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Downscaling merra mesoscale data for calculating the Annual energy production of norwegian wind farms

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windsim

Abstract

For many wind farm developers, obtaining meteorologically representative and accurate wind climatology data proves to be one of the most challenging aspects of their wind resource assessment campaign. As an alternative to the conventional technique of deploying multiple tall met masts and waiting several years for this data, we propose the use of mesoscale reanalysis model output statistically and dynamically downscaled using computational fluid dynamics (CFD).

Background & Method

In the proposed methodology, we use long term global mesoscale reanalysis data to scale CFD simulations, of varying complexity, in order to estimate the future AEP and to generate wind (speed and direction) time series comparable to those measured by met mast sensors. These 'synthetic' wind time series (referred to as virtual climatologies henceforth) primarily rely on (1) accurate CFD simulations and (2) properly defined forcing data from the mesoscale model. Before comparing the real production with the ones computed from the simulations, the main periods of bad quality data (i.e. data from maintenance periods) were discarded in order to ensure the validity of the method; a deeper cleaning was not possible due to missing information from the wind farms. In this study, modeled meteorological data from NASA's "*Modern-Era Retrospective analysis for Research and Applications*" (MERRA) reanalysis dataset [*1*] was used to scale CFD simulations carried out by the WindSim model. The major components of the downscaling procedure are:

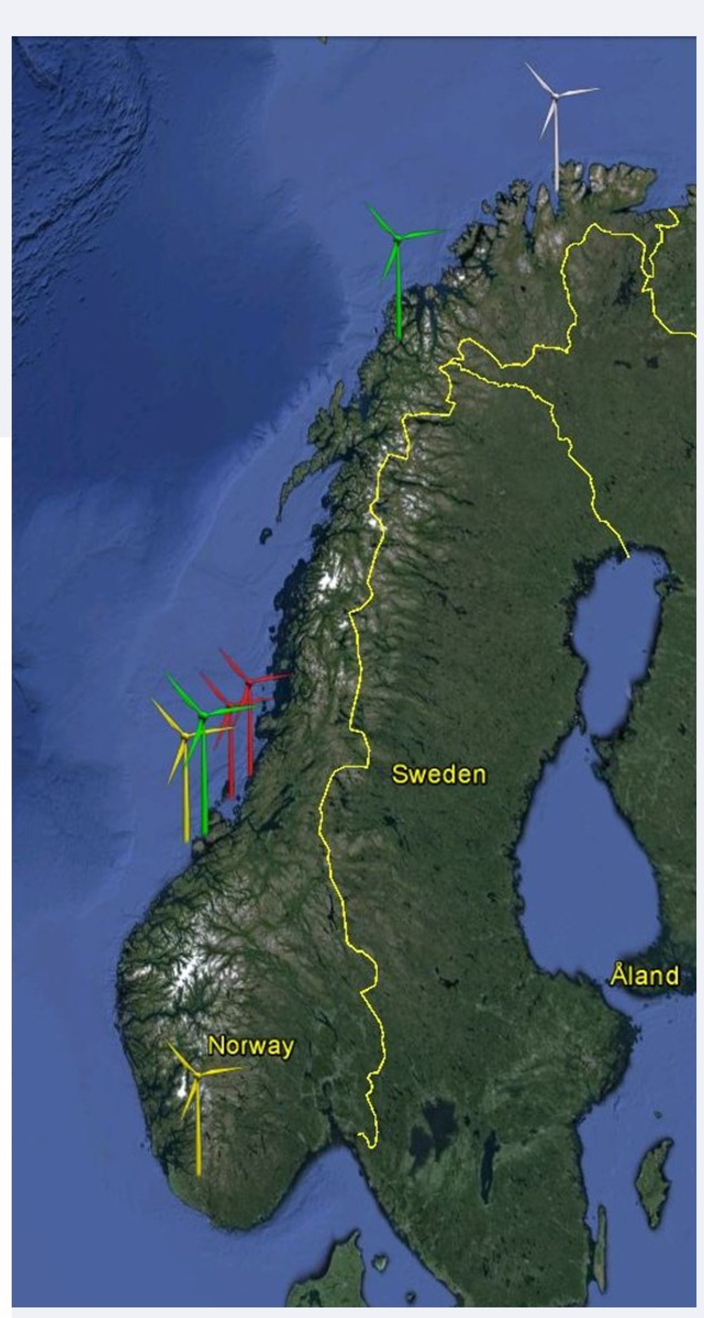
- Multiple MERRA grid points are utilized
- An in-house height and position correction is applied to each MERRA grid point to improve wind speed representativeness

Sites and Accuracy

The validity of the downscaling methodology was verified against 7 sites of varying atmospheric stability and terrain characteristics. At each site, the energy output calculated from virtual climatologies was compared to the real AEP data obtained from the farm operator.

During the development of this method, we observed that our model is usually underestimating. Taking under consideration that 6 out of 7 cases that we examined are located in the west coast of Norway, this underestimation is probably due to the breeze effect [2], which is not fully described by coarse resolution models like MERRA (see Fig. 4).

Fig. 1 (right): *The west coast of Norway, where the breeze effect is more dominant. The underestimation of each case is illustrated with different pin colors; green corresponds to underestimation<10%, yellow to underestimation<25% and red to underestimation>25%. The white pin corresponds to the only wind farm where overestimation was observed.*



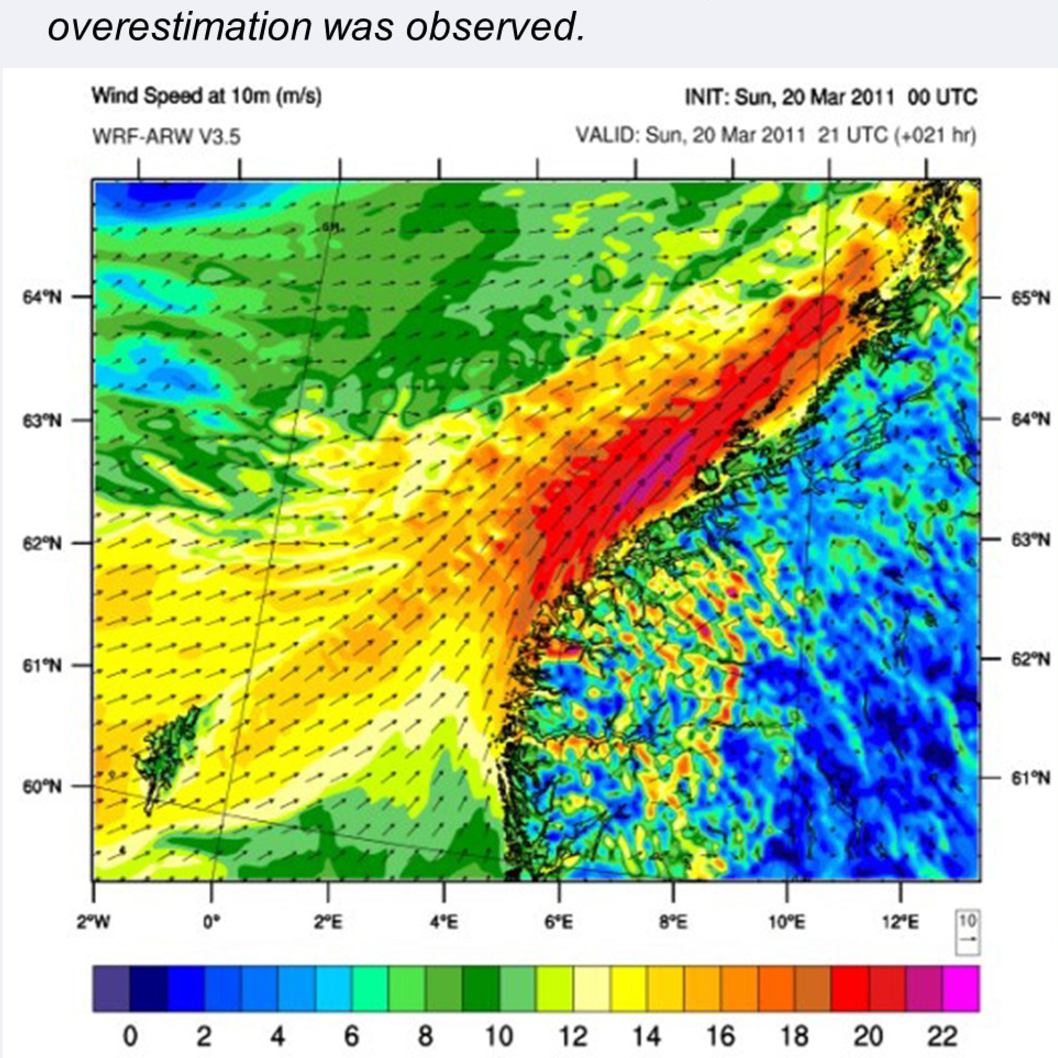


Fig. 2 (left): *Low-level Coastal Jet off the Western Coast of Norway [2]*

Energy Validation

Table 1 illustrates the accuracy achieved with our in-house algorithm. Main goal of this method was the precise estimation of the AEP, always with respect to the time series.

Wind Farm	Capacity (MW)	Data period	Simulated mean AEP with WindSim correction	Error	RMSE Normalized to Capacity
Kjollerfjord	39.1	7 years	125670.96	-5.12%	22.50%
Hitra	55.2	6 years	126634.56	6.03%	21.57%
Bessakerfjellet	57.5	5 years	88887.72	44.87%	26.59%
Smola	149.8	4 years	276780.96	14.24%	21.10%
Hog Jaeren	59.8	1 year	166422.48	20.81%	24.01%
Nygardsfjellet	32.2	1 year	78762.036	8.65%	33.23%
Valsneset	11.5	5 years	14357.64	53.18%	30.10%

Table 1: *Comparison of real wind farm energy production versus WindSim's downscaling and correction methodology.*

The power production estimation with and without in-house correction is represented in Figure 3. The correction brings the estimated production much closer to the observed production.

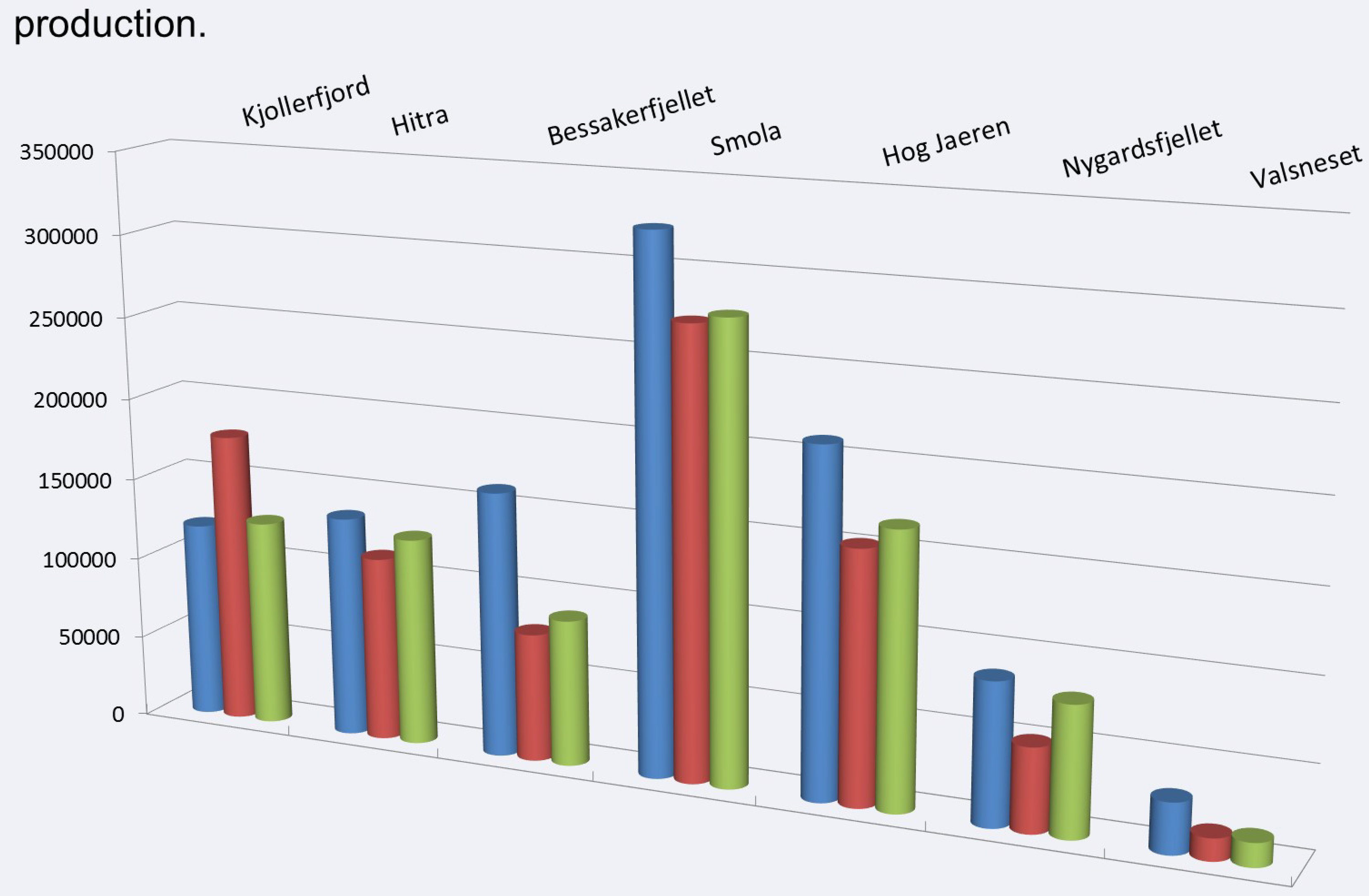


Fig. 3: *Real AEP (blue), Estimated AEP without correction (red) and Estimated AEP with WindSim in-house correction (green) for all 7 cases. All values are measured in MWh/y.*

The breeze effect is also verified by the fact that the underestimation is more dominant during the warmer months, when the thermal effect takes place.

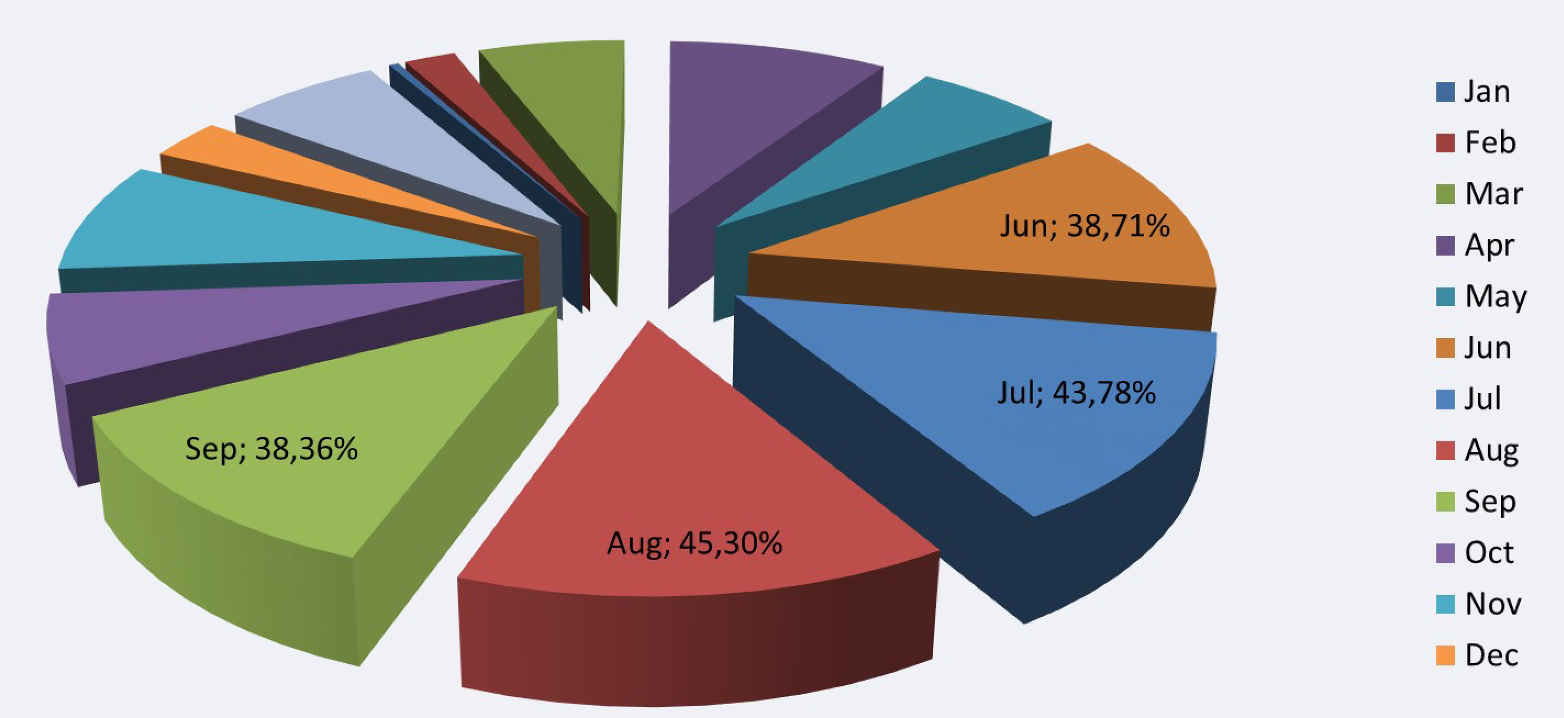


Fig. 4: *Monthly errors with WindSim correction for the Hog Jaeren wind farm. More significant errors were observed during June (orange), July (blue), August (red) and September (light green).*

Conclusions

We have developed a methodology for safely estimating the mean annual energy production of any wind farm around the world and for any height within the surface layer. The accuracy of this technique is largely sensitive to terrain complexity and even though it is not designed to describe local phenomena, AEP errors of less than 7% have been achieved so far and overall accuracy will be significantly improved if the breeze effect is taken into account.

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[1] "MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications" M. Rienecker and Coauthors, 2011, *J. Climate*, **24**, 3624–3648.
[2] "Analysis of a Low-level Coastal Jet off the Western Coast of Norway", Konstantinos Christakos, George Varlas, Joachim Reuder, Petrios Katsafados, Anastasios Papadopoulos, Energy Procedia 53 (2014) 162 – 172