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Extreme wind speed analysis in NSW based on historic BoM data

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ABSTRACT

The design wind speed and direction multipliers for a section of NSW has been re-analysed using observed 3 s gust wind speeds from anemometers maintained by the Bureau of Meteorology. A number of extreme value analysis techniques were employed to estimate the design winds speeds. It was found that there is a small variation in the estimated design wind speeds for a given station between the different analysis techniques. This difference is comparatively small compared with the variation in estimated design wind speeds between anemometers made worst by erroneous data recording and anemometer placement. Combining anemometers to produce regional wind speeds yields large variations where the difference can be as high as 50%.

1. Introduction

The design wind speed for a given site can be calculated using AS/NZS1170.2 (2011) and is based on five parameters: the regional wind speed, direction multiplier, terrain/height multiplier, topography multiplier, and shielding multiplier. The last three are site specific, however, the first two are specific to large geographical regions within Australia and New Zealand. Both are outlined in Section 3 of AS/NZS1170.2 and were determined by extreme value analysis of observed weather data. It is understood that the latest update to the wind-speed analysis in the Standard was conducted in 2010 using Dines anemometer information, which were phased out in the mid-1990s and were only located at 77 Bureau of Meteorology (BoM) stations across Australia.

Since the existing design winds were investigated, the BoM now maintain Automatic Weather Stations (AWS) throughout Australia at a much greater number of locations. Each station has typically collected 15 years of wind gust data. The data included daily maximum, thunderday data, as well as half hourly mean and gust measurements with additional measurements during extreme events. Unfortunately not all weather data was concurrent, with thunderday data being recorded during different periods and different stations. This provides an opportunity to revisit the analysis for design wind speeds using similar techniques to allow for direct comparison. The aim of this work is to revisit the analysis of the design wind speeds and direction multipliers for the north-east section of NSW.

2. Weather Data

Weather data at 48 AWS in the north-east section of NSW were retrieved from the BoM. Typically each station had collected about 15 years of wind gust data, although the quantity and quality of the data varied significantly. Some data sets extended back to dates earlier than the mid – 1990's where the quality of data was significantly worst for almost all stations. These earlier data would have been collected using the Dines anemometer, so the correction for gust duration needs to be applied with reference to the station metadata. Care should be taken with the metadata as the anemometer location is not necessarily located adjacent to the other meteorological equipment.

Before analysing the data for extreme values, the 3 s gust wind speed at each station was corrected to open country terrain using the Engineering Science Data Unit (ESDU) standard methodology to align with a 0.3 s gust duration used in AS/NZS1170.2. From the installation of the AWS, the Bureau of Meteorology reports peak wind speeds with a gust duration of 3 s, whereas the gust duration in AS/NZS1170.2 is shorter at about 0.3 s. The earlier paper trace recordings from the Bureau of Meteorology taken with a Dines anemometer measured an effective shorter duration gust depending on the type of Dines anemometer and the wind speed, but was typically equivalent to a 0.2-0.5 s duration gust depending on wind speed (Ginger, 2011). The measured gust wind speeds during different periods of measurement have been corrected accordingly to align with the wind speeds presented in AS/NZS1170.2. It is worth noting that anemometer location was found to be a significant issue with some anemometers providing virtually useless data by virtue of being placed in a valley, or on complex 3d topography.

Predicting extreme wind events for large return periods is difficult for mixed climates particularly with limited data. NSW is a mixed climate with high gust wind speeds caused by either, thunderstorms, synoptic events, frontal systems, or potentially the tail-end of cyclones in the upper north-east regions. Each storm type has its own statistical characteristics and therefore need to be separated prior to conducting the analysis. To improve the accuracy of the analysis, individual storms were identified and classified from each anemometer investigated. This was done by following a similar method outlined by Harris (1999) – a threshold wind gust speed was used to identify separate storms (in this work 19-21 m/s). However, in this work a custom data visualisation tool was built to cycle through each individual storm, allowing manual classification of storm types.

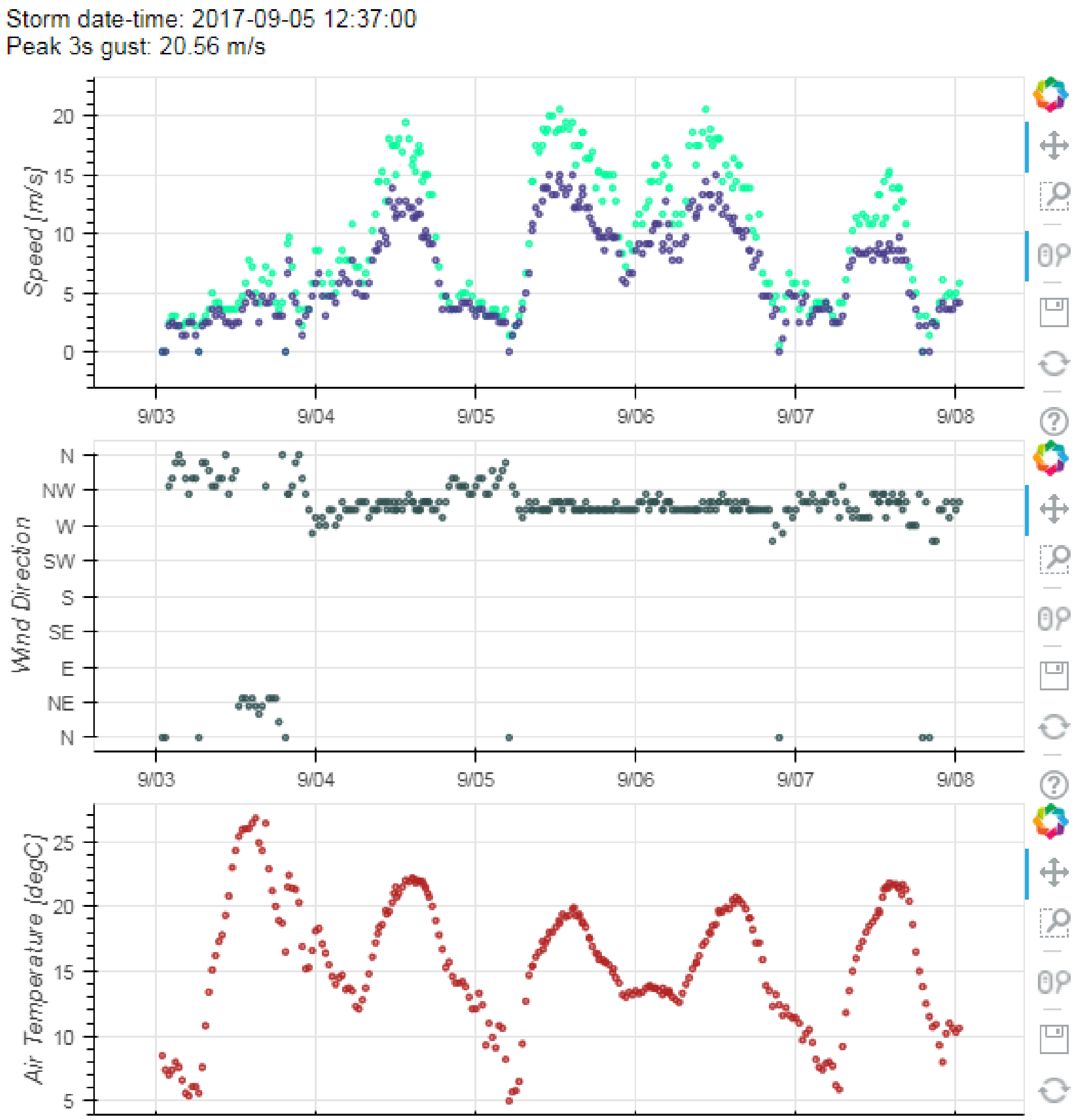

Figure 1 - Data visualisation of individual storms showing wind speed (mean and gust), wind direction and dry bulb temperature.

Figure 1 is a screenshot of the visualisation tool built to investigate individual storms. The tool displays a graph of wind speeds (mean and gust), wind direction, dry bulb temperature, and pressure (not shown), recorded by the anemometer, all of which is used to assist in classifying the storm. As indicated by the diurnal swing in wind speed and constant wind direction, and expected gust factor, this wind event would be classified as synoptic.

One of the unexpected advantages of such a data visualisation tool is that it allowed for an efficient way to interrogate storm data as recorded by the anemometer. This revealed the extent of the problems with anemometer data. Corrections for local terrain and gust wind speeds is the minimum requirements for "correcting" anemometer data, but one must still be vigilant with using the raw data directly. Figure 2 is a graph on anemometer data recorded on May 2011. This type of error could potentially be identified as erroneous by a computer - 3s gust wind speed of 53 m/s is clearly an error in the reading. However, many errors were found that could have only been picked up by visual inspection of the time series data.

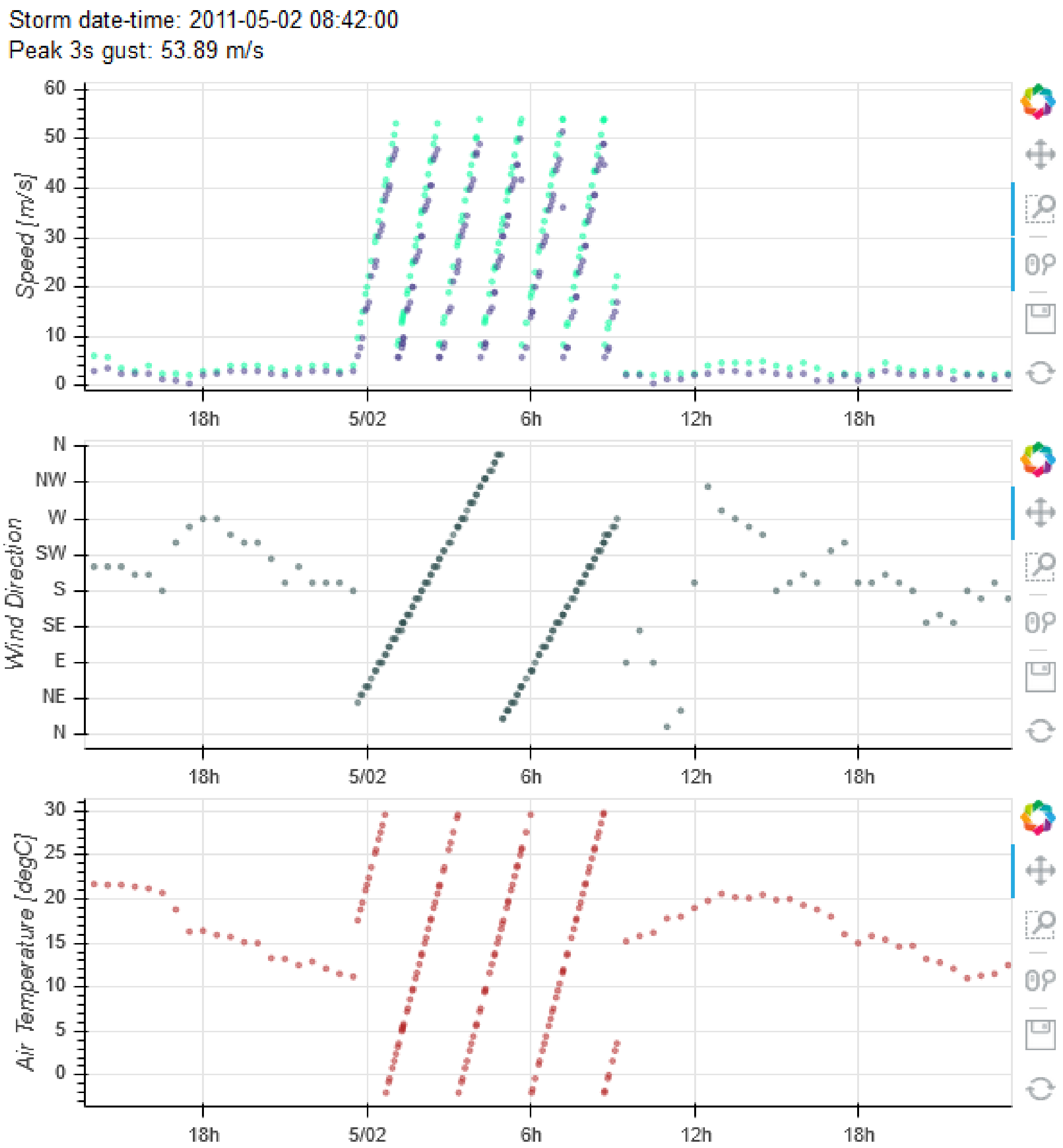

Figure 2 - Visualisation of erroneous anemometer data

3. Methodology

There have been a number of methods proposed to conduct extreme value analysis of wind speeds. Virtually all methods involve fitting recorded maxima wind speeds to a cumulative probability density distribution of the form:

$$\mathrm{F_U(U)} = \exp\left(-\left(1 - k\,\frac{\mathrm{U}-u}{a}\right)^{1/k}\right) \tag{1}$$

where model parameters *k*, *a*, and *u* are the shape, scale and location parameters, respectively.

The variations in the method centre on the means of determining the model parameters. Three common methods have been employed in this work as outlined by Holmes (2015); Gumbel, Gringorten, and Method of Moments. These methods extract annual maxima for each direction, ensuring that each maxima is related to an independent storm.

The process of extracting yearly maxima, despite being the typical approach, has limitations; it misses many storms in a year that can be used to improve that accuracy of the model parameters. To address this, a peaks-over-threshold method was employed to account for multiple storms in each year analysed. At the time of writing this paper, the Method of Independent Storms (MIS) and its variants are currently being investigated (Ref. Cook (2014), Harris (1999) and Harris (2009)).

4. Results

Each individual, corrected anemometer data was analysed using the methods discussed in Section 3. Figure 3 is the typical output from the annual maxima analysis for Moree Airport. The dots represent individual storms identified in the data for NE winds and the lines represent the probability distribution (1) fitted to the data. All three annual maxima methods are shown with a slight variation in the predicted gust wind speeds – about 5-10% range between the methods at 1000 year return period. A more important observation is the danger with projecting the probability distribution into the distant future from a small sample of data – it is clear that tail end estimate is very sensitive the distribution of the storms and the respective estimates of their return periods. To address the scarcity of data, a superstation analysis was also conducted on the data.

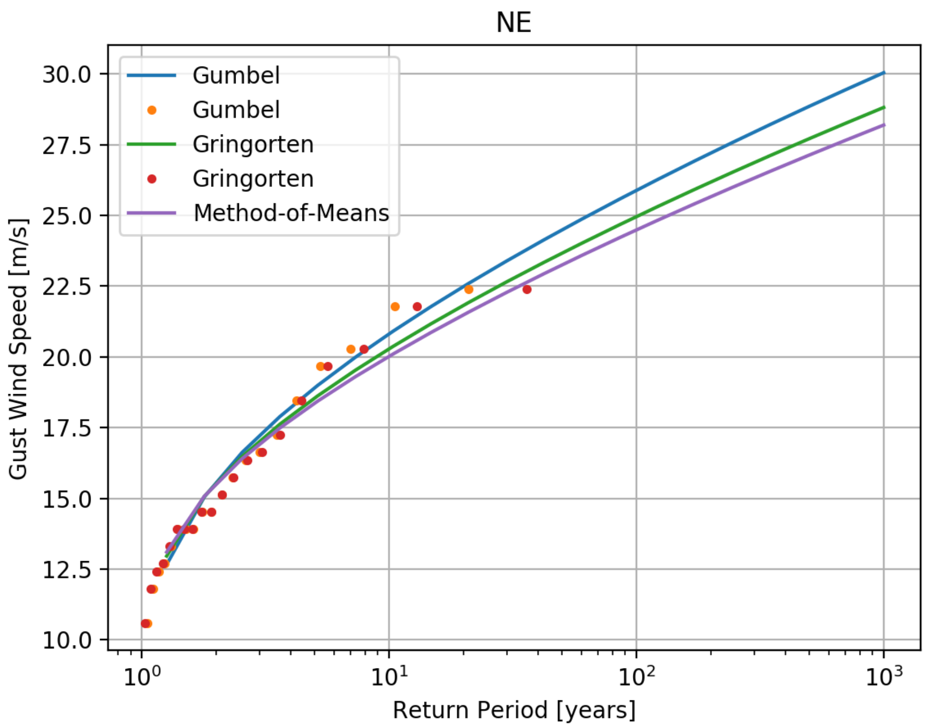

Figure 3 - Annual maxima method applied to Moree Weather Station (BoM id 053115) for NE winds

Combining the estimated design wind speeds for each anemometer into a regional design wind speed is difficult as the variation in estimates is very large. Figure 4 is a box plot of 1000 year design wind speeds for a group of anemometers located in central-to-north east NSW that overlap regions A1 and A3 as defined in Standards Australia (2011). For each wind direction the blue box extends from the lower to upper quartile values of the data, with a green line positioned at the median. The whiskers extend 1.5 interquartile range from the box to show the range of the data and the outliers are shown as circles past the end of the whiskers. Both of these regions have a regional design wind speeds of 46 m/s for a 1000 year return period. The figure shows a variation in the estimate of up to 20 m/s for some wind directions. This is not too surprising as some anemometers have limited storm data artificially assigning high return periods to low wind speed events. It is evident that most of the estimated 1000 year wind gusts speeds are lower than 46 m/s.

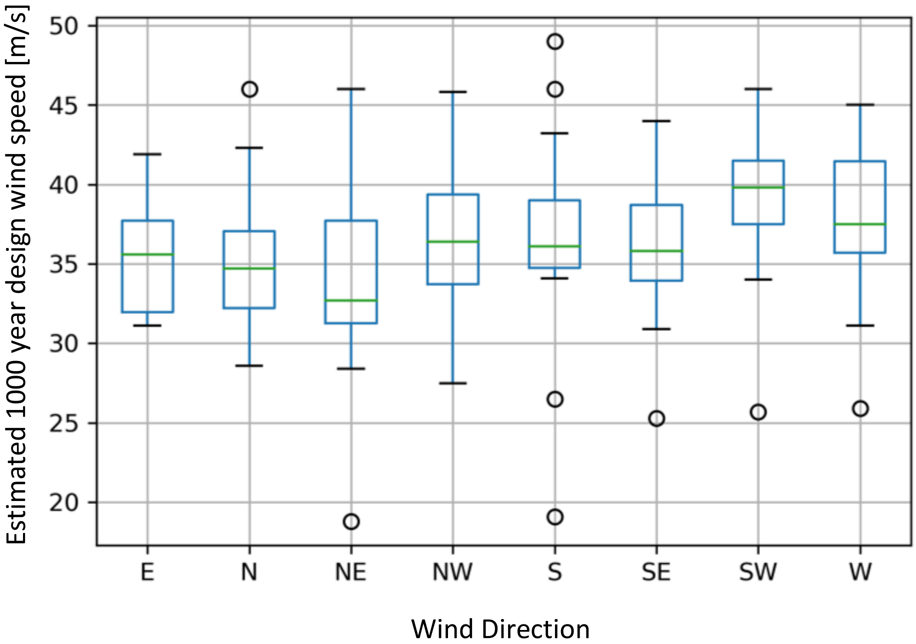

Figure 4 - Variation in 1000 year design wind speed estimates between anemometers based on annual maxima methods

5. Conclusions

The aim of this work was revisit the analysis of the design wind speeds for certain areas in NSW. The implementation of Automatic Weather Stations by the Bureau of Meteorology provides a good opportunity to revisit the design wind speeds across Australia. The analysis performed on the set of anemometer data thus far would indicate that the design wind speed could be revisited, in particular directional multipliers. However, this work has shown that extreme value analysis is fraught with danger, particularly when projecting towards high return periods based on only a few decades of data. In addition to the issues of extreme value analysis, one must be careful when using anemometer data; there are many issues with the recorded data and some errors were only possible to be found by visual inspection. The conclusion of this work is a call for collaboration, there is much work to be done and a concerted effort from all involved will provide a better outcome for the design wind speeds for the Standard.

Supporting Material

The Python program used to perform the annual maxima and independent storm analysis has been uploaded to GitHub, published under an MIT licence. It is freely available to use, edit and distribute.

https://github.com/AlexLSmith/extreme-value-analysis

References

Cook N. J., Harris R. I., Whiting R., 2003. Extreme wind speeds in mixed climates revisited, *Journal of Wind Engineering and Industrial Aerodynamics*, 91:403-422.

Cook N. J., 2004. Confidence limits for extreme wind speeds in mixed climates. *Journal of Wind Engineering and Industrial Aerodynamics*. 92:41-51.

Cook N. J., 2014, Consolidation of analysis methods for sub-annual extreme wind speeds. *Meteorological Applications*. 21:403-414.

Ginger J., 2011, Extreme windspeed baseline climate investigation project, Commonwealth department of climate change and energy efficiency.

Harris R. I., 1999, Improvements to the `Method of Independent Storms'. *Journal of Wind Engineering and Industrial Aerodynamics*. 80:1-30

Harris R. I., 2009. XIMIS, a penultimate extreme value method suitable for all types of wind climate. *Journal of Wind Engineering and Industrial Aerodynamics*. 97:271-286.

Holmes, J.D., (2015), “Wind loading of structures”, 3rd Edition, CRC Press Boca Raton, Florida, USA

Standards Australia, (2011), "Structural design actions. Part 2 Wind actions", Australian/New Zealand Standard, AS/NZS 1170.2:2011.