Determining severe wind hazard using a Regional Climate Model

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1. Introduction

A new model to assess severe wind hazard in Australia's 'Region A' (AS/NZS 1170.2:2002) is presented in this paper. The model is especially suitable for regions where there are no wind observations. The model uses simulation data produced by a high resolution regional climate model in association with empirical gust factors. It compares wind speeds produced by the climate model with observations (mean wind speeds) and develops functions which allow wind engineers to correct the simulated data in order to match the observed mean wind speed data. The approach has been validated in a number of locations where observed records are available. In addition a Monte-Carlo modelling approach is utilised to relate extreme mean wind speeds to extreme peak gust wind speeds.

2. High Resolution Climate Simulations

The climate simulation data used for this project was obtained from CSIRO's Conformal-Cubic Atmospheric Model (CCAM). Two runs of 50 years were simulated for the period 1951 to 2000, one for the Eastern states and the other one for the Western states of Australia. Hourly maximum wind speed (four lowest levels in the atmosphere) was saved for this study. Here we present results relating to the CCAM 10-metre height maximum hourly wind speed (maximum of time-step values within each hour) for the 50-year simulation period. The observed wind speeds used for this project were acquired from the Bureau of Meteorology (BoM) in 2006. Half-hourly datasets from a number of wind stations in southern NSW were used for algorithm development and testing. These datasets provide maximum wind gust and mean wind speeds in half-hourly intervals (the actual record has the mean speed and the 3 second maximum gust of the last 10 minutes of the half-hourly interval). For comparison with CCAM-modelled data, maximum daily mean wind speeds were calculated from the half-hourly mean observed wind speeds. To illustrate the technique, the CCAM correction algorithm was applied to 3 stations in Tasmania.

3. Bias correction algorithm

The aim of wind hazard analysis was to calculate return periods (RP) for maximum wind speeds. Geoscience Australia's Risk and Impact Analysis Group (RIAG) has developed a statistical model to calculate RP based on extreme value distributions (Sanabria & Cechet, 2007a). For this investigation, we use this statistical model to generate RP for both observed and CCAM-modell generated "maximum daily *mean* wind speeds". CCAM-modelled wind speeds were extracted from model gridpoints surrounding a given wind recording station. Four standard cases were considered:

Case 1 (nearest gridpoint or 0 km case);
Case 2 (2x2 gridpoints or 40 km case);
Case 3 (3x3 gridpoints or 60 km case);
Case 4 (5x5 gridpoints or 100 km case).

The algorithm also uses the concept of 'super-station' (Holmes, 1999). A super-station for Tasmania was constructed from observations of wind speed datasets from Hobart, Launceston and Wynyard airports. This super-station was named 'Tasmanian Region' or 'tasreg'. For this region, the four standard cases were defined by joining the corresponding speed datasets of the four cases of Hobart, Launceston and Wynyard respectively. Figure 1a shows the observed RP of Hobart Airport max daily *mean* speed and the CCAM wind speeds around the recording station as explained above. The same results for 'tasreg' are presented in Figure 1b, the full line is the *observed* RP of wind speeds.

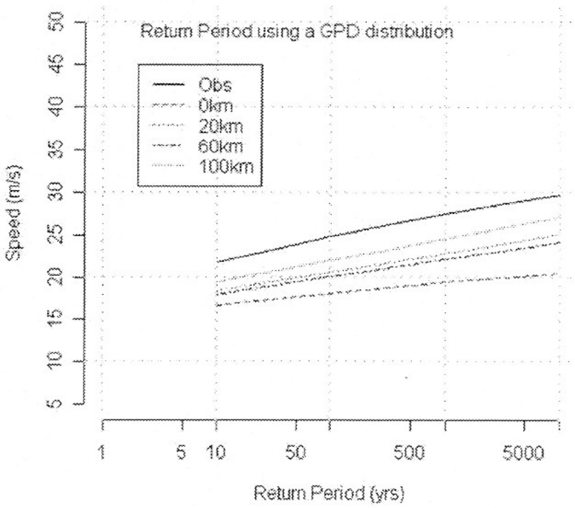

Fig. 1a. Hobart Airport observed and CCAM-modelled wind speeds.

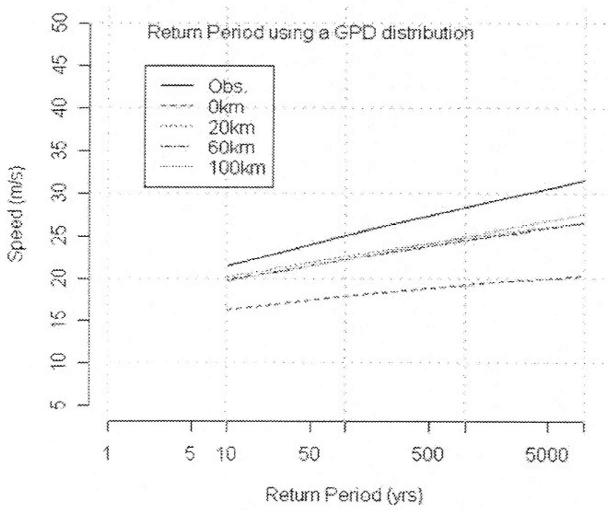

Fig. 1b. Tasmanian Region observed and CCAM-modelled wind speeds.

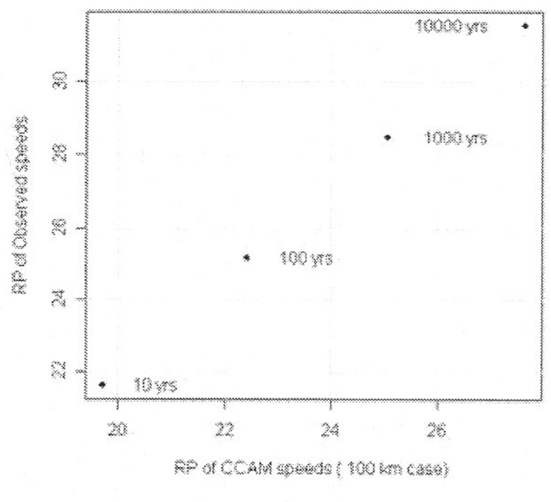

Fig. 2. Plot of RP of observed and CCAM_modelled wind speeds.

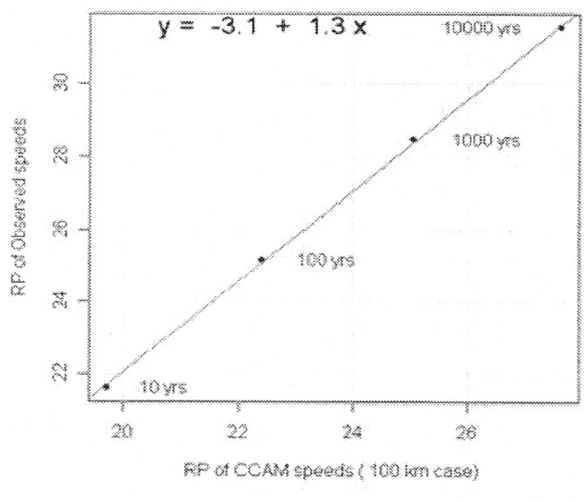

Fig. 3. Linear Regression of RP of obs. and CCAM speeds ('tasreg').

Figures 1a and 1b show that CCAM underestimates the RP for wind speeds in both 'tasreg' and the Hobart Airport cases. To better observe this bias, Figure 2 presents a plot of CCAM RP for the 100 km case of the Tasmanian Region (Case 4 above) and the observed max daily *mean* speeds. The black points are the corresponding RP of wind speeds for 10, 100, 1000 and 10000 years. It is clear that there is a strong linear correlation between the RP of CCAM speeds and the RP of observed speeds. The same strong linear correlation was observed between CCAM-modelled speeds and observed speeds at all Tasmanian observing sites. This characteristic of the modelled wind speeds was used to develop an expression to correct the bias of the CCAM-modelled speeds. A linear regression (LR) between CCAM speeds and observed speeds was calculated for each one of the 4 standard cases of the Tasmanian Region. Figure 3 shows the LR for Case 4 (100 km grid sampling case), with the regression expression printed at the top of the diagram. An average of the regression lines for all 4 cases was calculated. This average (of the 4 Tasmanian region 'tasreg' regression lines) was applied to the average of the RP of the CCAM modelled output for the 4 cases to correct the CCAM wind speed bias.

4. Results

Figure 4a & 4b show the corrected RP for Hobart Airport and Launceston Airport "mean wind speeds". The CCAM RP shown is an average of the RP of the 4 cases. This average RP was corrected using the average of the LR expressions of 'tasreg'.

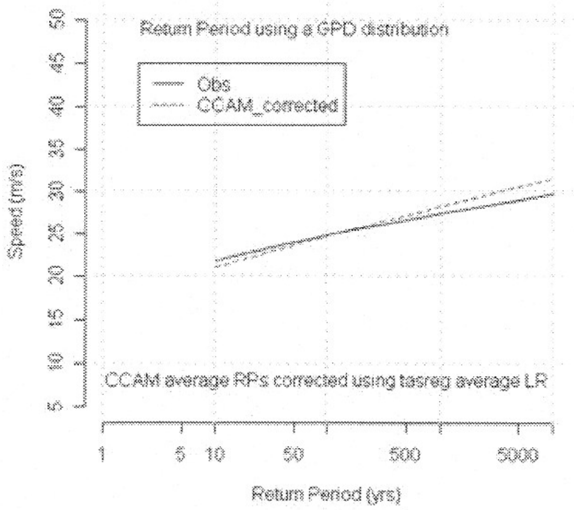

Fig. 4a. Hobart Airport observed and corrected CCAM wind speeds.

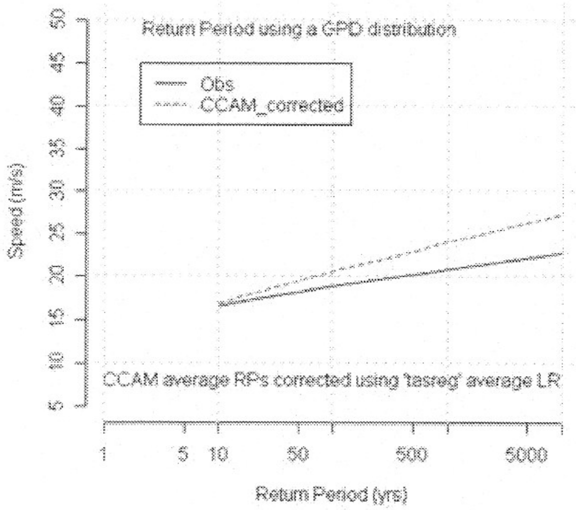

Fig. 4b. Launceston Airport observed and corrected CCAM wind speeds.

Comparing Figures 1 and 4, it is possible to see that the correction has substantially improved CCAM results. Table 1 presents a summary of the comparison between CCAM-modelled and observed RP of wind speed for the three airport sites; Hobart, Launceston and Wynyard. The maximum error by using CCAM-modelled speeds rather than the observed speeds is 6 per cent. In all but one case the CCAM corrected speeds are within the 95 per cent confidence interval (CI), indicating that there is a 95 per cent chance that the corrected CCAM return periods are representative of the actual hazard.. The percentage error is defined by the expression,

$$\text{Error} = [\text{abs}(\text{observed} - \text{CCAM RP})/\text{observed}]*100$$

Table 1. Comparison of corrected and observed maximum mean wind speeds for Hobart, Launceston and Wynyard; (a) Observed, (b) 95% CI, (c) Corrected CCAM, (d) Error (%)

	Hobart				Launceston				Wynyard			
RP	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
10	21.9	(20.2,24.9)	21.0	**4.1**	16.5	(15.3,18.2)	17.0	**3.0**	22.1	(20.2,24.6)	24.4	**9.4**
100	24.8	(21.8,28.9)	24.8	**0.0**	18.8	(16.6,21.0)	20.5	**9.0**	26.1	(22.7,29.5)	28.1	**7.7**
500	26.7	(22.5,31.4)	26.0	**2.6**	20.3	(17.7,22.8)	23.0	**13.3**	28.8	(24.8,32.8)	30.5	**5.9**
1000	27.5	(22.7,32.4)	28.3	**2.9**	20.8	(19.6,25.8)	24.0	**15.4**	29.9	(25.7,34.2)	31.3	**4.7**

The 500-year RP percentage error of the maximum mean wind speed for the three Tasmanian sites (based on the fit to the Tasmanian region; tasreg) ranges from 2.6 to 13.3 percent. The highest error occurs for the location with lowest maximum mean wind speed (Launceston). The errors are acceptable and the relationship will be used to influence a grided map of maximum mean wind speed for the Tasmanian region based on the 50-year CCAM model climate simulation (currently in prep.).

5. CCAM gridpoints; consideration of gust wind speed

The methodology allows the use of simulated data produced by a high resolution regional climate model (daily maximum mean "time-step" wind speed) to be used as a surrogate for an observed record. However, it is not the daily maximum mean wind speed that generally causes wind-related damage to infrastructure. It is the extreme wind speeds (3-second peak gusts) that cause the majority of the infrastructure and environmental damage. RP peak gust wind speed estimates are produced by utilising the CCAM gridded daily-maximum wind speed and empirical information regarding the gust factor (relationship between the peak gust speed and the 10-minute mean wind speed) obtained by considering the gust factor distribution derived only under elevated levels of wind hazard. This empirical data is sampled in a Monte-Carlo modelling approach (in association with the distribution of CCAM-modelled data) to simulate the time-evolution of extreme peak gust mean wind speeds for each CCAM gridpoint (Sanabria & Cechet, 2007b). This allows the CCAM modelled gridded daily-maximum mean wind speed to be utilised in the determination of the distribution of the gust wind speed.

6. Conclusions

A method for wind hazard assessment based on high resolution climate model simulations has been developed at Geoscience Australia. The model allows wind analysts to correct the wind speeds of simulated climate data (derived over an area) in order to match the observed wind speeds. The corrections were developed by considering four standard cases of extracting wind speed information from the climate model. Linear regression expressions relating simulated and observed daily-maximum wind speed were developed for the four cases. The climate simulation was corrected using the average of the linear regression of the four cases for a given observing station. Correction expressions for a number of regions in Australia have been developed using the technique discussed in this paper.

This approach is suitable for areas where there are no observing stations. In these areas, properly corrected wind speeds from high resolution climate model simulations can be utilised as part of an approach to determine return period wind hazard (peak gusts).

7. References

AS/NZS 1170.2 (2002) Structural design actions, Part 2: Wind actions, Australian/New Zealand Standard, 2002.

Holmes J.D. (2002). A Re-analysis of Recorded Extreme Wind Speeds in Region A. Australian Journal of Structural Engineering. Vol. 4 No. 1, 29-40.

Sanabria, L.A. and R.P. Cechet (2007a) A Statistical Model of Severe Winds. Geoscience Australia Record, 2007/12, 66p

Sanabria, L.A. and Cechet, R.P. (2007b) Monte-Carlo modelling of Severe Wind Gust. In: MODSIM 2007: proceedings of the Modelling and Simulation Society of Australia and New Zealand (MSSANZ), Queenstown NZ, December 2007. pp 1695-1701