J. Wind Eng. Ind. Aerodyn. 119 (2013) 48–52

Contents lists available at SciVerse ScienceDirect

Journal of Wind Engineering and Industrial Aerodynamics

journal homepage: www.elsevier.com/locate/jweia

Spatial persistence in wind analysis

Agustín Agüera-Pérez [a,b,*], José Carlos Palomares-Salas [a,b], Juan José González de la Rosa [a,b,1], Antonio Moreno-Muñoz [a,c]

[a] Research Group PAIDI-TIC-168: Computational Instrumentation and Industrial Electronics (ICEI), Spain
[b] University of Cádiz, Area of Electronics, EPSA Av. Ramón Puyol S/N, E-11202 Algeciras, Cádiz, Spain
[c] University of Córdoba, Area of Electronics, Campus de Rabanales, Leonardo da Vinci building, E-14071 Córdoba, Spain

ARTICLE INFO

Article history:
Received 21 January 2013
Received in revised form
13 May 2013
Accepted 19 May 2013
Available online 8 June 2013

Keywords:
Spatial wind distribution
Persistence
NWP
Weather stations

ABSTRACT

Spatial wind distributions are of high interest in many environmental and economic fields. The diversity of elements, geophysical frameworks and methodologies involved in wind spatial studies makes difficult the comparison among approaches, 'blurring' their contributions. This paper proposes an easy-to-implement model, inspired in the 'persistence' model used in wind forecasting, that can be used as reference in wind spatial studies. The main purpose is to provide a context in which both the difficulty of the concerned problem and the contribution of the applied model can be characterized, allowing the comparison among different studies.

1. Introduction

Surface wind fields are used as input information in different disciplines as wind energy production (Drew et al., 2013), wind loads in structures (Lu et al., 2012), fire propagation (Boboulos and Purvis, 2009), pollutant spread (Nozu and Tamura, 2012) or wind-induced damages to crops and forests (Usbeck et al., 2010). However, spatial wind distributions are difficult to simulate because they present a high variability resulting from the chaotic atmospheric dynamics (Clerc et al., 2012). In addition to these highly variable conditions, the diversity elements and methodologies involved in wind spatial simulations generate a wide range of possible combinations. Thus, the single advances and contributions have hardly been integrated in a general research frame for the scientific community. Consequently, results cannot be sufficiently contextualized and the models cannot be ranked according to their performance.

In order to show this issue, Table 1 approximately describes some recent articles, illustrating time scales (long-term up to 10 min), data (real measurements or synthetic data generated by Numerical Weather Prediction models), methodologies (statistical models, linear models, Computational Fluid Dynamics, Soft Computing), areas (from few to millions of km^2) and the ways in which results are validated.

Simply stated, the wind speed spatial distribution is properly estimated if values of the statistics overcome another estimations under similar validating conditions. Standard validation procedures are supported by real-life wind data, measured according to the directives by the World Meteorological Organization (1996). Typically, these conditions convey the selection of non-sheltered stations with instruments at 10 m a.g.l. However, each validation study has unique characteristics related to the local factors which affect the reference stations. In this sense, it is well known that wind over flat and open terrain is easier to simulate than over complex terrain (Sharples et al., 2010; Lop´ez et al., 2008). As a consequence, it is highly probable to obtain better results from a model that exploits flat terrain data as a source to validate. Thus, the direct comparison among validation results cannot be considered as conclusive about the accuracy and usefulness of the simulations.

Similarly, validation results do not describe the relative importance of both the methodology and the data used to estimate wind distribution. In extreme cases, a reliable wind model supported by faulty data may lead to worse simulations than an unreliable model supported by very descriptive data. Thereby, checking the level of description contained within the raw data is essential in order to establish a starting point in the model evaluation.

An analogous problem is associated to wind forecasting models because chaotic time series are more difficult to predict than stable ones. To solve this, 'temporal persistence' (TP) has been adopted as a reference model (Alexiadis et al., 1999; Kariniotakis et al., 1996). TP is considered the simplest method to forecast wind

* Corresponding author at: Research Group PAIDI-TIC-168: Computational Instrumentation and Industrial Electronics (ICEI), Spain. Tel.: +34 956028069; fax: +34 956028001.
E-mail address: agustin.aguera@uca.es (A. Agüera-Pérez).
URL: http://www.uca.es/grupos-inv/TIC168/ (A. Agüera-Pérez).
[1] Main Researcher of the Research Unit PAIDI-TIC-168.

0167-6105/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jweia.2013.05.011

Table 1
Recent studies.

Ref	Area (Km^2)	Time Resolution	Source	Validation	Model	Errors
Omer, 2008	2 505 000	Long-term	70 Stat	—	Statistical	—
Migoya et al., 2007	8000	Long-term	9 Stat	—	WAsP	—
Fadare, 2010	932 000	Monthly	20 Stat	8 Stat	ANN	MSE MAPE R
Pepper and Wang, 2007	50 000	Monthly	NWP+4 Stat	—	CFD (FEM)	—
Salameh et al., 2009	100 000	6 h-weekly	NWP	6 Stat	Statistical	Explained variance.
Hacène et al., 2012	100	3 h	1 Stat	1 Stat	CFD (mass-consistent)	BIAS comparison WAsP.
Cellura et al., 2008	25 000	1 h	29 Stat	29 Stat	ANN	Not specified
Fueyo and Sanz, 2010	500 000	1 h	NWP	20 Stat	CFD (MM5)	Scatter diagram of Weibull params
Boehme and Wallace, 2008	79 000	1 h	24 Stat	2 Stat	WAsP	BIAS RMSE
AL-Yahyai et al., 2012	212 000	1 h	NWP	6 Stat	Various	BIAS RMSE
Liu et al., 2011	1200	10 min	NWP	274 Stat([a])	CFD	RMSE
Carvalho et al., 2012	200	10 min	NWP	3 Stat	CFD (WRF)	STDE BIAS RMSE
Milashuk and Crane, 2011	10 000	10 min	3 Stat([b])	1 Stat	CFD (RANS)	Avg error STDE([c])
Ferragut et al., 2010	225	10 min	3 Stat	6 Stat	CFD	BIAS MAE

[a] Anemometric data from wind turbines.
[b] Only one station is used in each experiment.
[c] Results expressed as %.

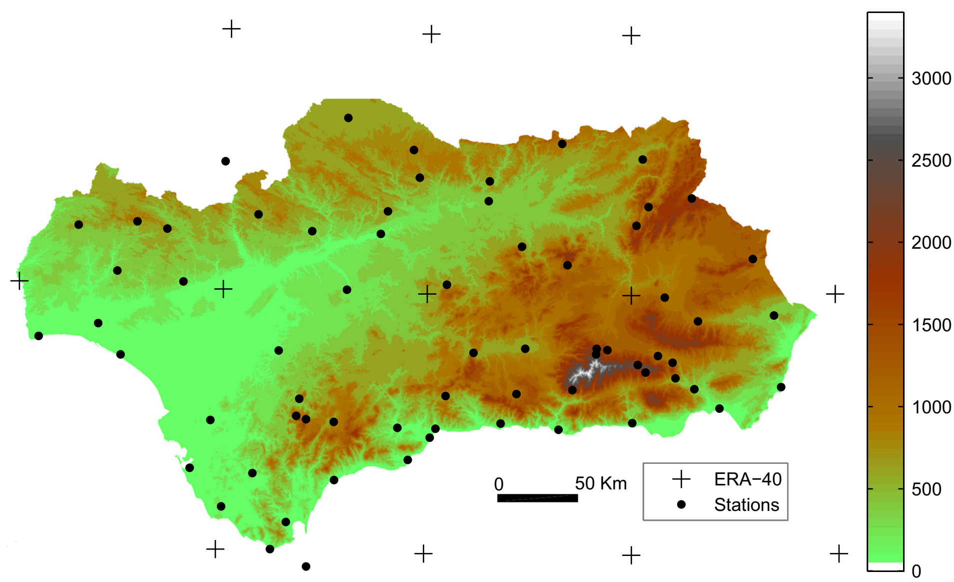

Fig. 1. Studied area and distribution of weather stations and ERA-40 nodes.

speed, since it assumes that the prediction is similar to the immediate former measurement. Hence, only those forecasting models that improve TP results will be promoted.

Provided with this scenario, the main goal of the present work is to transfer this concept to the spatial wind analysis, defining a reference model for an effective comparison of different methodologies. The definition, implementation and interpretation of the reference model are done in Section 3. Real data from weather stations and synthetic data from a NWP model (described in Section 2) are used to support the explanation. Finally, an example is addressed to present the real application.

2. Area and wind data

Andalusia is a region of approximately 87 000 km^2 located in Southern Spain. Grace to its geographical diversity, this land constitutes a perfect scenario to test wind models: mountains of 3500 m, extensive plains and large coasts, along with an important wind potential (more than 3.2 W of installed wind power).

Two different data sources are used: weather stations and Numerical Weather Prediction models. We have compiled data from 67 stations scattered over this area covering the full year 2010. These stations belong to three nets managed by public institutions focused on different objectives (meteorology, forestry, environment). Instrumental and data characteristics are similar among these stations, being the acquisition interval 10 min and the instruments height 10 m a.g.l. Wind speed values out of range ([0–40 m/s]) have been marked as errors. After this filter, valid values represented at least a 85% in each wind series. The information provided by these stations is grouped in four data sets derived from the same original data but presented in terms of daily, 6-h, hourly and 10-min values. These data sets will help test spatial wind properties regarding time scale.

At the same time, reanalysis data from European Center of Medium Range Weather Forecast (ERA 40) have been collected (corresponding to the complete year 2010 in steps of 6 h). Concretely, 12 nodes surrounding the studied region have been selected, and two data sets built considering by 6-h and daily values (Fig. 1).