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Development of a numerical wind atlas for South Africa

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Abstract

Two verified wind atlases have been developed for South Africa. The first adopted a statistical-dynamical approach and the second a novel, fully dynamical approach. We verify the atlases against an observational wind atlas generated from three years of data from 10 measurement masts. The statistical-dynamical method underestimates the generalized mean wind speeds at the observation sites whereas the fully dynamical method has lower biases and slightly overestimates the generalized mean wind speeds. The dynamical method captures thermally forced dynamical processes and also resolves topographically enhanced flows the statistical-dynamical method cannot.

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1. Introduction

The assessment of wind resource in regions where measurements are sparse usually involves the calculation of a generalized wind climate from observations and models to give an indication of the geographical distribution of wind resource for feasibility studies and decision-making processes. A number of methods are available to construct regional or global wind climates and include simple folklore, measurements only, measure-correlate-predict,

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reanalysis data, and mesoscale modelling [1]. The observation-based wind atlas (OWA) method has become a commonly used method in which microscale modelling produces a generalized regional wind climate based on some input data. The generalized wind climate of a region is an idealized wind climate that would exist if the surface had no obstacles, was flat, had uniform roughness and were subject to the same atmospheric conditions as the measuring position [1].

In regions with poor observational coverage, the OWA method and some form of mesoscale modelling can be combined. One such method uses the Karlsruhe Atmospheric Mesoscale Model (KAMM) [2] and the Wind Atlas Analysis and Application Programme (WAsP) microscale model, more commonly known as the KAMM-WAsP wind atlas method. This method is fully described in [3] and has been validated [4,5] and used to develop wind atlases in a number of regions, e.g. Europe [6,7], Egypt [8] and Finland [9]. More recently, this method has been extended to use the output from the Weather, Research and Forecasting (WRF [10]) Model [11,12].

The Wind Atlas for South Africa project (WASA) has produced two verified wind atlases for parts of South Africa using these two methods. An extensive description of the methods and results are available from [12]. The KAMM-WAsP method is based on a statistical-dynamical way of running the mesoscale model and combining the results, whereas the WRF-WAsP method uses WRF in a fully dynamical mode (see section 1.2). The two methods produced what is called Numerical Wind Atlases (NWA). The WASA project includes a measurement campaign that erected 10 masts with instruments at four levels; the data from which the observational wind atlas (OWA) was developed. A complete description is presented in [13,14].

The OWA results can be compared to generalized wind climates derived from the KAMM- and WRF-based NWA to assess the different mesoscale model methods in a wind energy context – as wind energy is a function of the cube of the wind speed, small differences in wind speeds may have large consequence for energy assessment e.g. a 5% difference in wind speed means up to a 15% difference in kinetic energy flux. The actual energy assessment depends on the wind turbine and its power curve.

This paper presents the two mesoscale model methods and subsequent microscale results to quantify the error of each and wind energy assessment implications.

2. Mesoscale methods

2.1. KAMM

This methodology adopts a statistical-dynamical downscaling approach [15] that assumes a robust relationship between meteorological situations at the large-scale and meteorological situations at the small-scale. The NCEP2 reanalysis data [16] between 1980 and 2009 are used as the large-scale field from which a number of wind classes (large-scale wind circulation states) are developed for three domains over South Africa (Fig. 1). Each of the wind classes (Fig. 2) is downscaled using the mesoscale model KAMM to capture regional scale topographic modification of the wind field. Post-processing of the results from all the simulations yields a wind resource map at the resolution of the model (5 km) at any chosen height above ground level, as well as a generalized [3] wind climate map or numerical wind atlas.

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