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Postscript to “Exact and general FT1 penultimate distributions of extreme wind speeds drawn from tail-equivalent Weibull parents”

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Abstract

We present a further contribution to the current debate on methodologies for assessing extreme wind speeds, adding further insights to a recent paper which derived exact and penultimate models for the FT1 distribution that account for asymptotic convergence and avoid the associated errors. This contribution addresses the issues of the upper tail shape of the parent distribution which controls the rate of convergence of the extreme to the asymptote and controls the power index of the variate of the penultimate model. We clear up two outstanding issues in the example data of the previous paper that resulted from contributions from more than one mechanism. We show that the Jenkinson-Lamb index may be used to separate the UK wind record into Cyclonic and Anti-cyclonic contributions, each of which is an excellent fit to one of a pair of Weibull distributions having similar shape parameters but differing scale parameters, that together form a disjoint parent distribution. It is the dominant Cyclonic component that controls the parameters of the penultimate distribution of extreme wind speeds in the UK, irrespective of direction.

Keywords: Asymptotic models; Disjoint distributions; Exponential distribution; Extreme-value statistics; Extreme wind speeds; Jenkinson-Lamb index; Parent wind speeds; Penultimate distributions; Storm maxima; Weibull distribution; Wind engineering

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1. Introduction

In a recent paper in this Journal [1] we reviewed long-established extreme-value theory and developed Cramér’s method for the penultimate extreme-value distribution into a new model of extreme wind speeds for the case of Weibull parents that avoids the issues of asymptotic convergence and the associated errors. This paper was written in response to an earlier paper by Simiu, Heckert, Filliben and Johnson (SHFJ) [2] which compared fitting the ultimate asymptotic Fisher Tippett Type I (FT1) distribution to extreme dynamic pressures,

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i.e. to the square of the wind speeds, with fitting an ultimate asymptotic Fisher Tippett Type III (FT3 or "reverse Weibull") to the extreme wind speeds. Our paper demonstrated that use of the FT3 asymptote to represent the distribution of extreme wind speeds was at best a pragmatic empirical representation that is useful only within the range of the data and provides inaccurate extrapolation to higher risks (longer return periods) as the FT3 distribution converges towards a fictitious limiting value which is an artefact of the model.

We developed our penultimate model for the case of extremes from a single-mechanism wind climate which is a good fit to a Weibull distribution in the upper tail of the parent, i.e. a tail-equivalent Weibull parent. The penultimate FT1 model has three parameters:

1. The position parameter of the FT1, the mode, U
2. The scale parameter of the FT1, the dispersion, $1/a$
3. A new shape index w

and takes the form:

$$\begin{gathered}\Phi_T\{\widehat{V}_T < v\} = \mathrm{e}^{-\mathrm{e}^{-a_T^w(\widehat{V}_T^w - U_T^w)}}\\ \text{or}\\ y_T = -\ln\left(-\ln\left(\Phi_T\{\widehat{V}_T < v\}\right)\right) = a_T^w(\widehat{V}_T^w - U_T^w)\end{gathered} \tag{1}$$

where T represents the epoch for the extreme, typically one year, and y_T is the Gumbel 'reduced variate' for that epoch. The position and scale parameters have been raised to the power of the shape index to preserve the units of the variable. The full derivation of Eq. (1) is given in the previous paper [1], where we showed that the new shape index w is also the shape parameter of the parent Weibull distribution. We also showed (in Appendix C) that the dispersion is related directly to the scale C and shape parameter w of the parent Weibull, whereas the mode is also controlled by the epoch T and the rate of independent events r. Usually, the rate of independent events r is unknown or can only be approximated.

We used data from the UK meteorological station at Boscombe Down to demonstrate the methodology and we compared the results when the model was fitted for minimum variance given a free choice of its parameters and also when the shape parameter w, alone or with the dispersion $1/a$, was estimated from the parent. We reported that the parent distribution predicted $w = 1.608$, while a free fit of the extreme data to Eq. (1) gave $w = 2.019$, but we did not comment on this difference as the penultimate FT1 model using either value remained within the 37% and 63% confidence limits. We made a fit to the upper tail of the parent distribution on the assumption that it was represented by a single-mechanism Weibull model. We also noted that the observations departed from the single-mechanism model and this was well-fitted by a second disjoint mechanism. These fits are reproduced here as Fig. 1.

Having obtained the two-mechanism fit, we omitted to go back and reassess our single-mechanism estimate. Our misjudgement stems from our familiarity with the joint case for extremes, as originally advocated by Gomes and Vickery [3], where the slope of the tail is given only by the dominant mechanism. We state this as a reason, not an excuse, and seek to correct matters by developing and demonstrating the theory to account for the two mechanisms. The main purpose of this postscript is to admit this misjudgement and to show that the contribution of the second, or further mechanisms, is important because they each contribute to the apparent slope of the upper tail in a disjoint distribution. In doing so, we provide further insights into the UK wind climate and reconcile our view of the role of the parent distribution with those of SHFJ [2].

Making a two-mechanism disjoint fit gives estimates of the parameters for both mechanisms and, for the fit shown in Fig. 1 the corresponding Weibull parameters are: $C_1 = 12.05$ kts, $w_1 = 1.81$, occurring for 37% of the time, and $C_2 = 10.02$ kts, $w_2 = 2.04$ occurring for 63% of the time. It is clear that the second mechanism is only slightly weaker than the first and occupies the greater proportion of the time, so we are dealing with more than just insignificant "morning breezes" [2] here. Allowing for the contribution from the putative second mechanism raises the estimate of w_1 for the first, dominant mechanism, closer to that of the free-fit extreme estimates.

Fitting combinations of disjoint distributions is a difficult process because it is well known that fitting distributions made up even of the sum of simple exponentials is notoriously poorly conditioned. It has been