Evolution of wind behaviour and of its potential for wind power production in Belgium during the last 30 years.

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Abstract

The number of wind turbines in the world grows significantly every year due to politics proposing green energy productions as solutions to mitigate climate change effects. However, this kind of energy is dependent on the weather. This implies that the wind production is irregular at a very short time scale. But the short time scale availability of the wind-based energy is important to the producers of energy as well as to the electric grid managers because the wind energy production can rise or fall rapidly which creates some financial and voltage variations.

For these reasons, we study the past evolution of the availability of the wind quantity by analysing the intermittence of the wind speed in Belgium during the last 30 years. To reach this goal, we use the regional model WRF (Weather and Research Forecast model) developed by the UCAR community users. The WRF model is forced by the NCEP2 Reanalysis model to obtain a regionalisation of the weather conditions over a domain centred on Belgium at a spatiotemporal resolution of 10 km and 1 min. This resolution allows to capture the minute-based time scale variability of wind speed and consequently the irregular behaviour of the wind power production.

To obtain a value of the wind intermittence, we calculate the persistence of a wind blowing continuously with a minimum speed of 1 ms^{-1}, then the persistence of a wind blowing continuously with a minimum speed of 2 ms^{-1}, etc. The persistence of the wind speed and its evolution over 30 years are characterised by : (a) the mean wind speed over a fixed period (monthly, seasonally, …), (b) the mean duration of a wind speed above x ms^{-1} over the same fixed period and (c) the evolution of (a) and (b) during the studied period.

This study will show the evolution during the last decades of the wind behaviour in Belgium and its potential for electricity production.

1. Contexts

The energy context

Knowing that CO_2 significantly influences our climate (IPCC, 2007a) and our heavy dependence on these fossil fuels which leads to a rapid decline in their reserves (IPCC, 2007b), wind energy is proposed as a solution to reduce greenhouse gas emissions.

The issue of wind energy

This kind of energy is dependent on the weather conditions. This implies that the wind production is irregular at a very short time scale (Fig.1). This intermittent behaviour of the wind-based energy is important to the producers of energy as well as to the electric grid managers because the wind energy production can rise or fall rapidly creating some financial and voltage variations.

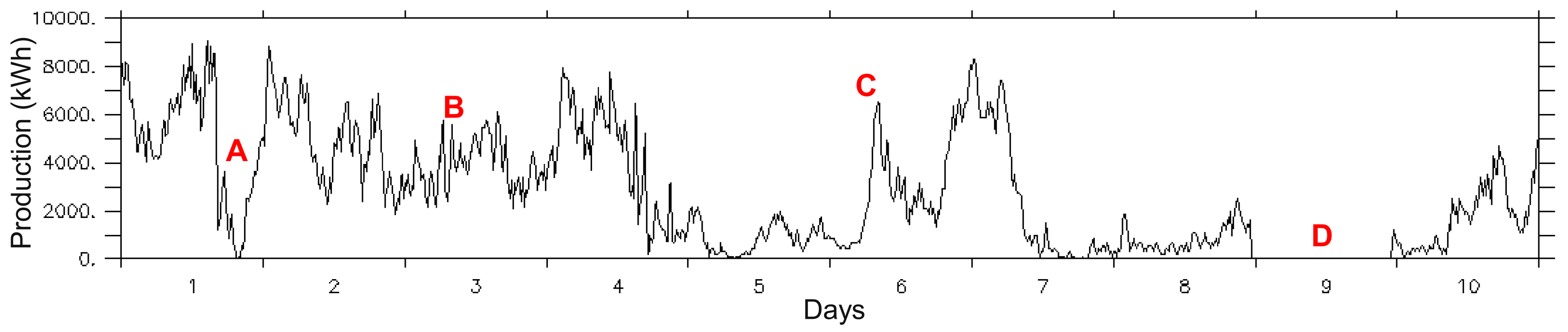

*Fig. 1 : Example of observed production (in kWh) in a wind farm in Ardenne (Belgium) on the first 10 days of April 2010. **A** is a remarkable fall of production, **B** is a long period of high variations, **C** is a remarkable increase of production and **D** is a long period without production.*

2. Methodology

Aim of this study

Obtain the evolution over the last 3 decades of the availability of the wind quantity by analysing the intermittence of the wind speed in Belgium.

Model to achieve this aim

We use the regional model WRF. This model is developed by the NCAR institute and it is shared by an OpenSource licence. The WRF model used here is forced by NCEP2 Reanalysis outputs and is centred over Belgium with a spatial resolution of 10 km. The outputs of WRF model are averaged every 12h. These periods approximatively correspond to the day time and the night time. These two periods correspond respectively to the high electricity consumption and to the low electricity consumption.

Methodology

On each period, we calculate the mean wind speed at the nearest level of 100m which corresponds to the mean height of wind turbine. We also calculate on these periods, the mean duration (in percentage of time) of a wind speed sorted by class of 1 ms^{-1}: [0,1[then [1,2[… [19,20[and finally [20,∞[

The evolution of the wind speed and the evolution of the behaviour of this wind in the last 3 decades are showed over Belgian territory. For that, we create maps with the trend cumulated of three categories of wind class in the last 30 years :

- **Low wind**: We combine the 5 wind speed classes from 0 m/s to 4,9 m/s
- **High wind**: We combine 5 wind speed classes from 8 m/s to 13,9 m/s
- **Strong wind**: We combine 5 wind speed classes from 16 m/s to max

3. Results

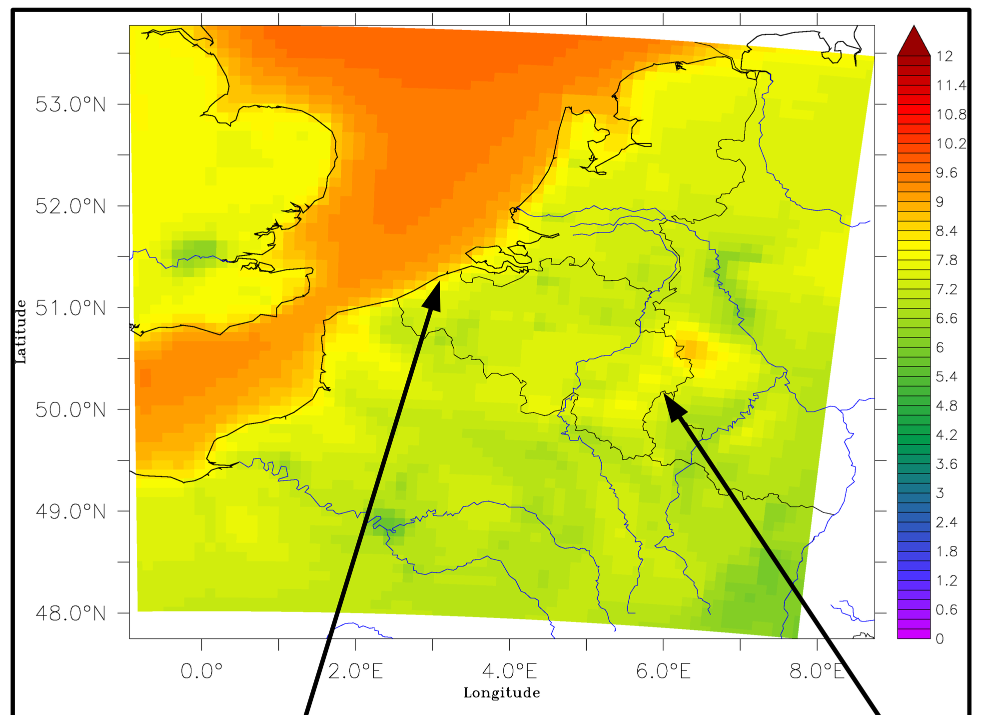

Fig.2 : Mean wind speed in the last 30 years

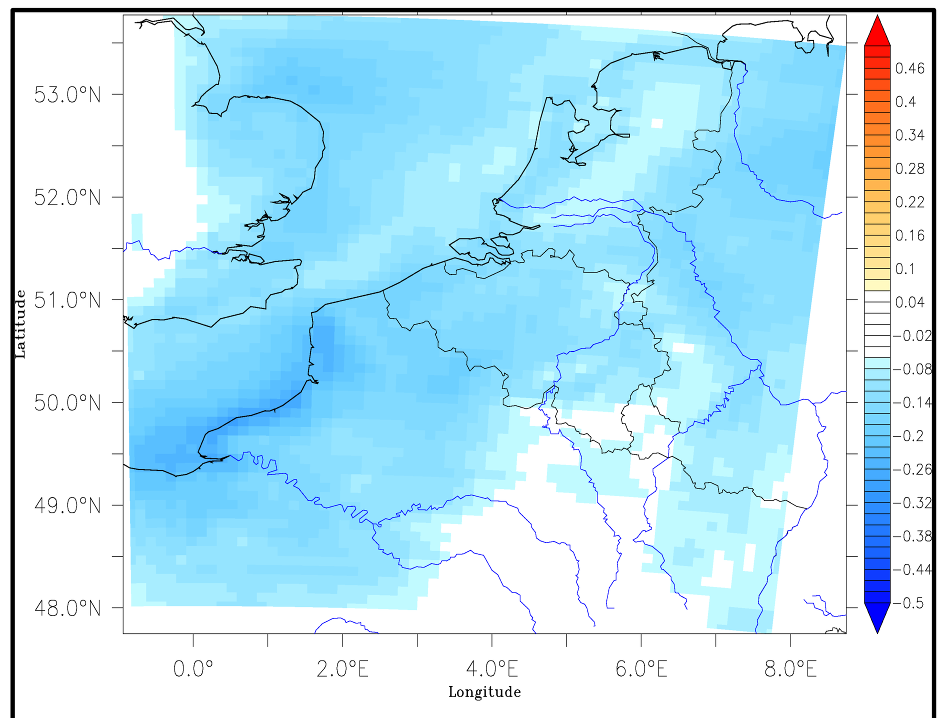

Fig.3 : Wind speed trend in the last 30 years

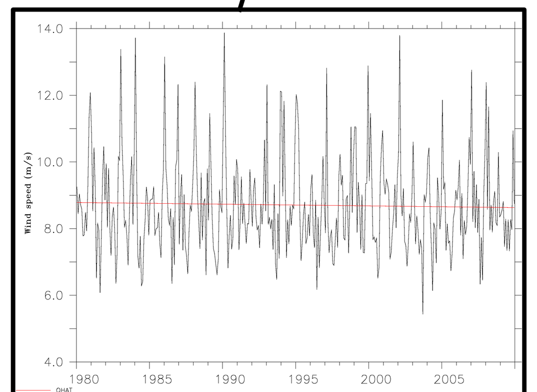

Fig.5 : Monthly mean wind speed and its trend during 30 last years in Ostende

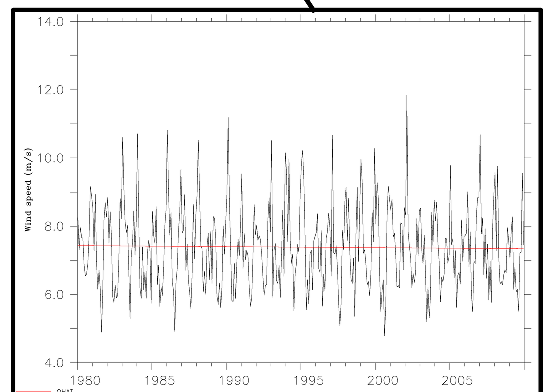

Fig.4 : Monthly mean wind speed and its trend during 30 last years in Saint-Vith

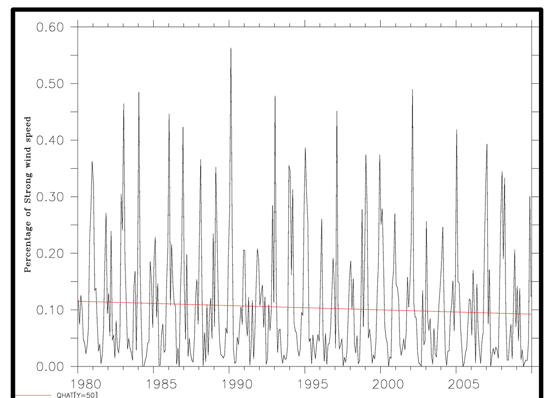

Fig.12 : Monthly mean wind speed and its trend during 30 last years in North Sea

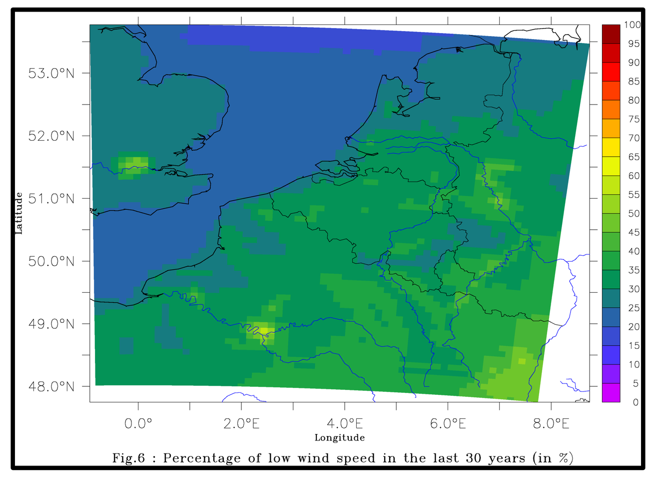

Fig.6 : Percentage of low wind speed in the last 30 years (in %)

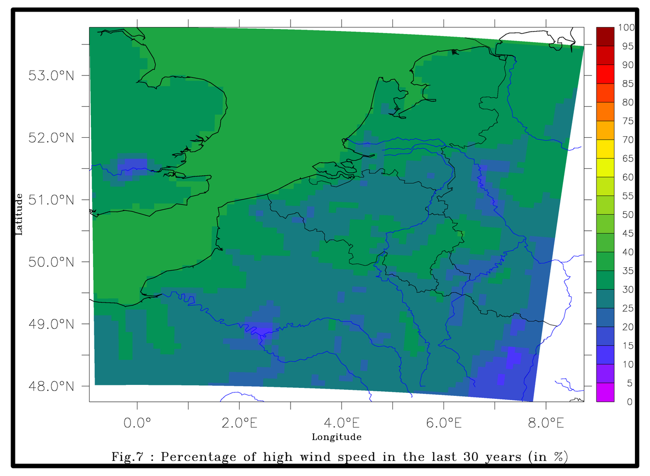

Fig.7 : Percentage of high wind speed in the last 30 years (in %)

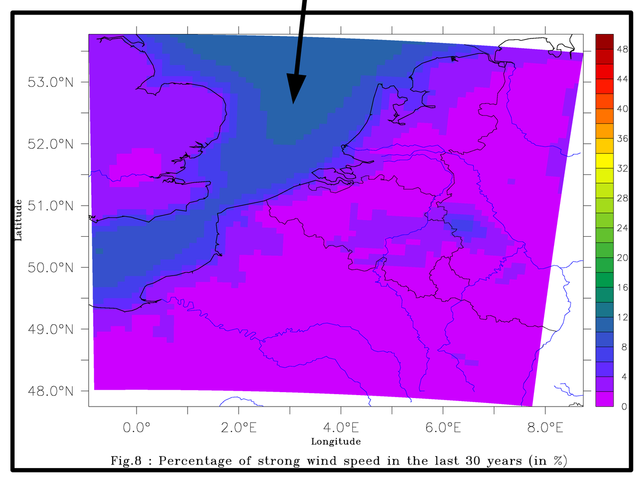

Fig.8 : Percentage of strong wind speed in the last 30 years (in %)

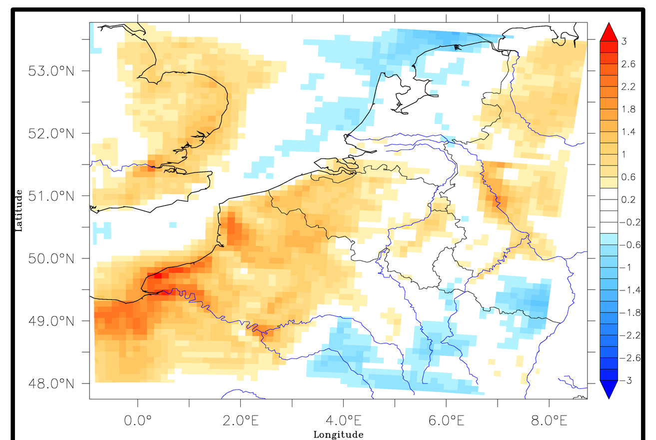

Fig.9 : Low wind speed trend in the last 30 years (in %)

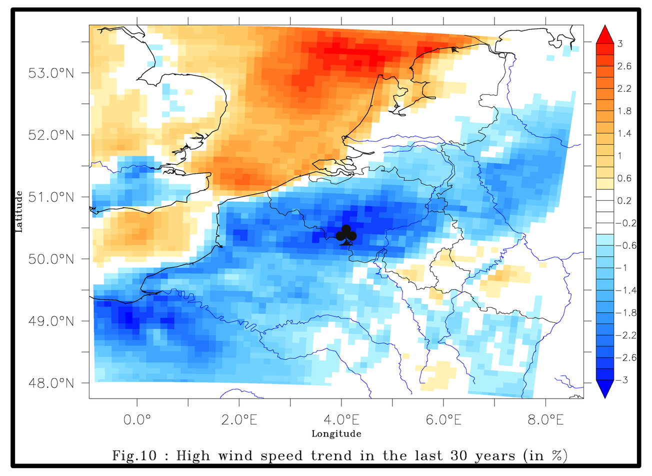

Fig.10 : High wind speed trend in the last 30 years (in %)

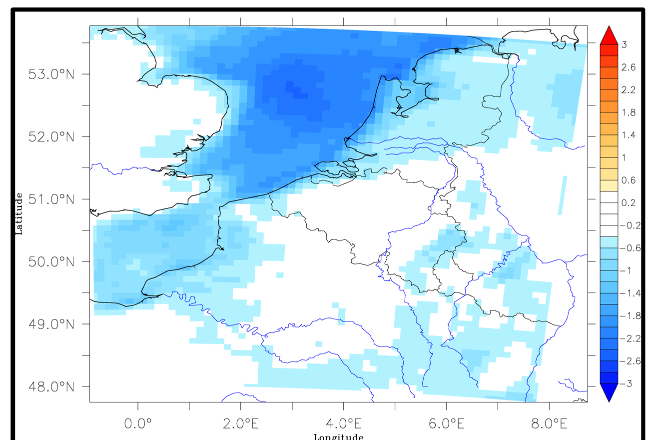

Fig.11 : Strong wind speed trend in the last 30 years (in %)

4. Discussions

Trend of the mean wind speed in the last 30 years

The trend of the mean wind speed in the last 30 years over a large domain centred over Belgium is not significant. When we compare two points, one in the Ardenne (Saint-Vith, Fig.4) and one on the Belgian coast (Ostende, Fig.5), we see a high interannual variability and no significant trend.

Trend of wind speed categories in the last 30 years

No trend is significant over the Belgian territory. The low wind speed class over the Seine estuary region slowly increase by 2,5 % (Fig.9) and the high wind speed class slowly decreases by 3 % (Fig.10). But these results over the Seine estuary region is not significant in comparison with the percentage of low (Fig.6) and high (Fig.7) wind speed classes over this region which are about 50 %. The same remark can be made about the high (Fig.10) wind speed class over Hainaut (♣) region (Belgium) which decrease by ~3% but this wind class composes about 50 % of the total wind in this region.

However, in the North Sea, we can see a decrease of the strong wind speed (Fig.11). This decrease by 3% is more significant because the mean percentage of this kind of wind in this region is about 10% (Fig.8). This means that the strong winds have decreased during the last 30 years of about 30% (Fig. 12).

Trend of wind speed during day time and night time

No significant change can be detected in the trend of day time and night time. The only two remarks are : The wind speeds are higher in the night time and the decrease of the trend is globally more important (~1%) for day time.

5. Conclusions

This study shows that no significant change in the last 30 years over the Belgian territory can be detected. The same remark can be made for the neighbouring countries. Thus, the wind power production in these regions in the last 30 years remained stable.

However, the North Sea region has a significant decrease of the strong wind speeds (≥ 16m.s^{-1}). These strong wind speeds are not favourable to the wind turbines, thereby a decrease of this category of wind speeds is profitable for the wind power production.

6. Future

In the near future, we will calculate the outputs of WRF model forced by ERA40 Reanalysis from the ECMWF institute. We will compare the outputs of WRF-NCEP2 and the outputs of WRF-ERA40 to confirm the conclusions of this study.

After that, we will calculate the outputs of WRF model forced by some Global Climate Models, firstly with their 20C3M scenario and secondly with their future projections. Finally, these studies should help to detect the wind speed changes in the next 50 years over the Belgian territory and neighbouring regions.

References

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