Consistency of Australia's extreme wind "Region A" observations

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1 INTRODUCTION

The Australian Bureau of Meteorology (BoM) have been recording peak gust wind speed observations in the Australian region for over 70 years. The current wind loading code and the performance of our infrastructure is based primarily on the Dines anemometer interpretation of the peak gust wind speed. Australian building codes through the Australia/New Zealand Wind Actions Standard [1] as well as the wind engineering community in general rely to a significant extent on these peak gust wind speed observations.

In the mid-1980's the Australian Bureau of Meteorology (BoM) commenced a program to replace the aging pressure tube Dines anemometer with the Synchrotac and Almos cup anemometers. Only six Dines anemometers remain in operation, mainly as backup or for high-speed measurement. During the anemometer replacement procedure, many localities had more than one type of anemometer operating, recording extreme events. The passage of Cyclone Vance through Exmouth in 1999 saw Dines and Almos anemometers, separated by 25 metres, recording peak gusts of 144 and 122 knots respectively [2]. A weak cyclone that passed through Townsville in April 2000 recorded a peak gust of 70 knots on the Dines and 59 knots on the Almos anemometer [3]. These systematic differences raise concerns about the consistency and utility of the peak gust wind speed database.

The Installation of the pressure-tube (Dines) anemometer (described in [4] and [5]) at Australian sites commenced in the 1930's. The Dines anemometers were factory calibrated under steady state conditions (mean wind speeds); however their response to transient wind conditions (gusts) was not determined. The BoM anemometer replacement program, which replaced the pressure-tube Dines instruments (paper chart recording) with cup anemometers (digital recording), had the potential to drastically change the characteristics of observed wind speed. It was well known that the Dines had a high minimum start-up speed (i.e. minimum speed before the instrument registers a reading) whilst the cup anemometers suffered from overspeeding (i.e. cups keep rotating even though wind has dropped) [6].

This paper presents the results of a reanalysis of the current BoM peak gust wind speed database for the non-cyclonic region (Region A) of the Australia/New Zealand Wind Actions Standard AS/NZS 1170.2 [1]. Region A was considered for this initial study as the observed record contains a significant number of extreme events (*synoptic* and *thunderstorm*) over decadal time scales (i.e. extreme events not dominated by one or two tropical cyclone events).

2 DINES - CUP ANEMOMETER INTERCOMPARISONS

A number of intercomparisons involving Dines and cup anemometers have been undertaken over the last 50 years or so; see for example [7]. Logue [8] compared both mean and gust wind speeds measured using a Dines co-located with a standard cup anemometer at the Irish Meteorological Service's Galway observing site during 1984. Overall the mean wind speeds from the two instruments compared well. However, the cup anemometer significantly underestimated the gust wind speeds when compared to those obtained using the Dines. The cup anemometer used by [8] is similar in design to the BoM instruments (i.e. heavy construction). These types of anemometers have a large distance constant (length of fluid flow past the sensor required to cause it to respond) compared to lightweight cup anemometers found on automatic weather stations [9].

3 METHODS AND DATA

Three datasets were acquired from BoM for these studies; maximum daily gust speeds, 3PM mean wind speed and weather description. Both maximum daily gust wind speeds and 3PM mean winds are considered to examine the range of wind conditions both within and outside the instrument calibration range. 3PM mean wind speed data was chosen as the mean wind speed reaches a peak at this time in the diurnal cycle. Meta data concerning the replacement of the Dines anemometers was also obtained from BoM. A total of 31 BoM recording stations distributed throughout Region A were selected for the analysis. To isolate the issue of anemometer replacement, only observing stations located at airports (consistent exposure) and with more than 30 years of record were considered. Figure 1 shows time-series plots of the daily maximum gust wind speed (above a threshold of 25 m/s) for the Sydney, Melbourne and Adelaide meteorological observing stations. Visual inspection indicates that the early part of the record (Dines anemometer) contains a greater number and also higher amplitude extreme events compared to the later part of the record (replacement anemometer). Other stations considered within the Australian Region A (dominated by synoptic and thunderstorm events) show similar time-series characteristics. The vertical broken line in Fig. 1 indicates when the Dines anemometer was replaced.

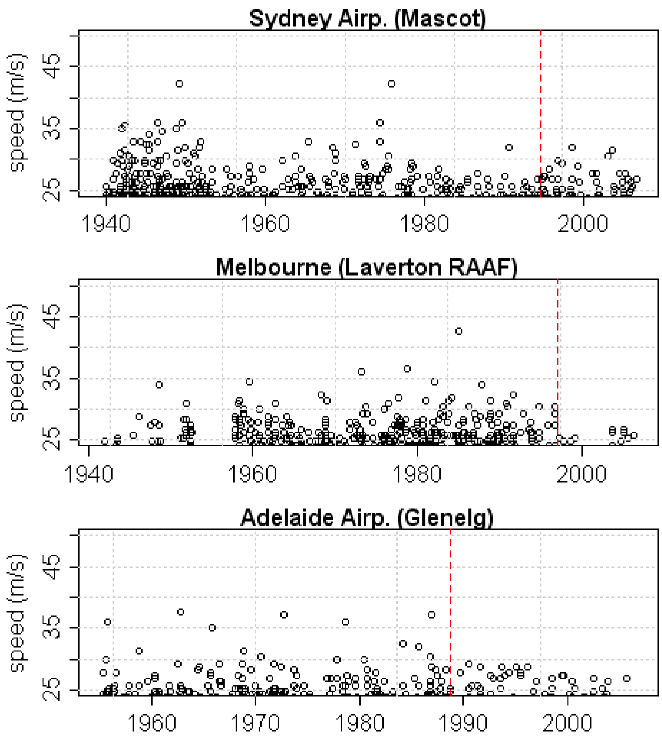

Fig. 1. Time-series plots of the daily maximum gust wind speed (above a threshold of 25 m/s) for the Sydney, Melbourne and Adelaide (airport) meteorological observing station

We utilise as a measure of the hazard the 500-year return period (500RP) exceedance level gust wind speed. This hazard level has been chosen as it represents the wind loading design level used for the construction of most of the residential, commercial and industrial buildings in Australia and New Zealand. Wind hazard was assessed by calculating the return period (RP) exceedance levels of maximum gust wind speed for each dataset by using Extreme Value Distributions (EVD). EVD's can determine RP exceedance levels of gust wind speeds well beyond the range of available data [10]. Typically an EVD uses yearly maximum; all other data is discarded. In practice better results are obtained by using the Generalised Pareto Distribution (GPD) utilised for this study, which allows the analyst to use all data exceeding a given threshold. For this preliminary analysis we only consider the *combined* (complete) dataset and not the component synoptic and thunderstorm extreme winds.

Calculation of exceedance levels of gust wind speeds should be considered incomplete if a confidence interval for the results is not presented. A confidence interval shows the range of values in which the true value of the exceedance levels lies for a given probability. For this study, we have determined confidence intervals with 95% probability; in other words the exceedance levels for 500RP of wind gust speeds with the interval in which the true value can be found in 95% of cases. There are two basic algorithms for calculation of the confidence intervals (CI) of results produced by EVD's: the 'Delta' method and the 'Profile Likelihood' method. Both methods have been implemented in the R environment by Gilleland and Katz based on [11]. The Profile-likelihood method as implemented in the R 'extRemes' package [12] was used for this study.

The analysis statistically examines the issue of inconsistency in the gust wind speed record by investigating the impact of instrument upgrade within the dataset. The dataset (time-series of measurements) is segmented into the Dines and replacement anemometer observing periods, with the Dines observing period the longest in length in all cases. The latter coincides with the installation of the new generation of cup-anemometers at most observing stations (major Australian airports). All stations considered are currently operational.

4 RESULTS

We have evaluated both the daily maximum gust and 3PM mean wind speed 500-year return period (500RP) exceedance levels for the total (*combined*) wind speeds for the wind stations selected. Observations have been segmented into the Dines and replacement anemometer observing periods. The 95% confidence interval (95CI) has been determined for both gust and 3PM mean wind speeds for the Dines anemometer segment of the record. Note that the width of the confidence interval is dependent on the frequency and consistency of the extreme events considered.

For the replacement anemometer 500RP exceedance level gust wind speed estimates, there are 17 observing stations where the replacement anemometer estimates fall below the lower 95% confidence interval (95CI) for the Dines segment of the observing record. For 24 of the 31 observing stations the replacement anemometer estimate fall below the corresponding Dines segment estimate. Considering the 3PM mean wind speeds, there are 18 observing stations where the replacement anemometer estimate falls below the lower 95CI for the Dines segment of the observing record.

5 DISCUSSION AND FUTURE DIRECTIONS

The visual inspection of the peak gust wind speed time-series for most sites considered in this study indicates in general that the early part of the record contains a higher frequency of extreme events, and in general also the largest amplitude extreme events.

A statistical analysis utilising extreme value distributions (EVD's) resulted in more than half of the observing stations considered (later part of the record) having both 500-year RP gust wind speed (17 of 31) and 3PM mean wind speed (18 of 31) exceedance level estimates being in the lower tail of the distribution for the early part of the observing record (period prior to equipment upgrade from Dines to cup anemometer). We should be cautious in interpreting the differences in the return period hazard for the two segments of the record. It is possible that the frequency of extreme wind speeds has actually declined [13]. The most recent part of the record has been dominated by a number of large El Nino events and only one La Nina event, where thunderstorms are known to be more prevalent [14]. The importance of the non-stationary climate needs to be considered when conducting a time series analysis. Circulation changes as discussed in [15] [16], possibly driven by anthropogenic climate change, could also affect the frequency and amplitude of extreme winds. The replacement anemometer part of the record is generally much shorter (20 years) than the Dines segment and it is possible that the very high maximum wind speeds have just not yet been sampled, although the reduced frequency of extreme events in the later part of the record is of concern. Even considering these issues, this preliminary analysis suggests that the consistency of the peak gust wind speed dataset is suspect, and that the problem requires further examination. This study indicates that it appears unlikely that the later part of the record can be considered consistent with the initial (Dines) segment of the record.

Further analysis is planned to consider coincident measurements where available. Coincident data from observing stations where the Dines and replacement cup-anemometer instruments were run in parallel for long periods need to be analysed to determine whether a systematic bias is evident for extreme events. At the Townsville RAAF Base, Dines and cup-anemometer instruments have been operating side-by-side for 18 years (Dines observations are only on paper record).

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