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Extreme winds for six South Australian locations

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ABSTRACT

This paper describes analyses of extreme winds for six SA locations: Adelaide (combining 3 stations), Ceduna, Mount Gambier, Port Augusta, Oodnadatta and Woomera. Recorded daily maximum gusts from both Dines anemometers, and automatic weather stations (AWS) were used. The data was separated in synoptic and non-synoptic wind events, corrected for terrain, and in the case of the AWS data, for gust duration. Non-synoptic gusts were found to dominate at all stations. Sampling errors and confidence limits for the predictions were estimated using a simulation ('bootstrapping') technique.

1. Introduction

Extreme wind gust speeds for Region A in Australia, as defined currently in AS/NZS 1170.2, are based on analyses of daily gust data from Dines pressure-tube-float anemometers that were processed in the 1990s. Since that time the Bureau of Meteorology has replaced the Dines instruments with Automatic Weather Stations (AWS), equipped with Synchrotac cup anemometers. All the additional data acquired since from South Australian AWS have been processed recently. This paper describes analyses for six SA locations: Adelaide (combining 3 stations), Ceduna, Mount Gambier, Port Augusta, Oodnadatta and Woomera.

2. Database

The eight stations used for this paper are the oldest anemometer stations operated by the Bureau of Meteorology in South Australia, and hence have the longest record lengths. The former Dines pressure-tube anemometers were replaced in the 1990s by automatic weather stations with cup anemometers and digital processing. The latter incorporates a 3-second moving-average digital filter, and a correction of the peak gust data to the nominal 0.2 second gust used in Australian/New Zealand Standard AS/NZS 1170.2 (Holmes and Ginger, 2012) is required.

Wind data from eight South Australian locations were processed: Adelaide Airport (1956-2016), Ceduna (1960-2016), Edinburgh (1973-2016), Mount Gambier (1951-2016), Oodnadatta (1960-2016), Parafield (1974-2016), Port Augusta (1972-2016) and Woomera (1949-2016). At Port Augusta, the Dines anemometer was located at the power station up to 1992. An AWS was later installed at the airport, producing data from 2001. For the present work, the data were combined and processed as if they originated from one station. The data from Adelaide Airport, Edinburgh and Parafield, all located within the Adelaide metropolitan area were combined, after corrections had been applied for the purpose of minimizing sampling errors (see later discussion). However, when a high gust (greater than 25 m/s) was recorded at more than one Adelaide station on the same day, only the largest value was used. There were many days when this occurred for synoptic winds, but relatively few for non-synoptic gusts produced by thunderstorms.

3. Corrections and storm-type separation

High gusts in South Australia are produced by a number of meteorological mechanisms, including large depressions (classified as 'synoptic'), severe local downdrafts or 'downbursts', and those associated with the passage of cold fronts. There are also cases which are a combination of these mechanisms. For the present analysis, wind gusts were classified as 'synoptic' or 'non-synoptic'. For the pre-1990s Dines anemometer gusts, the non-synoptic gusts of 45 knots or greater (uncorrected) were separated from the synoptic type by inspection and extraction of the daily charts. This is a time-consuming process, but less than it would be if synoptic gusts were included, as there are usually many more of the latter type in the database.

For the AWS data the following method was adopted:

- Identify the occurrence time of the peak gust, V_M , of the event.
- Compute the average V_B of recorded wind gusts in the two-hour time period before the occurrence of the peak gust.
- Compute the average V_A of recorded wind gusts in the two-hour time period after the occurrence of the peak gust.
- Compute the wind gust ratios, $R_B = V_M / V_B$ and $R_A = V_M / V_A$.
- If $R_B < 2.0$ and $R_A < 2.0$, the event was classified as a synoptic.
- If the preceding condition was not satisfied, the event was classified as 'non-synoptic'.

Corrections for terrain and gust duration were applied after separation of the gusts into synoptic and non-synoptic types. The terrain corrections for the Dines anemometer gusts were those used by C.M.L. Dorman in the 1980s (unpublished), and made available to the first author. For the AWS gusts, terrain corrections were made by a visual inspection of the surrounding terrain at the anemometer site, and classifying it according to the terrain categories described in AS/NZS 1170.2, including the TCs 1.5 and 2.5; a fetch length of about 500 metres was used, and the terrain was assessed for eight cardinal wind directions. The required correction factors for terrain were then taken to be the reciprocal of the values of $M_{10,\text{cat}}$ given for 10 m height in *Table 4.1* of AS/NZS 1170.2.

Corrections for gust duration are required for the AWS data, as the 3-second moving average gusts recorded by the Bureau of Meteorology are lower than the nominal 0.2-second gusts used in AS/NZS 1170.2, and those recorded by the Dines anemometers. The corrections are different for synoptic and non-synoptic gusts, and the values used were derived from Holmes and Ginger (2012).

The combined terrain and duration corrections for synoptic and non-synoptic gusts are listed in Tables 1 and 2 respectively. Two sets of values are given for Adelaide Airport, as the AWS anemometer there was relocated in 1995.

The derivation of the correction factors described above is complex and the values may contain errors. For the dominant non-synoptic gusts, neglecting any climate change effects, a measure of consistency between corrected Dines and AWS gusts is the annual rate of exceedence of such gusts above 25 m/s. These values are shown in Table 3.

There is generally good agreement between the calculated rates of Dines and AWS gusts, with the exceptions of Edinburgh and Parafield, stations in the Adelaide area most affected by urbanization. However, for those stations there is closer agreement between the rates of corrected gusts above higher thresholds (27 m/s and 30 m/s) and the corrections in Table 3 were retained. The higher rates of non-synoptic gusts at the northerly stations of Oodnadatta and Woomera in Table 3 are notable.

Table 1. Combined terrain and gust duration corrections for AWS data (synoptic)

Location	N	NE	E	SE	S	SW	W	NW
Adelaide Airport (1988-95)	1.11	1.23	1.36	1.36	1.36	1.23	1.11	1.11
Adelaide Airport (1995-)	1.23	1.23	1.23	1.23	1.23	1.02	1.11	1.11
Ceduna	1.23	1.11	1.11	1.11	1.11	1.11	1.11	1.23
Edinburgh	1.11	1.11	1.36	1.36	1.11	1.11	1.11	1.11
Mount Gambier	1.11	1.23	1.02	1.02	1.17	1.11	1.11	1.11
Oodnadatta	1.12	1.12	0.96	0.96	0.96	0.96	0.96	0.96
Parafield	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Port Augusta	1.11	1.11	1.11	1.02	1.11	1.11	1.11	1.11
Woomera	1.12	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Table 2. Combined terrain and gust duration corrections for AWS data (non-synoptic)

Location	N	NE	E	SE	S	SW	W	NW
Adelaide Airport (1988-95)	1.06	1.16	1.28	1.28	1.28	1.16	1.06	1.06
Adelaide Airport (1995-)	1.16	1.16	1.16	1.16	1.16	0.98	1.06	1.06
Ceduna	1.16	1.06	1.06	1.06	1.06	1.06	1.06	1.16
Edinburgh	1.06	1.06	1.28	1.28	1.06	1.06	1.06	1.06
Mount Gambier	1.06	1.16	0.98	0.98	1.11	1.06	1.06	1.06
Oodnadatta	1.07	1.07	0.93	0.93	0.93	0.93	0.93	0.93
Parafield	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Port Augusta	1.06	1.06	1.06	0.98	1.06	1.06	1.06	1.06
Woomera	1.07	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Table 3. Annual rate of non-synoptic gusts above 25 m/s

Location	Dines gusts	AWS gusts
Adelaide Airport	0.47	0.48
Ceduna	0.43	0.38
Edinburgh	0.35	0.71
Mount Gambier	0.49	0.48
Oodnadatta	0.92	1.00
Parafield	0.47	0.82
Port Augusta	0.71	0.67
Woomera	0.73	0.88

4. Extreme value distribution and fitting method

The most common extreme value distributions used to fit extreme wind data, are members of the family of generalized extreme value distributions (GEV) (Jenkinson, 1955). The Type I, or Gumbel, Distribution is a special case of the GEV, with the shape factor, k, fixed at 0.

In AS/NZS 1170.2, the long return-period predictions for Australian wind regions are made using the GEV with a small positive shape factor, k, of 0.1. The advantage of this distribution is that the predicted wind speeds at very high return periods are limited, whereas the Gumbel Distribution gives unlimited wind speeds, which is, of course, physically unrealistic, and unnecessarily conservative for ultimate limit states design.

Equation (1) gives the general form of the relationship between regional wind speed, V_R, and average recurrence interval, R, for the distributions used in AS/NZS 1170.2. Distributions with the form of Equation (1) were used to fit the combined Dines/AWS South Australian data for the present study.

$$V_R = C - D.R^{-0.1} \quad \text{(m/s)} \tag{1}$$

There are several methods available for fitting the GEV including method of moments and the maximum likelihood method. For the present work, a simple method for a GEV with a fixed shape factor, based on peaks-over-threshold (POT) data was used. The use of POT data allows use of all data above a defined threshold, instead of just the annual maxima, like traditional methods.

The method used here is summarized as follows:

1. Set a threshold V_0 – e.g. 25 m/s
2. Calculate average rate of exceedences of V_0, λ
3. Calculate average of all positive excesses above the threshold, E
4. Choose a shape factor, k, i.e. 0.1
5. Then calculate predictions for high average recurrence intervals, (Davison and Smith, 1990):

$$V_R = V_0 + \left(\frac{1+k}{k}\right) E\,[1 - (\lambda R)^{-k}] \tag{2}$$

5. Extreme value predictions

Figures 1 to 3 show the predictions of extreme wind speeds for both synoptic and non-synoptic winds for six locations. In Figure 1, the data from the three Adelaide area stations (Adelaide Airport, Edinburgh and Parafield) have been combined and analysed as a group (i.e. as a 'super-station'). For Adelaide, the total number of station-years processed was 78 for synoptic winds (AWS data only), and 144 for non-synoptic winds (Dines plus AWS data).

For average recurrence intervals of 100 years and greater, it is clear from Figures 1 to 3 that non-synoptic winds dominate at all locations, and only at Mount Gambier are synoptic wind gusts significant beyond 10 years. Table 4 shows the predicted values of regional wind speed from both synoptic or non-synoptic winds for the six locations, compared with the values currently given in *Table 3.1* of AS/NZS 1170.2. With the exceptions of Woomera and Ceduna at high average recurrence intervals, the predicted values are generally lower than those in the Standard.

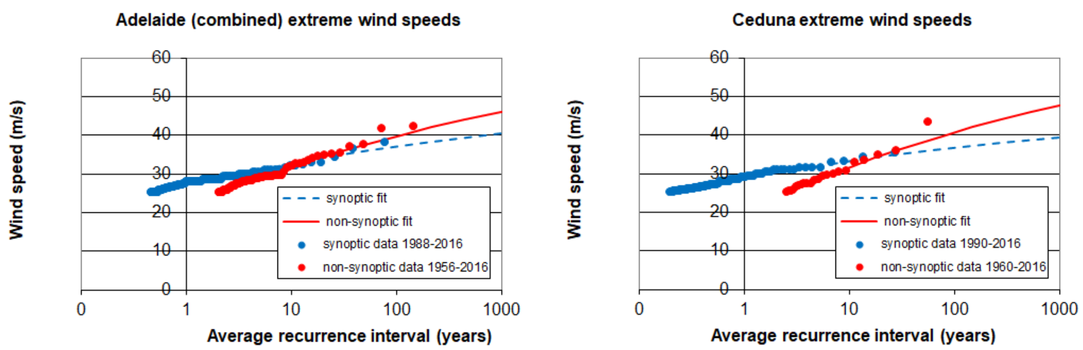

Fig. 1. Extreme wind predictions for Adelaide (combined) and Ceduna

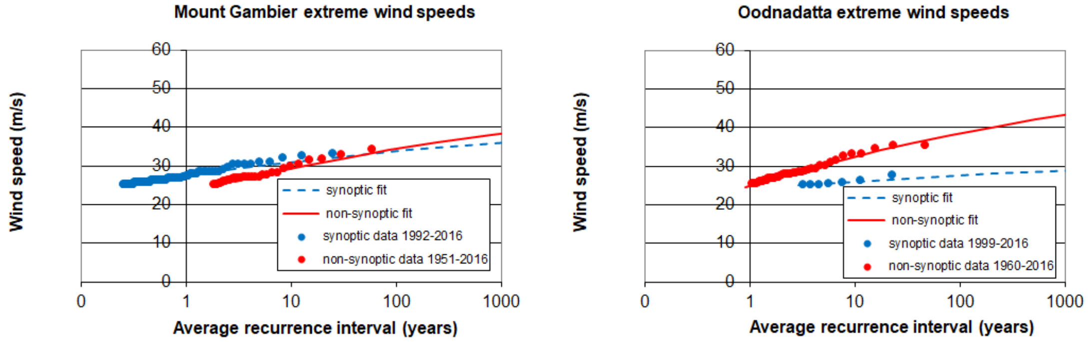

Fig.2. Extreme wind predictions for Mount Gambier and Oodnadatta

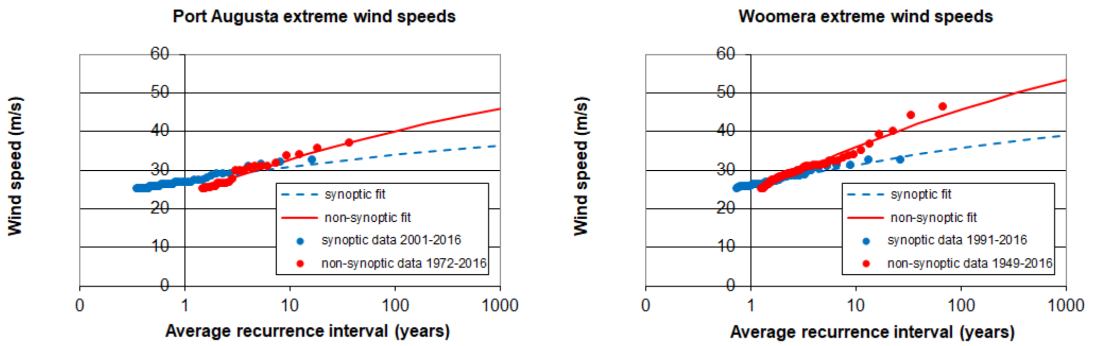

Fig.3. Extreme wind predictions for Port Augusta and Woomera

Table 4. Predicted extreme gusts (m/s) from both synoptic or non-synoptic events

Location	V_{20}	V_{50}	V_{100}	V_{200}	V_{500}	V_{1000}
Adelaide (combined)	35.9	38.3	40.1	42.0	44.3	46.1
Ceduna	36.0	38.6	40.7	43.0	45.8	47.8
Mount Gambier	32.6	34.0	35.0	36.0	37.4	38.4
Oodnadatta	34.4	36.8	38.5	40.0	41.9	43.3
Port Augusta	35.3	38.0	40.1	42.0	44.3	45.9
Woomera	39.1	42.9	45.6	48.2	51.2	53.4
AS/NZS 1170.2 (Reg A)	37	39	41	43	45	46

6. Confidence limits and sampling errors

As far back as the 1950s, Gumbel (1958) emphasized the importance of calculating confidence limits when making long return period predictions from limited data sets. A convenient way of doing this is by use of a simulation or 'bootstrapping' technique, in which a large number of samples of random data are generated using random numbers representative of the cumulative distribution function, with parameters determined from the actual data. This was carried out for the non-synoptic South Australian data, in which the excesses above a threshold of 25 m/s were simulated with the corresponding Generalized Pareto Distribution. 50 samples of data were generated, each with the same number of values as the actual data sample. Thus for Adelaide, 50 samples each with 71 values were generated. Space does permit a full discussion of the results of this here, however the standard deviation, 10 and 90 percentile values of V_{500}, determined in this way, are tabulated in Table 6.

Table 6. Sampling errors and 80% confidence limits for $V_{500,\text{ non-syn}}$ (m/s)

Location	**V_{500}**	**Std. dev., σ**	**10%ile**	**90%ile**	**$V_{500} + 1\sigma$**
Adelaide (combined)	44.3	2.09	41.7	47.1	46.4
Ceduna	45.8	4.22	40.6	51.2	50.0
Mount Gambier	37.4	2.11	34.4	40.2	39.5
Oodnadatta	41.9	2.16	39.5	45.2	44.1
Port Augusta	44.3	3.51	40.0	50.1	47.8
Woomera	51.2	3.04	48.0	55.6	54.2

Table 6 shows standard deviations in the estimates of $V_{500,\text{non-syn}}$ between 5 and 10% of the nominal value, and 80 percent confidence limits departing by up to +/- 6 m/s from the nominal value. However for Adelaide, for which data from three stations were combined, the confidence limits are narrower, and the standard deviation is significantly lower than for the other stations. Reasonable 'design' values are the nominal value plus one standard deviation, as given in the right-hand column of Table 6. On that basis, 500-year wind speeds in Ceduna and Woomera, are underestimated by the value for Region A in AS/NZS 1170.2. Winds at Mount Gambier are overestimated by the Standard.

7. Conclusions

In this paper, a re-analysis of extreme wind gust speeds from 8 South Australian stations with data from Dines anemometers, and automatic weather stations (AWS) equipped with cup anemometers, is described. Non-synoptic gusts were found to dominate at all stations. Sampling errors and confidence limits for the predictions were estimated using a simulation ('bootstrapping') technique. Wind speeds in Ceduna and Woomera, are underestimated by the values for Region A in AS/NZS 1170.2. Winds at Mount Gambier, appear to be significantly overestimated by the Standard.

AWS data from another 44 South Australian stations have been processed individually and combined into groups (unpublished report to ElectraNet Pty. Ltd.), and these results will also be considered before making any recommendations for the Standard

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