Calibration of Wind Directions in the Mediterranean Sea

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ABSTRACT

Statistical calibration of wind speed is fundamental for obtaining more accurate and consistent measurements in wind energy assessment. In this work, calibration techniques are presented for correcting wind direction at various locations in the Mediterranean Sea. The application of the data from devices, which are considered as reference data sources because of their high measuring precision, and results from numerical weather prediction models and remote sensing instruments, which are corrected since they are considered to be less accurate. The obtained results suggest that the proposed statistical procedure should be applied along with the calibration of wind speed, whenever accurate data are required.

KEY WORDS: directional variables; circular regression; calibration; wind energy; Mediterranean Sea.

INTRODUCTION

The accurate description of met-ocean variables, such as wind speed and direction, significant wave height, wave period and direction, ocean current speed and direction, is fundamental in many engineering, oceanographic and meteorological studies. From a mathematical point of view, the aforementioned variables can be roughly sorted into two categories: 1) linear variables (e.g., wind speed, significant wave height, wave period, ocean current speed) that take values on the real line, and 2) directional (or circular) variables (e.g., wind direction, wave direction, ocean current direction) that take values on a circumference of a unit circle. However, the statistical treatment of linear and directional data from the calculation of simple descriptive statistics to statistical inferences, is dissimilar due to the distinct and unique features of the latter data (e.g., bounded values in a closed space without true zero, sense of rotation, etc.).

Focusing on wind data, when they are available from various data sources, they are very often compared with each other in order to evaluate them and improve their accuracy by implementing validation and calibration procedures. This is due to the fact that each data source is characterized by its own advantages and shortcomings (Cavaleri and Sclavo, 2006; Soukissian and Papadopoulos, 2015). As regards linear variables, it is common practice in the relevant scientific community to consider in situ measurements (usually from oceanographic buoys, meteorological masts, etc.) the most reliable source for measuring such met-ocean parameters and then, assess and enhance the quality of less accurate data sources, such as satellite observations and numerical weather prediction (NWP) models. The primary theoretical background for such applications is linear regression analysis (Ebuchi et al., 2002; Sharma and D’Sa, 2008; Soukissian and Papadopoulos, 2015). In brief, the objective of this methodology is to establish a mathematical relationship between measurements from a reference source (independent variable) and other measuring devices and configurations (dependent variable) and then, apply an inverse procedure for calibration purposes (e.g., predict the independent variable given the dependent variable). However, calibration techniques are very rarely adopted for circular variables (SenGupta et al., 2013), although their accurate prediction seem to be significant in various applications.

In offshore wind energy projects, the reliable estimation of the local wind climate of a candidate area is very important for the assessment of the corresponding energy availability and consequently, for the economic viability of the corresponding structure or farm. For instance, wind direction is a critical variable as regards the micro-siting procedure of offshore wind turbines within an offshore wind farm, since wake effects can affect the efficiency of the optimal aligning of turbines to wind direction (Castellani et al.; 2015; Song et al., 2016). In this respect, wind direction not only should never be neglected in relevant applications but it should be determined as accurately as possible. In reality, the relevant scientific literature as regards calibration of wind direction from various data sources implemented through linear regression analysis is rather poor.

In this work, circular calibration models are presented in an attempt to correct wind direction obtained from both satellite sensors and NWP models with reference to oceanographic buoys deployed in the western and eastern Mediterranean Sea.

The outline of the paper is the following: firstly, the mathematical background theory of circular regression is reviewed, and the adopted regression model is introduced. Then, the concept of calibration follows with the presentation of three different approaches. In the next step, the proposed calibration models are applied on real wind data, after a short description of the data sources and a basic circular statistical analysis. Finally, the obtained results are compared with reference to five statistical measures, which are calculated before and after the calibration procedure, and some conclusions are drawn.