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An approach for the forecasting of wind strength tailored to routine observational daily wind gust data

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ABSTRACT

Daily wind gusts observed over Spain have been estimated by means of the statistical downscaling analogue model ANPAF developed by the authors. The model diagnoses large-scale atmospheric circulation patterns and subsequently estimates wind probabilities. Several data sets have been used: daily 1000 geopotential height (Z1000) field over the North Atlantic and the observational daily wind gust (WGU). Next, to give an additional value to the ERA-Interim wind gust data base (ERI), wind gust estimations from the analogue model were obtained to compare them with the wind gust data set from the ERA-Interim. The analogue method is based on finding in the historic geopotential height data base, a principal component subset of geopotential height patterns that are the most akin to a geopotential height pattern used as an input. Then, once the analogues are determined associated wind gusts are estimated from them.

Finally, within validation stage are shown some results relative to the comparison between the wind gust estimated and ERI data. The probabilistic results are shown by means of Brier Skill Scores. The results show that the ANPAF model gives good wind gust information in the inner Iberian Peninsula and highlight that the Atlantic atmospheric patterns are, in general, better to predict gusts in such area. Though in only few stations the ANPAF model provides less additional value than the ERA-Interim data base for extreme wind gust values, the analogue model generally provides pretty information in estimating wind gust in Spain to the ERI data set.

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1. Introduction

The fastest growing energy technology has been the wind energy during the last decades. In some European countries as Spain, Ireland, Germany or Denmark, wind power is extensively used. Advances in this source of energy give noticeable benefits as results. Therefore, many efforts are lead to using high potential wind energy resources. Forecasting, modelling and wind data assimilating for safe large-scale wind power integration are the objectives of several studies and research projects (Bermejo et al., 2011; Trombe et al., 2012). The improvement of wind power forecasts by means of dynamic modelling has been progressing along the development of limited area models or ensemble prediction systems, among other methodologies (Pinson, 2012; Pinson and Hagedorn, 2012). However, this methodology bears high computational costs. In order to overcome this problem, the so-called analogue method in a framework of temporal prediction can be used (Lorenz, 1969; Imbert and Benestad, 2005; Pascual et al., 2012). Different studies of climatic and short-range predictions have used the analogue methodology (Ruosteenoja, 1988; Dehn, M., 1999; Timbal and McAvaney, 2001; Timbal et al., 2003). Recently, several works of the authors using the downscaling analogue model ANPAF (ANalog PAttern Finder) have been developed to estimate extreme

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winds (Pascual et al., 2010, 2012). ANPAF finds those patterns within a set of atmospheric circulation patterns that are analogous to an atmospheric situation used as input in the model. Then, associated extreme wind probabilities in Spain using observational wind data are estimated (Pascual et al., 2012).

The ANPAF model starts by applying the principal component analysis (PCA), to the atmospheric circulation field to reduce the dimensionality of the large-scale atmospheric data. PCA is generally used to extract the most remarkable information in a data set, making objectively the meteorological interpretations of the final results (Singh, 2006; Sotillo et al., 2006; Valero et al., 2009; Martin et al., 2010; Aznar et al., 2010; Martín et al., 2011a,b; Garcia-Ortega et al., 2011; Sanchez et al., 2013; Pascual et al., 2013; Riesco et al., 2013). Once the PCA has been applied and the large-scale atmospheric statistical modes have been obtained, the created analogue method is used. There is a weighting function in the model that takes similarities between any given situation (the input pattern) and the past situations (obtained from the PCA) into account. In Pascual et al. (2012) several weighting functions minimizing the distance between the input pattern and the past situations were analysed and finally proposed. Thus, optimum of these distance functions is used to find the most similar atmospheric situations to a given input atmospheric pattern.

The ANPAF model can be considered as a data post-processing of the dynamical model in the sense that the input data is picked up from such model. Moreover, the dynamical model used as input in ANPAF provides estimations of wind gust data. Therefore, in order to propose the ANPAF model as a useful tool, it needs to quantify the degree of improvement that ANPAF provides against the dynamical model results. Following the procedure described in Pascual et al. (2012), the present study starts from obtaining wind gust estimations in Spain by means of the ANPAF downscaling statistical analogue method and comparing these results with the ERA-Interim wind gusts. The ERA-Interim is used as input model in ANPAF. Therefore, the comparison of the results of ANPAF and ERA-Interim will give added information about the skilful of the downscaling statistical analogue model. Thus, Section 2 is devoted to give a brief description of the data sets and the methods applied to the original data sets. Section 3 analyses the analogue results for the observational gust data, in terms of some deterministic and probabilistic tools, offering additional information when comparing these results with the gust data set of the ERA-Interim. The summary and discussion of the main results are drawn in Section 4.

2. Data and methods

In this paper, the daily 1000 hPa geopotential height at 12:00 UTC (Z1000) is used as large-scale atmospheric field. Z1000 data have been used taking into account both the ERA-40 Reanalysis (Gibson et al., 1997; Simmons and Gibson, 2000) and the ERA-Interim (Dee et al., 2011). The Z1000 data are given on a 1.2° × 1.2° latitude × longitude grid, spanning a 20° N to 60° N of latitude and from 51.5° W to 15.5° E of longitude. Although the Iberian Peninsula presents disparity in altitudes, near-surface geopotential heights are selected for representing the large-scale atmospheric circulation at a more realistic height level to obtain more accurate circulation patterns with the observational wind gust over Iberia. On the other hand, the observational daily wind gust (WGU_{OBSERV}) data, coming from in-situ measurements of the station network of the Spanish Meteorological Service (Agencia Estatal de Meteorología, AEMET) are also used. The WGU_{OBSERV} data used in this paper consists of 73 time series of daily wind gusts spatially irregularly distributed in Spain (Fig. 1). Both the observational and Reanalysis data bases present different time coverages (WGU_{OBSERV} from 1933 to 2009, ERA40 Reanalysis from 1971 to 2002 and ERA-Interim from 1990 to 2009). Therefore, taking into account the methodology employed in this paper, the two first data sets finally cover the common period from 1971 to 2002. In this paper, wind gust estimation results obtained from the analogue model are compared with the wind gust data set from the ERA-Interim (WGU_{ERI}). To do this, the WGU_{OBSERV} data set was reduced to a common time period similar to those of ERA-Interim and, finally, from 1990 to 2009 was used for both data bases.

Following Pascual et al. (2012), in this paper wind gust estimations are obtained by means of the methodology based on finding analogues, showing additionally some comparisons against the ERA-Interim data base. To do this, the ANPAF model (Pascual et al., 2012) developed for estimating daily mean wind speeds and daily wind gusts over Spain is used. As it is abovementioned the ANPAF model is based on finding, in a set of atmospheric circulation patterns, those patterns that are analogous to an atmospheric situation used as input in the model. Briefly, the idea is based on the comparison between two scores (one from the historical atmospheric circulation patterns, and another from the atmospheric input pattern) to determine the maximum similarity among them. Here Z1000 is used both as input pattern and as historical atmospheric circulation patterns with which to be compared. Because of the great amount in the freedom degrees of Z1000 it is needed to reduce the inherent noise in the data. To do this, a PCA is previously applied to the Z1000 data base (Joliffe, 1986; Preisendorfer, 1998), obtaining the *scores*, s_{tk}, that are the historical reference field. On the other hand, the atmospheric input pattern score, s_k, is obtained by the projection of the input pattern onto the PCA space and giving the input estimated score. As it is mentioned in the previous section, several distances based on Euclidean distance functions were defined and validated in Pascual et al. (2012). Here the already validated optimum distance function in such paper is used to find the most similar atmospheric situations to a given input atmospheric pattern. Basically, the function distance is based in the Euclidean metric taking into account the scores of the retained PCs and the atmospheric input pattern score, including as well the eigenvalues in order to weight the variability of the different retained PCs. The next step in the process is to find the time/date that minimizes such distance in the PCA space.

Summarizing, the analogue methodology is applied to the Z1000 field in order to find several analogues to a particular Z1000 input pattern. Once the retained different scores (s_{tk}) obtained by applying the PCA to Z1000, they are compared with an input Z1000 score corresponding to a day to be analyzed, S_k, taking the optimum distance function (d_t) into account. Thus, the most similar scores throughout the historic scores time record are found and a set of Z1000 analogues is finally obtained. From them, their corresponding

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