wind speed (gust) and mean wind speed for the same time period [5]. In order to capture the regional characteristics of Tasmania, BoM-provided half-hourly datasets for three selected stations (Hobart, Launceston and Wynyard Airports) were used. The datasets were joined to calculate a *regional* GF. This GF was used for the sampling process in the Monte Carlo simulation.

2.2.2 Stratified sampling

To guarantee that enough samples are generated in the tail of the MC distribution, the most important part of the distribution for wind hazard studies, a simple stratified sampling process was implemented. The numerical convolution of the daily maximum mean wind speed and gust factor was carried out for wind speeds from the distribution's mean (m_1) value onwards to higher values in order to generate the same sample size as in the original vector (mean wind speed). Mean wind speed values below m_1 are of no concern in wind hazard studies. The process is then repeated to generate the 'peak' samples: one fifth of the number of samples of the original vector is drawn from the 98% quantile onwards. The wind gust used in the calculation of the RP is the sum of both vectors. It was observed that the model is very sensitive to the percentage of samples used in each step: too many peak samples result in a high, flat curve. Too few peak samples result in a curve with very low values at high RP. The methodology explained above was developed empirically; it provides simulated RP curves which have a similar shape to those of the three selected stations.

2.3 High resolution climate model

The climate simulation data used for this project was obtained from CSIRO's Conformal-Cubic Atmospheric Model (CCAM). Simulations focusing on Tasmania using IPCC scenario A2, for the period 1960 to 2100 were used. Five coupled general circulation models (GCM) were used to drive CCAM (dynamic downscaling; [6]): CSIRO mark 3.5; ECHAM 5; GFDL_CM 2.1; MIROC 3.2 and UK Hadley_CM3. We extracted maximum hourly mean wind speeds (10 meter height over open terrain) from each of the five simulations using NCO tools. The mean hourly speeds were then transformed to maximum daily mean speeds using the R package 'zoo'. The final wind speeds utilised are the average of the 5 simulations considered.

2.3.1 Bias correction

The bias introduced by the fact that CCAM calculates area-average values whilst the recording stations give location-based winds has to be corrected; otherwise biased results could be obtained. To correct this bias consider the observed and CCAM-modelled RP of mean wind speeds at Hobart Airport as shown in Fig. 1. A linear regression expression (LR) between observed and CCAM-modelled mean wind speeds can be found to correct the CCAM-modelled RP of mean winds. The same expression can be used to correct the bias in the curves of gust speed RP to make the current climate results to coincide with the observed results.

For gridded results we combined the data from the Launceston and Wynyard sites to undertake the correction because both stations are located in the north of the state. The LR correction at 500-yr RP for these stations is 4.2 m/s. The correction for Hobart calculated from Fig. 1 is 7.2 m/s. Since this correction is different for the two locations, it is applied on a latitude varying scale (i.e. North/South) over the island of Tasmania.

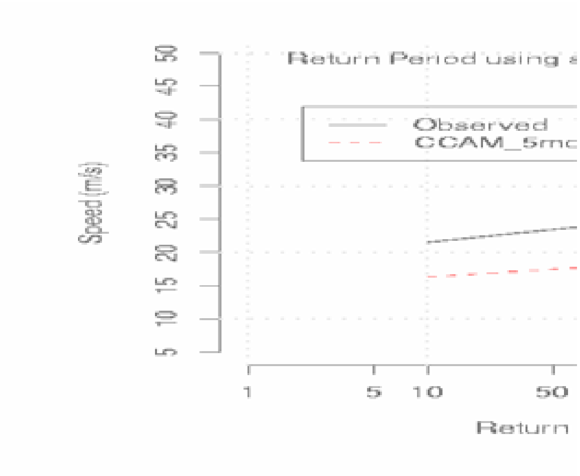

Fig. 1. Observed and CCAM modelled RP of mean wind speeds.

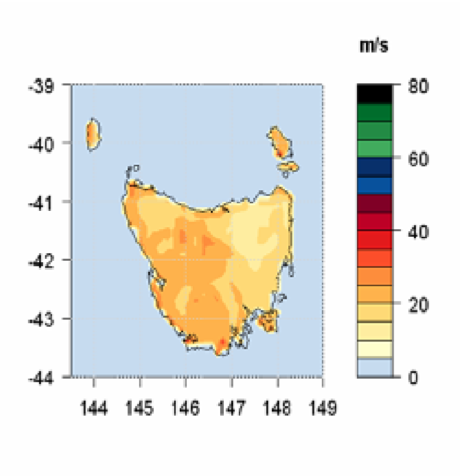

Fig. 2. CCAM 500-yr RP of mean wind speeds for Tasmania.

3 RESULTS

3.1 Current climate

The methodology was applied to the gridded data over the Tasmanian region to obtain RP of gust wind speeds. For each cell of the grid, mean wind speeds were extracted from the 5 CCAM simulations for the period 1961 to 1990 and the average value of the *mean* wind was calculated. The corresponding 500-year RP exceedance level of average mean speed is shown in Fig. 2. Then representative *gust* wind speeds in each cell were generated using the MC process discussed above. Finally, from these gust speeds, RP exceedance levels for 10 to 10000 years were calculated using the Statistical Model.

Fig. 3 shows the map of (synoptic) gust speed exceedance levels for 500-year RP under current climate. As expected the gust wind speeds follow closely the texture of the mean values (Fig. 2), in particular note the increase of synoptic wind speeds due to the effect of the mountain slope in both the west and the north-east parts of Tasmania.

3.2 Future climate

To gain some insight into possible future extreme gust wind speeds, simulated daily maximum mean wind speeds from a window of 20 years around the year 2070 (IPCC scenario A2), was extracted from the 5 CCAM climate simulations. Their corresponding gust wind speeds were calculated using the MC procedure and a RP curve for this 20-year window was generated using the statistical model. Fig. 4 shows the 500-yr RP exceedance level of gust wind speed for 2070, the RP have been corrected using the procedure discussed in Section 2.3.1. The poster [2] also shows the corresponding map for 2030.

Comparing Fig. 3 with Fig. 4, it is possible to visually observe an increase in gust wind speed hazard by 2070 compared to the current climate estimate. The increase is more noticeable in the north east coastal areas of the state and the mountainous region of the western regions. The results are highly dependent on the quality of the mean speeds provided by the climate models, and also the quality and representativeness of the observations (i.e. whether the locations of the three observing stations and the combined observed record length is representative of a long-term climatology for Tasmanian region extreme gust wind speeds).

4 CONCLUSIONS

A new model to assess severe wind hazard has been developed at Geoscience Australia. The model uses simulated daily-maximum mean wind speeds produced by a regional climate model to generate the corresponding gust wind speeds via a Monte Carlo process. Wind hazard is calculated by determining curves of RP (gust wind speeds) over the given region by using extreme value distributions. The methodology has been applied to the Tasmanian region utilising dynamically downscaling data from five GCM which provide a 14km grid of simulated data. A major characteristic of the methodology is that it provides some guidance to the regional change in synoptic wind hazard both for current climate and also for the A2 climate change scenario (average of 5 climate models considered).

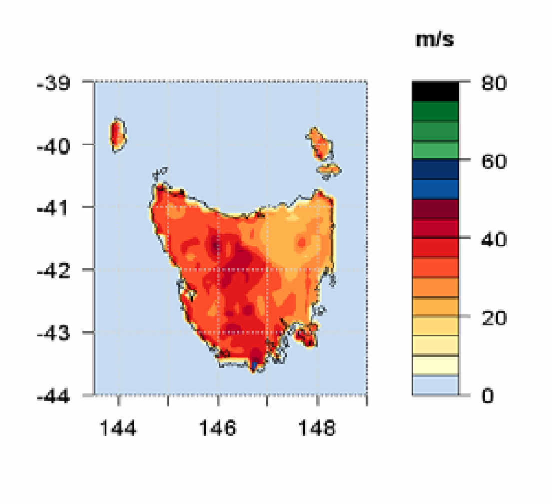

Fig. 3. Wind gust exceedance for 500-yr RP (current climate).

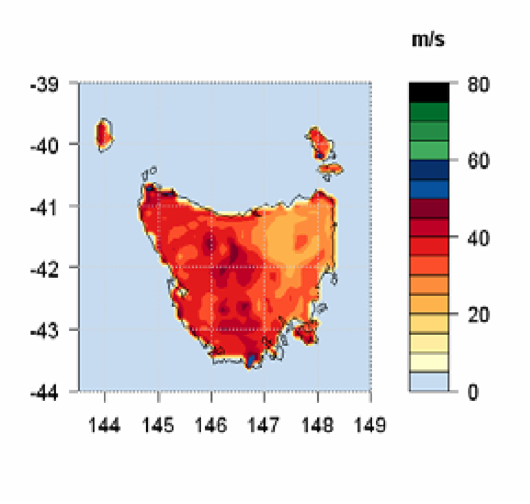

Fig. 4. Wind gust exceedance for 500-yr RP around 2070.

5 REFERENCES

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