Challenges in the user-oriented verification of wind speed climate predictions

Verónica Torralba[1], Francisco J. Doblas-Reyes[1,2], Nube Gonzalez-Reviriego[1], Llorenç Lledó[1], Raül Marcos[1] and Nicola Cortesi[1]

[1]Earth Sciences Department, Barcelona Supercomputing Center (BSC), Barcelona, Spain , [2]Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain

Seasonal forecast verification for wind energy

- Climate forecast verification tailored to the wind energy sector is aimed to quantify the adequacy of the forecast uncertainty estimates, but also to increase the trustworthiness of these users in the potential added value of these predictions for some particular applications such as the cash flow anticipation or the maintenance planning.
- The assessment of the probabilistic wind speed climate predictions for wind energy applications can be affected by the deficiencies in the forecasts and also in reference datasets: however if these shortcomings are properly characterized it is possible to generate useful information to be included in the wind energy decision making-processes.

Observational uncertainty

- Unavailability of wind speed observational measurements at global scale prevents the forecast verification based on real observations.
- Reanalysis products (ERA-Interim, JRA-55 and MERRA-2) are commonly used by the wind industry as reference datasets, but the quality of the wind speed from global reanalyses is linked to the different methodologies the reanalyses use to infer 10-metre wind speeds from the lowest model level and variations in the observational sources used in the assimilation process.
- Uncertainty has been illustrated in Figure 1 where important differences between the reanalyses in the wind speed long-term variability have been found which shows the sensitivity of the results to the choice of the reanalysis.

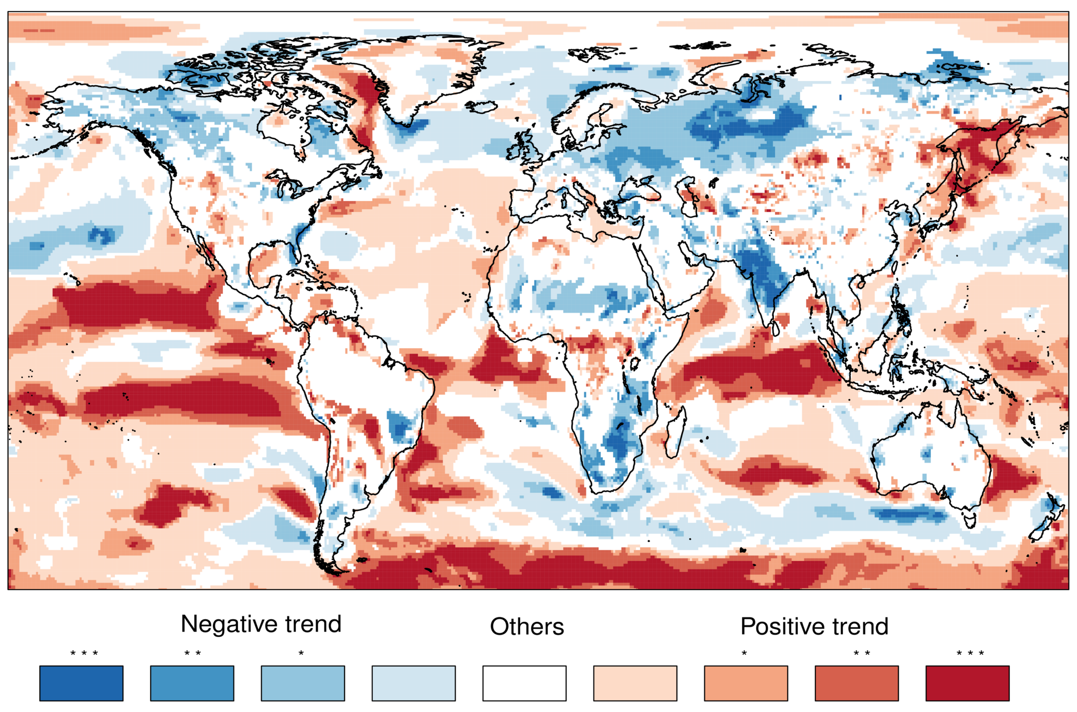

***Figure 1**. Comparison of the 10-m wind speed trends from ERA-Interim, JRA-55 and MERRA-2. Blues (reds) indicate agreement between the reanalyses about the negative (positive) trends for December-January-February in the period 1980-2015. Astersisk indicates that the trends are significant at the 95% confidence level: no asterisk indicates that they are not significant, (*) only one of the renalysis has significant trends, (**) two reanalyses have significant trends, and (***) the three reanalyses have significant trends.*

Prediction systems comparison

- The two state-of-the-art seasonal prediction systems ECMWF S4 and MétéoFrance S4 could be suitable for wind energy applications because they provide seasonal predictions of wind speed at 6-hourly basis.
- The predictions produced by these two systems have been compared to get an overview of their performance and investigate the contribution of the model error to the forecasts uncertainty.
- The comparison of these prediction systems (Figure 2) indicates that the ECMWF S4 displays higher predictability than the Météo-France S4 for wind speed seasonal forecasts, although both of them have positive values in many regions, which indicates that they could add value to climatological approaches.

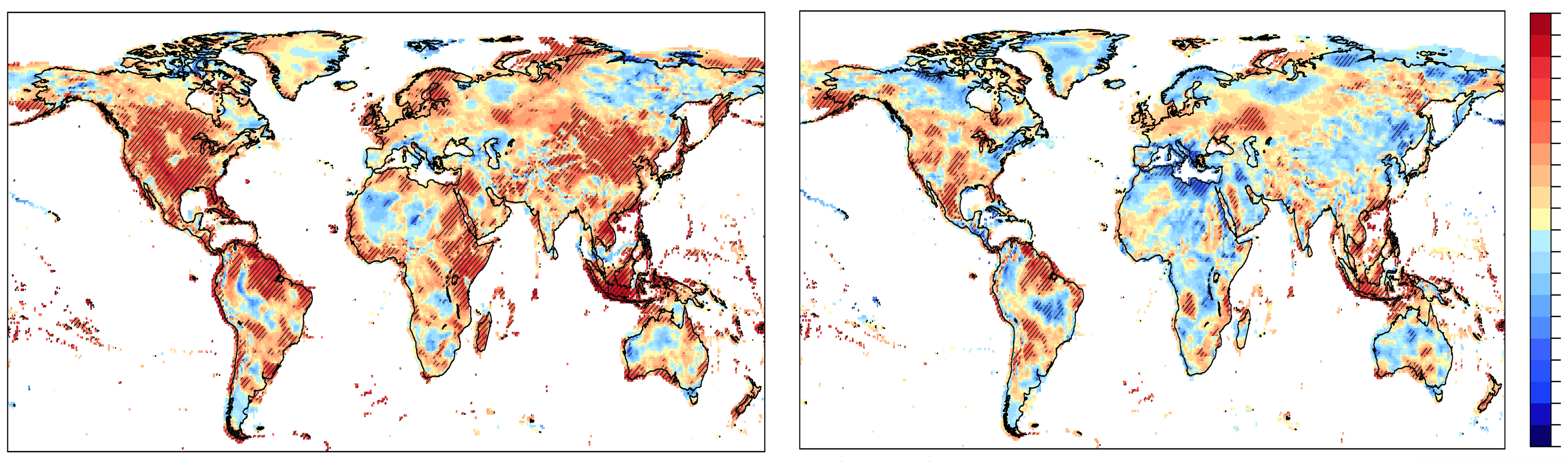

***Figure 2**. Temporal Correlation Coefficient for 10-m wind speed between the ensemble mean forecasts from ECMWF S4 (left)/Météo-France S4 (right) and ERA-Interim reanalysis in winter (DJF). These predictions are initialized the 1st of November for the period 1981-2012.*

Wind statistical properties

To investigate if the seasonal forecasts of wind speed are normally distributed is crucial from the wind energy point of view, because some wind energy applications use simple approaches to characterize the wind energy resources. From the prediction point of view, the study of the distribution normality could help to identify non-linear processes and to explore if they are properly reproduced by the climate prediction systems.

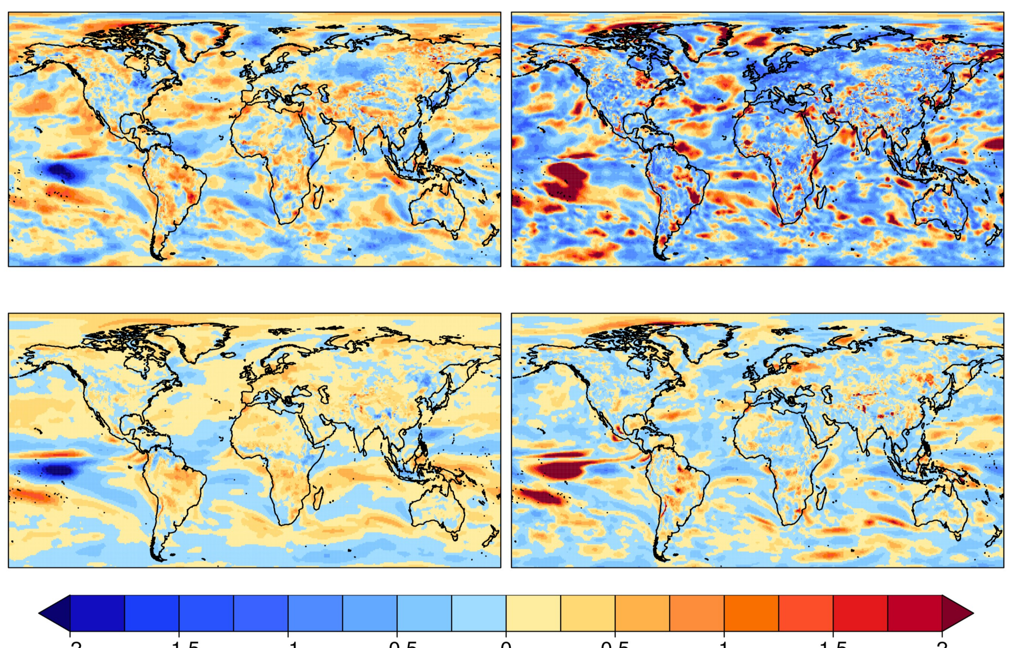

***Figure 3**. a) Skewness of the 10-m wind speed from ERA-Interim b) Kurtosis of the 10-m wind speed from ERA-Interim c) Skewness of the 10-m wind speed from ECMWF S4 and d) Kurtosis of the 10-m wind speed for the boreal winter (December-January-February) over the period of 1981-2015. ECMWF S4 seasonal predictions have been initialized the 1st of November.*

- Skewness of the seasonal predicted wind speed distribution at seasonal time scales (Figure 3) shows that the probability of severe wind speed values is higher than low extremes.
- Kurtosis values show that the predicted distribution has more similar tails to the normal distribution than the wind speed distribution from ERA-Interim (Figure 3).

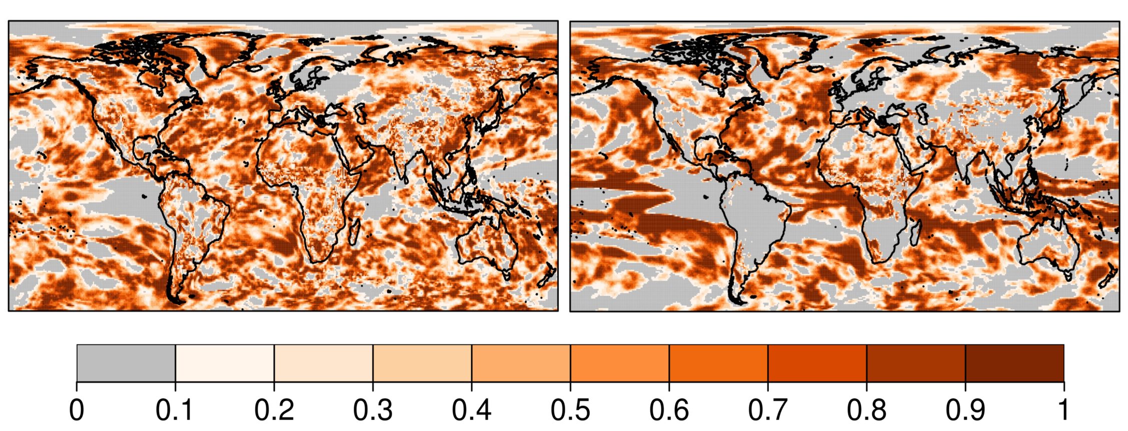

***Figure 4**. Shapiro Wilk goodness-of-fit normality test p-values for the 10-m wind speed in ERA-Interim (left) and ECMWF S4 (right). This corresponds to the boreal Winter (December-January-February) over the period of 1981-2015. ECMWF S4 seasonal predictions have been initialized the 1st of November.*

- The evaluation of the normality in the ERA-Interim (Figure 4) wind speed shows that in most of the regions around the world the normality hypothesis cannot be rejected. However, the number of rejections increases for the seasonal predictions.

Reliability assessment

Apart from biases in the mean and other moments of the distributions (Figures 3) of the predicted variables, for probabilistic forecasts additional difficulties appear such as the lack of forecast reliability. Three methods have been applied: simple bias correction, calibration and quantile-quantile mapping and theiir corresponding reliability diagrams are shown in Figure 5.

- The raw forecast displays poor reliability for the three events.
- The three bias correction methods produce corrected forecasts with better reliability than the uncorrected ones. They display more points falling along the diagonal and more homogeneously populated sharpness diagrams.
- Calibrated forecasts show for the three events slopes closer to one.

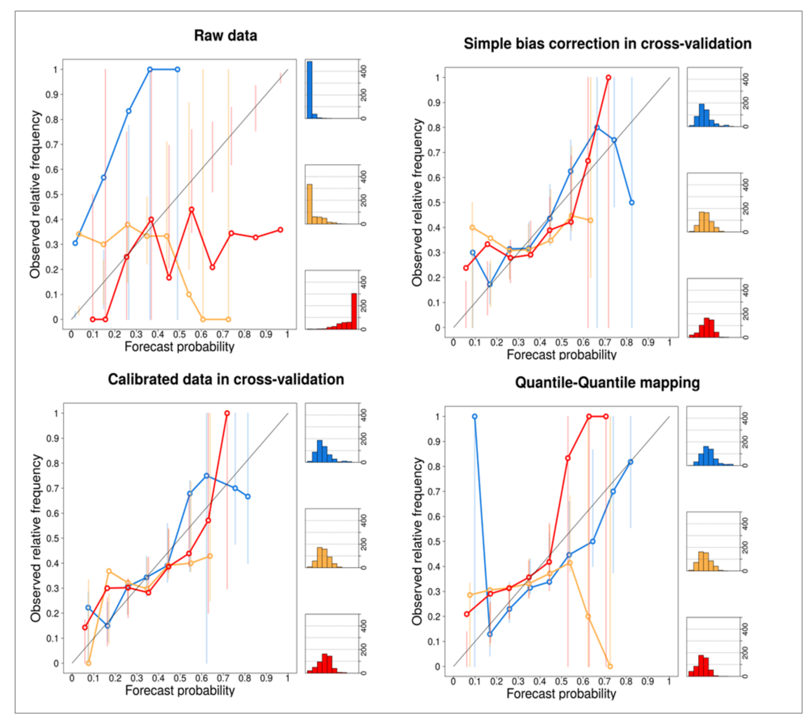

***Figure 5**. Reliability diagrams for tercile events with sharpness diagrams and consistency bars for the 10-m wind speed seasonal forecasts for the ECMWF S4 and ERA-Interim reanalysis in winter (DJF). These predictions are initialized the 1st of November for the period 1981-2012. The results correspond to a small region in Canada.*

Lessons learnt

- The use of more than one reanalysis in the verification of wind speeds is recommended for those users who employ reanalysis data for the evaluation of the long-term wind speed variability.
- Predictability information of different prediction systems could help to the wind energy users to decide which prediction system is more suitable to satisfy their specific needs.
- Due to systematic errors and lack of reliability in seasonal forecasts, bias-adjustment of probabilistic wind speed predictions is required. The predictions resulting from this post-processing stage show improved forecast quality and address the requirements of the users.
- Deviations from normality in both predicted and observed wind speeds are found, although in a different way. This shows that the differences from the normal distribution are not equivalent in the predictions and in the observations, therefore gaussianity assumptions should be avoided in the bias-adjustment processes.

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veronica.torralba@bsc.es

Barcelona Supercomputing Center – Centro Nacional de Supercomputación