Estimation of Extreme Wind Speeds in the Mixed Strong Wind Climate of South Africa

Andries C. Kruger[1], Adam M. Goliger[2], Johan V. Retief[3], Snyman S. Sekele[4]

[1]Climate Service, South African Weather Service, Pretoria, South Africa, Andries.Kruger@weathersa.co.za

[2] Built Environment, Council for Scientific and Industrial Research, Pretoria, South Africa, agoliger@csir.co.za

[3] Department of Civil Engineering, University of Stellenbosch, South Africa, jvr@sun.ac.za

[4]Climate Service, South African Weather Service, Pretoria, South Africa, Snyman.Sekele@weathersa.co.za

1 INTRODUCTION

The South African Weather Service, with the support of the Council for Scientific and Industrial Research (CSIR) and the University of Stellenbosch, is in the process of updating the extreme surface wind statistics for South Africa. A previous assessment was done by the CSIR in 1985 when only a limited number of climate stations over South Africa were available, which had sufficiently long time series of continuously recorded high-resolution wind data.

Due to the complexity of the South African strong wind climate, which has also been updated, data produced by the different strong wind producing phenomena should be analyzed separately to improve extreme wind predictions. Previous studies exist, one which e.g. distinguished between four extreme wind-generating mechanisms for Australia.

Annual extreme wind speeds are generated by different mechanisms, forthcoming from thunderstorm activity and the passages of extratropical low pressure systems, which were identified. Separate extreme value distributions for the different mechanisms were combined, and comparisons were then made between extreme wind gust values for long return periods estimated if the Fisher-Tippet Type I distribution were applied to only annual extreme wind gusts (single climate), and when combined distributions were applied (mixed climate).

For longer return periods the differences between the extreme wind speeds estimated from single and combined distributions become larger. This result is especially important in the design processes of structures with special importance e.g. power supply utilities, where extreme wind speed values for very long return periods are often required.

2 THE STRONG WIND CLIMATE OF SOUTH AFRICA

South Africa was zoned into geographical regions that indicate the most likely sources of strong winds, particularly the annual maxima of the 2-3 second wind gusts [1]. The awareness of different sources or mechanisms of extreme winds is recommended in the statistical analysis of high wind speeds, as it is an important factor in the selection or development of the most appropriate extreme value distributions to be fitted to the wind data. A map of the strong wind climatic zones can be described as a basic diagram indicating the spheres of influence of specific weather systems that are likely to cause strong winds.

The data that were utilised for the determination of the possible sources of annual maximum wind gusts were forthcoming from 91 weather stations, of which the positions are spatially well distributed throughout South Africa. The different sources of annual maximum wind gust values were identified as follows: The annual maximum 2-3 second wind gust values were identified for each year of the time series. Then the 5-minute time series of the climatic data, of which the variables are the maximum wind gust, mean wind speed, mean wind direction, surface temperature, rainfall, relative humidity and surface pressure, were plotted for those days that the annual maximum gusts occurred, to enable the identification of the causes of the maximum gusts. Evidence of the prevailing weather systems, identified from synoptic charts published in the SAWS Daily Weather Bulletin [2], was used to confirm the strong-wind producing mechanisms identified from the plots of the 5-minute time series.

The climatological analysis of the measured wind data produced six sources of annual maximum wind gust values. The fractions of annual maximum wind gusts caused by these sources are presented for each station utilised in the study. From the analysis it was found that the cold fronts and the other strong wind mechanisms derived from mature storms dominate along the coast and the adjacent interior, while the thunderstorms dominate further inland. Also, it is clear that the different strong wind zones that can be derived from this information will overlap. These derived zones are depicted on separate maps, which are presented in Fig. 1.

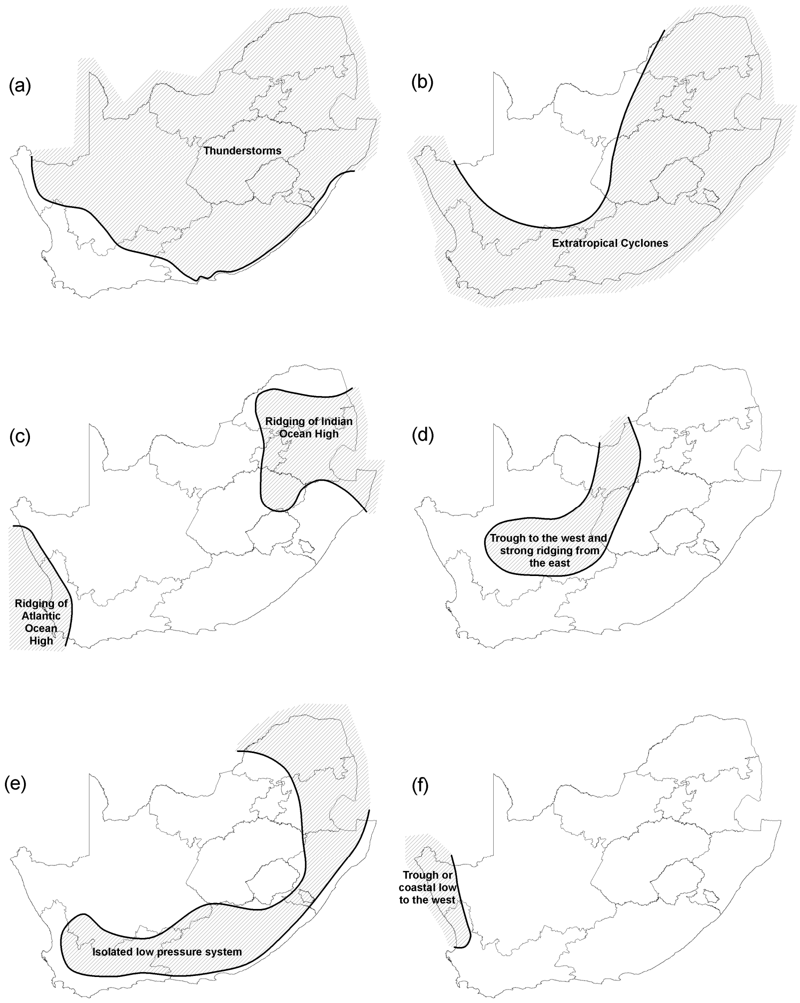

Fig. 1. Zones with extreme winds possible as a result of (a) thunderstorms, (b) cold fronts, (c) ridging of the Atlantic or Indian Ocean high pressure systems, (d) a surface trough to the west and strong ridging from the east, (e) convergence towards isolated low pressure systems or deep coastal low pressure systems on the coast, and (f) a deep surface trough to the west on the West Coast. Shading which extends over South Africa's borders indicates that the influence of the particular mechanism probably extend beyond the border or coastline [1].

3 THE ESTIMATION OF THE EXTREME WINDS

In mixed strong wind climates, alternative methods to the traditional Gumbel analysis method of estimating extreme wind speed probabilities, are advised. Such methods tend to yield more accurate estimates of annual wind speed maxima for long return periods greater than 50 years [3]; [4]; [5]. The method first developed by Gomes and Vickery [3] use the combined distribution of the strong wind events, determined as the sum of the individual risks of exceedances for each of the strong wind mechanisms. It follows then that for this methodology to be applied, the dispersion and mode parameters need to be determined for all the strong wind producing mechanisms. Firstly, these mechanisms need to be identified, and then the annual maximum wind gust values forthcoming from each strong wind mechanism identified. From the separate datasets for each strong wind mechanism, the distribution parameters are then estimated according to the usual ways for the Gumbel method. To illustrate the method, the annual maximum wind gust distribution for Uitenhage, which is located in the south-eastern interior of the country, is discussed. Here the most extreme wind gusts are caused by thunderstorms. However, cold fronts are the causes of the annual maximum wind gusts on eight of the available 11 years of data. The average of the values for cold fronts is 25,2 m/s, which is higher than the average of the values for thunderstorms at 19,8 m/s. However, the value of the dispersion parameter, α, is 1,8 for cold fronts and 3,8 for thunderstorms. This larger value for α results in a shallower slope in the extreme wind gust distribution graph for thunderstorms, as well as for the mixed climate, as presented in Fig. 2.

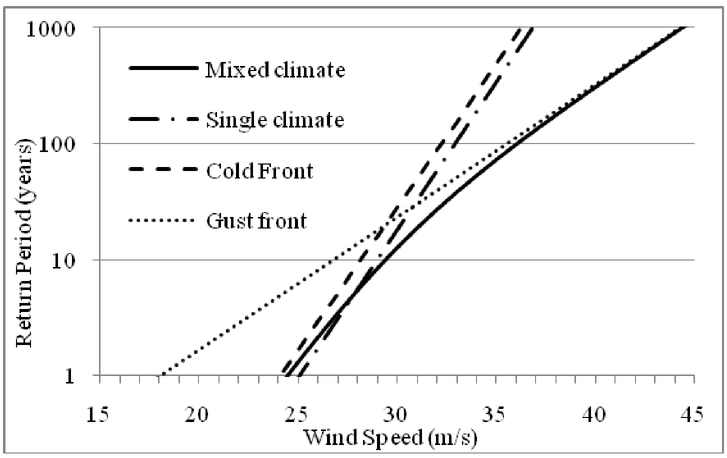

Fig. 2. Extreme wind gust distribution for Uitenhage.

4 CONCLUSION

For the estimation of quantiles for the return periods longer than approximately 50 years, it is advisable or "safer" to follow a mixed distribution approach. This method is applicable to the strong wind estimations in South Africa, as well as the other countries where most of the land area is influenced by more than one strong wind producing mechanism.

5 REFERENCES

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