Further Validation of a Synthetic Tropical Cyclone Climatology for Australia

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ABSTRACT

The paper updates the selected modelled and measured tropical cyclone wind speed validations presented in Harper & Mason (2016; AWES18) showing that the combined synthetic storm track methodology and associated surface wind modelling continues to provide a highly accurate estimation of extreme tropical cyclone wind risk across Australia. Insight is provided into the widespread adoption of these modelled wind speeds over the past decade, with over 80 applications across single sites, wind, and solar energy farms.The associated presentation will also provide examples of the historical deterministic accuracy of the wind modelling system and recommendations as to how to modernise the Standard's approach to design wind risk. This includes allowance for community-wide risk, separate from site-specific risk, and also the need to prevent political meddling in the criteria over time.

INTRODUCTION

The current AS/NZS 1170.2 regional design wind speed recommendations for tropical cyclone (TC) wind risk (SA 2021, Fig 3.1(A), Regions B, C & D) mostly date from analyses conducted in the late 1970s (refer Harper & Mason 2016; hereafter HM16). However, since that time there have been many significant developments in knowledge of TC structure and behaviour, remote sensing and data analysis, and numerical and statistical modelling techniques (Harper 2013). In addition, the availability of new observational wind and TC parameter datasets, changes in anemometer instrumentation response and analysis, and Bureau of Meteorology (BoM) operational forecasting and analysis procedures have demonstrably influenced wind risk studies. While some of the 1170.2 standard's regional boundaries have been slightly modified over time, and rules on transitions relaxed, there has been no wholesale reconsideration of V_R criteria. Additional so-called uncertainty factors F_C and F_D were introduced into the 2000 revision but, being unsupported by any rational analyses, these were removed in the 2021 update, which also added a practical consideration of the potential impacts of long-term climate change on TC wind hazard by the year 2100.

BACKGROUND

The current model foundations remain the same as reported in HM16, namely:

- A curated version of the official BoM historical TC track, intensity and size dataset to end 2014 provides the base climate reference;
- The synthetic track algorithm adopts a "double-vortex" surface wind and pressure model;
- Regression variables include 500 hPa winds, vertical wind shear and relative humidity derived from global re-analyses, as well as regionally varying MPI limits;
- Iinnovative inner and outer vortex scaling based on analysis of scores of historical TC events;
- The synthetic TC climatology model covers the whole of Australia (including Cocos (Keeling) and Christmas Islands) and now spans 50,000 years at a 3 h temporal fix resolution.

The ensemble of modelled synthetic TC tracks compares well with the observed track parameters to within 90% confidence limits using a bootstrap re-sampling technique. This verification has been undertaken by comparing a number of track parameters including:

- Peak intensity ΔPo CDF, exceedance and Average Recurrence Interval;
- North-South and East-West track speed CDF;
- Speed and Heading CDF and frequency histogram; and
- Duration within a model sub-domain CDF.

Interested readers are referred to HM16 for further details.

UPDATED STATISTICAL VALIDATION WITH SITE SPECIFIC AWS DATA

The 50,000-year synthetic TC climatology is used to drive the companion parametric surface wind model for any site of interest to provide directional maximum mean (V_{600}) wind estimates for all TC events over the chosen exposure period. Typically, a 300 km radius of influence for each modelled TC is applied to each site sample, the model timestep is set at 30 min and a single maxima is retained for each event. Based on verification with reliable offshore Automatic Weather Stations (AWS), the simulated winds from the modelled TCs are deemed representative of a flat +10 m AGL "Terrain Category 0" or Tcat 0, which has a roughness height one order of magnitude smaller than the current smoothest Tcat 1 terrain in AS/NZS 1170.2 (i.e. z0=0.0002 m). Transition to other terrain roughnesses is made by applying ESDU (2002a) boundary layer assumptions, and the modelled mean wind speeds are then converted to any preferred wind gust metric (e.g. AS/NZS 1170.2 $V_{0.2,600}$) by applying a modified ESDU (2002b) approach.

In this validation exercise the chosen comparison sites are deemed reliable well-exposed BoM AWS, ideally with records in excess of 50-year, and without topographic influences. In practice, data span must often be balanced by consideration of reliability in regard to instrumentation and location changes, which are frequently not fully documented. Airport sites are preferred but many are not immune from exposure changes over time. Some shorter records are included for geographic coverage.

In the graphical comparisons that follow between modelled and measured data, both the modelled and measured winds are adjusted to Tcat 2 (standard exposure). In the case of the measured winds, the continuous record is first decimated into 5-day maxima windows for independence. All non-Dines period DC gusts are converted to $V_{0.2,600}$ equivalents similar to Holmes and Ginger (2012). Next, the 16-directional roughness of the site is assessed. This uses the 30 min "HM" data now available at many AWS sites over the past 20 y, where the directional roughness is objectively derived from analysis of the turbulence intensity using the contemporaneous V_{600} and $V_{3,600}$ measurements. Modelled and measured winds are then simply event-ranked (n) in reverse magnitude and ARI $\log_{10}$-plotted according to the data span (m) as n/m. There is no curve-fitting of modelled or measured data and the two data sets are completely independent of each other. Also shown on each site-specific graph is the applicable AS/NZS1170.2 regional V_R curve, which includes the M_c factor.

The selection of AWS graphical comparisons are given in Figure 1 for Queensland east coast, Figure 2 for Gulf and Top-End and Figure 3 for Western Australia. Both BoM "HC" synoptic 3-hourly mean and "HM" 30-min mean winds have been used, together with the "DC" peak daily gusts. The "HC" is always the longer record but can under-sample storm peaks, while the "DC" is fully sampled. Goodness of fit is simply judged here visually but can be readily quantified by consideration of "confidence limits" obtained by bootstrap resampling of the modelled data using the span of the measured dataset. Figure 4 below shows an example for Townsville Aero with bootstrapped confidence limits of the modelled mean and gust wind using 1000 renditions with sample lengths equivalent to the data sample period of about 80 y. This shows the reliability of the model by easily bracketing all the measured high speed data at the 5%-95% variability range. The model mean curve lies above the under-sampled 'HC' data and tends to follow the 'HM' data, although that data record is much shorter than the 'HC'. The modelled mean 'DC' curve closely follows the data. The 5% and 95% non-exceedance limits of the dashed lines about the solid lines then indicate "confidence limits" that suggest that if the measured data lies within the indicated modelled "reliability" ranges then it can be regarded as reasonably having been randomly sampled from the 50,000 years of modelled data with that reliability.

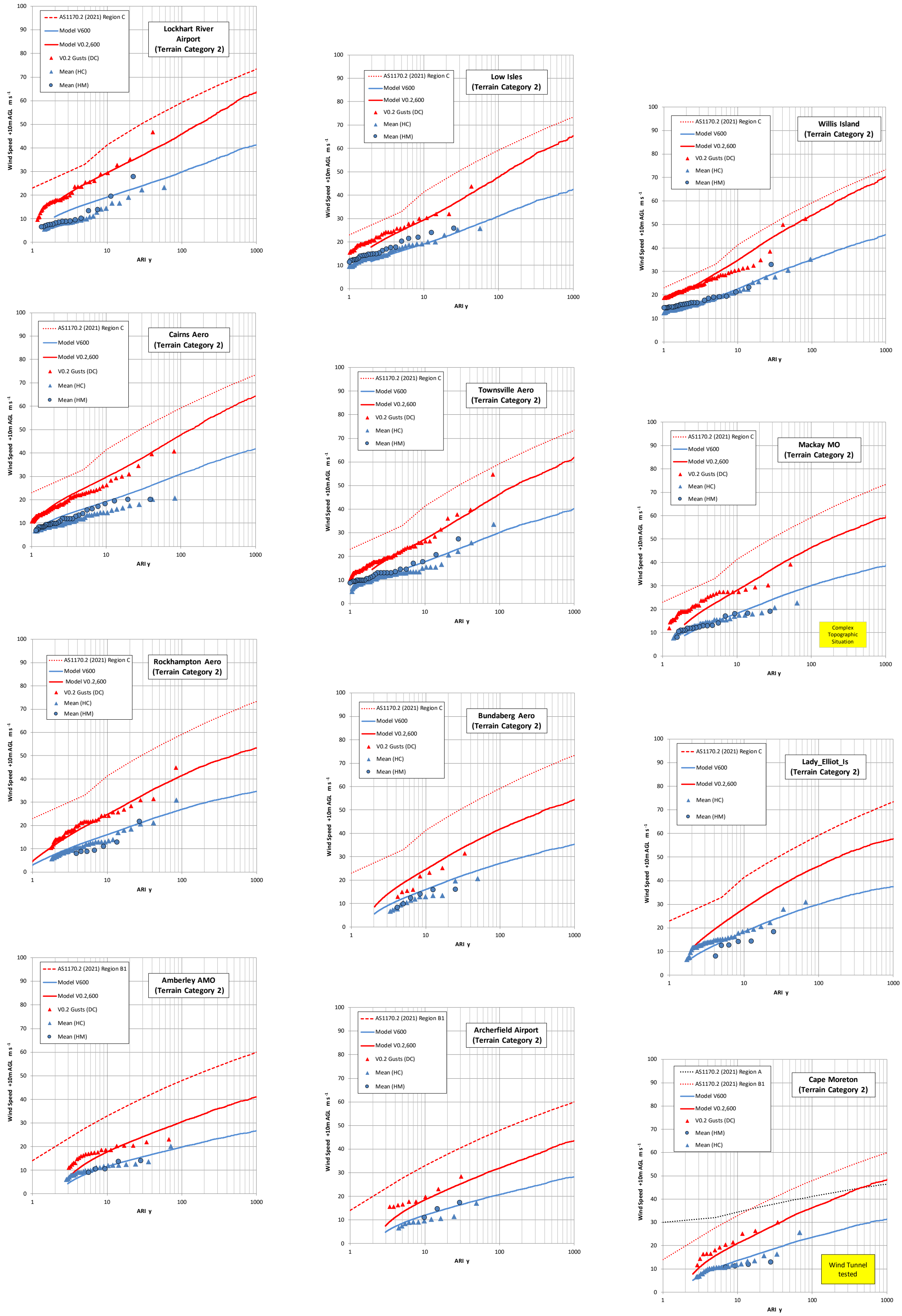

Figure 1. Queensland east coast validations

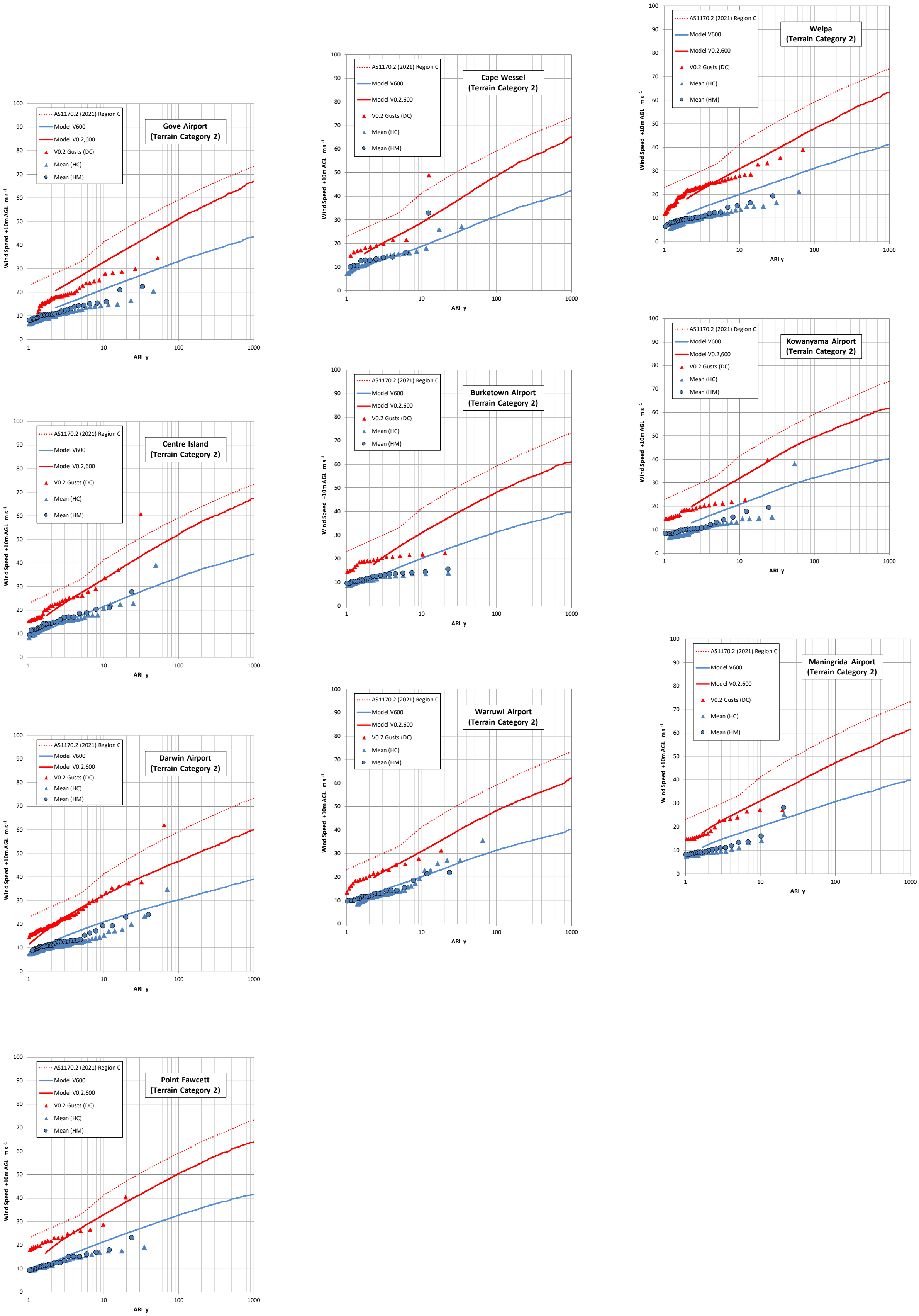

Figure 2. Gulf and top-end validations

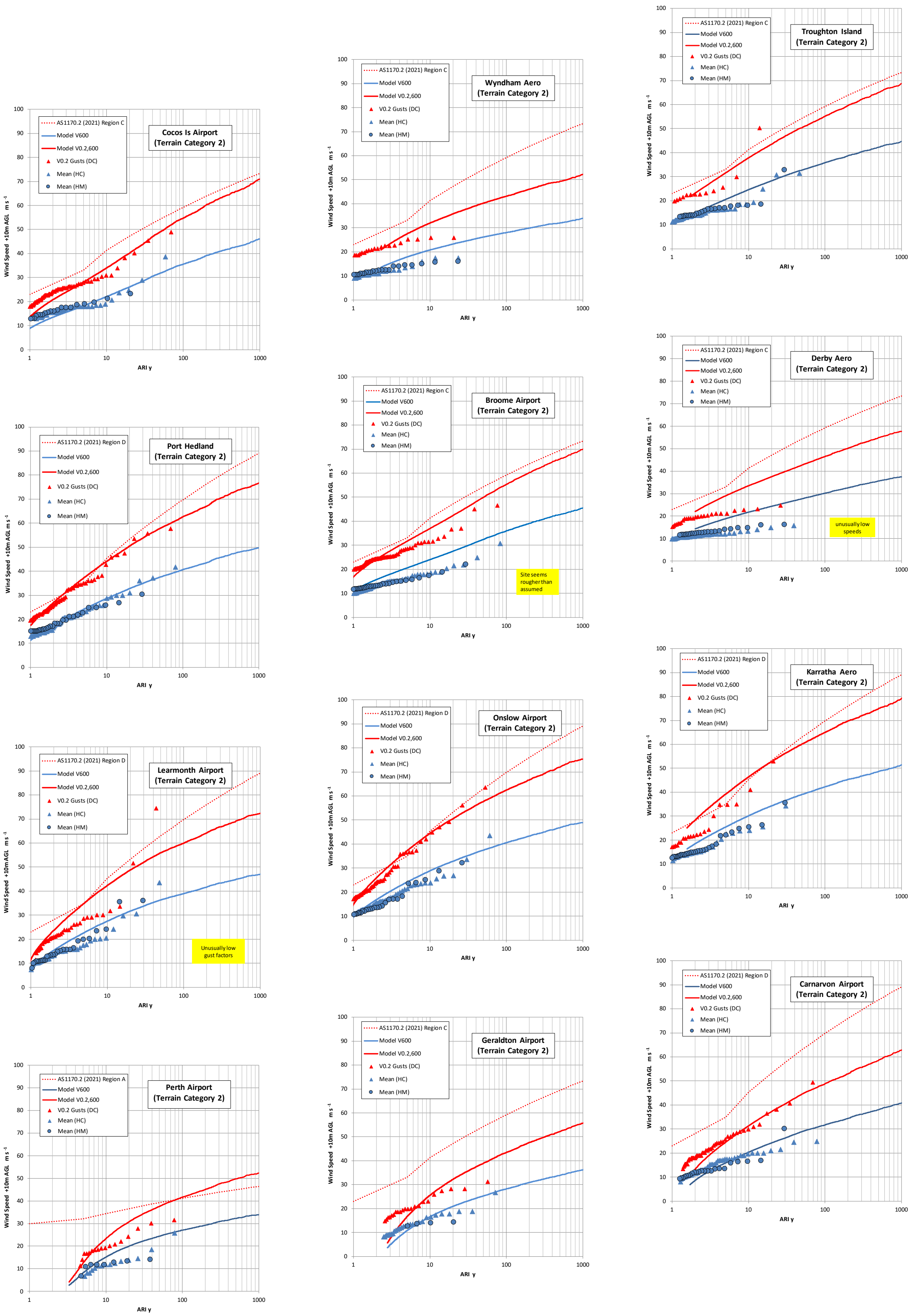

Figure 3. Western Australia validations

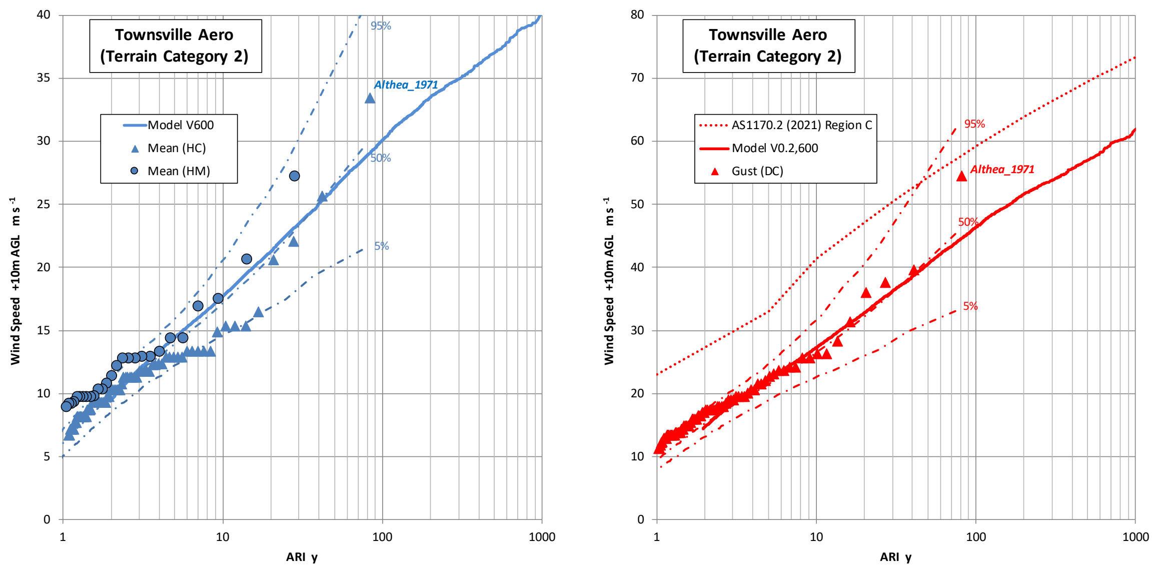

Figure 4. Townsville Aero bootstrapped "confidence limits"

PRODUCT UPTAKE

Since mid-2014 when the synthetic data first became available, there has been a steady uptake by a range of clients and projects across Australia. The original development was supported by the insurance industry seeking improved continental-scale TC wind and storm surge assessments. Individual building developments are now a principal interest, typically requested by wind engineering consultants who prefer to receive a full 50,000-year synthetic wind speed and direction time series for their own detailed analyses. Next are applications in the coastal environment where large spatial wind and pressure data time series for individual TCs can be provided to drive storm surge and ocean wave models for the design of port infrastructure or coastal adaptation. Finally, large scale solar and wind power projects seek to understand and optimise their risk profile in TC-prone or marginal climate regions.

CONCLUSIONS

The combined synthetic storm track methodology and associated surface wind modelling products described here demonstrably provide a defensible TC wind hazard criteria for those seeking greater certainty in their project risk profiles than that available from SA (2021).

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