Development of a wind energy climate service based on seasonal climate prediction

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Abstract- *Climate predictions tailored to the wind energy sector represent an innovation to better understand the future variability of wind energy resources. In this work an illustration of the downstream impact of the forecasts as a source of climate information, the post-processed seasonal predictions of wind speed and temperature will be used as input in a transfer model that translates climate information into capacity factor. This transfer model is based on multivariate regression that assumes a linear relationship between wind speed and temperature with the capacity factor.*

Key words: wind energy, seasonal forecasts, capacity factor, bias-correction, climate services

A. Introduction

Operational and economic issues related to wind energy require the modeling and forecasting of the wind power generation processes at a range of temporal and spatial scales (from minutes to decades) [1]. The wind industry has traditionally used forecasts at short (from hours to a few days) time scales due to the strong dependency between the wind energy production and the wind speed synoptic-scale variability [2]. At longer time scales, the need of climate information representative of the next few decades for resource evaluation has raised the interest of the wind energy users in climate projections [3]. Hence, climate predictions whose time scales vary from one month to a decade into the future can cover the existing gap between weather forecasting and climate projections.

At seasonal time scales current energy practices employ a simple approach based on a retrospective observed climatology. Instead, probabilistic seasonal forecasting can better address a long list of challenges to produce climate information that responds to the expectations of the users [4] and that can be used to make specific decisions that affect energy demand and supply, as well as decisions relative to the planning of maintenance work.

The large amount of information that arises from the seasonal forecasts (e.g. uncertainty, skill and reliability assessments, bias-correction techniques, probabilistic approaches) is hard to understand and in most cases the users are not able to incorporate it in a useful manner for their daily activities.

The main goal of this work is to develop tailored climate information that can be afterwards used as a tool to inform wind energy users with greater accuracy than their current approaches.

B. Data and Methods

The probabilistic seasonal forecasts of 10-m wind speed and 2-m temperature from the ECMWF seasonal prediction system, System 4 (S4), in the 1981-2014 period have been used. In addition, the 10- m wind speed and 2-m temperature data from ERA-Interim have been also used as reference dataset.

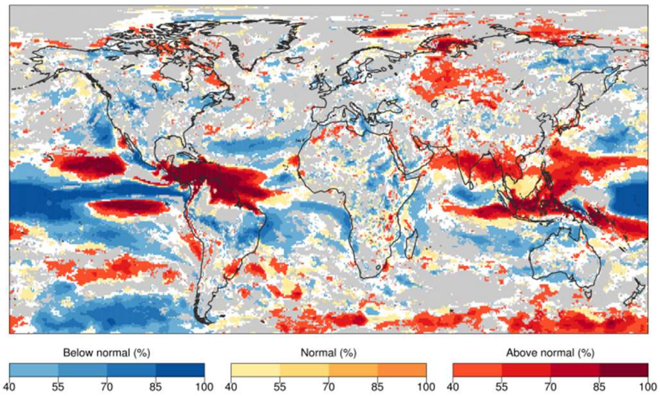

Figure 1*. ECMWF S4 10-m wind speed seasonal forecast for JJA 2015 initialized the 1st of May. The most likely wind speed category (below-normal, normal or above normal) and its percentage probability to occur is shown. White areas show where the probability is less than 40 % and approximately equal for all three categories. Grey areas show where the climate prediction model doesn't improve the climatology.*

Probabilistic forecasts have been used in order to provide users with information about the forecast uncertainty. An example of the probabilistic seasonal forecasts of 10-m wind speed has been illustrated in Figure 1.

The capacity factor (CF) is the average power generated over a period of time, normalized by the maximum power of a wind-turbine. It is a widely used indicator for the wind energy users which provides information about the extent of use in a power plant. The state-of-the art climate prediction systems don't produce this kind of variables, for that reason it is needed the development of an impact model to generate

CF seasonal predictions from climate variables. However, the capacity factor depends on many factors as for example the operating limitations of a wind farm that have not been considered in this analysis.

The impact model is based on a multivariate linear regression (Equation 1) that relates CF with wind speed (ws) and temperature (T).

$$CF(ws, T) = A\,ws + B\,T + C \quad (1)$$

This equation has been used to relate the climatological information of wind speed and temperature from the ERA Interim reanalysis and the seasonal forecasts of such variables for a target period.

The first step has been the estimation of the capacity factor values from the ERA-Interim reanalysis which has been used as reference by the methodology described in [5]. The wind speed, temperature and the derived capacity factor from ERA-Interim are fitted to the equation (1) in order to find the A, B and C coefficients.

As the prediction of wind speed and temperature is affected by biases, three different techniques for the bias-adjustment of ensemble forecasts are considered: simple bias correction, quantile-quantile mapping and calibration method. These methods have been applied on daily data and in "one-year out" cross-validation and they produce corrected forecasts with improved statistical properties. The impact of these different bias corrections techniques over the forecast quality has been explored in a forecast quality assessment.

The bias corrected seasonal predictions of wind speed and temperature has been used as input in the regression model together with the coefficients estimated previously for the reanalysis, and the seasonal predictions of CF are produced.

C. RESULTS

The seasonal average of the CF computed from ERA-Interim wind speed and temperature for a particular region in Canada has been illustrated in the Figure 2. It shows the relationship between the three variables used in the regression model and evidences that wind speed is the main driver of the CF. However, can be noticed that the highest values of CF are mainly produced for high temperatures.

The impact of the bias-adjustments of wind speed and temperature has also been explored. The forecast quality assessment demonstrates that the three considered methods produce forecasts with improved skill and reliability. This is a critical aspect of the forecasts from the user perspective because a good reliability guarantees the trustworthiness of the predictions.

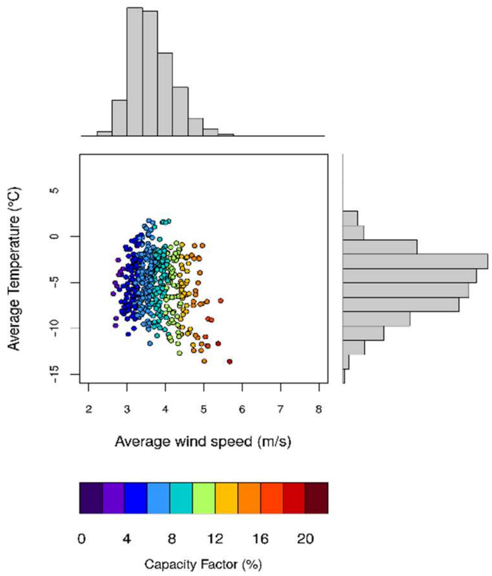

***Figure 2**. Scatter plot of the mean capacity factor (%) for a region in Canada [49.6º-51.7ºN and 246º-248.2º E] in DJF. Marginal histograms of ERA-Interim 10-m wind speed in the x-axis and 2-m temperature in the y-axis for the period of 1981-201.*

The estimated CF from the reanalysis and the bias-corrected forecasts have been used to estimate the predictions of the capacity factor. The output of the regression model is in terms of capacity factor values aggregated in terciles where each percentage indicates the probability of capacity factor being below-normal, normal and above normal. The forecast quality assessment of these predictions reveals that the estimated forecasts for this particular region has positive values which indicates the added value of the seasonal predictions of capacity factor relative to the climatological capacity factor.

D. CONCLUSIONS

This study describes a simple methodology to develop useful information for the wind industry that can be easily integrated in their decision-making processes. Transforming climate variables into a user friendly capacity factor is essential for the wind industry. The quality of these predictions as well as their benefit to the wind energy users should be further explored in different regions around the world.

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