Probabilistic storm forecasts for wind farms in the North Sea

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1 Introduction

In the last few years there has been a significant increase in Belgian offshore wind energy production, with more capacity being expected by 2020. Storm events over the North Sea can impact many of these wind farms at roughly the same time, because they are situated relatively close together in a narrow band in the North Sea. Each wind turbine has a characteristic cut-out (wind) speed, above which they will shut down as a protection measure. In case of a major storm, many wind turbines could shut down at the same time, creating a so called cut-out event for the wind farm(s). When such cut-out events occur at multiple wind farms at the same time, this can lead to large imbalance risks in the electricity grid. To better understand and predict such events, the Royal Meteorological Institute of Belgium (RMI) is involved in the development of a dedicated storm forecast tool for Elia, the Belgian transmission system operator for high-voltage electricity.

The aim is to forecast storm events, and associated cut-out events, a day ahead and up to two days, making use of weather models that generate wind speed forecasts at turbine height and location. Because there is a substantial uncertainty in the precise location, timing and intensity of a forecasted storm, and cut-out events are moreover very sensitive to whether or not a high wind speed threshold is exceeded or not, a probabilistic forecast approach is logical. Because Elia also required high temporal resolution forecasts (output every 15 minutes), a combination of a high resolution deterministic model and lower resolution ensemble weather prediction model was used. This allows both detailed forecasts and a good estimation of the uncertainty in the forecasts, thereby helping end users in their decision making process.

The storm forecast tool developed at the RMI makes use of the deterministic ALARO model (4 km resolution) combined with the ENS ensemble forecasts ($\sim$18 km resolution) of the European Centre for Medium Range Weather Forecasting (ECMWF), hereafter referred to as ECEPS. For the ALARO model, wind speed forecasts are calculated at turbine height from the model levels, while for ECEPS we use the 100m wind speed field. The wind speed forecasts are then used to give an ensemble forecast of the wind power in each wind farm. Since November 2018, the storm forecast tool is running operationally at the RMI, in a test phase for Elia. The forecasts are updated six times per day, twice for ECEPS and four times for ALARO, with an hourly timestep for ECEPS and 15 minutes for ALARO, up to a lead time of 60 hours.

2 Forecast examples

Case studies have been performed over a 7 month period from 01 September 2015 until 31 March 2016, which contained several big storm events, leading to cut-out events. We show some forecast examples from this period. Note that we have anonymized the figures by removing the names of the wind farm(s) and by only showing relative wind power, i.e. amount of power is relative to the maximum attainable power of the wind farm.

2.1 Cut-out event of 28 March 2016

All wind farms consisting of wind turbines with a 25 m/s cut-out speed experienced a cut-out event on 28 March 2016, due to wind speeds reaching significantly higher than the cut-out speed, which was forecasted well, see figures 1 and 2. Both ALARO and a significant amount of ECEPS members predicted wind speeds above 25 m/s and even above 30 m/s during the day.

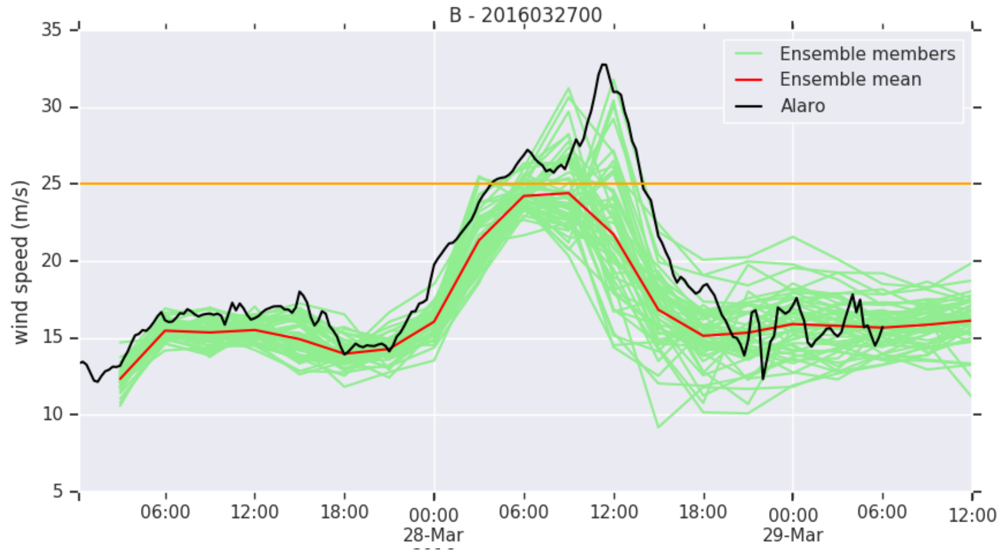

Figure 1: Ensemble wind speed forecasts from 27th of March 2016 (00h UTC) for wind farm B.

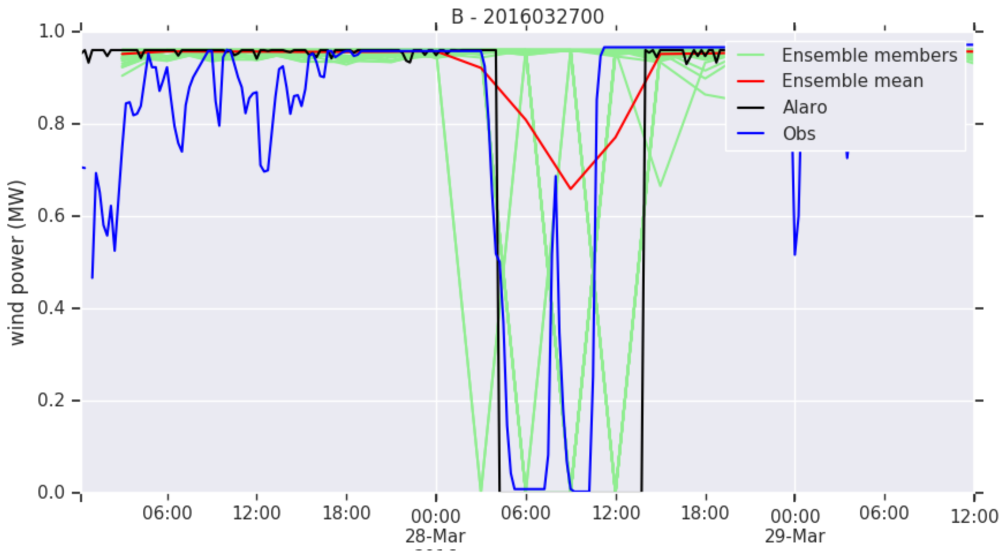

Figure 2: Ensemble wind power forecasts from 27th of March 2016 (00h UTC) for wind farm B.

2.2 False alarm for 28 March 2016

None of the wind farms consisting of wind turbines with a 30 m/s cut-out speed experienced a cut-out event on 28 March 2016, even though some ECEPS members and ALARO predicted wind speeds above the cut-out speed see figures 3 and 4. Whether this should be considered as a false alarm or not, depends on how much risk the forecast user wants to take, i.e. on the probability threshold above which the forecast user will take action.

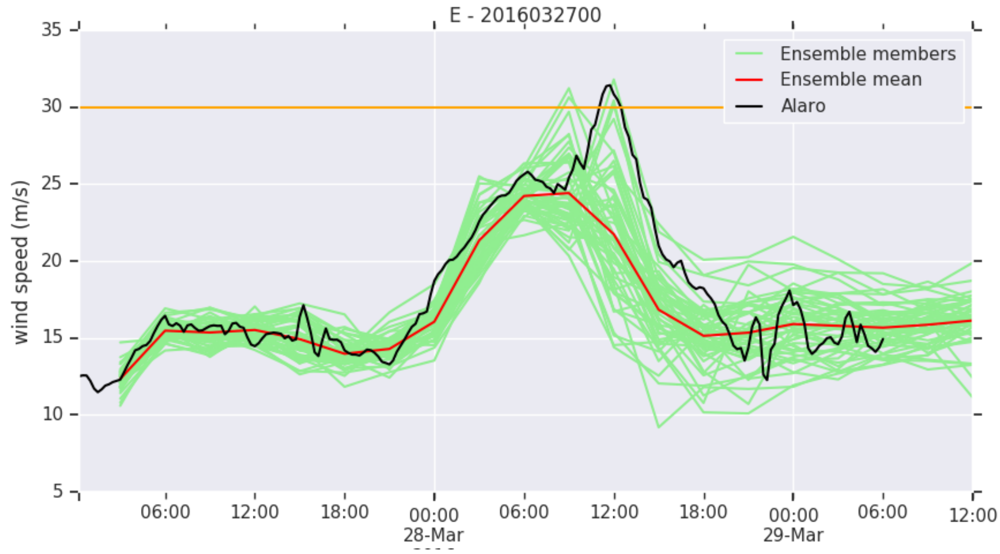

Figure 3: Ensemble wind speed forecasts from 27th of March 2016 (00h UTC) for wind farm E.

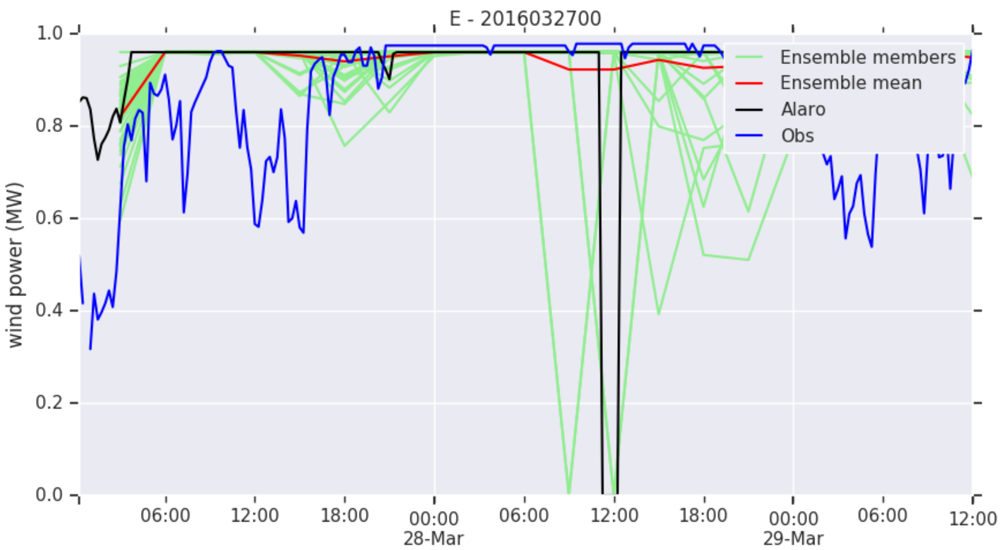

Figure 4: Ensemble wind power forecasts from 27th of March 2016 (00h UTC) for wind farm E.

2.3 Some near misses for 29-30 November 2015

On 29 and 30 November 2015, some small cut-out events occurred that were not predicted by the storm forecast tool (in hindcast mode), see figures 5 and 6. The forecasted wind speed was very close to the cut-out wind speed of 25 m/s, but just below it. As this example, and the previous 'false alarm' example shows, these cut-out events are very sensitive on the chosen wind speed threshold(s), which can be tuned in the storm forecast tool (and for each wind farm), depending on whether more false alarms or more misses are preferred.

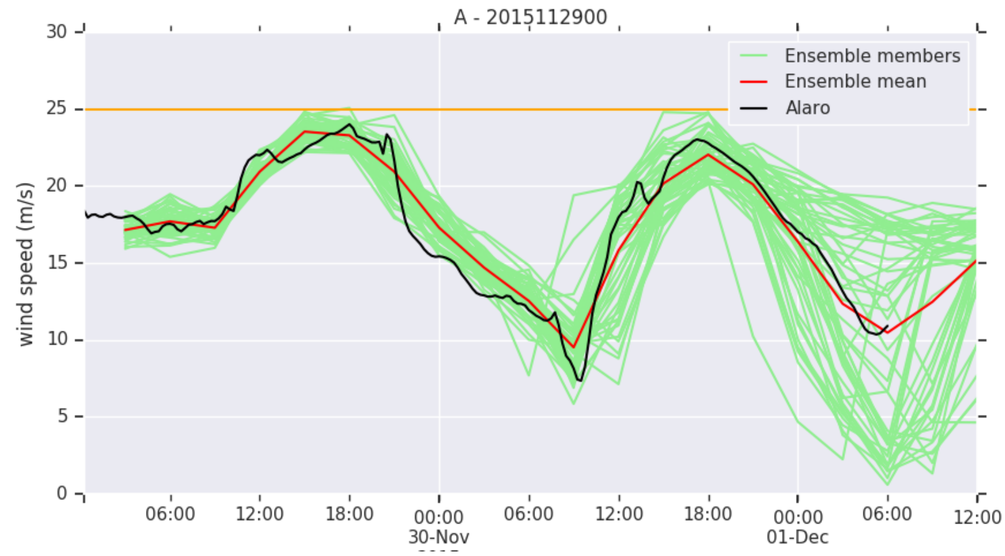

Figure 5: Ensemble wind speed forecasts from 29th of November 2015 (00h UTC) for wind farm A.

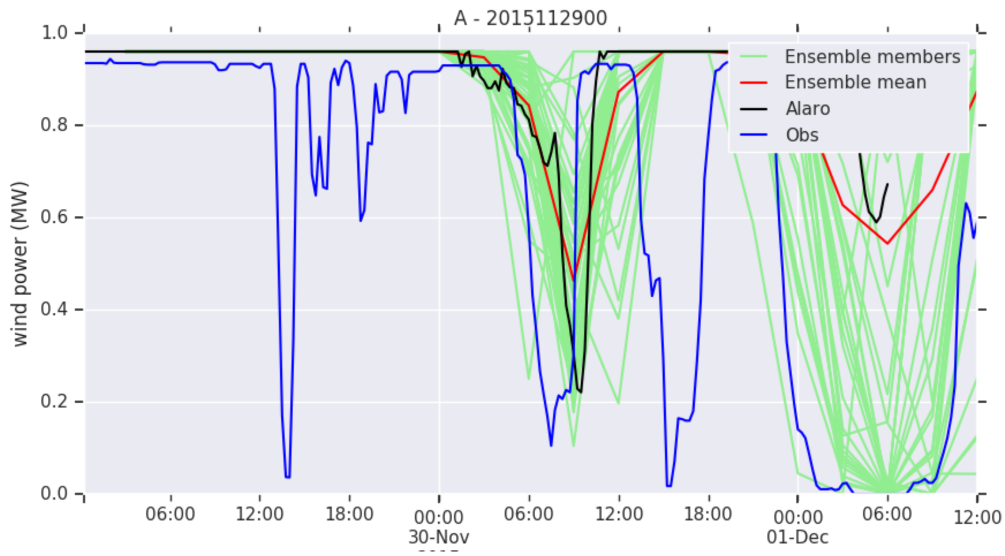

Figure 6: Ensemble wind power forecasts from 29th of November 2015 (00h UTC) for wind farm A.

2.4 Wind drop of 09 February 2016

A cut-out event occurred on 08 February 2016 at the wind farms where the wind turbines had a cut-out speed of 25 m/s, followed by a drop in the wind speed on the next day. As the figures 7 and 8 show, both events had a similar effect on the wind power, and were both forecasted well. Note also that there can be a large uncertainty in the wind power not only close to the cut-out speed, but also in the area between 5 m/s and 15 m/s. This is because the wind power depends on the cube of the wind speed, and because at 15 m/s the turbine will usually already be at its maximum (rated) power, while at 5 m/s it will still be close to its cut-in speed and power. The ECEPS ensemble forecasts capture this uncertainty nicely.

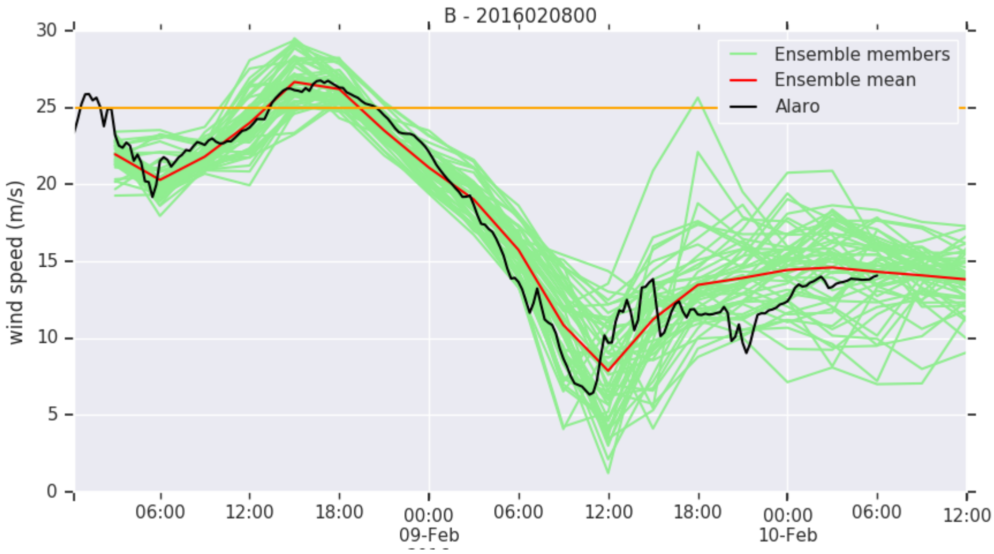

Figure 7: Ensemble wind speed forecasts from 8th of February 2016 (00h UTC) for wind farm B.

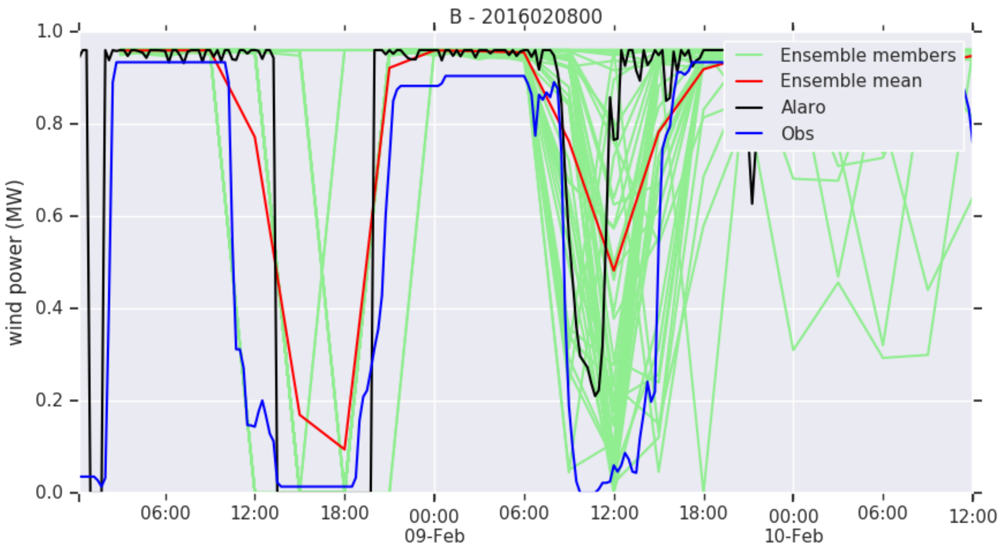

Figure 8: Ensemble wind power forecasts from 8th of February 2016 (00h UTC) for wind farm B.

3 Verification

We verified 100m wind speed of ALARO and ECEPS against 100m wind observations that were made available by one wind farm, for a 5 month period from 01 September 2017 until 31 January 2018. In figures 9 and 10 we show RMSE, spread and bias of the ECEPS ensemble mean and ALARO, all for the 00h UTC runs.

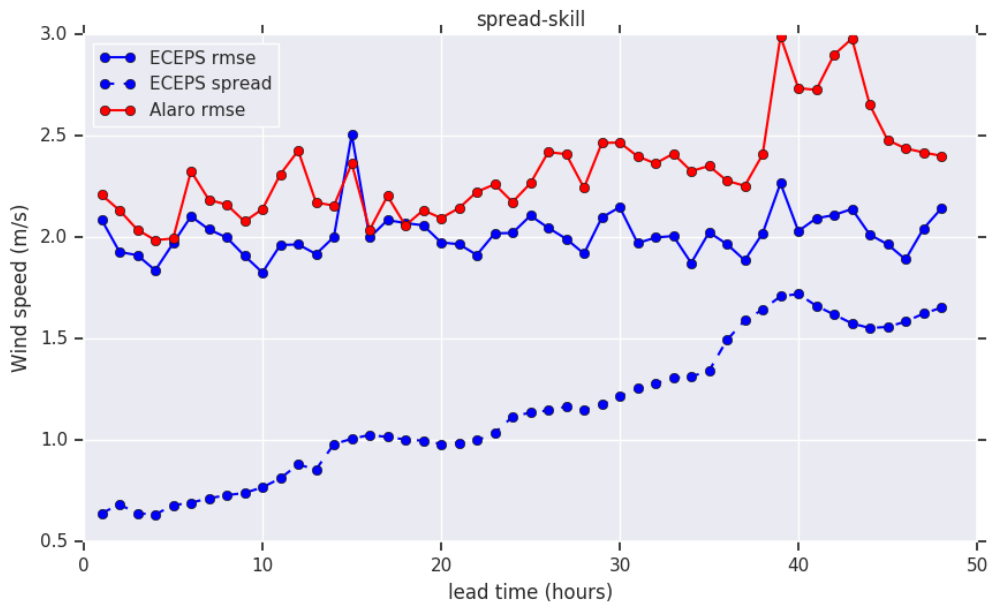

Figure 9: RMSE and spread for the ensemble mean of ECEPS, together with RMSE of ALARO (00h UTC runs).

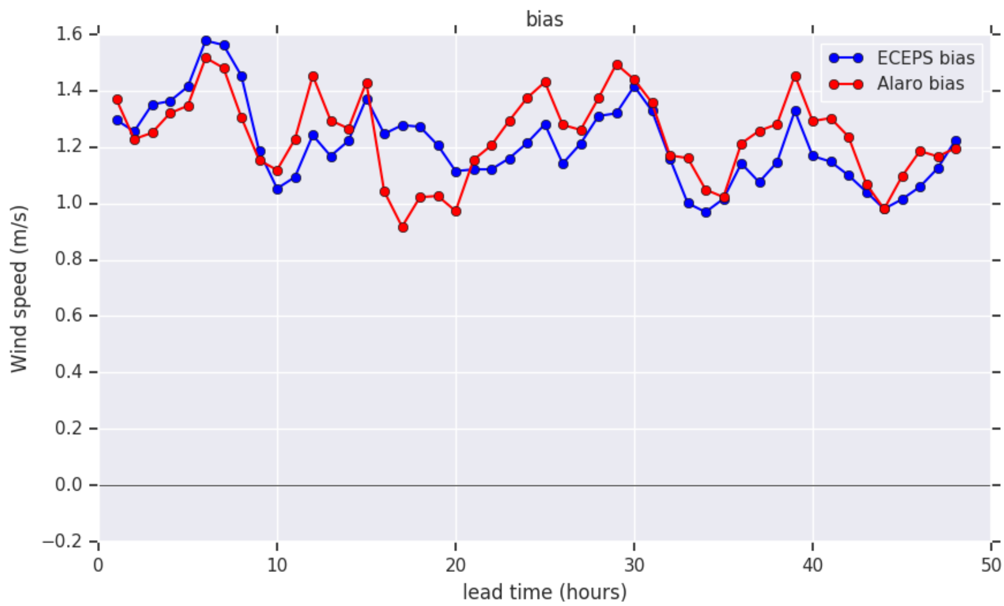

Figure 10: Bias for the ensemble mean of ECEPS and ALARO (00h UTC runs).

As can be expected, the ECEPS ensemble is underdispersive in the first day, but has a good RMSE to spread ratio near the end of the second day. Both ALARO and ECEPS have a similar bias, but ALARO seems to have a somewhat worse RMSE, which is also seen when comparing with the ECEPS control member in figures 11 and 12. However, it's possible that at least in part the ALARO model suffers from a double penalty problem, due to its higher variability, as seen in the forecast examples, as a result of its higher temporal and spatial resolution. This needs to be investigated further. Moreover, the ALARO forecasts are still useful to quantify the gradient of a drop in wind production at temporal scales (15 minutes and 30 minutes) that are not available from the ECEPS members (1-hourly output).

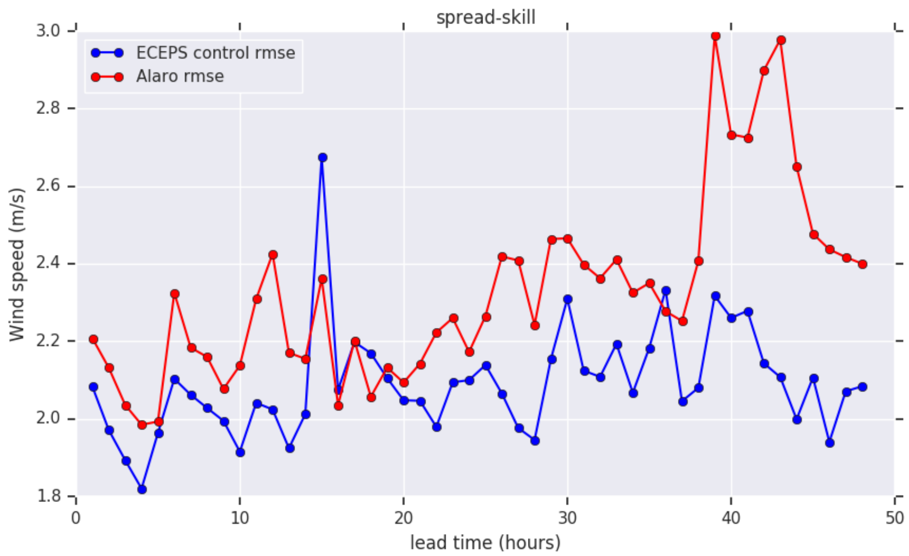

Figure 11: RMSE for the control member of ECEPS and ALARO (00h UTC runs).

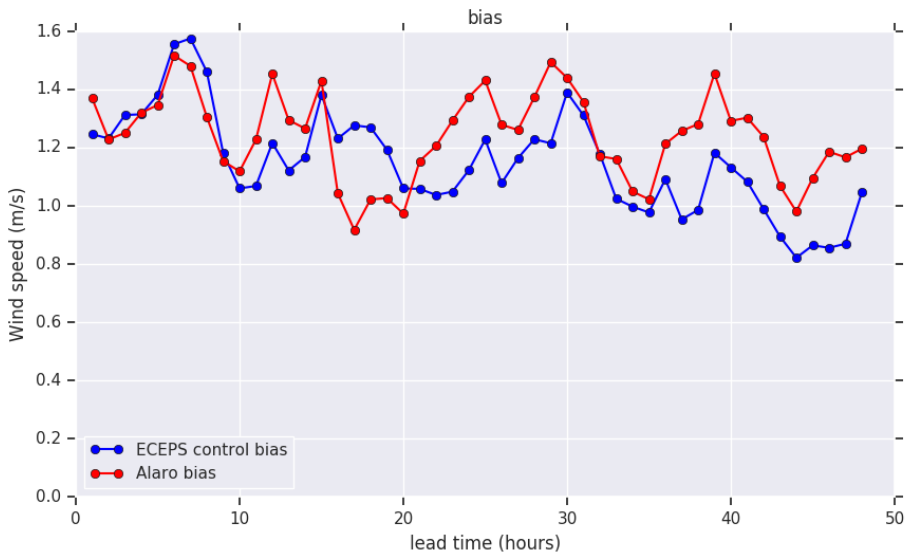

Figure 12: Bias for the control member of ECEPS and ALARO (00h UTC runs).

4 Conclusion and future plans

The wind power forecasts used in the storm forecast tool seem adequate to predict important power losses and gains, with a good indication of the uncertainties involved. During the historical periods studied, no big storm events were missed. However, the cut-out events are very sensitive to which cut-out speed is used as a threshold. Some further tuning to optimize false alarms, hits and misses might therefore still be useful. We also intend to look into some postprocessing methods to improve the bias and spread of the ECEPS wind speed forecasts, and investigate their impact on the wind power forecasts and the prediction of cut-out events.

5 Acknowledgements

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