A new spatial prediction model and its application to wind records

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With 6 Figures

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Summary

Contour maps of any meteorological variable cannot give radius or area of influences around the measurement station by considering the records at surrounding sites. The main purpose of this paper is to propose a trigonometric point cumulative semivariogram (TPCSV) concept for deciding on a spatial dependence function and then its use for regional prediction. The TPCSV provides a unique opportunity for the establishment of a regional objective prediction method whereby the radius of influence helps to predict wind velocity at any site by using the weighted averages. The spatial correlations and weightings are obtained through the TPCSV provided that the distance between two sites is known. If the slope of TPCSV is greater than 80° after some distance, then beyond this distance the regional correlation is considered as negligible. The implementation of the proposed methodology is presented for 68 wind velocity measurement stations in Turkey. The proposed method yields the least prediction error compared with other objective methodologies. It is seen that areas of influence at Central Anatolia are generally bigger than coastal areas of Turkey.

1. Introduction

Atmospheric component variations have spatial and temporal features, but in literature temporal variations are often modelled more frequently, and hence there is a need for spatial variation modelling techniques. Spatial variation in many meterological parameters is becoming increasingly significant. Generally, space and time variations are studied separately from each other. Unfortunately, spatial relationships between measurement stations are not studied in detail for point predictions where the measurement of the atmospheric variable is not available.

There are various methods for data interpolation from measurement stations to any desired point, but all lack natural spatial dependence feature (Schlatter, 1988). The first objective analysis method in meteorology is the surface fitting type devised by Panofsky (1949). In this method, the analysis value is represented as a continuous mathematical function, which fits irregularly, spaced observations. Among these methods are the polynomial interpolation (Panofsky, 1949); orthogonal polynomials (Dixon, 1969, 1976); splines (Fritsch, 1971); and finally, spectral approaches (Flattery, 1970). In the empirical linear interpolation approach, the value of any regional variable, ReV, at a particular location is estimated as a weighted sum of observations from the surrounding measurement sites. Among such interpolation techniques are the iterative successive correction methods (Cressman, 1959); and Barnes analysis (Barnes, 1964). Statistical
objective analysis estimation methods determine the weights applicable to each measurement point. The major approaches in this category are the optimal interpolation (Gandin, 1963); the covariance models for atmospheric variable (Buell, 1958); adaptive filtering (Kalman, 1960; Şen, 1980, 1983); and recently, the cumulative semivariogram, (CSV), method (Şen, 1989, 1997). On the other hand, variation techniques include more mathematical abstraction than others such as the incorporation of dynamic constraints (Sasaki, 1958); and fitting models to data at different times (Ledimet and Talagrand, 1986).

The term geostatistics is now widely applied for regional variability modelling in earth sciences as a special branch of applied statistics originally developed by Matheron (1963). Unlike random variables, the ReV has continuous spatial change. The semivariogram (SV) is used to express the rate of this change along a specific distance orientation (Davis, 1986).

As for the wind energy, the spatial modeling procedures are not available in the literature except classical contour maps, which cannot help to make dynamic predictions. Lalas et al. (1983) have shown that the adjusted Weibull and lognormal distributions are adequate for the wind potential estimation in the Aegean Sea region. Additional assessments of wind power in this region are performed by various authors such as Şahin and Şen (1995), Şahin et al. (1998), Öztopal et al. (2000), Şahin and Şen (2001). However, these studies assess data by not considering regional dependence function.

The main purpose of this paper is to develop a methodology that first depicts the regional dependence from an irregular set of stations scattered in an area. Subsequently, radius and area of influences are obtained for each site. By considering the measurement sites within the area of influence the regional prediction is obtained by weighted average method. The application of the methodology is achieved for a set of wind measurement sites in Turkey.

2. Classical methodologies


Any phenomenon that evolves in the atmosphere has spatial and temporal variabilities that are recorded time wise at a single point or spatial wise at many irregular points. It is the purpose of any regional study to search for simple but effective means for capturing the regional dependence structure of the phenomenon concerned. Such an efficient procedure is proposed by Matheron (1963) in mining reserve simulation studies. His proposal is known in the literature as the semivariogram (SV) method which provides basis for the optimum interpolation approach through the Kriging method. Ordinary SV shows the change of regional variability in terms of half-squared differences between two station records and the distance between these stations. In general, the greater the distance the more will be the independence, i.e. at small distances the two records are expected to be closer to each other, and consequently, the change of half-squared differences with the distance is expected to have a non-decreasing form. Unfortunately, this theoretical requirement has not always been observed in the experimental SVs. On the other hand, Şen (1989) has explained the reasons for such discrepancies and subsequently suggested a new version of the SV called the CSV where rather than the half-squared differences, only their summations are considered in depicting the regional dependence.

The PCSV as a version of ordinary CSV suggested by Şen (1989) was applied to investigate some meteorological data by Habib (1993). This is a simple procedure for measuring and then interpreting the regional variability of the ReVs such as the wind speed and energy amounts at various irregularly scattered stations within a given study area. The PCSV procedure is proposed, herein, in identifying the spatial behavior of any variable around a site. In other words, it presents the regional effect from all other sites within the study area on this site, and hence, the number of PCSVs is equal to the number of sites. Comparisons and groupings of the PCSVs provide valuable information for the heterogeneity and isotropy involved in the ReV concerned. The treatment of the following steps leads to