Long term wind variability over Australia

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1 INTRODUCTION

Inter annual and longer term variations in wind speed are useful climate indicators and are critical to a variety of sectors including the wind energy, building constructions, coastal erosions, evaporation rates, etc. Specifically for wind energy, accurate estimates of long term variations would assist in improving the planning, financing and operations of wind farms. Estimates of wind power yields are normally computed on relatively short time periods (1-2 years) but there are several climate features that vary on scales longer than 2 years such as for instance the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the North Atlantic oscillation, the Pacific decadal Oscillation, etc. These features affect various climate variables including winds and it is therefore apparent that errors in, say, wind energy yield estimates may be introduced by looking at relatively short records [1, 2 & 3].

A large network of daily wind observations over Australia both at 2-m and 10-m heights has been analysed in order to study long term linear trends and the relationship between year-to-year wind variability and two of the most important climatic indices, ENSO and IOD. While some records may be potentially very useful as climate indicators because of their length (some go as far back as the 1920s), there are several issues to be considered before carrying out statistical analyses on these data. Factors to be taken into account include location, proximity to obstructions, length of continuous data record and other data quality consideration such as sudden steps caused by changes in instrumentation.

2 AVAILABILITY AND QUALITY CONTROL OF WIND OBSERVATIONS

In this paper we analyse a large wind observation network for both 2-m and 10-m heights over Australia, the bulk of which starts from the 1970s. We started by considering the 2-m height data as they have been used in previous studies, e.g. to look at the effect and changes on evapo-transpiration [4, 5]. These 2-m observations are daily wind run data (i.e. measured as daily averages) acquired from the Australian Bureau of Meteorology (BoM). Similarly to [5], the wind run data were excluded if quality control (QC) flags indicated that they were considered wrong, suspect, or inconsistent with other known information and if wind run exceeded five times the standard deviation of the entire time series. Unlike in [5], accumulation spikes with information on the number of accumulated days were retained by accounting for the accumulation period. Also since the main objective here is to analyse long term variability, only data covering a continuous period of at least 15 years were retained (even if ideally a longer period, of say 30 years, would be more suitable). In addition to this QC based solely on flags and reasonable data filters, a supplementary quality control was carried out for each station. This individual analysis took into account a visual analysis of the time-series, an examination of the siting map of the station provided by the BoM, an analysis of satellite maps (e.g. Google maps), interrogations to other experts. Additional issues encountered include:

- Accumulation spikes without info on the number of days
- Other outlying spikes with no suspect quality flag (real or artificial?)
- Sudden steps or ramps, up or down or both.
- Steep overall trends (due to urbanisation or vegetation or climate?)

- Possible confusion about whether data is taken at 10-m[1] or 2-m
- Data reported with inconsistent units
- Many stations have not been sited according to the BoM specifications and are close to bluff bodies, vegetation, buildings, or on a hill or 'steep' slope
- Many stations do not have site diagrams and can not be located easily

As a result of our QC, the number of 2-m stations was reduced by almost a quarter. Figure 1 shows the temporal evolution of the data availability with the green line representing the selected 2-m wind run data and the black line its original total. Wind run observations are available also at a height of 10-m. The same quality control procedures were applied to the 10-m data: of the total number of stations given by the red line only less than 10 stations were retained (blue line). Clearly, such a number is generally not sufficient to yield statistically significant results. For this reason, 10-m observations from Automatic Weather Stations (AWSs) were also considered. With the extra requirement that the AWS data should be close to the retained 2-m wind run stations whenever possible, between 20 and 30 AWSs were kept (magenta line).

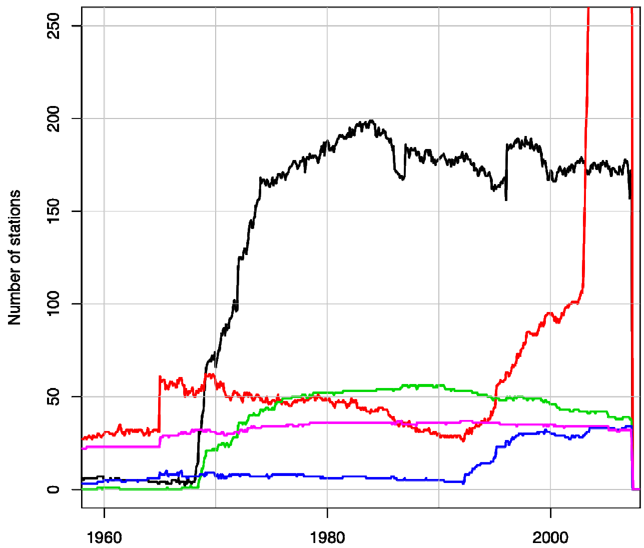

Figure 1 – *Number of stations before and after the quality control (QC): wind run observations at 2-m (black, before QC, and green, after QC) and 10-m (red, before QC, and blue, after QC). The magenta line represents the retained 10-m daily averaged observations from Automatic Weather Stations.*

3 WIND TRENDS FROM WIND OBSERVATIONS

Several recent studies have reported declining winds in the last decades across the globe. For instance, [6] found that "the averaged rate of decrease in annual mean wind speed over China is $-0.018\ \mathrm{ms^{-1}a^{-1}}$", and stated that "this decrease in strong winds also may lower the potential for wind energy harvest in China" (see also [7]). Declines have been observed for parts of the United States of America too [8]. Similarly, and more relevant for this paper, [5, 6] found an average wind decrease of $0.009\ \mathrm{m\ s^{-1}\ a^{-1}}$ over Australia for the period 1976-2006. Although the number of stations retained following our QC procedures is not sufficient to produce an average wind trend for the whole of Australia, there appears general agreement between our trends as shown in Figure 2 and those computed by [6, their Figure 1d][2].

[1] As discussed later, wind run observations are also available at 10-m.

[2] Note that unlike for the studies mentioned, we computed relative trends (i.e. as a fraction of the mean wind speed) as we consider this measure more informative than the absolute wind speed. Also, for comparison purposes the same period as in [6], 1975-2006, was taken.

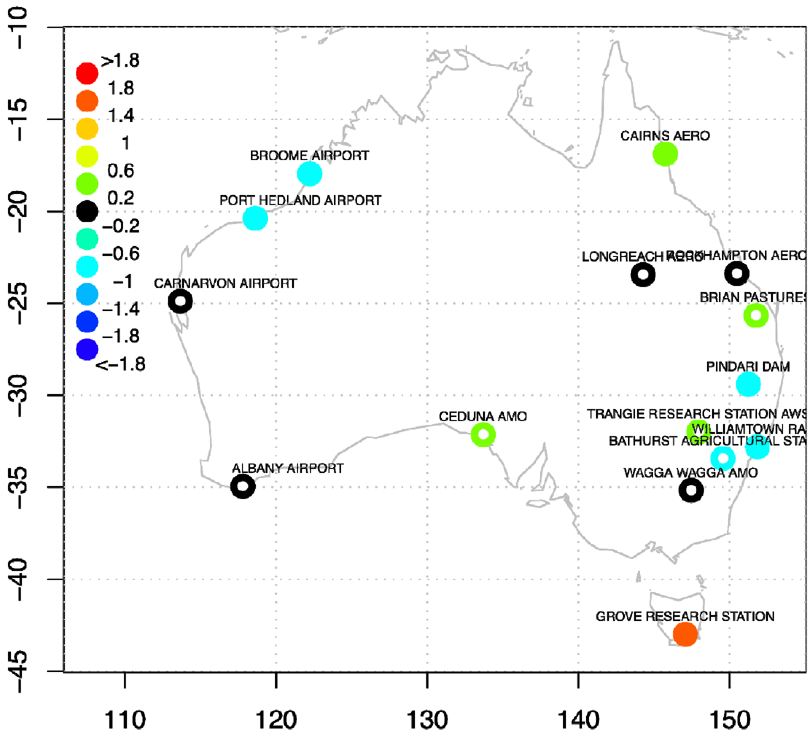

Figure 2 – *Relative wind trend (i.e. trend divided by the mean wind) of the 2-m wind run data for the 1975-2006 expressed as % per annum. Solid circles are used for stations where the trend is significant at the 5% level. The trends and their significance test were computed by means of an auto-regressive model, similarly to what done in [9]. Note that only stations covering the entire 32-year period were considered.*

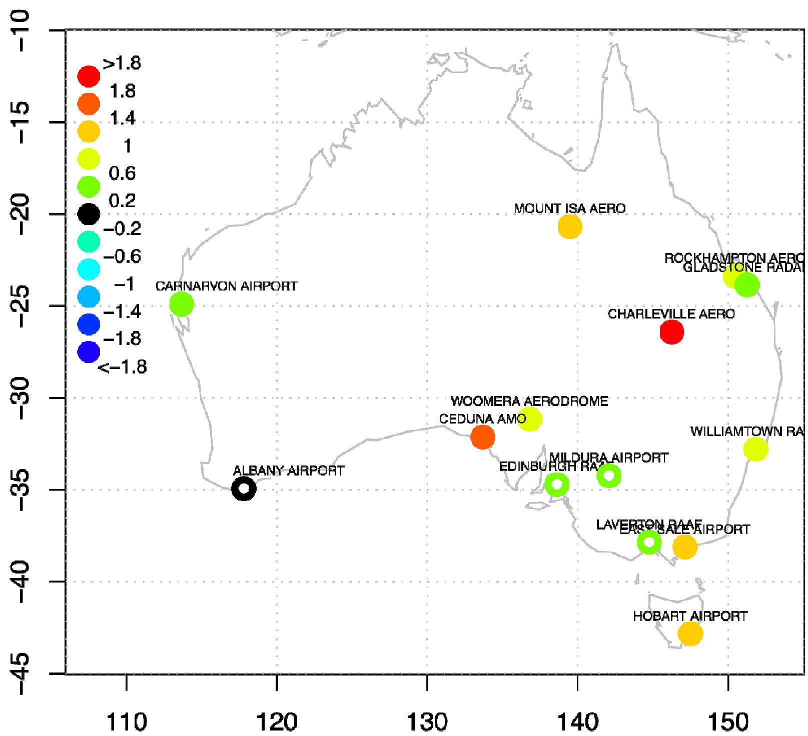

Figure 3 – *As in Figure 2 but for the 10-m wind speed data.*

Somewhat surprisingly, the results are different when the 10-m daily averaged AWSs data are used (Figure 3). Now all the computed trends are non-negative, with several of them significantly different from zero at the 95% confidence level. It is not immediately obvious why the trends at 2-m are different, and often with opposite sign, from the 10-m data. It may be expected however that being further away from the effects of near-surface processes, the 10-m data should provide a better representation of the actual near-surface wind trends. If one also considers that the 2-m wind run stations are often sited near vegetation, building or other obstructions (our QC only removed data with obvious external influence), a lower wind speed trend is not unexpected.

Wind speed trends at 10-m height have also been computed using three re-analysis products: (i) from the National Center for Atmospheric Research (NCEP/NCAR), (ii) ERA-Interim (EI) from the European Centre for Medium-range Weather Forecasts and (iii) JRA25 from the Japanese Meteorological Agency. For all three re-analyses the trends averaged over Australia are mildly positive[3]: 0.022 % a^{-1} for NCEP, 0.025 % a^{-1} for EI and 0.074 % a^{-1} for JRA.

4 WIND INTER-ANNUAL VARIABILITY

In order to isolate the effects of extreme climatic conditions on wind speed, the relationship between wind speed and three states of both ENSO and IOD (positive [i.e. top ca. 20%], negative [i.e. bottom 20%] and neutral conditions) is computed. Figure 4 shows the summary statistics for all stations in the period 1987-2007[4]: in all cases the signals are weak (up to about 15% of stations) indicating only a modest influence of ENSO and IOD on wind speed. Taking values above 5% as potentially important, wind speed appears to be more affected by the IOD (largest values for the positive-neutral and positive-negative pairs at 10-m in Winter). Some impact of ENSO can be seen at 2-m in Summer for the El Niño–neutral pair. However, the fact that the signals at 2-m generally differ from those at 10-m may be an indication of noise in the statistics, although a somewhat different geographic distribution between stations at the two heights is also a factor.

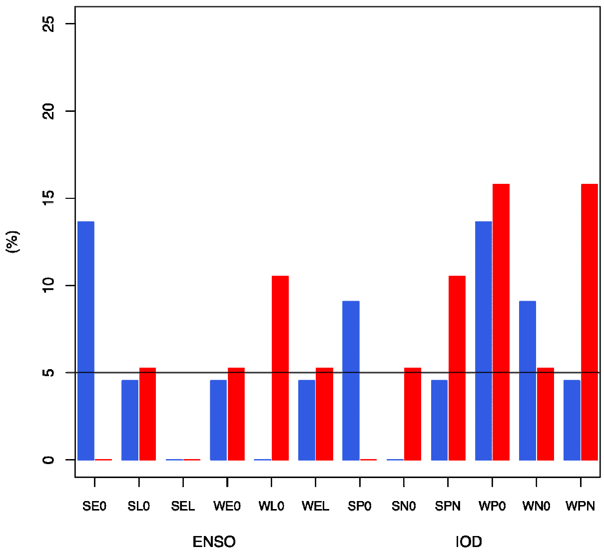

Figure 4 – *Percentage of cases for which the 5% significance level (using the Kolmogorov-Smirnov test) for pairs of climatic states (e.g. separation in wind between El Niño and La Niña significantly different from zero) and as a function of season and as height (blue for 2-m and red for 10-m). In the x-axis labels, the first letter "S" and "W" stand for Summer and Winter respectively. The first six pairs of bars are for ENSO states (E: El-Niño [i.e. positive ENSO], 0: neutral, La Niña [i.e. negative ENSO]) and the second six are for IOD (P: positive, 0: neutral, N: negative).*

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[3] These trends are for a shorter period, 1989-2006, mainly because of re-analyses product availability.

[4] A shorter period has been selected in order to include more stations (22 for 2-m and 19 for 10-m) so as to achieve more robust statistics.

5 SUMMARY

In this paper a large number of wind observations over Australia have been analysed for their long term trends and interannual variability. After a thorough quality control procedure, it was found that the wind speed trend for the 1975-2006 period is sensitive to the height of the station, to the extent that the sign of the trend changes from being largely negative in the 2-m data (as in [6]) to predominantly positive in the 10-m data. Further, although not shown here, the trend is also sensitive to the period selected. The impact of important climatic signals such as ENSO and IOD on Inter-annual wind speed was found to be weak, with a larger effect associated with the IOD in the winter months.

6 REFERENCES

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