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Comparison and validation of full-scale data from wind measurements in the Cape Peninsula, South Africa

Andries C. Kruger[1], Adam M. Goliger[2], Xiaoli. G. Larsén[3], Ryan Bradley[4] and Johan V. Retief[5]

[1]Climate Service, South African Weather Service, Pretoria, South Africa
[2]Built Environment, Council for Scientific and Industrial Research, Pretoria, South Africa
[3]Wind Energy Department, Risø Campus, Technical University of Denmark, Denmark
[4]School of Civil & Environmental Engineering, University of the Witwatersrand, South Africa
[5]Department of Civil Engineering, University of Stellenbosch, South Africa

Corresponding author: Andries C. Kruger, Andries.Kruger@weathersa.co.za

Abstract

The complexity of the wind climate of Cape Town and its surroundings can be shown by the measurements of specific wind phenomena by weather stations around Table Mountain. It is shown that there are substantial differences between wind speed characteristics affecting various parts of the city. These differences between the wind at the different locations are further complicated by the main strong wind mechanisms prevailing in the region, i.e. north-westerly winds from passing extratropical cyclones, mainly in the austral winter, and south-easterlies from ridging high-pressure systems, mainly in the summer months. This initial investigation is the precursor of a broader study involving wind tunnel modelling, wind measurements and climate modelling, to provide a comprehensive analysis of the spatial variability of strong winds in the Cape Peninsula.

1 Introduction

Severe wind-climatic conditions characterise the Cape Peninsula in South Africa. During the warm season (October to March) this part of subcontinent is directly affected by the south-easterly Trade Winds developing over the southern Atlantic and Indian Ocean. In the austral winter months (May to August) the geographical region is subjected to the mid-latitude frontal depressions, originating over the ocean in the south. The passage of the associated cold front is usually associated with precipitation events and a decrease in temperatures, often resulting in snowfall over the mountainous areas surrounding Cape Town.

The climatic conditions affecting the Cape Peninsula are complex and, over the years, the South African Weather Service introduced several weather stations within the larger metropolitan area of Cape Town and its surroundings (within a radius of about 50 km). Following a few large scale devastating strong-wind events in the Cape Town area, the records of wind speed and direction from various recorders were compared and analysed. In some instances a fair consistency between the records was observed while in some other cases the correlation was poor (both in terms of wind magnitude and direction). It was assumed that the differences between the data sets from various stations are largely due to the dominant topography prevailing over the Cape Town area.

The current paper presents the preliminary comparisons of the data. It forms an initial stage of a comprehensive project in which wind-tunnel topographical modelling will be employed in order to explain and quantify the differences, which are apparent. The mesoscale Weather Research and Forecasting model and its Large Eddy Simulation mode will be used at the same time to investigate the flow over the complex topography.

2 Climatic conditions

The south-easterly strong wind events are usually associated with the ridging (and approach) of the Atlantic Ocean high pressure system (behind a cold front) from the west. An example of such system is presented in Figure 1a, which presents the synoptic chart for 7 November 2012 at 12:00 GMT. It can be seen that the system was relatively strong, with a highest pressure isobar of 1028 hPa. The centre of the system was located to the south-west of the subcontinent, with subsequent ridging into the Western Cape interior.

An important characteristic of such synoptic scale systems is that they produce consistent and strong magnitude south-easterly winds affecting large geographical regions. These winds can only be modified by local influences, i.e. the surrounding of a specific site or topography, and this issue is of importance to the current study.

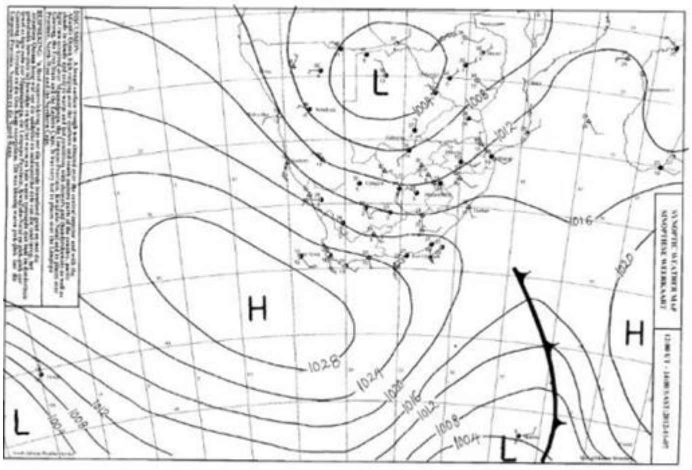

Figure 1a. Typical synoptic situation which generates strong south-easterly winds over the south-western Cape: 7 November 2012 at 12:00 GMT (South African Weather Service, 1992-2013).

Figure 1b presents the synoptic chart for 15 July 2008 at 12:00GMT. This situation often occurs in winter (about once a week), where a cold front approaches the subcontinent from the west. As the front close in, the winds are from the north-west and reach their peak strength with the passage of the front. As the front moves over a specific location the winds change from north-west to south-west.

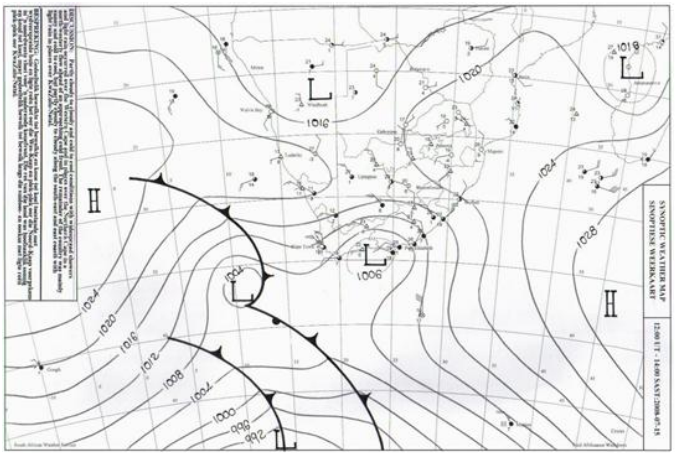

Figure 1b. Typical synoptic situation which generates strong north-westerly winds over the south-western Cape: 15 July 2008 at 12:00 GMT (South African Weather Service, 1992-2013).

3 Influence of Table Mountain

An aerial image of Table Mountain and the adjacent topography is presented in Figure 2. It can be seen that the mountain (with an elevation of about 1 000 m asl) dominates the southerly approach to Cape Town CBD and the port, while Lions Peak and Signal Hill, to the right of the CBD, dominates the western and north-western approach.

Figure 2. Cape Town topography

The influence of the prominent topography on wind conditions within the greater metropolitan area of Cape Town is significant both in terms of the wind magnitude and directional pattern. This has been investigated by Goliger et al. (1990 and 1992). In Figure 3 the directional distribution of local winds in the lee of dominant topography (over the Cape Town city centre and the harbour) is presented. This corresponds to the azimuth of 170° of the free-stream flow approaching the peninsula. It can be seen that the pattern is very complex and spatially sensitive. In some places a significant reorientation of the flow direction is present. Quantitative measurements, which were carried out, indicate drastic changes in mean, peak wind speeds and intensity of turbulence.

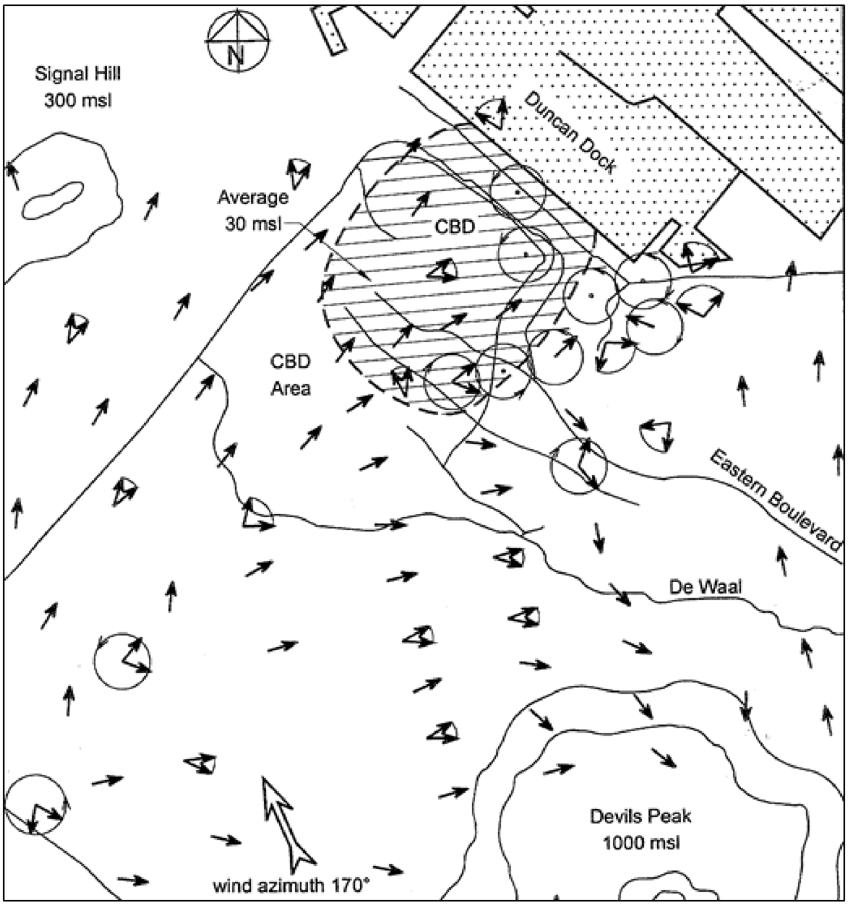

Figure 3. Directional flow pattern in the lee of Table Mountain (Goliger et al., 1992).

4 South African Weather Service wind measurement network

The locations of four SAWS weather stations selected for the current study, is presented in Figure 4, namely:

- Cape Town Weather Office at Cape Town International Airport (due to its excellent positioning to be treated as the reference station),
- Cape Town Royal Yacht Club,
- Kirstenbosch, and
- Molteno Reservoir.

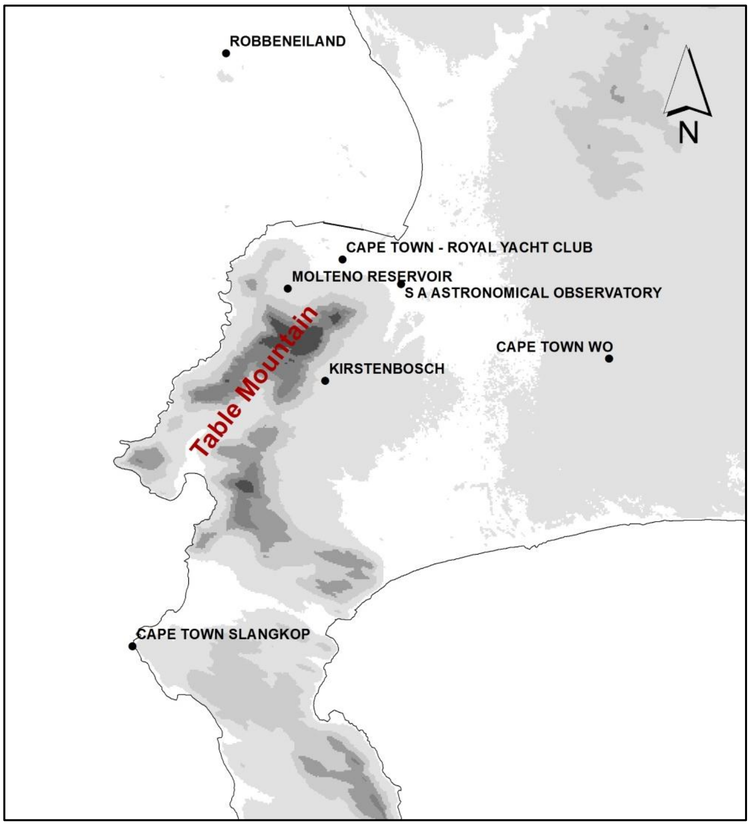

Figure 4. Positions of wind recording stations around Table Mountain.

Table 1. Information on weather stations utilised in the study.

Station name	Latitude	Longitude	Elevation (m)	Data period (5-min)
Cape Town Weather Office	33.9789 S	18.600 E	42	1992-10
Cape Town Royal Yacht Club	33.9204 S	18.443 E	11	2001-05
Kirstenbosch	33.9919 S	18.432 E	156	2010-02
Molteno Reservoir	33.9375 S	18.410 E	97	2001-04

5 Wind data

The differences between wind data from various wind speed recorders will be demonstrated on the basis of the wind speed/direction records from Cape Town International Airport (Figure 5a, treated as the reference data) and CT Royal Yacht Club (Figure 5b), corresponding to the synoptic conditions presented in Figure 1a. Both weather stations are located within a distance of less than 20km, with the airport station having a good wind exposure while the wind flow over the Yacht Club being significantly affected by Table Mountain.

Substantial differences between both time traces are apparent. This is in terms of the overall character, the magnitude of wind speeds and directional characteristics. For example, until about 08h00 the airport data indicates wind speeds below 10 m/s while at the same time the Yacht Club experienced fluctuating wind speeds between 15 and 20 m/s. Furthermore, the airport instrumentation did not record a peak greater than 25 m/s. The Yacht Club data indicates a constant wind azimuth of more or less 180° whereas the Airport directions fluctuate between about 130 ° and 180°.

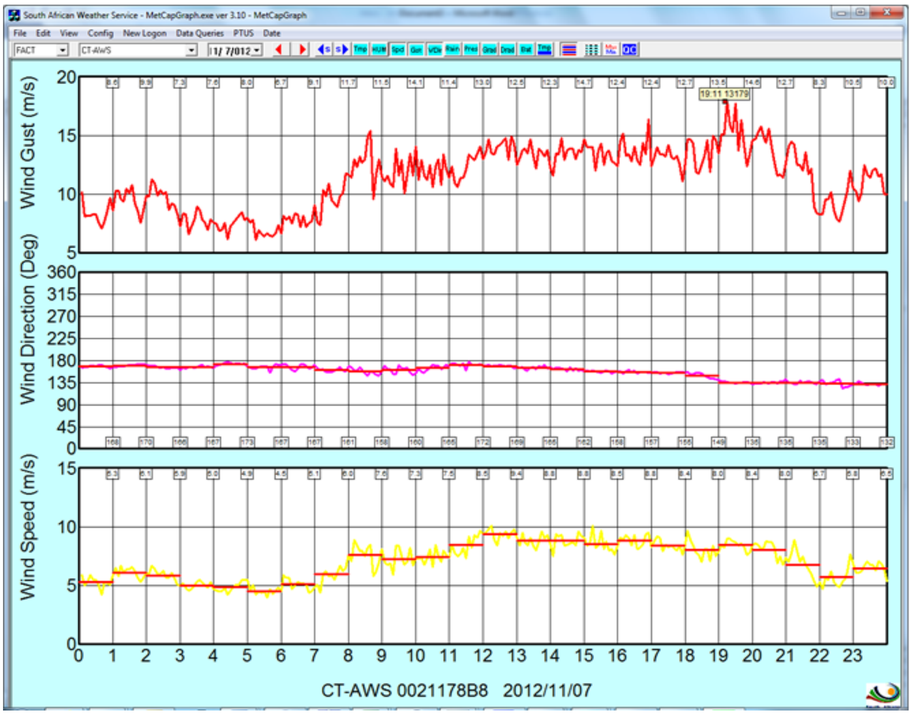

Figure 5a. 5-minute graph of wind gust, speed and direction as measured at Cape Town International Airport on 7 November 2012.

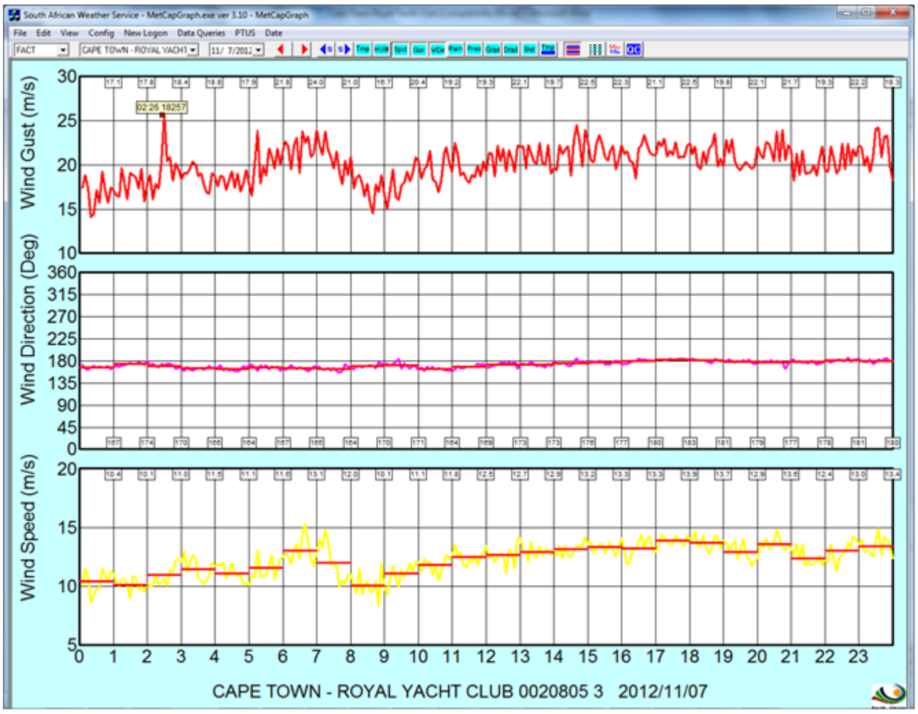

Figure 5b. 5-minute graph of wind gust, speed and direction as measured at the Royal Yacht Club on 7 November 2012.

6 The WRF simulation

The WRF model and its LES mode will be used to simulate the two events shown in Figure 1a and b. The Climate Forecast System Reanalysis (CFSR) data are used as the initial and boundary forcing.

The horizontal resolution is set to be a couple of hundreds of meters for innermost domain covering that shown in Figure 3. The required spatial resolution is examined through the spectral analysis of the topographical data of high resolution. The limitation of the WRF model in resolving fine resolution variability will be discussed. The WRF outputs of wind speed and direction will eventually be compared to the site measurements as well as the wind tunnel experiments.

7 Summary

This summary paper demonstrates the complexity of the wind climate of Cape Town and its surroundings, which results in substantial differences between wind speed characteristics affecting various parts of the metropolitan area. The investigation forms an initial stage of a broader study involving wind tunnel and climate modelling, in order to explain some of the reasons and to quantify the differences between the data obtained from various locations in the area under investigation.

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