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Basic meteorological stations as wind data source: A mesoscalar test ☆

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ABSTRACT

Wind data represent a critical element in different processes associated to wind energy production, as wind resource assessment, wind forecasting, or wind farm control. A large amount of available information is often excluded from the analysis because it is acquired at stations that do not respect completely the World Meteorological Organization (WMO) standards, so that their corresponding collected data could be unreliable for wind energy purposes. However, even if they are distorted by surrounding elements, these abundant data processed as a whole could be an important source of wind measurements. The present work tests the usefulness of the information provided by a group of basic meteorological stations focused on agricultural monitoring. This is done using a simple linear model which extracts a regional wind description from the real measurements. The validation is performed by contrasting with two advanced numerical estimations of the wind climate in the area. The visual and numerical comparison among the estimations shows that basic stations could be considered an interesting source of information, able to help in many wind areas, but also able to supply models specifically designed to work with this kind of data.

1. Introduction

Most of the meteorological stations placed in a large area (destined to agriculture, pollution or fire vigilance) are not used as wind data source because they do not fulfill the minimum requirements to assure a certain degree of reliability in the acquired information, as suggested by World Meteorological Organization (1996). These stations are generally affected by ground effects or obstacles which distort the measurements, and therefore, the evaluation of one of them could not be representative of the wind climate over the area. The imprecision and errors in the acquired data are usually amplified by the position (≈ 2 m a.g.l.) and quality of the instruments. Changes in locations, absent data and measurements out of range are additional problems associated to the recorded time series.

On the other hand, low-quality stations[2] are obviously more abundant than the high quality ones and, in some areas, they are the only real data source. Therefore the exclusion of low quality stations generally involves the exclusion of a large dataset of available real measurements. Furthermore, there exists an increment of this kind of wind data published in Internet sites from public institutions, or even amateur observers, which offers real time and historic time series easy to acquire.

This increasing amount of available data forces to revise the established role of these stations in wind analysis. Considering the presented framework, this study tests the information provided by a net of basic but numerous stations, despite their individual unreliability.

The inclusion of low quality stations in wind analysis represents an enormous expansion of the usable wind data. Thus, the development of methodologies to recycle these excluded data could help in all those aspects in which wind databases are involved (wind resource assessment, wind forecasting, wind farm control, extreme winds, etc.), providing a statistical background to extend, validate or improve the results of the applied methods and calculations (de la Rosa et al., 2011 describes a possible application). Hence, this subject is worthy of a specific study in order to establish a starting point from which different methodologies, depending on the concerned problem, can be implemented to take the most of these data.

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[2] In the present paper, the term ‘low-quality station’ is referred to those stations which do not fulfill the WMO criteria in wind measurement (locations, height, sampling frequency,...). The use of this adjective is not related to errors in calibration or instruments.

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This paper is structured as follows. Section 2 contains a review of the data sources used in different wind resource evaluations. Section 3 describes the models and methodology used in this study to validate the information obtained from low quality stations. Section 4 analyzes the area and wind data involved in the procedure. The description of the proposed model is made in Section 5. Finally, Sections 6 and 7 describe the results and conclusions of this work, respectively.

2. Review of wind data sources in wind potential assessment

The wind potential assessment consists in estimating the near-surface wind distribution to obtain maps in which good emplacements could be enclosed. The principal problem to model the near-surface wind field lies in the variability of wind characteristics at local scales, which involves the difficulty to extrapolate real measurements, specially in complex terrain. Thus, data quality and data density strongly determine the methodologies, accuracy and reliability associated to each estimation. Data are, thereby, a critical element in wind resource assessment.

We have considered appropriated an overview of wind data sources in order to evaluate the possibilities of low quality stations (LQSs) as an additional data source. Attending to the consulted literature about wind resource assessment, meteorological stations are the principal source of information to estimate the wind resource over a selected area. Numerical Weather Prediction (NWP) Models based on simulations of atmospheric global dynamics are the other current source of wind information.

This section can be supported and extended by consulting the study of Al-Yahyai et al. (2010b).

2.1. Surface data

The wind climate estimations based on surface data are generally supported by high quality stations previously subjected to a selection process. The principal objective of this selection is the exclusion of faulty data which could introduce an erroneous description of the wind in the area. So, the historical series and surroundings of the stations are evaluated in order to avoid missing, illogical, or out of range data and sheltering obstacles able to distort the wind information. An overview of the numerous tests and arguments involved in the determination of reliable stations, extendable to all selection processes, is gathered in the inshore analysis of Montenegro (Burlando et al., 2009). Attending to the commented considerations, 18 unreliable stations were ignored and the resulting Montenegro wind map was based on 6 surface stations. The study of Liguria Region (Castino et al., 2003), in which only 14 stations were selected from 140 revised stations, shows how the selective criteria can reduce the number of available stations drastically.

As result of the process, the managed databases can be considered reliable and solid, but the elimination of stations generally generates a low-density grid of measurement points unable to describe mesoscalar or microscalar wind characteristics. Thus, besides the quality of the measurements and the used methodologies, the availability of reliable stations also determines the accuracy of the result.

This assumption can be illustrated considering three wind resource estimations performed over Sicily (Cellura et al., 2008), Hungary (Radicsa and Bartholy, 2008) and Oman (AL-Yahyai et al., 2010a). Each evaluation is based on about 30 stations of similar characteristics and therefore, *a priori*, the used databases contains analogous wind information. However, the differences in the density of stations (1 station per 860, 3200, 7300 km^2 respectively) indicates a clearly different degree of description.

The cases of Sudan (Omer, 2008) and Nigeria (Fadare, 2010) are significant because they can be representative of a high percentage of areas around the world where nets of high quality meteorological stations are not extended enough. Thus, despite that 70 stations with 10 m masts were collected in the evaluation of Sudan, the resulting density of stations is very low (1 station/35 000 km^2). The study of Nigeria gives even a lower density (1 station/51 000 km^2) using 18 stations to evaluate and 10 to validate. These evaluations are based on serious methodologies and procedures, but the use of high quality data penalize the resolution of the estimation, and the addition of more measurements points seems to be suitable.

The most restrictive requirement in the selection processes is the height of the measurement. In order to avoid negative sheltering and ground effects (the principal cause of unreliability), it is suitable the use of stations with masts as high as possible. There exist few studies supported by ideal wind stations with masts of 50 m or higher (Belu and Koracin, 2009; Raichle and Carson, 2008) and even measurements at different levels (Wichser and Klink, 2008). But, probably due to the limited number of stations with these characteristics, no extrapolation technique has been performed in these works and therefore results may be interpreted for guidance only. The search of this kind of information, non-affected by ground distortions, maybe the reason why data acquired below 10 m are rarely considered. In the same way, basic meteorological stations with masts around 2–3 m a.g.l. are not mentioned in none of the revised studies, which indicates that it is assumed that they cannot offer useful wind information. The result is that the majority of these studies is performed using data measured at 10 m a.g.l. (Cellura et al., 2008; Radicsa and Bartholy, 2008; AL-Yahyai et al., 2010a; Burlando et al., 2009; Omer, 2008; Fadare, 2010; Migoya et al., 2007; Bekele and Palm, 2009).

Once wind data from surface stations are collected the principal method to evaluate the wind potential over an area is the statistical analysis (Belu and Koracin, 2009; Raichle and Carson, 2008; Wichser and Klink, 2008; AL-Yahyai et al., 2010a; Omer, 2008). Other works use the extended wind analysis software WAsP to process the observations (Radicsa and Bartholy, 2008; Migoya et al., 2007), despite this tool has limitations in the extrapolation distance and over complex terrains (Bowen and Mortensen, 2004). ANN (Cellura et al., 2008; Fadare, 2010) and CFD (Burlando et al., 2009) models are other tools applied to generate wind maps based on surface measurements.

2.2. NWP data

As mentioned before, in the cases that real measurements are not the principal data source, the wind data are supplied by NWP models. The NWP models generate numerical simulations of the global atmospheric state, which are reanalyzed and stored by some public organizations in meteorological databases, as National Center for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) or European Centre for Medium-Range Weather Forecasts (ECMWFs).

Some studies evaluate wind characteristics directly from these databases, and real measurements are then used to validate (Khan and Iqbal, 2004; Khan et al., 2004; Jewer et al., 2005). But NWP data are generally used as input of models which generate smaller scale grids in order to infer the near-surface wind field. This process, called downscaling, is performed using statistical (Salameh et al., 2009) and/or dynamical considerations. A very extended dynamical downscaling model is the PSU/NCAR fifth-generation Mesoscale Model (MM5) which calculates atmospheric characteristics in a regional scale (NCAR, 2011). In wind resource assessment, the MM5 output is frequently used as initial