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Identification of zones of strong wind events in South Africa

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Abstract

This paper summarises the initial stage of development of a wind damage/disaster risk model for South Africa. The aim is to identify the generic zones of various types of strong wind events. The extent of these zones will form the basis for determining the characterisitics of typical wind events and subsequently their probabilities of occurrence. No information of this nature is currently available for South Africa.

Keywords: Wind climate; South Africa; Wind risk model

1. Wind damage/disaster in South Africa

In South Africa, in the absence of significant seismicity, wind forms one of the most devastating environmental factors affecting the built environment. Several significant wind disasters have occurred including recent events at:

- Welkom, 1990 with damage to 4000 houses and 17 power lines,
- Cape Peninsula, 1997 with damage to 4500 housing units (both formal and informal), and
- Umtata, 1998 with 18 people dead and damage to a large number of houses and buildings.

Despite this, no risk model of wind damage for South Africa is available for the disaster management purposes, as the relevant authorities and insurance industry are

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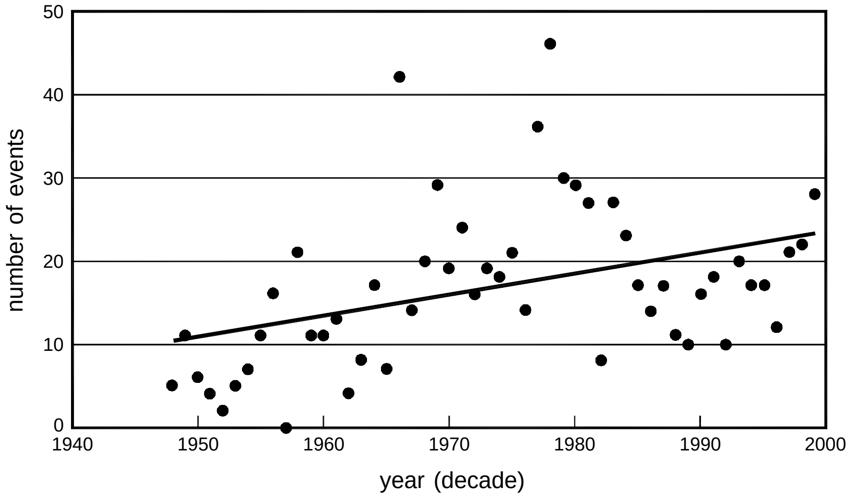

Fig. 1. Yearly distribution of wind damage events in South Africa.

occasionally faced with devastating events of significant social and economical implications.

A database on wind disasters has been set up [1] and the initial analysis indicates a linear trend in which the number of wind damage events reported is increasing, as presented in Fig. 1. This trend could be attributed, to some extent, to increasing population (and therefore development) density, improvement in the reporting procedures and also possibly of climatic change. About 30% of the damaging wind events are tornadoes. A detailed analysis of those events has been published in Goliger et al. [2] including a risk map of tornadic strike as presented in Fig. 2.

2. Wind disaster model

A wind damage/disaster management model is currently being developed as a joint effort between the CSIR and the University of Stellenbosch. This model will include all types of wind events and will consider the influence of several contributing factors, which can broadly be grouped as follows:

- climatic factors, i.e. the characteristics and occurrence of severe storms generating the high winds, wind magnitude, duration, etc.,
- local factors, i.e. the exposure, topography, density, etc.,
- accumulation of assets as a function of population density, distribution of wealth and consequent expansion of the built environment, and
- vulnerability of structures related to engineering aspects of design and construction, mechanism of failure, including the issue of informal human settlements without engineering inputs.

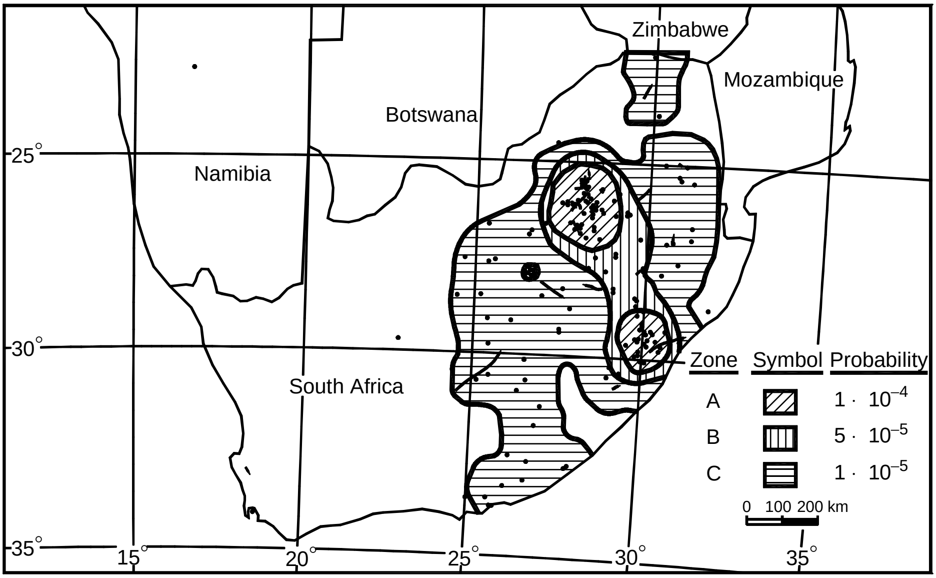

Fig. 2. Mean rate of occurrence of tornadoes in South Africa (per year per km^2).

The current paper summarises the development of a map of geographical zones of dominant types of strong winds in South Africa. No information in this respect is available apart of general meteorological division of the country into 15 climatic zones, without any consideration given to wind climate [3].

3. Risk of wind damage

The risk of wind damage at a particular point is related (amongst others) to the probability of wind speeds of damaging magnitudes being exceeded at that point, and such philosophy has also been adopted in international codification practice. The basic design wind speeds for a geographical area are determined by an extreme value analysis of the measured time series at specific locations within that area, using one of the recognised tools of extreme value analysis. The acceptable levels of occurrence of extreme winds are determined and depending on the density of the recording stations, contour lines of wind speeds are developed.

Some of the wind risk models presented in the literature are based on this principle such as the model for potential cyclonic damage in Australia developed by Leicester et al. [4].

This method assumes that any point within a geographical area of concern, has the same probability of occurrence of extreme winds. From a disaster management point of view, the shortcoming of this assumption is that it does not take into account the type and spatial extent of individual extreme events. Furthermore, as far as South African conditions are concerned, two other shortcomings are apparent, namely:

- the assumption ignores the climatic diversity of the country (ranging from sub-tropical climate to deserts), i.e. the differences in characteristics of extreme wind events, which are significant, and
- the poor distribution of reliable, long-term recording stations (16 covering an area of 1.2 million km^2), constitutes poor representativity of the data.

Another approach is to consider the spatial extent of representative strong wind events (i.e. their footprints) and their average rate of occurrence within a geographical area and from that to determine the probability of damaging winds per unit area. Such approach has been used by McDonald [5] in his analysis of the risk of tornadic strike and more recently Drayton et al. [6] in their study of winter storms in Europe.

The current model follows the latter approach and is based on geographical zones of dominant types of strong winds and the data on their occurrence and extent. The development of such information on the basis of statistically sound analysis is not feasible for South Africa as it would require a separate long-term research project together with substantial financial resources. In such a project, a large number of individual events would have to be identified, monitored, studied and indexed, in respect to their type, geographical extent (using a GIS system) and wind characteristics.

In this situation, it was decided to develop a 'first approximation' set of data based on the limited information from relevant literature and by accessing, extracting, analysing and interpreting the information, expertise and experience of selected experts at the SA Weather Bureau. The development process was carried out by means of a series of informal workshops and discussions organised, facilitated and documented by the CSIR.

4. Zones of strong winds

Two distinct types of extreme winds were identified as

- inland, and
- coastal/frontal.

The development process of zones of strong winds was aimed at identifying the dominant types of extreme winds in each zone and does not exclude various 'overlaps' between zones. Furthermore, the process was aimed at those wind characteristics which affect the lowest regions of the boundary layer (i.e. the built environment), as opposed to the climatological origin and upper level mechanisms of the air mass movement. The entire process was based on a principle in which in case of any doubts or lack of information, assumptions were made in which the contributing factors were underestimated rather than overestimated. An iterative analysis of various types of wind events in South Africa has lead to the identification of the following zones of strong winds:

- Zone 1: weak to moderate thunderstorms with an occurrence rate between 20 and 50 days with thunder per year,
- Zone 2: weak, moderate and strong thunderstorms with an occurrence rate between 50 and 80 days with thunder per year,
- Zone 3: all above plus intense thunderstorms (i.e. super-cells and squall lines) which produce tornadoes and downbursts,
- Zone 4: Coastal low-busters.
- Zone 5: Cut-off lows Easterly and Westerly,
- Zone 6: Coastal low-shallow South-Easterly, and
- Zone 7: Mid-latitude low.

4.1. Inland winds

The extreme inland winds originate typically as a result of severe convective activity. The extent of Zones 1 and 2 (and to a lesser extent Zone 3) was derived from an interpretation of the data sheet on yearly distribution of recorded thunderstorm flashes in South Africa [7] and the Weather Bureau publication [3]. Their distribution is presented in Fig. 3.

An attempt was made in the current project to develop a set of generic characteristics of thunderstorms in Zones 1–3. This was based on several publications [8–11]. In many cases because of the lack of relevant data, the information had been inferred and/or extrapolated. The spatial extent (i.e. a footprints) of 'representative' thunderstorms for each type have been derived from the Lemon Technique [11]. The average number of occurrences was obtained by interpreting and extrapolating the results of the analysis of more than 3000 events recorded during the research programme in Bethlehem [9].

The above data enabled us to determine an average occurrence rate for each type of thunderstorm event, by considering the coverage area of the Bethlehem radar and normalising it by the average number of events per year and average area of each type of event. The resultant information is summarised below.

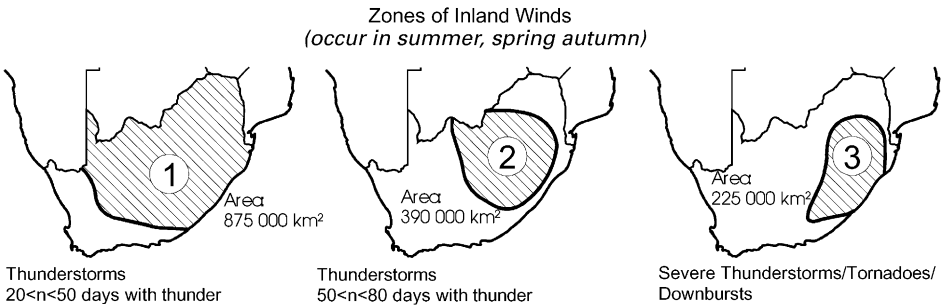

Fig. 3. Zones of inland winds.

4.1.1. Zone 1

The width of weak to moderate (Airmass) thunderstorm cells in South Africa is typically 10 km and the length (i.e. the total travel distance) about 30 km. The travel speed is typically between 20 and 30 km/h. The maxima gust wind speeds at ground level are in the order of 20–30 m/s and the duration 20–30 min (for a single cell storm).

4.1.2. Zone 2

Zone 2 experiences weak, moderate (see Zone 1) and also strong thunderstorms. The width of a strong thunderstorm cell is typically 15 km and the length (i.e. the travel distance) about 45 km. The travel speed is about 30 km/h. The maxima gust wind speeds at the ground level are in the order of 25–30 m/s.

4.1.3. Zone 3

Zone 3 can experience the weak, moderate, strong and intense thunderstorms. The spatial extent of typical intense thunderstorm is 30×60 km but there is no information on their travel speed, which is assumed to be 30 km/h. The maximum wind speeds generated are between 30 and 50 m/s, and these are often associated with localised events like downbursts and tornadoes. About 10 intense thunderstorms, on average, develop in South Africa per year, approximately over Gauteng, Mpumalanga, KwaZulu Natal and the Eastern Cape.

4.2. Coastal winds

The coastal winds result from frontal low-pressure systems. These systems may occasionally be accompanied by convective activities and in extreme cases can produce tornadoes, like the one over the Cape Flats on 29 August 1999 [12]. The distribution of Zones 4–7 is presented in Fig. 4. Their extent was established on the basis of the inputs of the Weather Bureau experts acknowledged in Section 6 and also the research of Hunter [13]. Note also that at the time of preparation of the current paper, some aspects relating to the extent of the coastal events were still under investigation and are not reported in the paper.

4.2.1. Zone 4

The Busters are linked to the passage of shallow (about 1 km high) coastal lows moving north-eastwards along the eastern coast of the country between Algoa Bay (west of East London) and the Mozambican Channel. The width of the zone is about 800 km and the inland penetration is 50 km.

About 30 busters occur on average per year, with 10 of them being assumed to be more severe (say up to 30 m/s) and remaining 20 with wind speeds of up to 20 m/s.

The busters can develop very rapidly with a sudden rise in wind speeds from calm to 20 m/s and this can be devastating to shipping operations and coastal structures. The typical duration of busters is between 20 and 30 min.

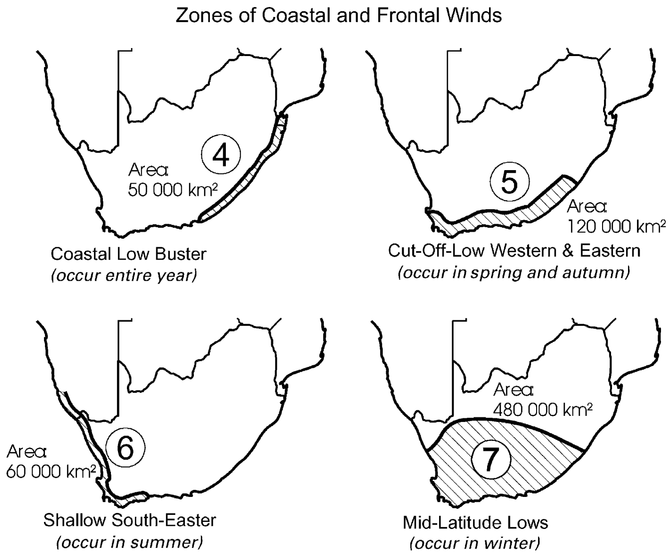

Fig. 4. Zones of coastal/frontal winds.

4.2.2. Zone 5

The Cut-Off Lows develop in extra-tropical cyclones: Easterly cut-off lows affect the coast lines between the Cape Town and Maputo and Westerly ones, the western and southern coast. In the south-western Cape the cut-off lows are influenced by the dominant topography.

The width of these systems is typically between 300 and 400 km and they penetrate about 100 km inland. On average about 10 events occur in Zone 5 per year.

4.2.3. Zone 6

Shallow South-Easterly Trade Winds develop as a result of localised coastal lows and their influence extends along the western and southern coast of South Africa, from Luderitz to Mossel Bay. In Namibia, a marked component of the afternoon sea breeze is evident.

The spatial extent of the coastal-low south-easters is more or less 500 km along the coast and 50 km inland. Because of their low depth (about 1 km), they can be influenced by topography.

A typical example of such winds is the famous ‘Cape Doctor’. Its average duration is between 1 and 2 days (1–2), although often several coastal lows form one after the other, and the total duration (including the periods of calm) appears to be 5–7 days.

It is estimated that in total, about 30 events of 1–2 day duration occur along the coast. The wind speeds generated by the South-Easterly winds are between 25 and 40 m/s.

4.2.4. Zone 7

The mid-latitude large-scale low-circulation systems can affect the coastal areas between the Port Nolloth (on the Namibian border) and East London. Inland they can extend up to 1000 km from the southern coastline as far as Upington and Kimberley. The peak wind speeds are associated with a frontal passage. A typical example was the wind devastation of Cape Town and its surroundings on 16 May 1984.

Between 5 and 10 (5–10) events occur per year and their average area is about 800×800 km. The typical range of wind speeds is between 20 and 30 m/s but occasionally they can reach up to 50 m/s.

5. Authorisation

The authors authorise the 3EACWE Organising Committee to include the contribution in the Conference Proceedings and affirm that no third party copyright restrictions will be violated.

6. Conclusions/future research

A 'first approximation' division of South Africa into generic zones of various types of strong wind events has been developed. Where possible, this includes the initial information on the spatial extent of those events, average number of occurrences and the magnitude of wind speeds. This information will form the basis for the development of a spatial model of risk of wind damage in South Africa. A significant amount of long-term research would be necessary to validate and increase the accuracy of the data.

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