Interests of using a regional model to forecast wind power production

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Abstract

European policies have decided to reduce the greenhouse gas emissions of 20% and to reach 20% of renewable power production by 2020. Increasing wind power is one of the numerous solutions to reach these goals. However, this kind of energy production depends on the meteorological conditions and gives it an intermittent behaviour. The wind speed variations cause voltage and frequency fluctuations that are unacceptable for the power grid. Therefore, forecasting production will become essential with the aim of integrating this kind of energy production into the power grid.

We compare two kinds of models : A global one and a regional one. The first model using the GFS outputs (0,5° and 3h) is not precise enough in space and time to correctly forecast the wind speed in punctual wind farms. That is why we apply some specific tunings on these forecasts. These tunings depend on the air density, the wind direction and the stability of the air mass.
The second model using the WRF outputs (4km and 15min) runs over the Belgian territory. Initial conditions are forced by the GFS outputs at 0.5° and WRF computes a physical based spatio-temporal downscaling of the meteorological variables. Some slight tunings are also needed to adjust the wind power forecasts by comparison to the wind power observations.

The interests of using a regional model are : The outputs are available in a precise resolution, thus the errors created by the spatial and temporal resolution of GFS are decreased, the high production events are successfully forecasted, the roughness rose is not needed and the WRF model are configurable to adapt the forecasts the best as possible to the wind farms.

1. Contexts

The climate context

It is now almost certain that our excessive consumption of fossil fuels, accounting for 85% of anthropogenic emissions of CO2 significantly influence our climate (IPCC, 2007a).

The energy context

In addition, our heavy dependence on these fossil fuels leads to a rapid decline in their reserves (IPCC, 2007b), an increase of its extraction costs and thus a rise of its price.

Policies responses

European policies have decided to reduce the greenhouse gas emissions of 20% and to reach 20% of renewable power production by 2020. Increasing wind power is one of the numerous solutions to reach these goals.

2. Issue of wind energy

The problematic of the wind energy is its intermittent production. Indeed, this kind of energy is dependent of the weather conditions. This implies :

- If the wind speed drops, the electrical production also drops (event A on Fig.1)
- If there is no wind, there is no electrical production (event B on Fig.1)
- If the wind speed is too high, the electrical production stops (event C on Fig.1)

The important variations in short time scale of the electric production are unacceptable for the power grid. Therefore, to ingrate the wind energy on the electric grid the most efficiently as possible we must forecast the wind production minimum one day in advance and every 15 minutes which is the time step of the electrical sector.

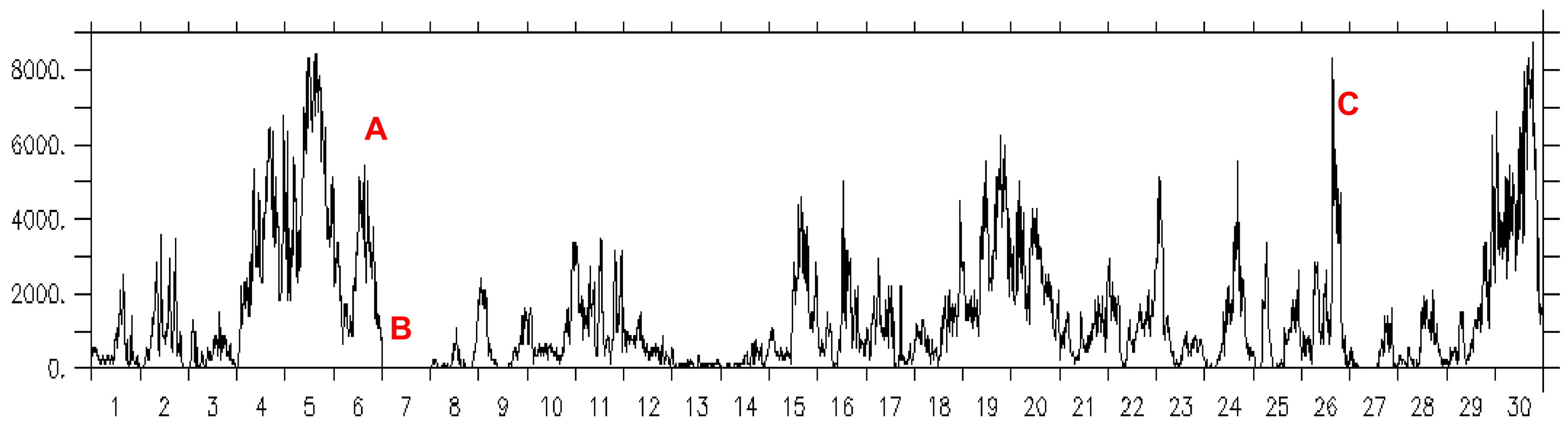
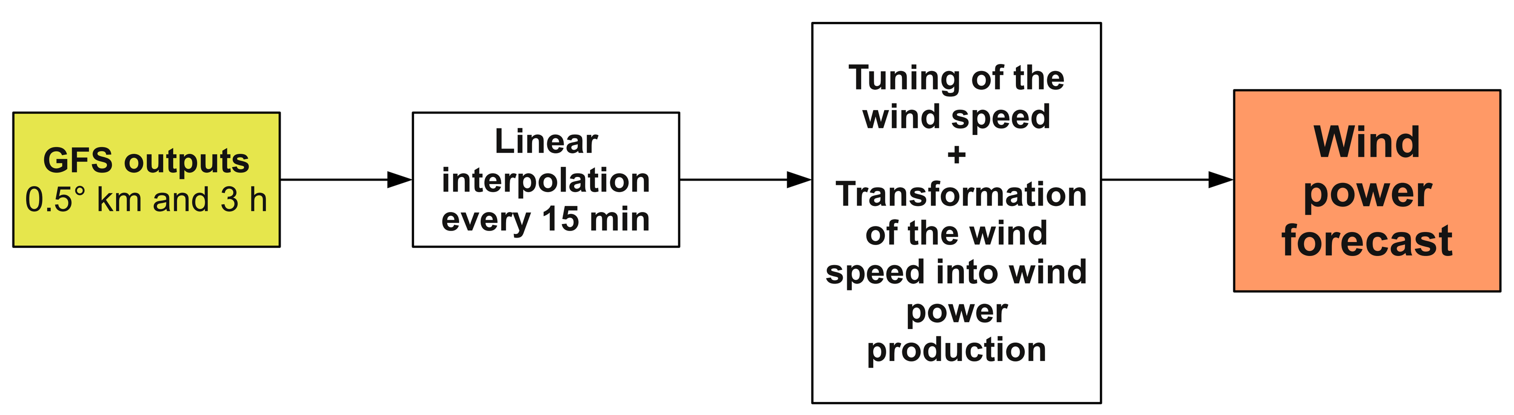


Fig. 1 : Example of observed production (in kWh) in a wind farm in Ardenne in Belgium on September 2010.
X is a remarkable event.

3. Process to obtain wind power forecast

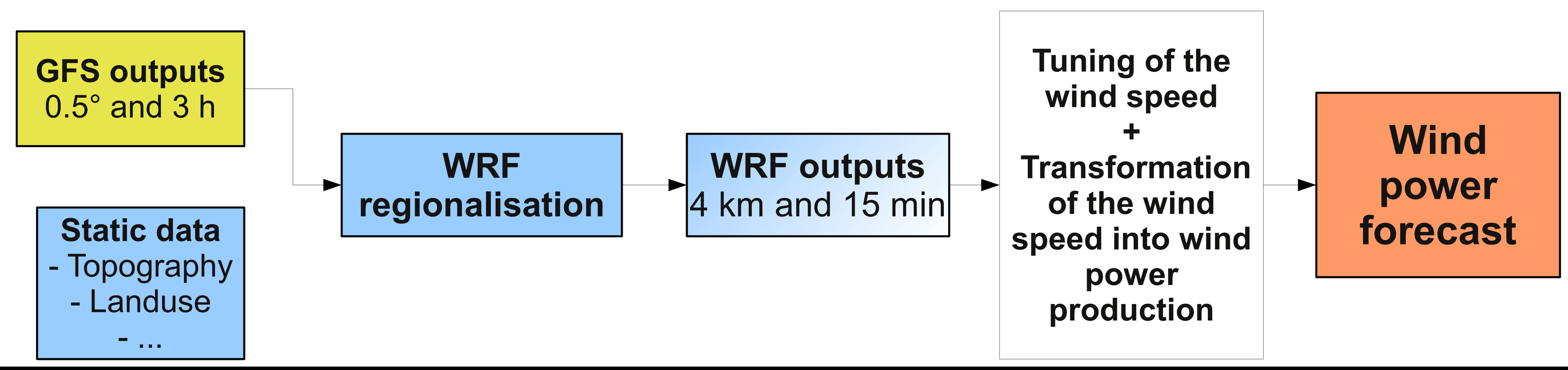
GFS (Global System Forecast) Model

The GFS model is a global model available over the world, with a spatial resolution of 0.5° and a temporal resolution of 3 h. The outputs are provided by the NOAA institute and thus are not configurable as we wish. To calculate the wind power production forecasts for tomorrow this model takes about 20 min. It downloads the GFS outputs, it calculates a linear interpolation every 15 min, it adjusts the wind speed with a roughness rose and others parameters, and finally, it transforms the wind speed into electric production.



WRF (Weather Research Forecast) Model

The WRF model is a regional model provided by the NCAR/NCEP institute. The source codes are free and thus configurable as we wish. The WRF model used here is forced by GFS outputs, is centred over Belgium and have a spatial resolution of 4 km and a temporal resolution of 15 min. To calculate the wind power production forecasts for tomorrow this model takes about 1 h. It downloads the GFS outputs and some static data, it calculates the regionalisation of the GFS outputs every 15 min and with a spatial resolution of 4 km, it slightly adjusts the wind speed, and it finally transforms the wind speed into electric production.



4. Evaluation and results

Four evaluation indexes

RMSE (Root Mean Square Error) $\sqrt{\frac{1}{n\sum(obs - forecast)}}$

r² (Coefficient of determination) $\left(\frac{(n\sum(obs\,forecast)) - (\sum obs \sum forecast)}{\sqrt{(n\sum obs^2 - (\sum obs)^2)\,(n\sum forecast^2 - (\sum forecast)^2)}}\right)^2$

PC (Percentage) $\sum\left(1 - ABS\left(\frac{obs - forecast}{obs}\right)\right)$

PC60 (Conditioned percentage) $If\,(obs \geq 60\%\,\max prod)\;then \sum\left(1 - ABS\left(\frac{obs - forecast}{obs}\right)\right)$

Results

From January 2010 to September 2010

	GFS	WRF
RMSE	1544	1426
r²	0,5552	0,6103
PC	9966	9832
PC60	1236	1322

Seasonally

From January to March

	GFS	WRF
RMSE	1815	1604
r²	0,59	0,68
PC	3224	3373
PC60	846	879

From April to June

	GFS	WRF
RMSE	1328	1327
r²	0,45	0,47
PC	3352	3099
PC60	144	161

From July to September

	GFS	WRF
RMSE	1451	1332
r²	0,54	0,57
PC	3389	3361
PC60	246	281

Globally, we can consider that WRF model is better than GFS.

The PC index is better for the GFS model but the PC60 index indicates that the forecasts are better for the WRF model. Thus, the forecasts are better for the high productions, which are the most important productions for the producer of electricity.

The winter months results do not look like the results of the other periods because the freezing conditions continuously stop the wind turbine and thus the production.

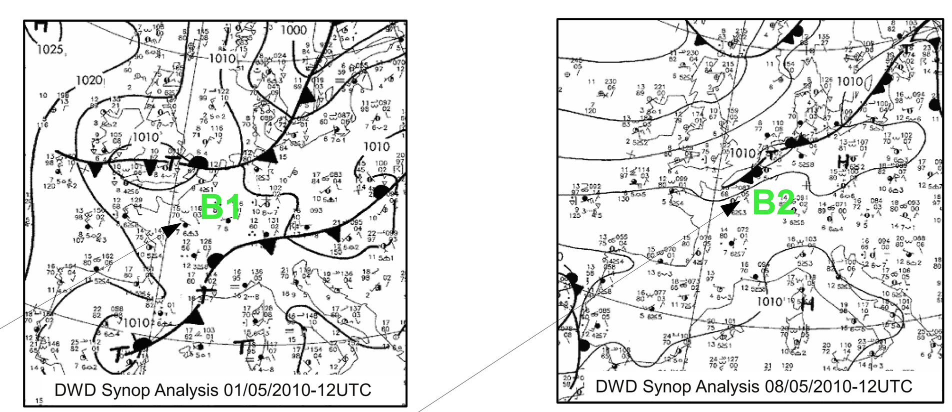
5. Analysis of a forecasted period

A : Production peaks correctly forecasted by WRF and not by GFS

B : Some remarkable events are not forecasted neither by GFS nor by WRF : Near cold front or a convective area

C : Some wrong WRF forecasts also appeared

D : One or more wind turbines halt for maintenance or security reasons



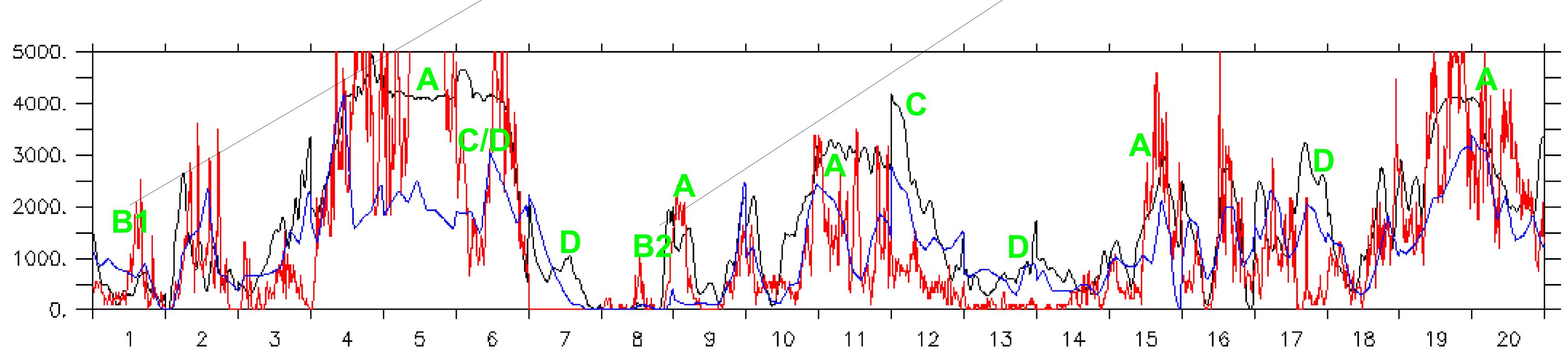


Fig 3 : Example of production observed (red line), GFS production forecast (blue line) and WRF production forecasts (black line) in kWh for the first twenty days of May 2010. X is a remarkable note with a legend in the text.

6. Conclusions

Interests of using WRF :

- The **Outputs** are available at a resolution of **4km** and **15 min.** This precise resolution decreases the errors created by the spatial and temporal interpolation of the GFS outputs.
- **The production peaks** are successfully **forecasted and the high production events are more important for the users of these forecasts.**
- The Influences of the **topography** are integrated in the WRF calculation, thus the roughness rose is not needed.
- The WRF model is **configurable** as we wish, thus We are not dependant on an other meteorological organism

Disadvantage of using WRF :

- WRF is forced by GFS outputs, this leads that if the GFS forecasts are wrong, the WRF forecasts will also be wrong

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