Reanalysis of "Region A" gust wind speeds

R.P. Cechet and L.A. Sanabria
Risk and Impact Analysis Group, Geoscience Australia
Email: bob.cechet@ga.gov.au

1 Introduction

Australian building codes through the Australia/New Zealand Wind Actions Standard as well as the wind engineering community in general rely to a significant extent on the peak wind gust speed observations collected over more than 60 years by the 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 the Dynes anemometer interpretation of the peak gust wind speed. In the early 1990s BoM commenced a program to replace the aging pressure tube Dynes anemometer with the Synchrotac and Almos cup anemometers. As of October 2008 only six Dynes 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 during the recording of extreme events. The passage of Cyclone Vance through Exmouth in 1999 saw Dynes and Almos anemometers separated by 25 metres recording peak gusts of 144 and 122 knots respectively (Reardon *et al*, 1999). A weak cyclone that passed through Townsville in April 2000 recorded a peak gust of 70 knots on the Dynes and 59 knots on the Almos anemometer (Reardon, 2000). These systematic differences raise serious concerns about the utility of the peak wind gust database.

This paper presents the results of a reanalysis of the current BoM peak wind gust database for the non-cyclonic region (Region A) of the Australia/New Zealand Wind Actions Standard AS/NZS 1170.2 (2002). Region A was considered for this initial study as record length would contain a significant number of extreme events (*synoptic* or *thunderstorm*) over decadal time scales (i.e. extreme events not dominated by one or two tropical cyclone events). A total of 31 BoM recording stations distributed throughout Region A were selected for the analysis. To isolate the issue of anemometer replacement, only wind stations located at airports (consistent exposure) and with more than 30 years of records were considered.

2 Dynes - Cup Anemometer Intercomparisons

A number of intercomparisons involving Dynes and cup anemometers have been undertaken over the last 50 years or so (most primarily concerned with the differences in the mean wind speed; see for example Smith, 1981). Logue (1986) compared both mean and gust wind speeds measured using a Dynes co-located with a standard cup anemometer at the Irish Meteorological Service's Galway observing site (during the year of 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 Dynes. The cup anemometer used by Logue (1986) is similar in design to the Bureau of Meteorology (i.e. heavy construction). These types of anemometers have a large distance constant compared to lightweight cup anemometers found on automatic weather stations (Sparks, 1997). Since the gust wind speeds recorded by the Dynes are higher than those from the co-located cup anemometer it is clear that the effective gust duration of the Dynes gust wind speed measurements must be less than the equivalent cup anemometer values (Miller, 2007).

3 Methods and Data

Two types of datasets were acquired from BoM for these studies; maximum daily gust speeds and weather description. The later contains a three-hour classification of the weather conditions at the recording station. The present weather is described by 100 codes abridged from the WMO code indicating the type of weather conditions during the past hour. Ten codes for the past weather are also given to represent the most significant weather conditions within the past three hours of observation but not during the most recent hour. Using these symbols it is possible to identify the time at which *thunderstorms* are present at the recording station, as explained in Sanabria & Cechet (2007).

The first step in the data preparation process was to merge both types of datasets into a speed-weather dataset. The second step extracted the speeds corresponding to *thunderstorms* from the merged dataset. The new datasets are termed the *thunderstorm* dataset; what is left after the *thunderstorms* are removed are the *synoptic* wind speeds. The original dataset is called the *combined* wind dataset. The final step in wind hazard assessment was to calculate the return period (RP) of maximum wind speed for *combined*, *thunderstorm* and *synoptic* wind speeds. This was undertaken by using Extreme Value Distributions (EVD) which can calculate RP of wind speeds well beyond the range of available data (Coles, 2001). Typically an EVD uses yearly maximum; all other data is discarded. In practice better results are obtained by using the Generalised Pareto Distribution (GPD) which allows the analyst to use all data exceeding a given threshold 'u' (Sanabria & Cechet, 2007).

One of the problems found in fitting a GPD to given wind speed datasets was the selection of the appropriate threshold value ‘u’. High threshold values result in the selection of only a few data points, most likely not enough for a good fitting of the distribution. Low values result in too many samples which are most likely not independent from each other. On the other hand return period calculation using GPD distributions are very sensitive to the threshold selection. Although there are methods to help modellers select the appropriate threshold for a given dataset they are mostly visual, subjective techniques, prone to producing inaccurate results and inappropriate for large scale applications. The computer-based, automatic algorithm discussed in Sanabria & Cechet (2007) was utilised here.

Calculation of return periods of wind gusts 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 return period lies for a given probability. In this work we are interested in finding confidence intervals with 95% probability, in other words, we want to find the return period of wind speeds with the interval in which the true value of the return period can be found in 95% of cases. There are two basic algorithms for calculation of the confidence intervals (CI) of results produced by extreme value distributions: The ‘Delta’ method and the ‘Profile Likelihood’ method. Both methods have been implemented in the R environment by Gilleland and Katz based on Coles' book (2001). Applying the methods to temperature data, Gillelland and Katz (2005) found that the Profile-likelihood method gave better results because it considers the asymmetry of the data.

Since wind speed data is highly asymmetric the Profile-likelihood method as implemented in the R ‘extRemes’ package by Gillelland and Katz (2005) has been used for this study. In this case both the upper and lower bounds for the RP should be presented since they are asymmetric with respect to the expected (mean) value.

4 Results

Columns 3-5 of Table 1 presents the 500-year return period (RP) with 95% confidence interval for the total (*combined*) wind speeds of the wind stations selected, using all data in the dataset period. The start year of the recording period is shown between brackets. All stations are operational. The maximum daily wind gust was used to generate the RP presented in Table 1. The last two columns show the 500-year RP utilising a shorter segment of the dataset (1980-2006) & (1990-2006).

To illustrate the results presented in Table 1, Figure 1 presents a few RP plots showing the corresponding curves for *combined*, *thunderstorm* and *synoptic* winds. Notice the location of each RP curve: *combined* winds are higher than the corresponding *thunderstorm* winds but the latter tends asymptotically to the *combined* winds. *Synoptic* wind speeds are consistently lower than *combined* wind speeds. They are also lower than *thunderstorm* speeds for medium and high return periods but higher for low return periods with a crossover between the two of between 10 and 100 years in most cases. There are however curves which separate from the trend (not shown here for lack of space). Most of these issues can be traced back to the quality of the dataset used. For cases in which the merged dataset of speed and weather show a large number of missing values, the result is a *synoptic* wind dataset with very few - mostly low - values and hence its curve is very low with respect to the other two. The opposite is true for *thunderstorm* datasets, they have few, very high values; for this reason their curves can be slightly higher than the corresponding *combined* winds, especially for high RP. The asymptotic behaviour of the *thunderstorm* winds shows that the extreme winds in these datasets for some locations (but not all) are dominated by these types of winds. Figure 1 also shows that each type of wind poses a different hazard to the environment (dependent on the return period) and hence separation of the types of winds present in the dataset is important for a more realistic modelling of wind hazard.

Table 1. 500-year RP of *combined* wind with 95% CI

	Station name	RP	Low CI	high CI	1980-2006	1990-2006
1	Adelaide Airp. (1955)	42.6	37.8	49.7	41.4	34.9 *
2	Albany Airp. (1965)	42.0	38.3	46.1	39.6	34.4 *
3	Alice Springs Airp. (1952)	41.6	37.3	46.0	41.9	41.2
4	Canberra Airp. (1939)	37.3	34.4	41.6	39.8	40.1
5	Ceduna AMO (1940)	39.8	37.3	42.3	41.6	35.7 *
6	Charleville Airp. (1945)	42.6	38.7	46.5	43.2	31.8 *
7	Cobar MO (1962)	39.3	33.6	51.2	39.8	41.0
8	Coffs Harbour MO (1959)	37.1	33.6	42.7	40.4	34.8
9	East Sale Airp. (1951)	41.3	38.1	45.1	42.2	43.8
10	Esperance (1969)	44.1	40.1	50.2	44.3	43.3
11	Forrest Airp. (1958)	45.5	42.8	48.4	43.4	39.3 *
12	Giles MO (1956)	42.0	37.4	48.1	43.0	43.6
13	Halls Creek Airp. (1962)	41.8	37.5	46.2	37.5	40.2
14	Hobart Airp. (1958)	38.6	35.2	44.1	40.1	36.1
15	Kalgoorlie-Boulder Airp. (1939)	43.8	38.8	50.0	40.4	40.9
16	Launceston Airp. (1941)	38.8	35.1	44.2	37.5	34.8 *
17	Laverton RAAF (1941)	42.3	38.7	45.9	43.7	38.5 *
18	Longreach Airp. (1966)	44.4	40.1	48.7	39.6 *	37.9 *

19	Meekatharra Airp. (1959)	41.9	38.0	45.8	38.7	41.3
20	Mildura Airp. (1957)	45.6	39.2	66.8	41.3	35.0 *
21	Moree Comparison (1964)	42.4	34.4	61.9	41.0	41.6
22	Mount Gambier Airp. (1948)	40.3	37.5	43.0	38.2	36.2 *
23	Mount Isa Airp. (1966)	43.5	36.1	57.0	41.7	42.6
24	Nowra Airp. (1955)	41.8	38.3	46.8	43.3	44.3
25	Oodnadatta Airp. (1941)	41.3	38.1	46.1	40.2	34.7 *
26	Perth Airp. (1944)	38.8	34.9	44.1	39.9	40.2
27	Sydney Airp. (1939)	44.8	40.6	54.4	39.5 *	40.0 *
28	Tennant Creek Airp. (1969)	37.6	34.0	41.3	38.6	38.1
29	Wagga Wagga AMO (1942)	41.0	36.7	46.8	38.7	40.4
30	Williamtown RAAF (1942)	42.2	39.1	45.4	41.9	40.6
31	Woomera Airp. (1949)	45.8	41.6	50.0	41.9	40.6 *

The analysis undertaken to examine the problem of inconsistency due to the use of different instruments within the dataset considered two subsets of the total wind observing record: (1) dataset for the period (1980-2006); (2) dataset for the period (1990-2006). The latter coincides with the installation of the new generation of cup-based anemometers at most observing stations (major Australian airports). The 500-year RP for these sections of the dataset are presented in columns 6 and 7 of Table 1. The values which are not within the 95% confidence limit (CI; columns 4 and 5) are marked with an asterisk.

Considering the 500-year RP (mean; 50% percentile) value for each site (complete dataset) compared to the two subsets; for (1980-2006) there are 17 sites with a 500-year RP estimate below the mean for each site (whole dataset) whereas for (1990-2006) this increases to 24 of 31 sites.
Considering the 500-year RP (lower 95% CI) value for each site (complete dataset) compared to the two subsets; for (1980-2006) there are 2 sites with a 500-year RP estimate below the low 95% CI for each site (whole dataset) whereas for (1990-2006) this increases to 13 of 31 sites.

With more than a third of 500-year RP estimates (1990-2006) in the lower tail of the supposedly parent distribution (whole record), it appears highly unlikely that the later part of the record can be considered consistent with the whole record. This issue would be even more significant if the "whole record" was considered in two parts; pre- and post- 1990. Obviously there will be differences from site to site and the most recent part of the record has been dominated by a number of large El Nino events (and only one La Nina where *thunderstorms* are known to be more prevalent). Even considering these issues, this preliminary analysis suggests that the consistency of the peak wind gust dataset is suspect, and that the problem requires further examination.

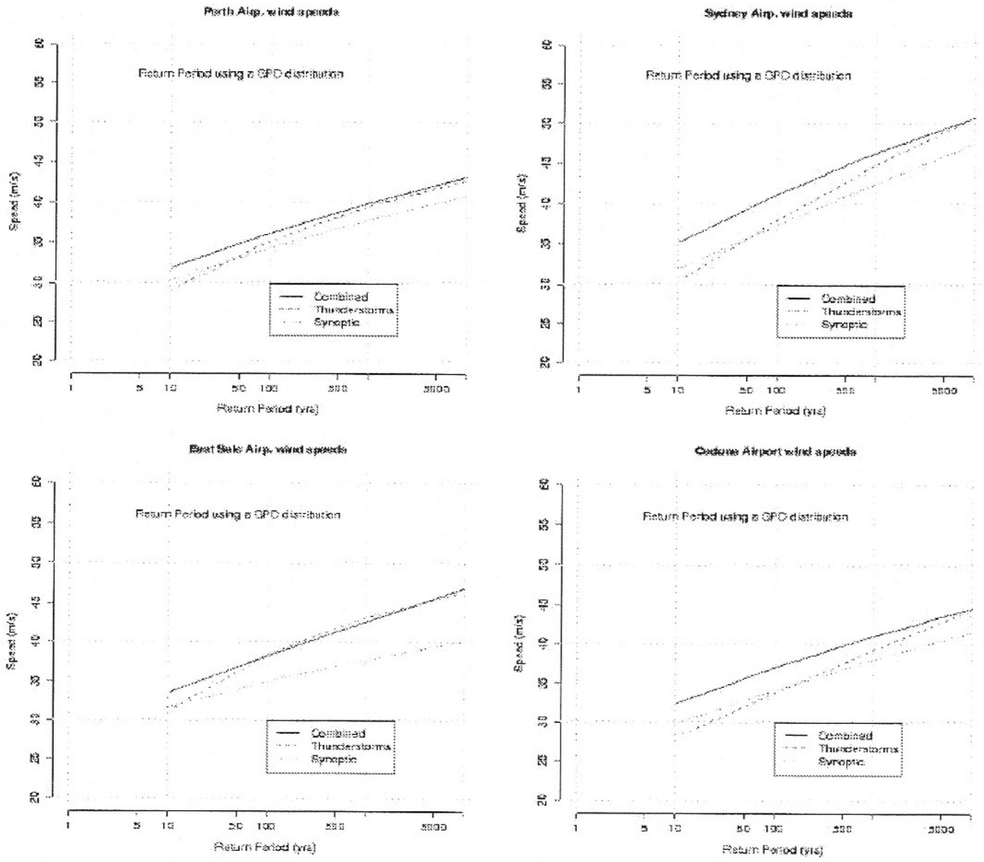

Figure 1. RP of the three types of winds; synoptic, thunderstorm and combined.

5 Future Directions

The Cyclone Testing Station (CTS) at James Cook University has recently acquired a prototype Pressure Load Actuator (PLA) from the University of Western Ontario, Canada. A detailed field investigation of the characteristics of the Dynes (at BoM field station where they are still operating) is now possible. The PLA is designed to apply fluctuating positive and negative pressure loads to the structure of a house at frequencies of up to 10 Hz, and could easily be adapted to apply a fluctuating positive pressure to the open tube of the head of the Dynes. Since the PLA is specifically designed to take some form of input pressure time history, this feature could also be implemented as part of the calibration. Testing in the field would require the construction of some form of scaffolding so that the Dynes anemometer head can be easily reached and the PLA attached. This procedure should provide sufficient information to fully specify the dynamic response of the Dynes over the range of operating conditions and hence determine the resulting effective gust duration and its variation with the mean wind speed. A study following the above procedure has been scoped and is being considered for funding by the Department of Climate Change; study partners are CTS, Geoscience Australia, Bureau of Meteorology, JDH Consulting, Systems Engineering Australia as well as contributions from Windtech Consultants, VIPAC and the Australasian Wind Engineering Society.

6 Conclusions

The study compares estimates of the 500-year RP peak wind gust hazard magnitude derived of varying observing record lengths obtained from 31 "Region A" BoM sites. The methodology was formulated to explore the consistency of peak wind gust measurements due to issues surrounding equipment upgrading. Three observing record lengths were utilised; total record, 1980-2006 & 1990-2006. Comparison of results indicated that the period 1980-2006 is similar to the total record, whereas the recent period (1990-2006) appears to have a reduction in significant events (13 of 31 sites have a mean 500 year RP below the 95% confidence limit for the 500 year RP estimate using the total record). Future plans have been prepared (submitted for funding) to provide sufficient information to fully specify the dynamic response of the Dynes over the range of operating conditions.

7 References

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