11B.1 OPTIMAL APPLICATION OF CLIMATE DATA TO THE DEVELOPMENT OF DESIGN WIND SPEEDS

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1. INTRODUCTION

Accurate extreme wind statistics are important for the design of a safe and economic built environment. The recent revision of the South African Wind Loading Code for engineers (SANS 10160-3:2011) will also include a reassessment of design wind speed statistics. In addition, the Wind Atlas of South Africa (WASA project) focuses, amongst others, on the development of a Regional Extreme Wind Climate (REWC) for South Africa. Wind farms are planned for areas with relatively strong and sustained winds, with wind turbines classed according to their suitability for different wind conditions. The REWC statistics are used during the construction and design phase to make assumptions about the local strong wind climate that the wind turbines will be exposed to, with the local environment and topography as additional input.

The simultaneous development of the REWC and revision of the extreme wind statistics of South Africa created an opportunity to bring together a range of expertise that could contribute to the optimal development of design wind speed information. These include the knowledge of the statistical extraction of extreme wind observations from reanalysis and model data, the quality control and extreme value analysis of measured wind data, the reliability basis of statistical results, and the principles of wind action on structures and its standardization.

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2. METHODS AND RESULTS

2.1 *Reanalysis and Model Data*

The estimation of extreme winds with reanalysis and model data has the advantage that it is possible to obtain statistics at a relatively high spatial resolution. This is especially the case for mesoscale model data where, in South Africa, statistics could be estimated at a resolution of 4km. New methods are continuously researched to obtain high spatial resolution statistics from data with a low time resolution, typically at six-hour intervals.

In the case of the reanalysis data, the extreme wind quantiles are estimated using the Annual Maximum Method (AMM), with the Gumbel distribution (Gumbel 1958). The annual maximum winds of the standard conditions are derived using two approaches, namely the application of the geostrophic wind (Larsén and Mann 2009), as well as the surface wind and a generalization procedure (Badger et al. 2010 and Larsén *et al.* 2012a). Spectral correction is then applied (Larsén *et al.* 2012b) in order to augment the wind variability in a certain range of frequency, to the modelled time series. However, the temporal variability of the wind speed is missed out by the smoothing effect embedded in the numerical modelling.

WRF simulations were done for yearly strongest storms at each grid point of CFSR reanalysis data from 1998 – 2010, for different regions in South Africa, exhibiting either complex topography or strong wind climates. Particularly for regions with complex topography, this was done to resolve the high-density statistics over sizable regions where no measurements exist. Figure 1 presents the 50-year 10-min wind at standard conditions for the South-Western Cape, one of the most topographically complex regions in South Africa.

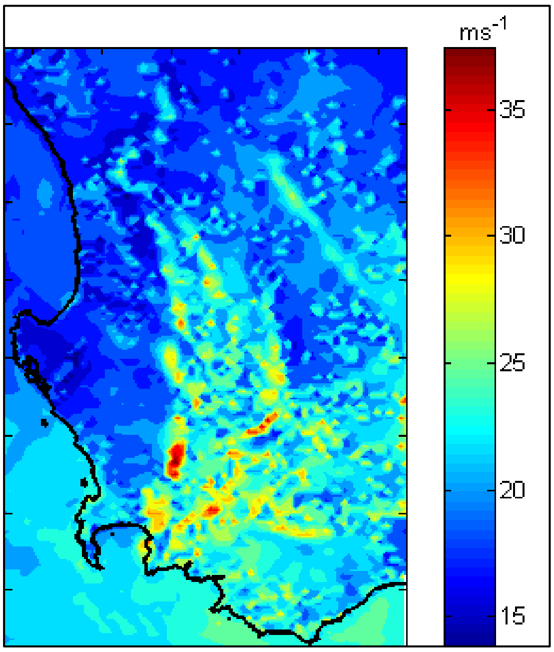

Figure 1. 1:50-Year 10-min wind speed (m/s), from WRF simulations at 4-km resolution.

2.2 *Measured Data*

South Africa is, in some regions, dominated by a mixed strong wind climate (Kruger *et al.* 2010). Figures 2(a) and (b) present the dominance of the different strong wind mechanisms at the hourly and 2-3 s gust time-scales respectively. The methodologies using reanalysis of the data can become inappropriate for shorter time scales, as these were developed for strong wind climates dominated by synoptic-scale systems. Therefore, the extreme value analysis of the measured data serves as the major input in the development of extreme wind statistics, especially at the very short time-scales.

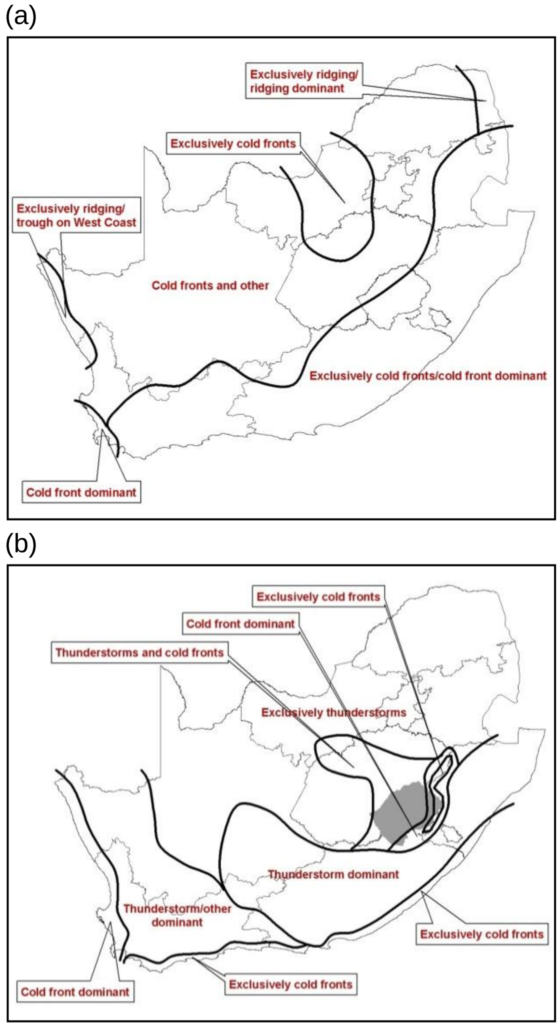

Figure 2 (a and b). Dominant strong wind mechanisms at the hourly and 2-3 s gust time-scales respectively (Kruger 2010).

In the analysis of measured data, various factors are considered which influence the appropriate analysis of the data, including record lengths, relevant strong wind mechanisms, and types of instrumentation and measuring environments. Figures 3 (a and b) presents the 1:50 year design wind speeds at the hourly- and gust-scales respectively, derived from the analysis of the wind measurements at 74 weather stations distributed throughout South Africa.

Figure 4 presents an optimal procedure, highlighting the sequence of the various factors to be considered in the analysis of measured wind data.

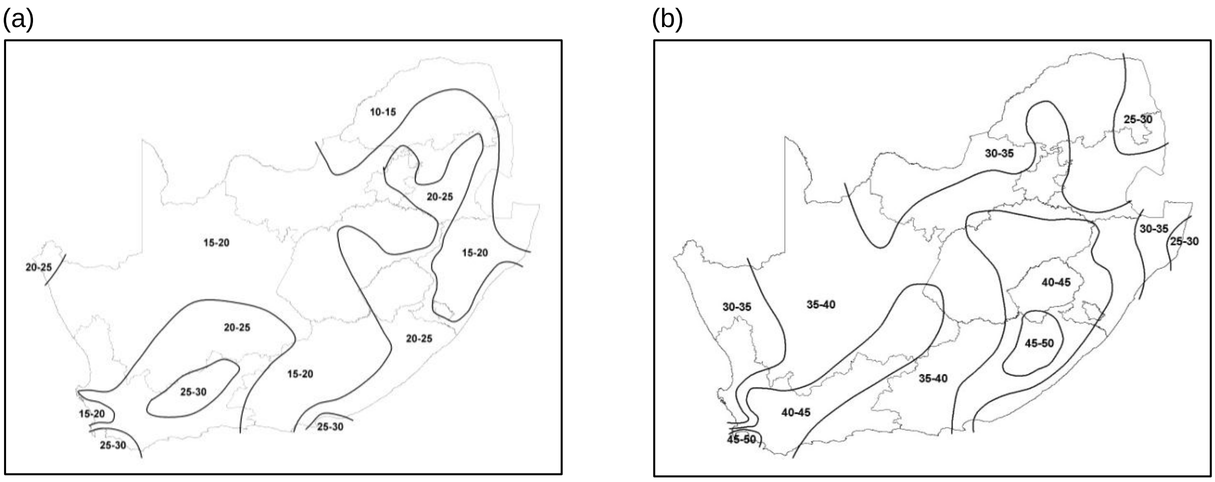

Figure 3 (a and b). 1:50-Year hourly wind and 2-3 sec gust speeds (m/s) respectively, estimated from measured data.

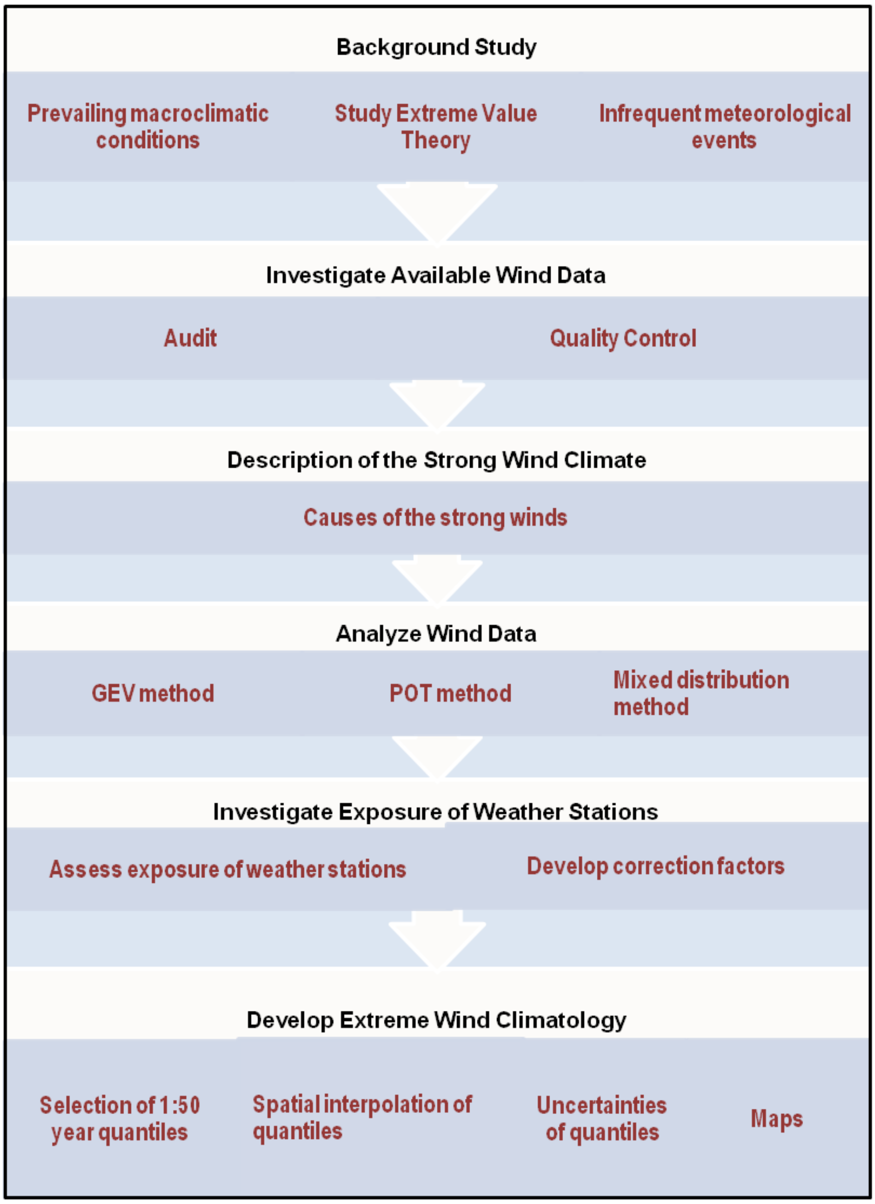

Figure 4. Optimal procedure for the estimation of design wind speeds from measured data (Kruger 2010).

2.3 *Combinations of results from different approaches*

Figures 1 and 3 illustrate the different results obtained from the approaches discussed. While it can be argued that with the optimal analysis of measured data more accurate results can be obtained, many regions across the world are hampered by inadequate weather observation networks. The synthesis of reanalysis and model data provides an opportunity to overcome this challenge to a large degree. However, the reliability of the results ultimately depends on the accuracy of the data, but to a larger extent the prevailing strong wind climate. Especially at shorter time-scales where mesoscale systems sometimes dominate, results from measured data should be deemed to be more accurate.

Figure 5 presents the 1:50 year 10 min wind speed for the WASA Phase I domain over South Africa, as derived from measured data. It was found that the results from reanalysis and model data (see example in Figure 1) conformed to a large extent to the results shown in Figure 5. Figure 6 presents the combined results from model and measured data for the WASA Phase I domain.

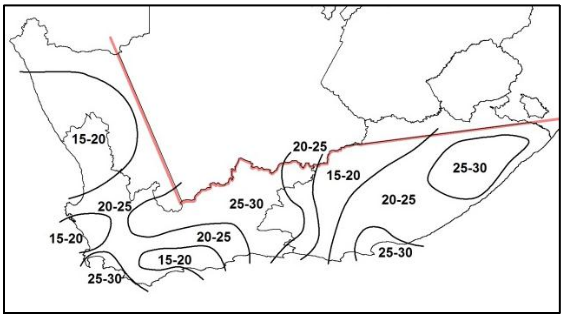

Figure 5. 1:50 Year 10 min wind speed (m/s) for the WASA domain, derived from measured data.

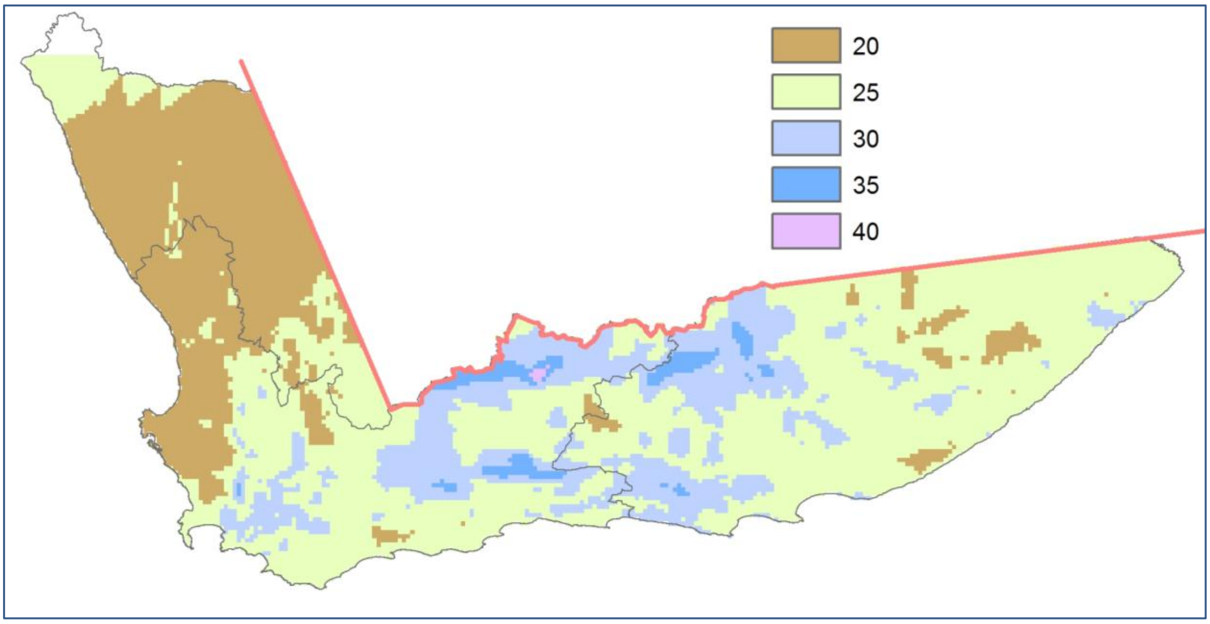

Figure 6. 1:50 Year 10 min wind speed (m/s) for the WASA domain, derived from model and measured data combined.

3. RELIABILITY ANALYSIS

The probability models applied in the reliability analysis should represent both the natural variability of strong winds and the uncertainties resulting from the phenomenological and statistical bases of the models. In converting the probability models into operational design procedures, provision needs to be made in terms of regional characteristics on the one hand and a range of design conditions and situations.

Based on standardized structural design procedures strong wind, at a given location, is typically defined in terms of a 50-year return period quantile defined as the characteristic value. Regional distribution is obtained by mapping the results from the network of observations with sufficient resolution to capture geographical trends, but also sufficiently simplified to be used for operational design (Retief *et al.* 2013). Normalized probability models per strong wind sub-region are used to derive design values from the characteristic value wind map.

4. SUMMARY AND CONCLUSIONS

Figure 7 presents a summary of the optimal approach for the estimation of design wind speeds from climate data. The components thereof include the different statistical models to analyse the data, of which the results serve as input into the strong wind models. These again are the major inputs for the reliability models and the strong wind maps. While the reliability framework is considered in the reliability models and the following reliability calibration, the eventual output is the safety factors to be considered in the optimal design of the built environment.

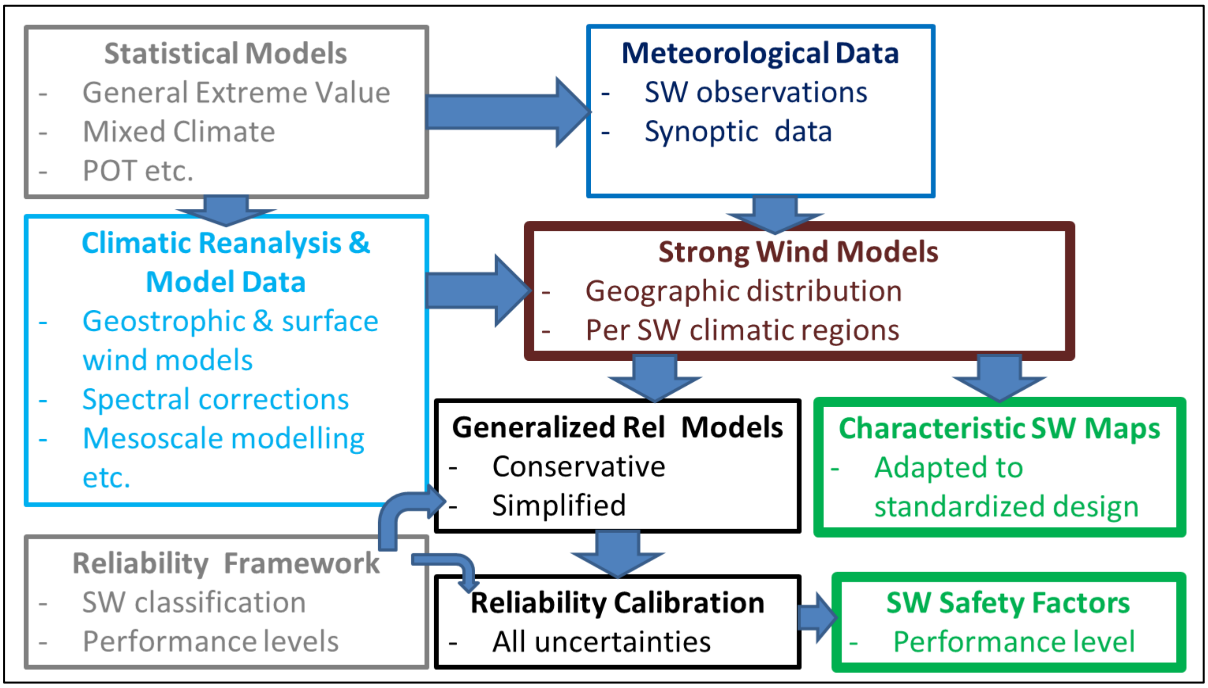

Figure 7. Summary of an optimal approach for the estimation of design wind speeds from climate data.

Investigations so far addressed the unique limitations of both the estimation of the REWC and design wind speeds with measured or reanalysis/model. For the measured data these mainly refer to the quality of the data, the density of the observation network and the significant spatial and regional tendencies of the strong wind climate. For the reanalysis/model approach in South Africa, these refer to the different strong wind mechanisms, prevalence of thunderstorms as a source of strong winds, and the dominance of mixed strong wind climate conditions in some parts of the country. The optimal consideration of these associated strengths and limitations is required in the integration of the results of different approaches.

Eventually, strong wind probability models for the optimal design of the built environment are developed. These take into consideration the inherent uncertainty associated with the occurrence of strong winds, as well as the simplification required to characteristic and design values for use by practitioners in the built environment on the basis of reliability analysis. The process of integrating REWC probability models into the wind engineering and reliability calibration has been initiated as part of the comprehensive approach taken.

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