Seasonal forecast verification of extreme events for the wind energy sector

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I. Introduction

• A number of studies (Peterson 2000, Ulbrich et al. 2001, Marchigiani et al. 2013, Pascual et al. 2013) reported that severe extreme wind and wind storms are responsible for physical destruction, loss of life and property, and economic losses. For this reason, **a more accurate assessment of the distribution and the probability of occurrence of extreme and severe wind speeds is a necessary condition to improve forecasts that might lead to better protection against such climate risks.** This is also a fundamental prerequisite for reducing the uncertainty in the future variability of energy supply and/or demand in the wind energy sector.

• Recently, many researchers have investigated extreme wind speeds for a variety of scopes. However, little research has been performed on the evaluation of prediction performance for extreme wind speeds at the seasonal time scale. **The current study is focused on the seasonal predictions of extreme wind speeds to provide information useful for energy network management**.

• **The main objective of this study is the evaluation of the ability of the seasonal climate prediction systems in forecasting extreme wind speed to minimize the risk of unexpected energy network unbalance.**

II. Data and methodology

i. Forecast systems and observation datasets

Two seasonal forecast systems have been employed over the period 1991-2012: ECMWF-S4 (Molteni et al. 2011) and METFR-S4 (Voldoire et al. 2013). **The systems were selected taking into account the availability of 6 hourly 10m wind speed within the target 3-month seasons at 0-4 months lead time**. Each seasonal forecast system has **retrospective forecasts integrating 7-months with the first day of May and November** as start dates.

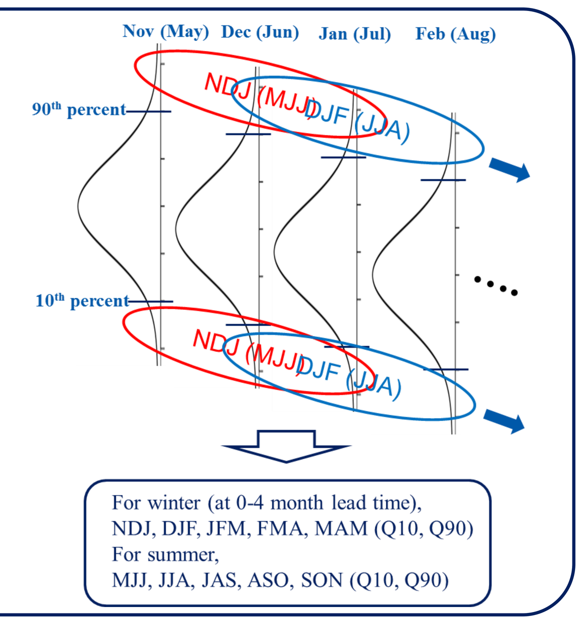
Table 1. Description of the seasonal forecast systems used

Prediction System	AGCM	Resolution	OGCM	Resolution	Ensemble member
ECMWF-S4	IFS CY36R4	TL255L91	NEMO 3.0	1° lat x 1° lon L42	51
METFR-S4	ARPEGE 5.2	TL127L31	NEMO 3.2	1° lat x 1° lon L42	15

ii. Methodology

• For the purposes of this study, we have defined a climate extreme as any value below (or above) the 10th (or 90th) percentile of the chosen variable for a given month.

We first measured **wind extreme values exceeding the 90th percentile (Q90) threshold (and below the 10th percentile, Q10) of the wind speed output for each ensemble member** obtained from the climate prediction systems separately for each month. Afterwards, we computed the **seasonal averages for each 0-4 month lead time** (e.g., for the 1st November start date, seasonal averages November to January (NDJ), December to February (DJF), and so on until March-to-May (MAM)). Finally, we **assessed the quality of the two individual prediction systems when forecasting the seasonal mean of the monthly wind speed extremes** over the common period (1991-2012).



iii. Verification Measures

• To quantify the performance of the 10m wind speed extreme forecasts, three types of verification measures were applied: the ensemble mean correlation coefficient, fair ranked probability skill score (FRPSS), and reliability and sharpness diagram (Jolliffe and Stephenson 2003, Wilks 2006).

III. Forecast skill assessment for extreme climate events

i. Ensemble Mean Correlation Coefficient

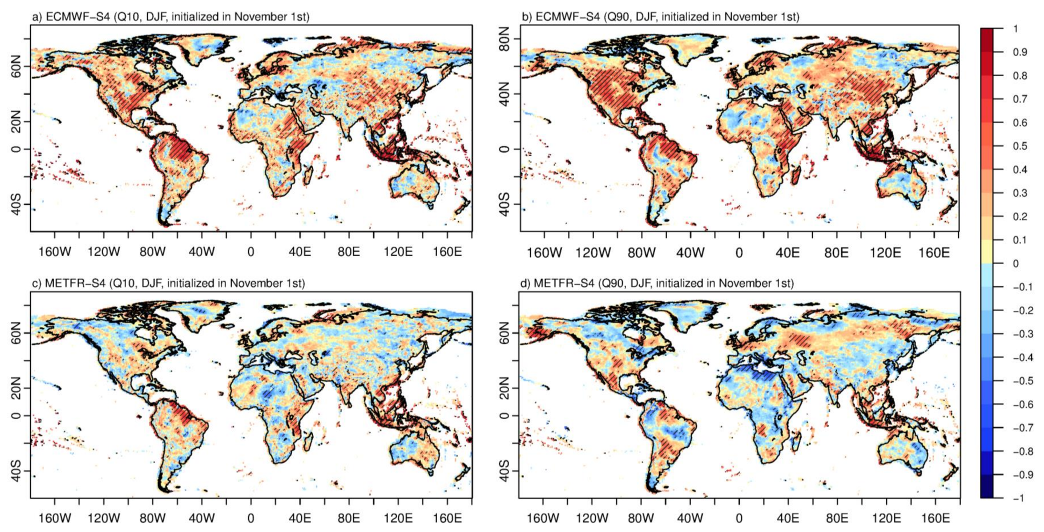


Fig 1. Ensemble mean correlation between the observed (ERA-Interim) and predicted (ECMWF-S4 and METFR-S4) extreme 10m wind speed over the globe during winter (DJF as the 3-month-average at 1-month lead initialized in November 1st) over the period 1991-2012. Left and right columns are ensemble mean correlation of extreme values for the 10th (Q10, a and c) and 90th percentile (Q90, b and d) threshold calculated from the 6-hourly 10m wind speed within a given month. The hatched areas depict the regions where the correlation is significant at the 90% confidence level from a two-tailed Student's t-test.

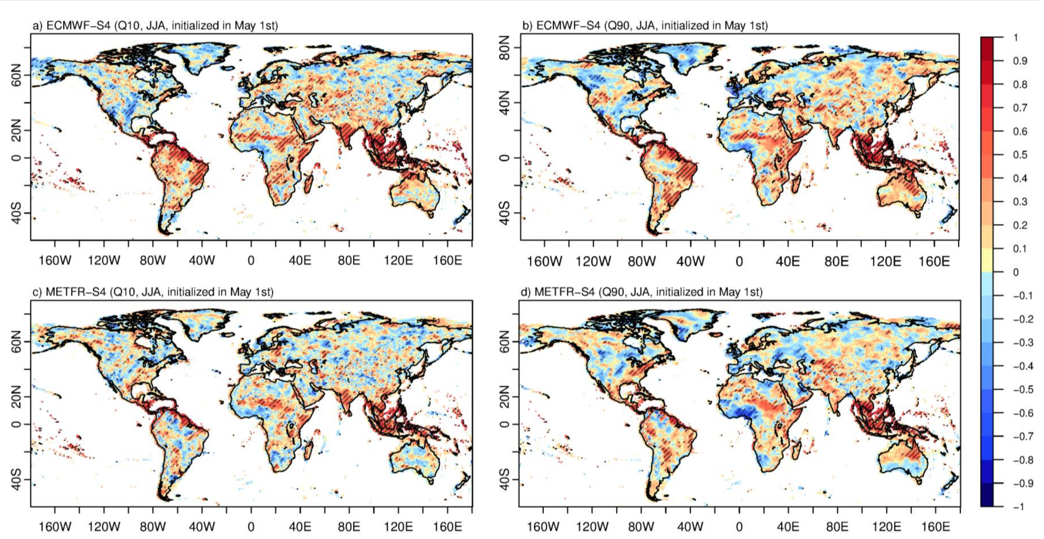


Fig 2. Same as Fig. 1, but for summer (JJA as the 3-month-average at 1-month lead initialized in May 1st)

- Extreme forecast skill of the ECMWF-S4 is significantly superior to that of METFR-S4 over the whole global region during both seasons.
- Skill in Q90 tends to indicate slightly better performance.
- Winter has higher skill than summer, except for a few areas, such as tropical regions.

ii. Fair Ranked Probability Skill Score (FRPSS)

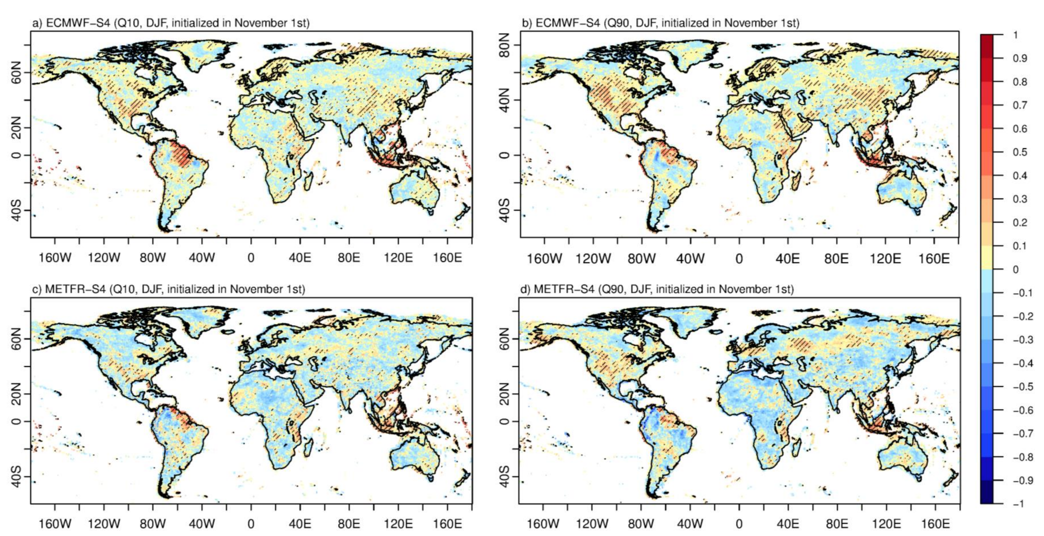


Fig 3. Fair Ranked Probability Skill Score (FRPSS) of (a and b) ECMWF-S4 and (c and d) METFR-S4 with respect to the ERA-Interim climatology as the reference for extreme 10m wind speeds over the globe during winter (DJF as the 3-month-average at 1-month lead initialized in November 1st) for the period 1991-2012. Left and right columns are the seasonal mean of extreme values for the 10th (Q10, a and c) and 90th percentile (Q90, b and d) threshold calculated from the 6-hourly 10m wind speeds within a given month. The hatched areas depict the regions where the FRPSS is significant at the 95% confidence level from a one-tailed Z-test.

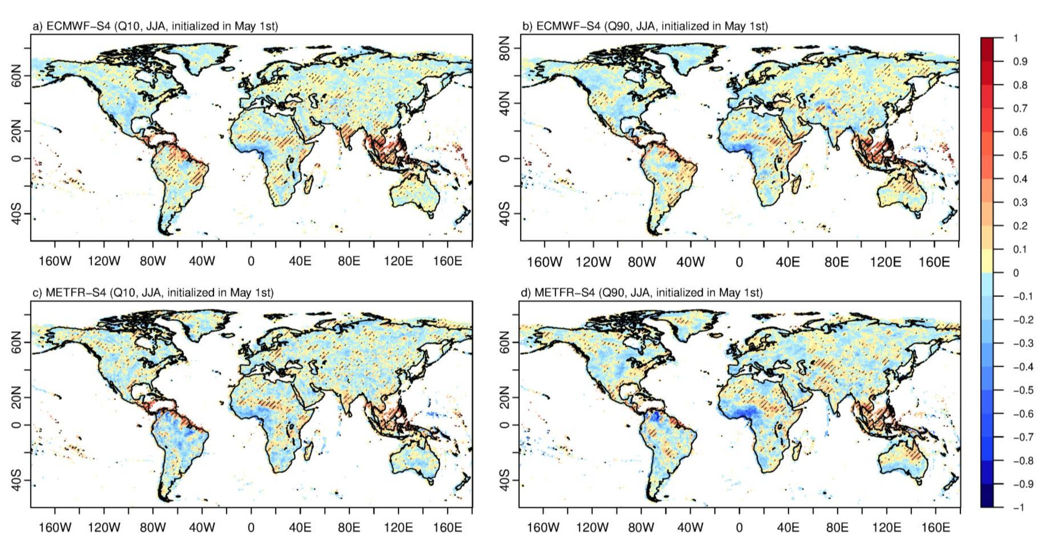


Fig 4. Same as Fig. 3, but for summer (JJA as the 3-month-average at 1-month lead initialized in May 1st)

- The significant spatial distributions of FRPSS for the seasonal extreme wind events for each prediction system are very similar to those of the TCC during both seasons.
- The significantly positive skill of extreme seasonal winds from ECMWF-S4 is more widespread than METFRP-S4.
- DJF extreme wind events based on both percentile thresholds tend to show much better skill in almost every region.

iii. Reliability Diagram

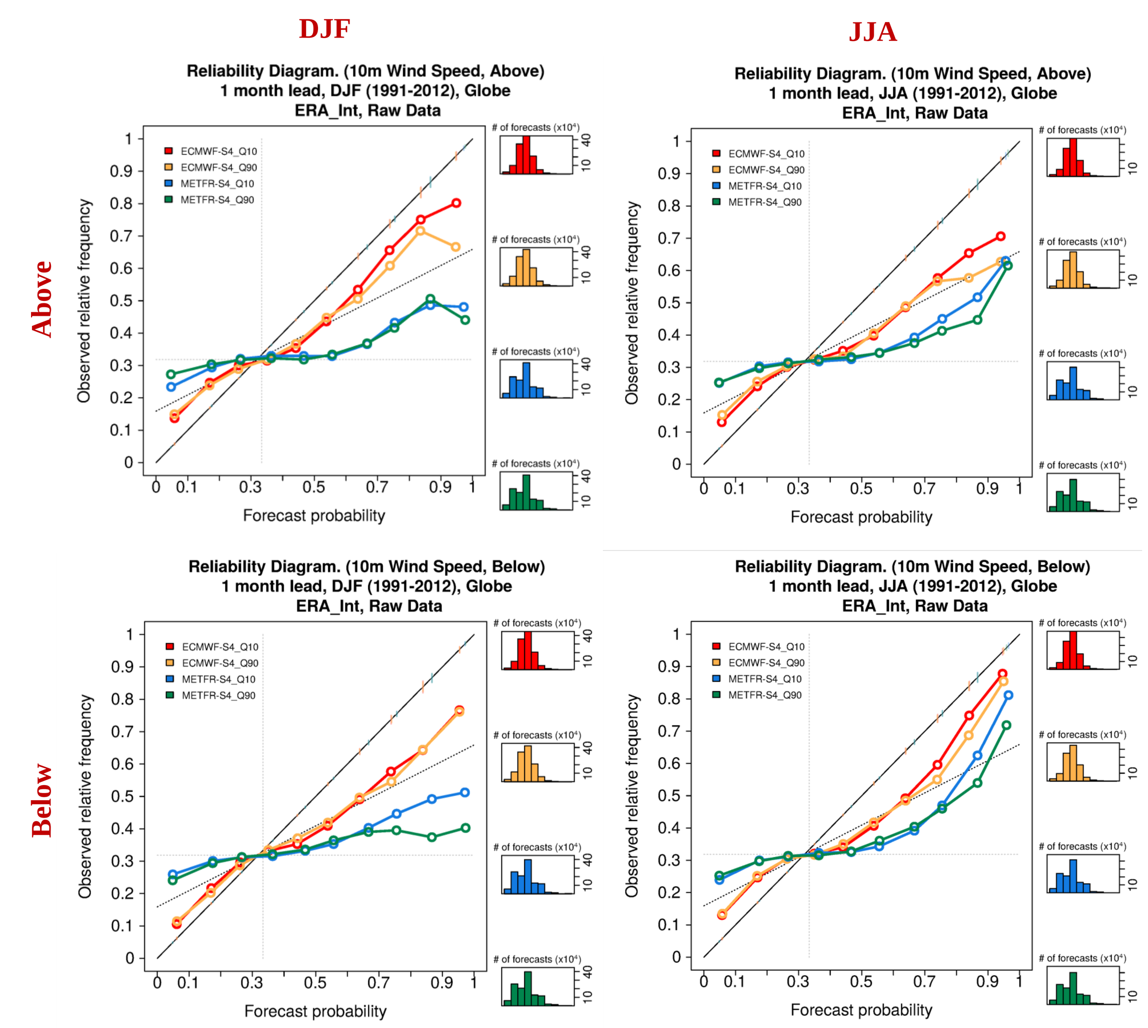


Fig 5. Reliability diagrams (lines) for probabilistic categorical forecasts of global 10m wind speed in terms of winter (left column) and summer (right column) predictions obtained by wind extreme values exceeding the 10th (Q10) and 90th percentile (Q90) threshold for ECMWF-S4 and METFR-S4 prediction systems. Upper and lower rows are for the above and below normal categories, respectively. Vertical color bars on the diagonal within the reliability diagrams depict consistency bars for a 95% confidence level in each bin. The histograms (bars) at the right of the reliability diagrams represent sharpness diagrams which are the relative frequency distributions of the probability forecasts.

- The ECMWF-S4 prediction system is much more reliable for both (Q10 and Q90) thresholds and for both (above and below) categories than METFR-S4 prediction system during winter and summer.
- The ECMWF-S4 tends to have a rather less sharpness histogram than METFR-S4 for both seasons.

IV. Summary and conclusions

• We have evaluated the forecast ability of two global seasonal climate prediction systems to foresee extreme climate wind speed. After measuring the wind extreme values classified by Q10 and Q90 thresholds from the 6-hourly 10m wind speed for each given month, we have obtained the seasonal extreme events as the 3-month average at 0-4 month lead time.

• The extreme forecast skill of the ECMWF-S4 **is significantly superior** to the METFR-S4 in most of the regions during both seasons, although the METFR-S4 forecasts show slightly better skill in a few areas. The significantly positive FRPSS of extreme seasonal winds from ECMWF-S4 is more widespread than METFR-S4.

• Forecast quality assessment of seasonal extreme wind events shows the possibility of getting helpful climate information to prepare unexpected energy unbalance that can be caused by extreme wind speeds in wind energy industry. Nevertheless, the conclusions of this study should be taken with caution because we have used a rather small sample (hindcast period is only 22 years long, the maximum available) in terms of characterizing extreme wind events from simulations.

V. Acknowledgements

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VI. References

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